Expert Consensus on Navigation-guided Unilateral Orbital Fracture and Orbital Floor Reconstruction Techniques

Yang HE[1], Yi ZHANG[1], Guang Yan YU[1], Chuan Bin GUO[1], Guo Fang SHEN[2], Xin PENG[1], Xiao Jing LIU[1], Jing WANG[1], Wen Bo ZHANG[1], Yan Pu LIU[3], Xiao Ming GU[4], Wei Dong TIAN[5], Li LU[6], Zu Bing LI[7], Shi Lei ZHANG[2]; Society of Oral and Maxillofacial Surgery, Chinese Stomatological Association

Orbital fracture and orbital floor reconstruction surgery is characterised by limited surgical exposure and high risks. Before the advent of digital technology, the design and implementation of the surgical scheme for orbital floor reconstruction surgery mainly depended on the intuitive understanding of imaging and the clinical experience of surgeons, with strong unpredictability and experience dependence. Surgical navigation systems with real-time positioning and imaging functions, when used in orbital reconstruction surgery, can detect the real-time intraoperative position, avoid risks, and assist in locating the reconstruction position to ensure the accuracy of orbital reconstruction, with the help of a preoperative surgical plan. Many studies have confirmed its effect. Unilateral orbital fracture and orbital floor reconstruction surgery is one of the earliest and most widely used surgical techniques in maxillofacial surgery. Experts from the Society of Oral and Maxillofacial Surgery, Chinese Stomatological Association have fully discussed and formulated this expert consensus on navigation-guided unilateral orbital fracture and orbital floor reconstruction techniques to standardise the clinical surgical procedures and promote its application.

Key words: *navigation technique, orbit fractures, unilateral*
Chin J Dent Res 2020;23(1):51–55; doi: 10.3290/j.cjdr.a44336

1 Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, P.R. China.
2 Department of Oral and Craniomaxillofacial Surgery, Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, P.R. China.
3 Department of Oral and Maxillofacial Surgery, School of Stomatology, Air Force Military Medical University, Xi'an, P.R. China.
4 Department of Oral & Maxillofacial Surgery, The Third Medical Centre of Chinese PLA General Hospital, Beijing, P.R. China.
5 Department of Oral & Maxillofacial Surgery, West China Stomatology Hospital, Sichuan University, Chengdu, P.R. China.
6 Department of Oromaxillofacial-Head and Neck Surgery, School of Stomatology, China Medical University, Shenyang, P.R. China.
7 Department of Oral and Maxillofacial Surgery, School of Stomatology, Wuhan University, Wuhan, P.R. China.

Corresponding author: Prof. Yi ZHANG, Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, 22# Zhongguancun South Avenue, Haidian District, Beijing 100081, P.R. China. Tel: 86-10-82195158; Fax: 86-10-82195158. Email: zhangyi2000@263.net

This article was first published in the Zhonghua Kou Qiang Yi Xue Za Zhi (Chinese Journal of Stomatology) 2019;54(7):440–444 (in Chinese), and this is the second publication using the same contents as the original publication.

Orbital fracture and orbital floor reconstruction surgery is characterised by limited surgical exposure and high risks. Surgical navigation systems with real-time positioning and imaging functions, when used in orbital reconstruction surgery, can detect the real-time intraoperative position, avoid risks and assist in locating the reconstruction position to ensure the accuracy of orbital reconstruction, with the help of a preoperative surgical plan. Many studies have confirmed its effect. Unilateral orbital fracture and orbital floor reconstruction surgery is also one of the earliest and most widely used surgical techniques in maxillofacial surgery.

Experts from the Society of Oral and Maxillofacial Surgery, Chinese Stomatological Association have fully discussed and formulated this expert consensus on 'Navigation-guided unilateral orbital fracture and orbital floor reconstruction techniques' to standardise the clinical surgical procedures and promote its application[1-7].

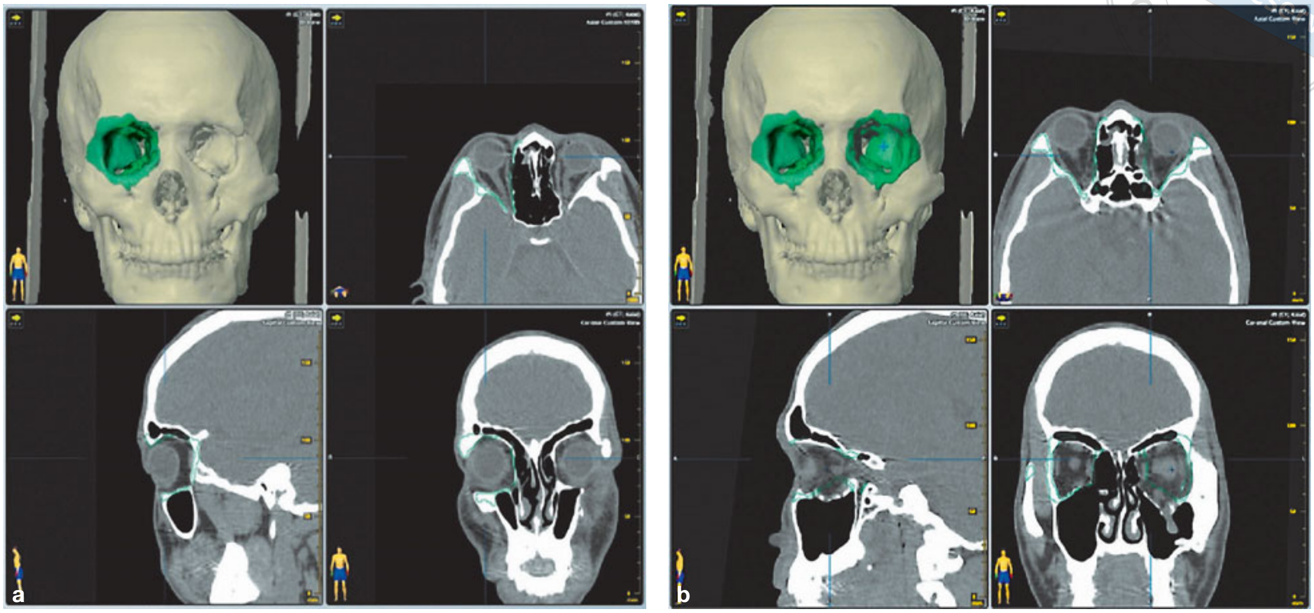

Fig 1 **(a)** Orbit of the unaffected side segmented and **(b)** mirrored to the affected side.

Indications for the technique

- Unilateral orbital fracture or large orbital wall defects (orbital fracture ≥ 50%, or orbital defects ≥ 2 cm^2) diagnosed by computed tomography (CT);
- Forced duction test (+); CT scans showing incarceration of the extraocular muscle, which impedes eyeball movements, causing continuous diplopia;
- Significant enophthalmos (≥ 2 mm difference in the eminence of the eyeballs).

Equipment required for the technique

Data acquisition equipment

Data from CT scans should be commonly used in bone surgery, and a helix slice thickness less than 1.25 mm can meet the accuracy requirements for maxillofacial surgery.

Digital surgical software

Digital surgical software can be mainly used for preoperative surgical planning and postoperative evaluation of navigation-guided surgery. The navigation-related digital surgical software should have the following features:

- Three-dimensional (3D) reconstruction and measurement (including the length, angle and volume) of the data;
- Surgical planning, including modules such as segmentation, merging, repositioning and mirroring;
- Postoperative evaluation of the accuracy of surgery and surgical outcome. To evaluate the accuracy of navigation-guided surgery, symmetry measurements and 3D colour map analyses should be used often to compare the bone location between the preoperative design and the actual surgical results.

Surgical navigation system

The surgical navigation system is the key part of the navigation operation, and many surgical navigation systems have emerged both in China and internationally. Passive infrared positioning is more convenient and flexible, and is currently the most commonly used location method.

Spatial registration methods comprise the fiducial-based, paired-point transformation (i.e. coordinate registration) and the surface contour matching (i.e. non-coordinate registration), and the combination of the two[5,6,8-10]. All of the above methods meet the requirements for maxillofacial navigation surgery.

Orbital reconstruction material

Titanium meshes are commonly used for orbital reconstruction and are currently the first-choice material for post-traumatic orbital reconstruction due to their convenience of fabrication and biocompatibility. Titanium meshes for orbital reconstruction include computer-assisted prefabricated individual titanium meshes and standard orbital reconstruction titanium meshes, both of which meet the requirements for orbital reconstruction[11-14]. Other types of materials include non-metallic materials such as porous polyethylene implants.

Preoperative data acquisition and surgical planning

Preoperative data acquisition

All patients should undergo preoperative spiral CT scans. The CT data should be exported as DICOM files.

According to different registration methods, the following aspects need to be noted during data acquisition: 1) For the surface contour matching method, the data acquisition time should be as close as possible to the operation time, and the scanning range (usually from the cranial dome to the hyoid bone) must include the registration area; 2) For the fiducial-based, paired-point transformation method, the registration point must be marked before the CT examination. The pre-implanted metal screws, the maxillary occlusal plate with metal markers, the metal markers attached to the skin surface, and landmarks of maxillofacial bone tissue should usually be used. The range of registration points should be as close as possible to the surgical area.

Based on the preoperative CT scan, the enophthalmos degree of the affected side should be measured, and the extraocular muscle incarceration and range of orbital defects should be inspected.

3D construction and segmentation

The preoperative CT data should be imported into the navigation planning software and the CT imaging threshold should be adjusted to the range of the bone window to complete the 3D reconstruction of the maxillofacial region. The segmentation module can be used to separate and label the orbital structures of the unaffected side, including the orbital wall, intact orbital rim and optic nerve foramen.

Mirroring orbital data of the unaffected side and adjustments

The patient's head position should be adjusted, and the median sagittal plane should then be set according to the plane that passes through the nasion, the centre of the sella and the centre of the line that joins the left and right external acoustic foramens. The mirroring module of the software can be used to mirror the 3D object on the normal side to the affected side, and the mirrored 3D object can be adjusted to match the orbital rim and non-fractured orbital walls of the affected side. Subsequently, the orbital fracture area and areas that need to be repositioned are shown in the software. Finally, navigation plans can be generated and transferred to the navigation system before surgery.

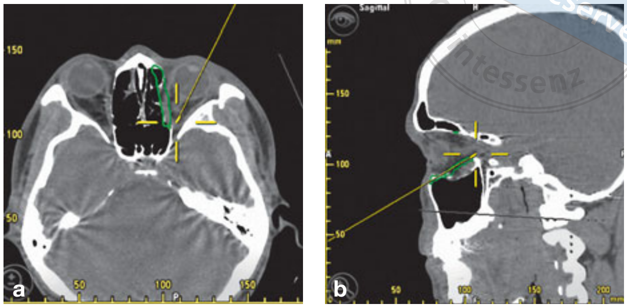

Fig 2 **(a)** Navigation-guided orbital reconstruction, indicating the medial orbital wall reconstruction, and **(b)** posterior border of orbital floor reconstruction.

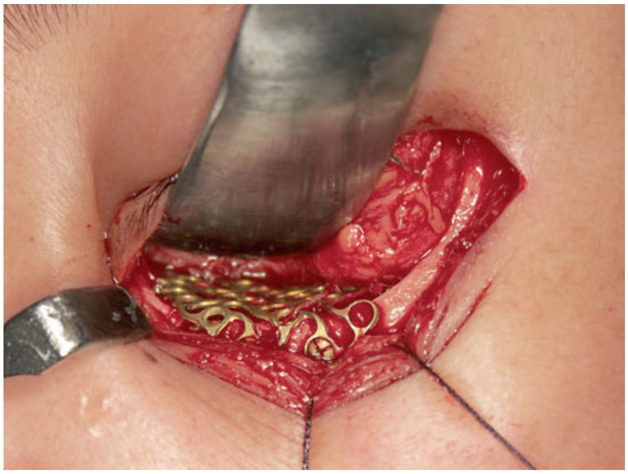

Fig 3 Fixing the titanium mesh to the inferior orbital rim.

It should be noted that for impure orbital fractures, it is necessary to reduce and fix the periorbital fractures first and reconstruct the orbital wall when the orbital rim is intact. Similarly, when the preoperative design is conducted, periorbital bone fragments should be segmented first and the mirror operation should be performed after virtual reduction.

Navigation surgery

Registration

First, the navigation data should be imported into the navigation system before surgery. After the induction of general anaesthesia, an incision of approximately 1 cm should be made on the parietal bone and the reference frame should be fixed with reflecting balls to the patient's skull to identify the patient's position. The

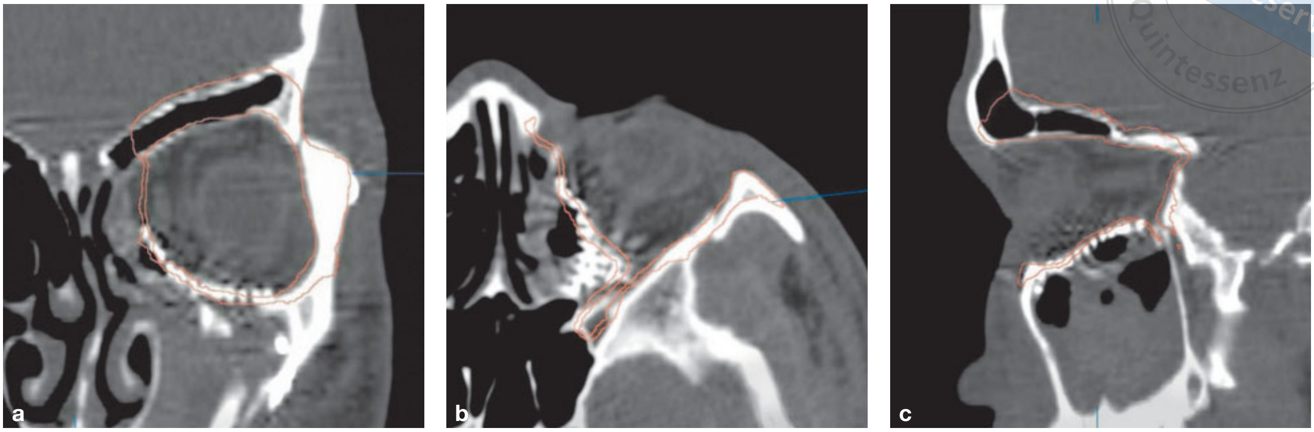

Fig 4 Relationship between the postoperative position of the titanium mesh and the preoperative plan in different planes: **(a)** coronal plane; **(b)** axial plane; and **(c)** sagittal plane.

reference frame needs to be fixed rigidly to avoid intraoperative loosening, and the fixing location should be distal to the natural bone suture. The infrared detection device can be directed at the surgical field, and the detection area should manifest the reference frame and the surgical area, simultaneously. The registration operation can then begin via fiducial-based paired-point transformation (i.e. coordinate registration) or surface contour matching (i.e. non-coordinate registration).

Orbital reconstruction surgery

Periorbital approaches (transconjunctival, transcutaneous or trauma-derived incision) are often used in orbital fracture surgery. Careful dissection should be used to expose the fractured orbital walls and reduce the herniated orbital soft tissue. When the dissection reaches the deep part of orbit, the navigation probe should be used to precisely detect the real-time intraoperative position and expose the entire wall defect widely, backward up to the posterior border of the defect.

The prefabricated individual titanium mesh or standard orbital titanium mesh should be inserted and positioned into the defect area with reference to the orbital reconstruction data of the affected side in the navigation system and the navigation probe. Usually, the navigation detects whether the posterior end of the titanium mesh is superior or inferior, and whether the titanium mesh of the medial orbital wall is medial or lateral. The position of the titanium mesh should coincide with the position on the preoperative plan and the boundary should cover all the defect area.

To avoid optic nerve damage, the 'safe distance' of orbital reconstruction surgery should be less than 35 mm posterior to the orbital rim. Once the titanium mesh is positioned satisfactorily, the internal fixation can be applied to the orbital rim using titanium screws, and the reconstruction position can be immediately evaluated using the navigation system.

Evaluation

The outcome of treatment for clinical symptoms such as diplopia and ocular invagination after orbital fracture is influenced by varying factors. Hence, only orbital reconstruction effects are evaluated here.

Postoperative spiral CT images should be acquired, and the titanium mesh reconstruction effect evaluated from the axial, coronal and sagittal positions. At the coronal position, the position and shape of the titanium mesh should be evaluated, and the height and angle of the inner-lower wall junction should be checked for their consistency with that of the healthy side. At the axial position, the reconstruction effect of the titanium mesh on the median wall of the orbital should be evaluated. At the sagittal position, the reconstruction effect of the orbital floor must be evaluated to determine whether the orbital soft tissue is entirely reduced, the titanium mesh covers the defect range, and the implant is too deep, medial or superior. The preoperative planned and postoperative CT scans should be compared to check if there is obvious deviation between the postoperative position and depth of the titanium mesh and that of the preoperative virtual plan.

References

1. Zhang Y. Digital surgical technique to accurately reconstruct orbital fracture. Zhonghua Kou Qiang Yi Xue Za Zhi (Chinese Journal of Stomatology) 2012;47:463–465. [In Chinese]
2. Zhang ZY, Feng ZQ, Gong X, He Y, An JG, Zhang Y. Evaluation of the navigation system for orbital wall reconstruction in unilateral orbital fractures. Zhonghua Kou Qiang Yi Xue Za Zhi (Chinese Journal of Stomatology) 2012;47:657–661. [In Chinese]
3. He W, Zhang Y, He Y, An J, Gong X, Huang T. Correction of enophthalmos following orbital fracture with computer-assisted navigation system. Zhonghua Kou Qiang Yi Xue Za Zhi (Chinese Journal of Stomatology) 2014;49:641–644. [In Chinese]
4. Zhang Y, Liu XJ. Impact of digital technology on clinical practices: perspectives from surgery. Zhonghua Kou Qiang Yi Xue Za Zhi (Chinese Journal of Stomatology) 2016;51:205–209. [In Chinese]
5. Yu H, Shen G, Wang X, Zhang S. Navigation-guided reduction and orbital floor reconstruction in the treatment of zygomatic-orbital-maxillary complex fractures. J Oral Maxillofac Surg 2010;68:28–34.
6. Bell RB, Markiewicz MR. Computer-assisted planning, stereolithographic modeling, and intraoperative navigation for complex orbital reconstruction: a descriptive study in a preliminary cohort. J Oral Maxillofac Surg 2009;67:2559–2570.
7. Bly RA, Chang SH, Cudejkova M, Liu JJ, Moe KS. Computer-guided orbital reconstruction to improve outcomes. JAMA Facial Plast Surg 2013;15:113–120.
8. Lübbers HT, Jacobsen C, Matthews F, Grätz KW, Kruse A, Obwegeser JA. Surgical navigation in craniomaxillofacial surgery: expensive toy or useful tool? A classification of different indications. J Oral Maxillofac Surg 2011;69:300–308.
9. Novelli G, Tonellini G, Mazzoleni F, Bozzetti A, Sozzi D. Virtual surgery simulation in orbital wall reconstruction: integration of surgical navigation and stereolithographic model. J Craniomaxillofac Surg 2014;42:2025–2034.
10. Wilde F, Schramm A. Intraoperative imaging in orbital and midface reconstruction. Facial Plast Surg 2014;30:545–553.
11. Baumann A, Sinko K, Dorner G. Late reconstruction of the orbit with patient-specific implants using computer-aided planning and navigation. J Oral Maxillofac Surg 2015;73:S101–S106.
12. Rana M, Chui CH, Wagner M, Zimmerer R, Rana M, Gellrich NC. Increasing the accuracy of orbital reconstruction with selective laser-melted patient-specific implants combined with intraoperative navigation. J Oral Maxillofac Surg 2015;73:1113–1118.
13. Shin HS, Kim SY, Cha HG, Han BL, Nam SM. Real time navigation-assisted orbital wall reconstruction in blowout fractures. J Craniofac Surg 2016;27:370–373.
14. Azarmehr I, Stokbro K, Bell RB, Thygesen T. Surgical navigation: a systematic review of indications, treatments, and outcomes in oral and maxillofacial surgery. J Oral Maxillofac Surg 2017;75:1987–2005.