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Predictability in orbital reconstruction. A human cadaver study, part III: Implant-oriented navigation for optimized reconstruction

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ABSTRACT

Navigation-assisted orbital reconstruction remains a challenge, because the surgeon focuses on a two-dimensional multiplanar view in relation to the preoperative planning. This study explored the addition of navigation markers in the implant design for three-dimensional (3D) orientation of the actual implant position relative to the preoperative planning for more fail-safe and consistent results. Pre-injury computed tomography (CT) was performed for 10 orbits in human cadavers, and complex orbital fractures (Class III/IV) were created. The orbits were reconstructed using preformed orbital mesh through a transconjunctival approach under image-guided navigation and navigation by referencing orientating markers in the implant design. Ideal implant positions were planned using preoperative CT scans. Implant placement accuracy was evaluated by comparing the planned and realized implant positions. Significantly better translation (3.53 mm vs. 1.44 mm, $p = 0.001$) and rotation (pitch: $-1.7°$ vs. $-2.2°$, $P = 0.52$; yaw: $10.9°$ vs. $5.9°$, $P = 0.02$; roll: $-2.2°$ vs. $-0.5°$, $P = 0.16$) of the placed implant relative to the planned position were obtained by implant-oriented navigation. Navigation-assisted surgery can be improved by using navigational markers on the orbital implant for orientation, resulting in fail-safe reconstruction of complex orbital defects and consistent implant positioning.

1. Introduction

The treatment of orbital defects aims at optimal reconstruction of lost anatomical boundaries (Essig et al., 2013; Dubois et al., 2015a, 2015c; Schreurs et al., unpublished results). The form factor of preformed orbital plates enables realistic reconstruction of most orbits (Metzger et al., 2007; Andrades et al., 2009; Strong et al., 2013; Dubois et al., 2015d, unpublished results). However, intraoperative errors may lead to misplaced implants, resulting in poor clinical outcomes (Dubois et al., 2015a, 2015b). Despite a steep learning curve (Cai et al., 2012), navigation-assisted surgery may be beneficial for orbital reconstruction. Several authors have shown accurate orbital reconstruction and reduced rates of repeat procedures with the application of navigation guidance (Collyer, 2010; Cai et al., 2012; Markiewicz et al., 2012; Zhang et al., 2012; Essig et al., 2013; Yu et al., 2013; Dubois et al., 2015b). However, none of the previous clinical studies included a control group in their study design.

A recent cadaveric study demonstrated that navigation-assisted orbital reconstruction significantly improves implant positioning, enabling more accurate reconstruction than a traditional solitary transconjunctival approach (Dubois et al., 2015e, unpublished results). The disadvantage of computer-assisted surgery (CAS) is the calibration error in the registration phase, which is not unusual. Several authors have suggested that a calibration error smaller than 1 mm in all dimensions (x-, y-, and z-axes) is acceptable (Markiewicz et al., 2011, 2012; Widmann et al., 2012; Yu et al., 2013; Essig et al., 2013). Accordingly, the perfect orbital reconstruction is one in which the error in implant positioning is less than or equal to the calibration error in CAS.

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Most current navigation systems provide additional intraoperative information if anatomical boundaries are realized by the multiplanar view. Notably, although three-dimensional (3D) information is available, surgeons focus on two-dimensional (2D) multiplanar images (Fig. 1). Such views show only outlines and not implant position, increasing the possibility of errors in implant positioning. The aim of this pilot study was to explore the suitability of implant-oriented navigation to optimize orbital reconstruction.

2. Material and methods

Five human cadaveric heads of previously used specimens were obtained from the Department of Anatomy of the Academic Medical Hospital, University of Amsterdam, providing 10 orbits for this study.

In each case, the orbital floor and medial wall were fully exposed through a standard transconjunctival incision. Complex orbital defects (Classes III and IV) were created by Piezosurgery (Mectron S.p.A., Carasco, Italy). Computed tomography (CT) scans (Somatom Sensation 64, Siemens Medical Solutions, Forchheim, Germany) of the cadaveric heads were obtained of the intact orbits (pre-injury, T0), orbital defects (preoperative, T1), and reconstructed orbits (postoperative, T2). The scan parameters were as follows: collimation, 20 × 0.6 mm; 120 kV; 350 mAs; pitch, 0.85; field of view, 30 cm; matrix, 512 × 512; slice thickness, 0.75 mm; slice increment, 0.4 mm; bone kernel, H70s; bone window, W1600/L400.

Initially (image-guided method), all of the orbits were reconstructed under image-guided navigation (Curve, BrainLAB AG, Feldkirchen, Germany). In the second session (implant-oriented method), the orbits were reconstructed by the same surgeon using implant-oriented navigation. All orbits are reconstructed by one surgeon (L.D.). During preoperative planning (iPlan 3.0.5, BrainLAB AG), navigational markers were embedded in the implant design to serve as reference points (Fig. 2). These markers enabled intraoperative implant orientation by providing feedback on displacement relative to the planned position of the markers (Fig. 3). In both sessions, the same preformed orbital mesh (KLS Martin Group, Tuttlingen, Germany) was fixed with a single osteosynthesis screw. Drill holes were camouflaged between the sessions by filling them with DuraLay (Reliance Dental Manufacturing Co., Worth, IL, USA).

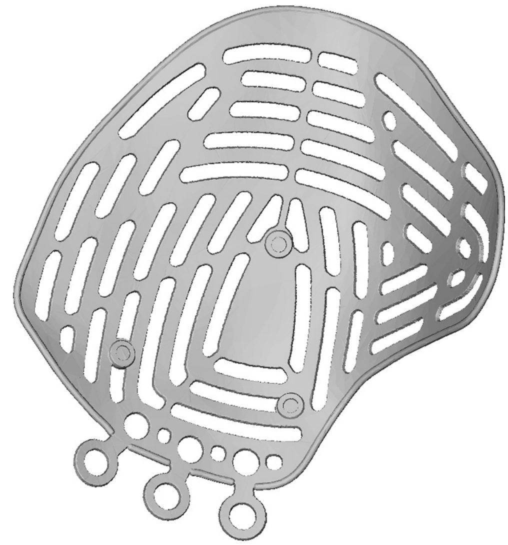

Fig. 2. Navigational markers embedded in the implant design.

2.1. Contour analysis

The quality of reconstruction was evaluated using iPlan software (version 3.05, BrainLAB AG). The optimal implant position was

Fig. 1. Surgeon's focus for multiplanar view showing two-dimensional implant orientation.