

Virtual Surgical Planning and Intraoperative Imaging in Management of Ballistic Facial and Mandibular Condylar Injuries

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KEYWORDS

• Ballistic • Gunshot • Virtual surgical planning • Intraoperative imaging

KEY POINTS

- The type of ballistic determines the extent of the injury and timing of treatment.
- Staged treatment not only is helpful for surgical planning but also allows for more predictability.
- Virtual surgical planning can help determine treatment sequence and decrease operative time.
- Intraoperative imaging helps increase operative accuracy and helps prevent cumulative error and in some cases reoperation.
- Intraoperative navigation can help identify fracture fragments and assist with hardware placement.

Introduction

Gunshot wounds to the maxillofacial area are relatively common in the United States. However, with increasing terror attacks around the world, treatment of gunshots should be part of every facial trauma surgeon's armamentarium.

Imaging is essential in managing facial gunshots. Although computed tomographic (CT) scan has become the mainstay of imaging for extensive facial injury, the use of and availability of intraoperative CT scans are still limited. Virtual surgical planning, on the other hand, does not require additional equipment; it does, however, require additional time for preoperative planning.

In order to manage and treat gunshot wounds, it is crucial to understand the extent of the injury. The extent is determined by the energy produced by the projectile. The kinetic energy equation ($KE = 1/2 \text{ mass} \times \text{velocity}^2$) illustrates the importance of velocity. It is therefore helpful to separate ballistic injuries by velocity.

- High velocity greater than 300 m/s
- Low velocity less than 300 m/s
- Shotgun

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Ballistic injuries inherently bare the question whether the ballistic fragments should be removed. Guidelines exist to answer that question.

Open versus closed treatment of condyle fractures is still debated and often depends on training background. It is, however, important to determine if the condylar fragment is salvageable and if application of hardware is possible on the remaining condylar fragment.

Surgical Technique

Preoperative planning

Given the close anatomic proximity, ballistic injuries to the condyle are often associated with vascular injury. Controlling bleeding is essential in the initial evaluation. Packing and targeted ligation can assist in hemostasis. Ligation of the external carotid artery usually is not very effective. On the other hand, superselective angiography with embolization can be helpful and should be considered in selective cases with difficult-to-control hemorrhage.

Once hemostasis is achieved, the mechanism of the injury needs to be considered. High-velocity gunshot wounds cause injury by 3 mechanisms:

1. Penetration
2. Cavitation
3. Fragmentation

Penetration injuries are caused by the direct path of the projectile as it passes through the body. Cavitation injury is caused by the energy dispersed by the projectile; this is also referred to as "shock wave." The damage caused by cavitation is often not clinically visible on initial examination.

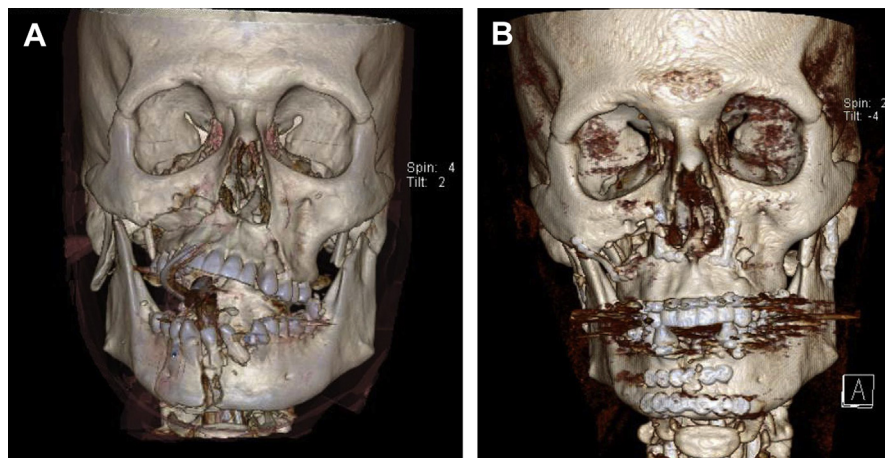


Fig. 1 Injury resulting in maxillary cant and impaction (A), which will need to be addressed before aligning the mandible to the maxilla (B).

Fragmentation can not only come from the projectile itself but also can come from secondary sources when the bullet engages solid structures such as bone, teeth, or dental restorations.

Low-velocity gunshots have much less energy, and as a result, a smaller, more linear path of injury with less cavitation. Low-velocity injuries still carry an 11% mortality within the first 24 hours.

Timing of treatment needs to be considered and should depend on the velocity of the injury. Infection rates are similar between delayed and immediate reconstruction and should therefore not be the determining factor for timing. Particularly in high-velocity injuries, there is an increased amount of wound contracture and die back, which can lead to less predictable results and future functional deformities. It is advisable to first debride the wound and allow for die back to occur before permanent reconstruction.

The invention and implementation of Intraoperative Perfusion Assessment Systems in which a fluorescent tracer is injected intravenously and perfusion is recorded with a fluorescent camera could help determine the extent of the ballistic injuries not visible to the human eye. This imaging modality can identify a lack of perfusion and possibly more accurately identify the amount of die back that is to be expected. At this point, how to best implement this technology and what clinical indications it has is yet to be determined, and it is hoped will be elucidated in future research studies.

The necessary delay in definitive treatment to allow for die back to occur allows time for virtual surgical planning. Staged treatment is often mandated to accommodate for other associated injuries. Although delayed reconstruction is preferred, there have been reports that found the need for fewer and less complex revisions after immediate reconstruction.

A high-quality 1-mm-slice CT scan is ideal for virtual surgical planning and often required when considering custom hardware fabrication. Although larger slice spacing CT scans can be used to make the virtual planning, they are less accurate and do not allow for custom hardware fabrication. Dental restorations and other implanted metallic material can cause significant scatter in medical grade CT scans. Cone beam computed tomography (CBCT), on the other hand, causes less scatter but is often not available in the hospital setting. Digital CT scans are easily uploaded for virtual surgical planning. Planning can be done by the surgeon independently, but it is often helpful and more efficient to enroll the help of an experienced third party, usually resulting in a virtual planning session easily accessed via phone or Internet.

Questions to consider for planning include the following:

1. Is the maxilla stable? (Fig. 1)
2. Is there a Unilateral or a bilateral condyle fracture?
3. What is the state of the dentition?
4. Is there loss of posterior mandibular height? (Fig. 2)

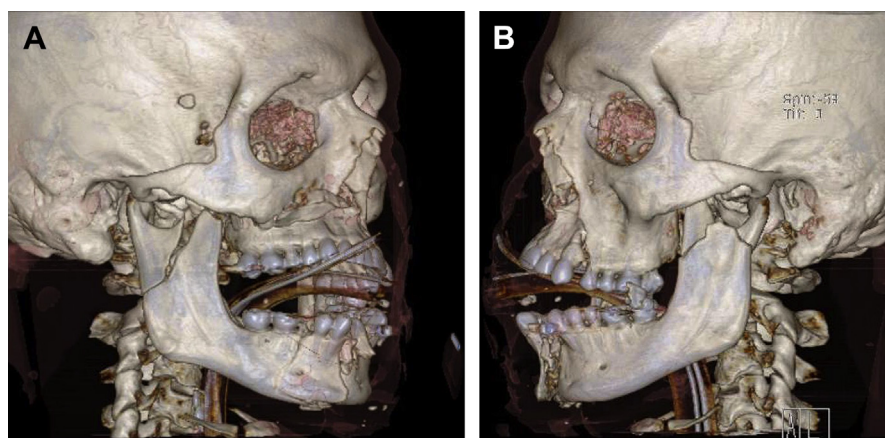


Fig. 2 Loss of condylar height bilaterally as the right (A) and left (B) fracture segments overlap.

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