

Utilization of Computed Tomography Image-Guided Navigation in Orbit Fracture Repair

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INTRODUCTION

It is estimated that approximately 25% of facial trauma involves an orbital fracture.¹ Surgical repair of orbital fractures is only required when restoration of orbital anatomy, volume, or function is necessary. A variety of techniques have been described to reconstruct orbital fractures, and all are associated with low morbidity.^{2–4} However, even in the hands of an experienced surgeon, complications such as orbital dystopia, extraocular muscle injury, diplopia, and blindness still occur.^{5,6}

In the current age of advancing technology, surgeons are constantly pioneering new modalities that improve surgical accuracy and reduce perioperative morbidity. Computed tomography (CT) image-guided navigation is one technology that may prove useful in maxillofacial surgery. It allows a surgeon to utilize real-time intraoperative localization of skeletal landmarks based on a preoperative CT scan.^{7,8} Initially introduced in the late 1980s, CT image-guided navigation allowed neurosurgeons the ability to better locate intracranial tumors.⁷ Today, CT image-guided navigation is used in most intracranial neurosurgical procedures, and its use has expanded to several surgical subspecialties.^{9–14}

Orbital reconstruction is highly reliant on anatomical accuracy and localization. As a result, preoperative planning and intraoperative anatomical identification is critical. Planning for orbital reconstruction is routinely based on preoperative CT scans. The ability to use preoperative imaging at the time of surgery allows precise

anatomical localization. The authors hypothesize that the use of CT image-guided navigation in orbit fracture reconstruction is feasible and improves surgical accuracy. This modality may prove to reduce complications and morbidity in many complex maxillofacial procedures in the future.

MATERIALS AND METHODS

All subjects who underwent orbit fracture reconstruction utilizing CT-guided navigation at the University of California Los Angeles Medical Center and the University of Kansas Medical Center were included for study. The study period extended from July 1, 2010 to October 1, 2011. Institutional review board approval was obtained at both institutions. Medical records were reviewed to collect patient demographics, preoperative consultation, radiographic imaging, operative reports, and postoperative complications and follow-up.

Intraoperative CT Image Guidance

A preoperative maxillofacial CT scan with 0.5- to 1-mm cuts in the axial, coronal, and sagittal planes was performed preoperatively (Fig. 1). The images were loaded into the Brainlab image guidance system (Brainlab, Feldkirchen, Germany) or the Medtronic surgical navigation system (Medtronic, Minneapolis, MN) on the day of surgery. Intraoperative surface marker registration and verification was performed using a blunt registration probe prior to navigational probe use (Fig. 2).

Orbital exposure was obtained through a transconjunctival incision without a lateral canthotomy. A transcaruncular extension was added if medial orbital wall reconstruction was necessary. After preseptal dissection and subperiosteal undermining, the fracture was completely exposed. The posterior aspect of the fracture (the posterior bony edge) was identified using the straight, blunt, image-guidance probe (Fig. 3). This surgical landmark corresponded to the posterior shelf of the maxilla for orbital floor fractures and the ethmoid bone for medial wall fractures. Once the posterior fracture location was confirmed, the distance between the posterior aspect of the fracture and the orbital rim were measured. These values were compared to the preoperative CT scan for accuracy and anatomic conformation.

Orbital reconstructions were performed by a variety of techniques including: calvarial bone graft, MEDPOR containing titanium mesh (Newnan, Georgia), titanium MatrixMIDFACE

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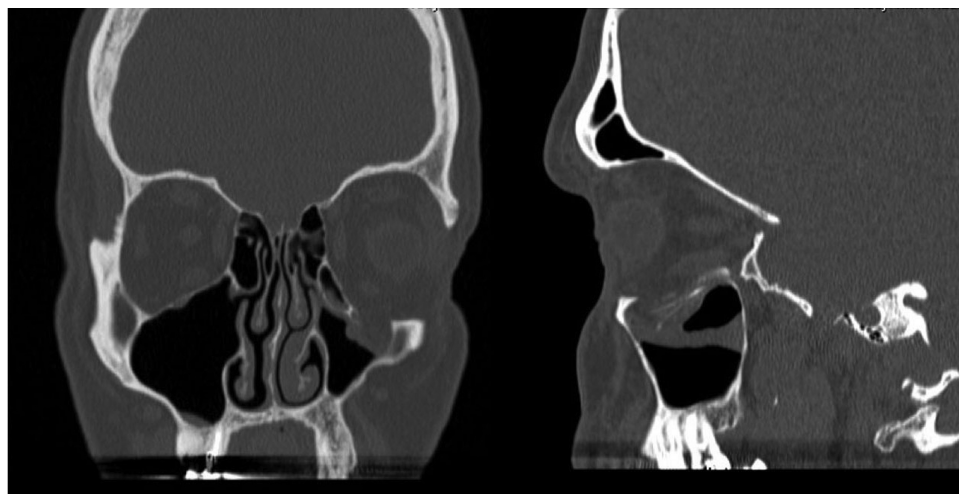


Fig. 1. Preoperative coronal and sagittal computed tomography scans of left orbital floor fracture (9 mm × 30 mm). A small amount of fat herniation is noted.

performed orbital plate (DePuy Synthes, West Chester, PA), and 0.4-mm SUPRAMID foil (S. Jackson, Inc., Alexandria, Virginia) implants. Once correctly positioned, the anatomy of the reconstruction was confirmed using the straight image-guidance blunt probe again (Fig. 4). The probe was positioned at the posterior aspect of the implant, and its location was confirmed just above the posterior shelf on the CT image-guidance system. The periorbital contents were then redraped and the incision was closed. A postoperative CT scan was taken to confirm the reconstructive plate position after the first procedure of the series. Postoperative CT scans were not obtained in subsequent patients as it was not clinically indicated (Fig. 5). Patients were seen for follow-up at 2 weeks, 1 month, 2 months, 4 months, and 6 months.

RESULTS

Eight patients were evaluated for orbital floor fractures, had complete records, and were included in this study. Ten orbital reconstructions were performed on the eight patients (two cases were bilateral). Preoperative CT scans confirmed an orbital floor blow-out fracture in all cases. The medial orbital wall was also involved in three cases. There were six males and two females in the

study, with the average age being 29.2 years (range, 26–42 years). The primary preoperative symptom was diplopia (12.5%). Operative indications included entrapment (12.5%) and risk for post-traumatic enophthalmos (87.5%), both of which were determined based on examination by the primary surgeons (B.T.A. and J.P.B.) and an ophthalmologist. Patients were categorized to be at risk of post-traumatic enophthalmos based on the presence of one or more of the following: enophthalmos, exophthalmos, entrapment, orbital floor comminution, or an orbital floor blow-out fracture > 50% the diameter of the floor. There were no preoperative concerns found on ophthalmologic evaluation prior to surgical repair. All surgeries were performed within 2 weeks of the initial injury.

The distance from the anterior orbital rim to the posterior aspect of the fracture was a mean of 36 mm (range, 34–41 mm) on preoperative CT scans. Intraoperative localization of the posterior fracture element after CT image-guided localization was confirmed to within 1 mm (mean, 35.5 mm) in all participants in this study. After calvarial bone graft or implant placement, accurate anatomic reconstruction was localized to 1 to 2 mm in



Fig. 2. Frameless computed tomography-guided navigation. (Left) Headpiece attached to patient intraoperatively, and blunt probe is used as a guide to direct functions on the image-guidance display screen. (Right) Image-guidance display screen showing intraoperative marking with blunt probe facilitating noninvasive, intraoperative, anatomical landmark registration. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

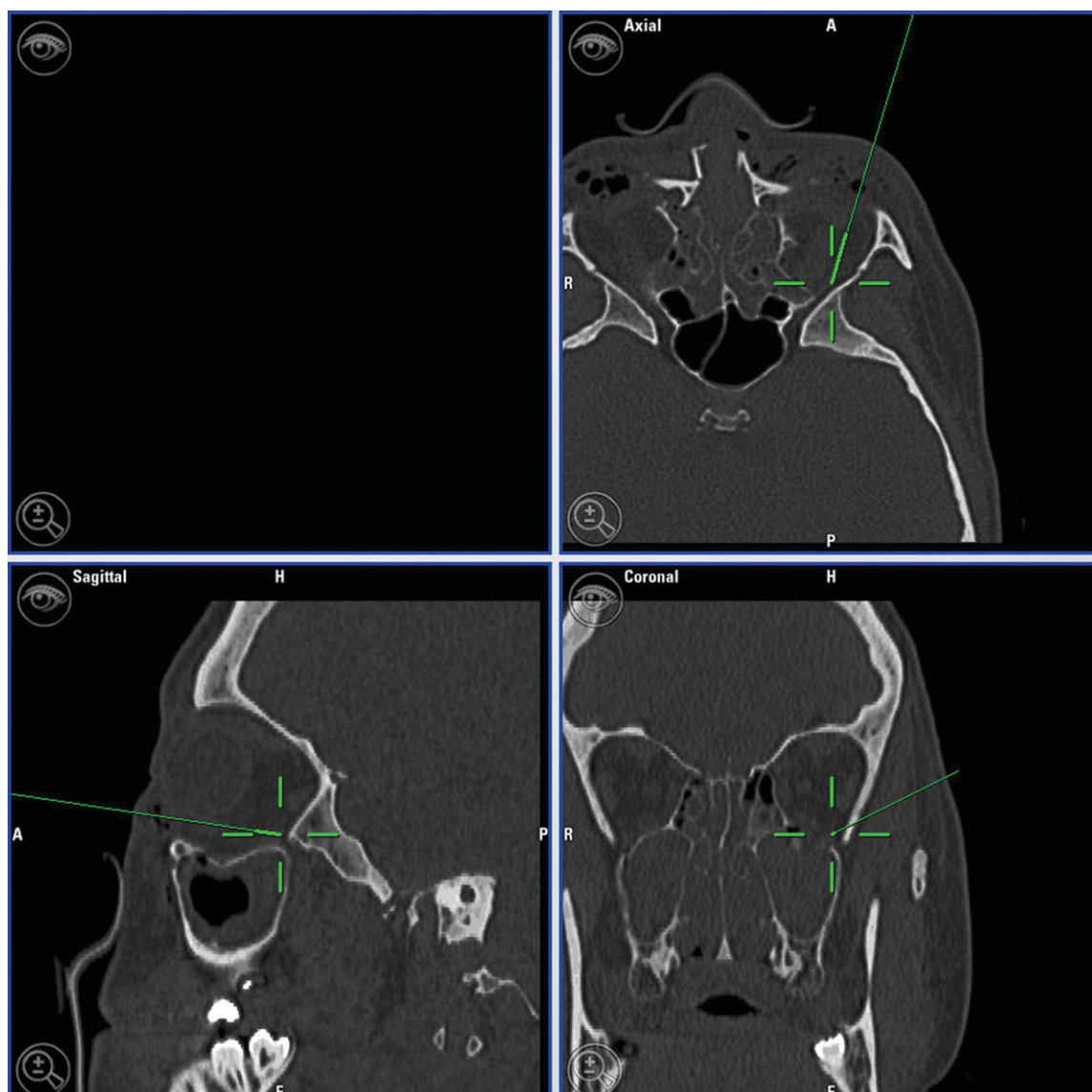


Fig. 3. Intraoperative navigation with computed tomography-guided system. Blunt probe is used to identify the posterior aspect of the orbit floor fracture. Probe position is confirmed on the display screen in the axial, coronal, and sagittal planes. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

all cases (values varied with the thickness of the reconstruction material).

All patients were observed overnight in the hospital following surgery and discharged home the following day. Postoperative follow-up was carried out to 6 months postoperatively in all patients. There were no postoperative complications identified. Ocular function was restored completely in all cases postoperatively. No enophthalmos was noted and no asymmetries were seen on comparison of the nonoperated eye in unilateral procedures (six cases). In bilateral cases, correct anatomic position of the anterior cornea was noted 14 to 18 mm anterior to the lateral orbital rim on physical exam.

DISCUSSION

Orbital trauma is a common encounter for head and neck surgeons. Indications to surgically reconstruct or-

bital fractures include: 1) entrapment, 2) significant enophthalmos, 3) increased orbital volume, and 4) comminution of the orbital floor > 50%.

The orbital floor has a concaved curvature when viewed sagittally. The posterior shelf of the maxilla represents the posterior limits of the floor and represents the start of the optic canal. The shelf is comprised of both maxilla and sphenoid components. This anatomic landmark is approximately 40 mm from the orbital rim. Its identification is often difficult during surgery because of displaced orbital contents, intraoperative bleeding, and poor lighting. Inexperienced surgeons are often apprehensive to dissect too far posteriorly for fear of injuring the optic nerve. A common misconception in orbital floor reconstruction is that the floor reconstructive material only needs to cross the "vertical equator" of the globe to provide adequate support for orbital structures.

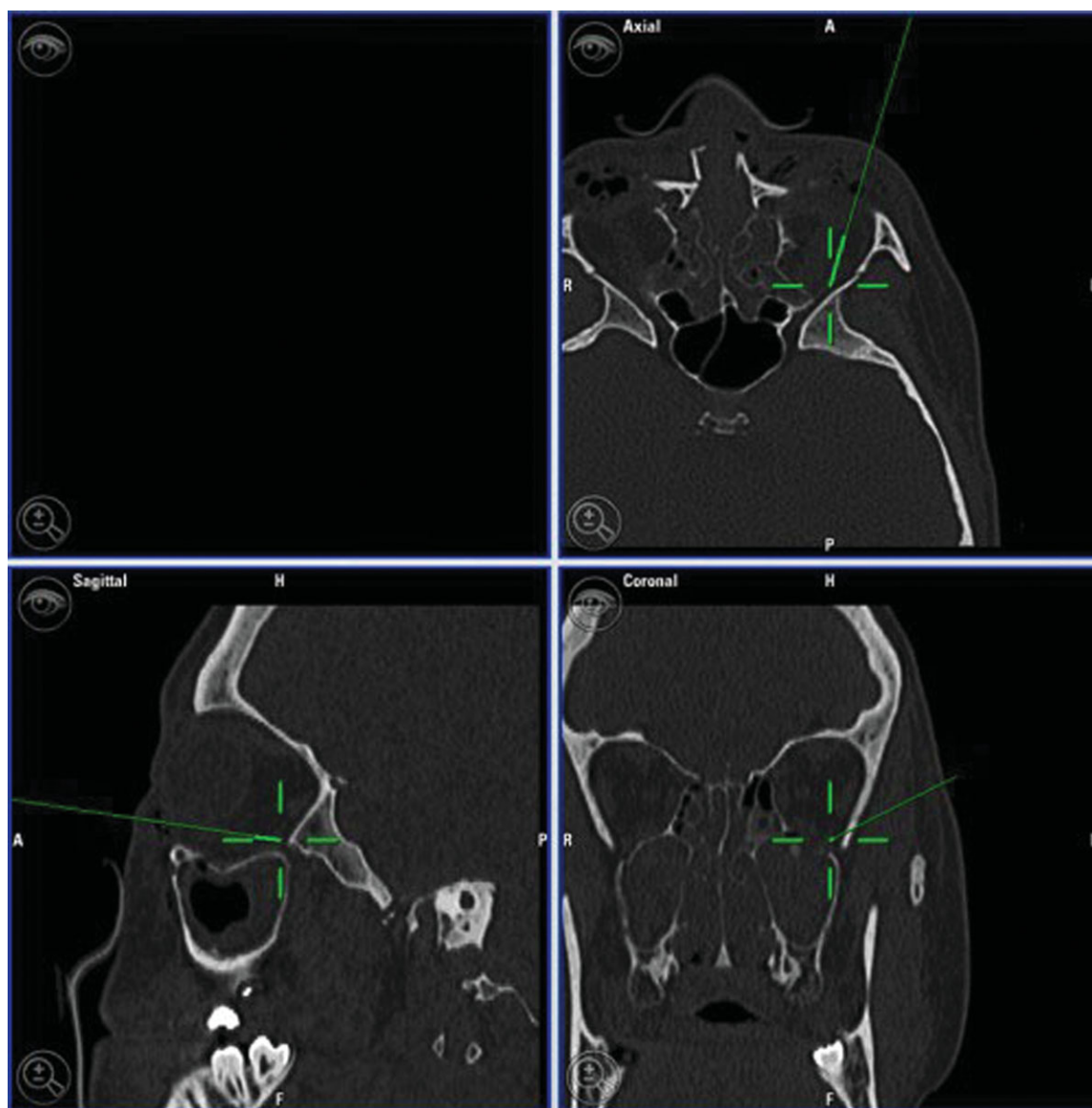


Fig. 4. Intraoperative navigation with computed tomography-guided system. Blunt probe is used to confirm reconstruction plate positioning on the posterior shelf of the maxilla. Probe position is slightly higher (approximately 1 mm) and accounts for the reconstruction plate thickness. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

However, failure to reconstruct the entire orbital floor by resting the cranial bone graft or implant material on the posterior shelf of the maxilla may result in malpositioned plates (Fig. 6). This can lead to increased orbital volume and a higher incidence of clinically significant enophthalmos. Of note, all patients in this study were isolated orbit fractures with the exception of one patient who had an accompanying naso-orbitethmoid (NOE) fracture. We did not find that the NOE fracture altered the accuracy of the intraoperative measurements or confirmation of plate position. There was no displacement of the anterior orbital rim in the patients treated in this study. In the event that the anterior orbital rim (or the chosen point of reference) is displaced, it is important for the surgeon to note the displacement on preoperative

scans and incorporate it into preoperative measurements to prevent skewed intraoperative measurements.

A postoperative CT scan was obtained in the first patient of the study; however, a postoperative scan was not obtained in subsequent patients in this study. The research team determined that a postoperative CT scan was not clinically indicated unless a postoperative complication occurred or if intraoperative navigation was unsuccessful in confirming plate position. Normal vision, absence of entrapment, and globe symmetry were present in all patients up to 6 months postoperatively. On completion of reconstructive plate placement intraoperatively, the blunt probe was successfully utilized to confirm plate position in all documented cases (Fig. 4). The successful localization of plate placement intraoperatively highlighted an advantage of this technology for

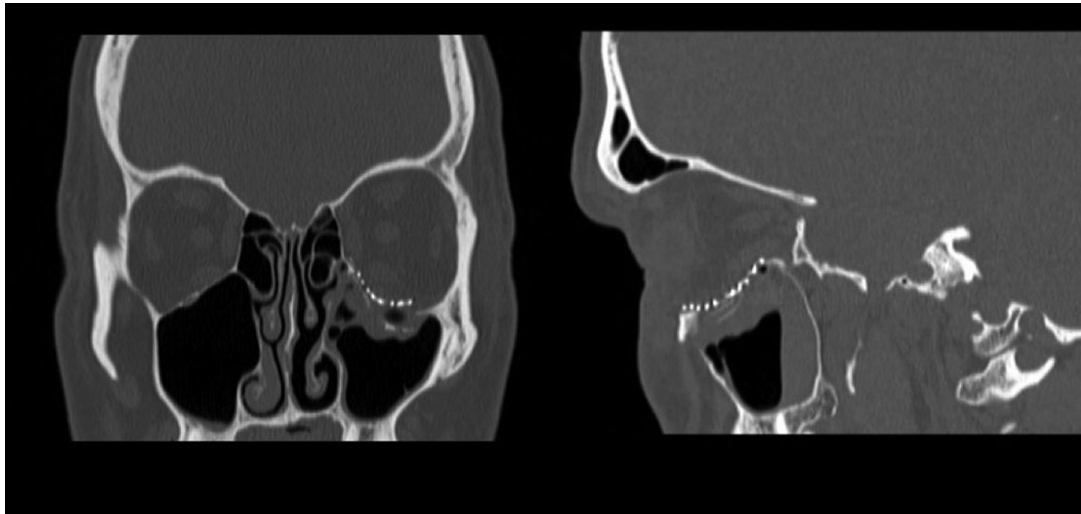


Fig. 5. Postoperative coronal and sagittal computed tomography scans. Reconstructive plate is noted to rest on posterior maxillary shelf in both views.

situations where a postoperative scan may be desired by the surgeon. In those situations, intraoperative image guidance potentially eliminates the necessity of obtaining a postoperative CT scan, therefore avoiding the cost of the scan and associated radiation exposure to the patient.

CT image-guided navigation allows the surgeon the ability to localize fixed anatomic positions such as bone by viewing real-time images in the axial, coronal, and sagittal planes. In addition, intraoperative navigation helps reduce unnecessary surgical manipulation and eliminate dangerous dissection close to the optic canal.¹² This technology provides a real advantage in orbit sur-

gery for both experienced, and more importantly, surgeons less familiar with the orbital anatomy.

CONCLUSION

Anatomy is an important consideration in surgical planning and execution of orbital reconstruction where the primary aim is reestablishment of native globe position. Intraoperative CT image-guided navigation aides in the safe identification of the posterior fracture limits facilitating near anatomic reconstruction. With time and experience, we predict that this technology can assist in the prevention of plate malposition and avoidance of unwelcome postoperative complications.

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Fig. 6. Inadequate orbital reconstruction with plate malposition. Computed tomography scan demonstrating displaced orbital volume (green triangle) as a result of the reconstructive plate (green arrow) not resting on posterior maxillary shelf.