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Updates in Facial Fracture Management

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Abstract

Facial fractures are common injuries that frequently necessitate plastic surgery intervention, and motor vehicle accidents are among the most common etiologies of facial fractures. Current passenger restraint devices have consistently proven to decrease the rates of facial fractures in MVCs, but improvements should be pursued to further reduce fracture rates and the severity of maxillofacial injuries sustained in these accidents. Innovations in plate fixation systems, imaging technology, and virtual surgical planning contribute to the dynamic landscape of facial fracture management. Well-designed prospective and controlled studies of these technologies are necessary in order to establish rigorous, evidence-based guidelines.

Introduction

Motor vehicle accidents are among the most common etiologies of facial fractures, but this landscape is changing due to increased focus on automobile safety. The management of facial fractures continues to evolve thanks to the development of innovative technologies and approaches. This manuscript will explore the effects of passenger restraint devices on automobile-related facial fractures and review recent advances in facial fracture management.

Passenger Restraint Devices

Automobiles have long been recognized as a major cause of occupant morbidity and mortality. Maxillofacial injuries are the most common injuries sustained by passengers in motor vehicle collisions (MVCs), and MVCs are the most common cause of maxillofacial fractures [1]. As a result, automobile production and operation has been subject to legislation emphasizing passenger safety, including regulations mandating seat belts and airbags in all cars manufactured in the United States since 1997 [2,3]. Passengers are also subject to regulation as attested by the "Click It or Ticket" campaign employed in recent years. It is widely accepted that passenger restraint devices decrease mortality. Multiple authors have investigated the relationship between passenger restraint device use and the development of maxillofacial injuries in MVCs. Seat belts and air bags have been shown to significantly decrease the incidence of facial fractures in MVCs from 1:40 in the unrestrained passenger to 1:449 when both seat belts and airbags were utilized [4]. Passengers restrained with seat belts and/or airbags suffer facial fractures less frequently than unrestrained drivers. In one study, unrestrained drivers sustained maxillofacial fractures most frequently (18.4%), followed by those wearing a seat belt only (10.0%), those restrained by an airbag only (5.3%), and those with a seat belt and air bag (4.3%) [5]. A recent meta-analysis revealed that the use of seat belts alone (OR 0.46) and seat belts with air bag deployment (OR 0.59) both decreased the incidence of facial fractures in MVCs when compared to unrestrained occupants. Air bag deployment alone (OR 1.00) was not effective in preventing facial fractures [6]. However, other authors have reported that drivers sustain fewer facial fractures when airbags are deployed either alone or in combination with a seat belt [7] and that the most important effect of the airbag is to decrease the incidence of facial fractures [5]. One retrospective study found that seat belt use did not decrease the incidence of major maxillofacial fractures sustained in MVCs [8], though this appears to be an outlier.

The severity of the maxillofacial injury is often communicated using the 1990 revision of abbreviated injury scale (AIS-90), which grades injuries from 1 (minor) to 6 (clinically untreatable). Since maxillofacial injuries are seldom fatal, both high-energy and low-energy injuries are given similar scores. For example, both a simple mandibular fracture and a minor superficial laceration are given an AIS-90 score of 1 [8]. Therefore, the objective severity of a maxillofacial injury is often independent of passenger restraint device use [1,8]. Most evidence supports the practice of passenger restraint devices as a means to reduce the frequency of maxillofacial fractures. The best outcomes are consistently demonstrated when air bags and seat belts are used in combination. Though the AIS scores of maxillofacial injuries are relatively low, these injuries are associated with significant financial, functional, and aesthetic ramifications. As MVCs are still the leading cause of facial fractures, the development of more reliable and effective injury prevention systems is necessary.

Updates in the Management of Facial Fractures

Effective management of facial fractures is crucial to restore compromised form and function, and typically involves open reduction and internal fixation. An essential component of fracture management is achieving adequate fracture segment reduction and stabilization, and miniplate osteosynthesis is the standard approach to achieve this [9]. In recent years, multiple modifications to the standard miniplate have been proposed.

Bioresorbable fixation systems

Titanium plates and screws are the gold standard for fixation of craniofacial fractures, and their use has been thoroughly investigated. Despite this, there are many disadvantages to metal fixation hardware including infection, hardware visibility and palpability, hypersensitivity to temperature variation, interference with radiologic evaluation, leaching of metal ions into the soft tissues, and the stress shielding effect [10]. Furthermore, titanium plates need to be removed in roughly

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10% of cases, subjecting the patient to an additional operation [11-15]. These shortcomings inspired the development of bioresorbable implants with hopes of minimizing hardware-associated complications and the need for hardware removal. Studies have proven that the mechanical strength of bioresorbable hardware is, in fact, inferior to that of titanium hardware [16,17]. Therefore, the use of bioresorbable fixation devices must be limited to select patients. Bioresorbable devices provide adequate stability to maintain reduction in low load bearing regions of the face, such as the zygoma, maxilla, and upper regions of the face [18-20]. Many studies have demonstrated satisfactory bone healing and stability (compared to metallic fixation) when applied in these regions [10,18,21-24]. Metallic plates are the standard devices for internal fixation of mandibular fractures. An *in vitro* study using sheep mandibles demonstrated significant stability differences between mandibular angle fractures fixed by resorbable and titanium miniplates [25]. Because the mandible is a load bearing bone, bioresorbable systems may not be strong enough to provide adequate stability in some fractures, particularly those that are comminuted or in the setting of multiple fractures of the mandible [23,24,26,27]. Biodegradable systems may be an option in compliant patients with simple fractures. Bioresorbable fixation systems stabilize fracture segments long enough for fracture healing and union to occur then degrade, thereby reducing complications frequently encountered with metallic hardware such as palpability, visibility, cold sensitivity, and need for removal. Of course, these devices are associated with their own complications. A meta-analysis including 1673 patients found that the bioresorbable group experienced significantly more complications when compared to the titanium group (RR 1.20), specifically foreign body reaction (RR 1.97) and mobility (RR 5.64) [28]. As mentioned previously, they are weaker than titanium counterparts. A heat source is often required to allow the polymer chains to bend without breaking, and the ensuing working time can be limited to 8-10 seconds [24]. Pretapping the screw threads is required before screw insertion [29]. Relatively higher costs and increased operative time have been a barrier to bioresorbable fixation devices supplanting metallic hardware as first-line options in most practices.

Three-dimensional fixation systems

Three-dimensional fixation systems are essentially two miniplates joined by interconnecting crossbars. They are not actually three-dimensional structures, but their closed quadrilateral-shape yields stability in three dimensions when secured with bone screws [30]. Multiple studies have found them effective treatment alternatives to standard miniplates in the management of mandibular angle fractures (MAF) [31,32]. MAF fixation with 3D plates is associated with fewer complications, and the plates are often less time intensive and simpler to apply compared to standard miniplate systems [33,34] Though less thoroughly investigated, one study supports the use of 3D plating systems in the fixation of midface fractures [9].

Locking plate systems

Locking plates utilize double threaded screws that lock into both the bone and the plate to create an internal "external" fixator of sorts. Thus, the fractures segments can be stabilized without compressing the bone tightly to the plate [35]. As a result, locking plate systems offer many advantages including easier plate adaptation (as the plate does not require intimate contact with underlying bone), less impairment of blood supply to underlying bone, and less screw loosening [35,36]. *In vitro* studies have demonstrated that locking plate systems provide more stability and greater resistance to displacement than standard miniplates

[36,37]. Locking plates are often used in reconstructive procedures and are considered valid alternatives to conventional miniplates [38-40]. Prospective studies have found similar complication rates between the use of locking and nonlocking plates [41,42]. As such, any differences in complication rates are more likely related to bone quality and surgical technique than the fixation system, and the decision to use locking or nonlocking plates should be based upon cost and ease of placement [42]. Clearly, however, locking plates require less bending to adapt the plate to the bone.

3D modeling, computer-assisted design, and virtual surgical planning

The unique three-dimensional contour and nonlinearity of the facial skeleton presents challenging management issues for facial fractures, and recent advances in software technology and 3D modeling have revolutionized management. Three-dimensional modeling can be used as an adjunct to standard preoperative preparation. 3D models may serve as a template upon which fracture fixation plates are precontoured prior to entering the operating room, thus reducing operation time [43-46]. 3D printers have also been used to create custom-designed titanium implants [47,48] that may be preferred over conventional implants due to their precise fit and reduced surgical time [47,49]. 3D modeling can be used to rehearse complex procedures, giving surgeons the opportunity to become familiar with the approach and troubleshoot problems prior to entering the operating room [47]. One author's institution has been using three-dimensional modeling and virtual surgical planning for all craniomaxillofacial reconstructive and ablative cases for more than 5 years [50]. Virtual surgical planning and model design allows the team to design the optimal approach preoperatively, construct guides for the surgeon to follow intraoperatively, and compare the actual outcome to the virtual design [50]. These technologies have been used to reconstruct a multitude of craniofacial defects of the midface [49], mandible [43], and orbit. Orbital wall fractures are ideal candidates given the complex anatomy and challenging exposure of the orbit and difficulty restoring its precise volume. Many of the common complications associated with these injuries have been addressed and successfully managed with computer-assisted surgical planning and 3D modeling [51-53]. As the costs continue to decline and software tailored to craniofacial reconstruction is developed, the role of 3D modeling and computer-assisted surgical planning will continue to evolve.

Intraoperative 3D imaging

Computed tomography (CT) is the standard imaging modality to evaluate midfacial fractures and is typically repeated postoperatively to confirm adequate reduction. However, the indications for intraoperative imaging are poorly defined and based mostly on surgeon preference [54]. Advances in cone beam CT (CBCT) coupled with intraoperative C-arm systems render intraoperative 3D imaging a feasible option in craniofacial surgery. Intraoperative imaging provides immediate postreduction feedback that allows the surgeon to immediately correct any errors in fracture reduction, thereby optimizing fracture repair and avoiding potential reoperations [55-57]. Revision rates have varied from 14% to 26% when intraoperative imaging is incorporated into the surgical plan [57-59]. Some authors suggest utilizing intraoperative imaging during repair of all midface fractures [60-63]. Intraoperative imaging does have disadvantages including expense and availability of the scanner, concerns about excessive radiation exposure, increased operative time, and increased costs [56,59]. As most intraoperative revisions have occurred in more complex cases [59], many authors recommend the use of intraoperative imaging only in the most complex

facial fractures [54,56,59]. Though benefits of intraoperative imaging have been demonstrated, controlled prospective studies should be conducted before concrete recommendations are devised.

Conclusion

Current passenger restraint devices have consistently proven to decrease the rates of facial fractures in MVCs, but improvements can be made to further reduce fracture rates and the severity of maxillofacial injuries sustained in these accidents. Innovations in plate fixation systems, imaging technology, and virtual surgical planning contribute to the dynamic landscape of facial fracture management. Well-designed prospective and controlled studies of these technologies are necessary in order to establish rigorous, evidence-based guidelines.

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