Review Article

Computer-assisted navigation in orbitofacial surgery

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The purpose of this systematic review is to investigate the most common indications, treatment, and outcomes of computer-assisted surgery (CAS) in ophthalmological practice. CAS has evolved over the years from a neurosurgical tool to maxillofacial as well as an instrument to orbitofacial surgeries. A detailed and organized scrutiny in relevant electronic databases, journals, and bibliographies of the cited articles was carried out. Clinical studies with a minimum of two study cases were included. Navigation surgery, posttraumatic orbital reconstruction, computer-assisted orbital surgery, image-guided orbital decompression, and optic canal decompression (OCD) were the areas of interest. The search generated 42 articles describing the use of navigation in facial surgery: 22 on orbital reconstructions, 5 related to lacrimal sac surgery, 4 on orbital decompression, 2 articles each on intraorbital foreign body and intraorbital tumors, 2 on faciomaxillary surgeries, 3 on cranial surgery, and 2 articles on navigation-guided OCD in traumatic optic neuropathy. In general, CAS is reported to be a useful tool for surgical planning, execution, evaluation, and research. The largest numbers of studies and patients were related to trauma. Treatment of complex orbital fractures was greatly improved by the use of CAS compared with empirically treated control groups. CAS seems to add a favourable potential to the surgical armamentarium. Planning details of the surgical approach in a three-dimensional virtual environment and execution with real-time guidance can help in considerable enhancement of precision. Financial investments and steep learning curve are the main hindrances to its popularity.

Access this article online
Website:
www.ijo.in
DOI:
10.4103/ijo.IJO_807_18
Quick Response Code:

Key words: Computer-assisted orbital surgery, image-guided orbital surgery, navigation-guided optic canal decompression, navigation-guided orbital decompression, navigation surgery, posttraumatic orbital reconstruction

Orbital surgery is technically challenging because of its complex three-dimensional (3D) bony anatomy, crowding of vital soft tissues in a closed narrow space, and difficult illumination in posterior orbit.

Surgical simulation was originally laboratory-based where a 3D skull model was created using stereolithographic (STL) technology and the patient's computerized tomography (CT) scans. The planned surgical procedure was performed on these models. Orbital implants could be precontoured on these models and used as intraoperative guides[1-3] [Fig. 1].

Intraoperative navigation and computer-assisted surgery (CAS) was initially used in the field of neurosurgery for accuracy in planning the approaches, localizing tumors during surgery, and assessing the surgical margins following ablative surgery. It is now widely used by ENT surgeons for functional endoscopic sinus surgery and skull base surgeries. The use of intraoperative navigation in craniomaxillofacial surgery started in Europe in the late 1990s and early 2000s.[4-6] It is increasingly gaining foothold in orbit and orbitofacial surgery in recent times.

Intraoperative image-guided navigation system is a useful tool to guide the surgeon in identification of bony landmarks especially in cases where the anatomy is distorted, in planning complex reconstructions and verifying adequate reconstruction and symmetry, in precise localization of tumors and its relation to the surrounding vessels and nerves, and also in orbital decompressions while using microdrills in posterior orbit.

In complex trauma, achieving symmetry with the other unaffected orbit is very challenging and also vital to avoid diplopia and give a good cosmetic outcome. Navigation guidance allows use of 3D image data of the patient to support the surgeon right from the diagnosis and operational planning to intraoperative real-time guidance and verification of reconstruction. This systematic review aims to investigate and emphasize on common areas for use of CAS, such as traumatology, foreign body and tumor removal, and orbital reconstruction surgery. This review scrutinizes the literature systematically over the years regarding the most common indications, treatments, and outcomes of CAS. We can hereby assert that the development seen during the recent years could qualify CAS as a powerful and promising weapon to

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Manuscript received: 14.05.18; Revision accepted: 10.03.19

Cite this article as: Udhay P, Bhattacharjee K, Ananthnarayanan P, Sundar G. Computer-assisted navigation in orbitofacial surgery. Indian J Ophthalmol 2019;67:995-1003.

the surgeon. This review is the first of its kind to study a wide range of indications. This study provides an update on computer-assisted navigation in orbitofacial surgery with regard to its role in reconstructive and aesthetic procedures.

Methods

A systematic review of use of computer-assisted navigation in orbitofacial surgery was done with the use of targeted data source like PubMed, Ovid, MEDLINE, and Scopus using key words such as "Navigation surgery, post traumatic orbital reconstruction, computer-assisted orbital surgery, image guided orbital surgery," navigation guided orbital decompression, and navigation guided optic canal decompression (OCD). A total of 148 abstracts reviewed and 42 full-text articles were taken for reference [Fig. 2]. Relevant articles published in English regarding the use of CAS were screened. The inclusion criteria were clinically controlled trials and case reports involving CAS with a minimum of two or more patients being included. The exclusion criteria were articles with no objective end point of the surgical outcomes. The abstracts of relevant articles were studied with regard to the inclusion or exclusion criteria. After perusal of the abstracts, the chosen articles were reviewed in details. As per the inclusion criteria, the search was augmented by a search of the bibliographies of the included articles and a manual search of the relevant journals. Detailed account of the preoperative setup of the gantry to intraoperative maneuvring of the stylet was elaborated. A comparison between optical and electromagnetic registration was made [Table 1].

Basic Technique

While using navigation, the patient's anatomy is correlated with the preoperative scan images on the navigation platform, which allows real-time intraoperative tracking of bony landmarks and occasionally soft tissue landmarks. Intraoperative navigation has its origins from the concept of stereotaxy. Stereotaxy, a popular tool in neurosurgery, involves the use of external reference markers for location of internal surgical landmarks. This has paved way to the current generation of equipment used for intraoperative navigation.

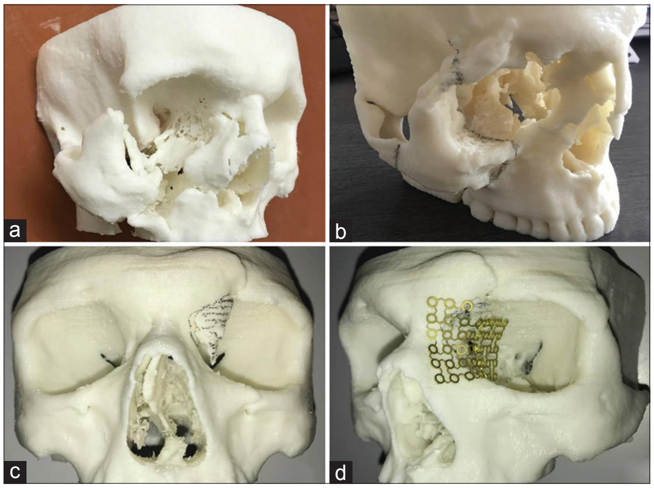

Figure 1: (a) Stereolithographic model, (b) osteotomy planned on the model, (c) bone fragment marked and removed, (d) implant precontoured on the model. The models in a, b, and c and d belong to three different patients

Intraop navigation essentially functions on two different principles:

1. Electromagnetic navigation, where the emitter fixed to the operating table rail emits electromagnetic field around the surgical site and the navigation probe is used for navigation based on its relative position within the field. However, as this technique uses an electromagnetic field, most surgical instruments create disturbances and artifacts due to their ferromagnetic nature.
2. Optical-guided navigation systems where light sources like LED or infrared cameras emit beams which reflect the position of the navigation probe using optical sensors.

The armamentarium for intraop navigation involves the following components:

1. The instrument console which contains the instrument panel, the display screen, and the operating software.
2. The operating software which includes the planning and navigation mapping modules.
3. The patient tracker which can be mounted on the patient or on a clamp like the "Mayfield" neurosurgical clamp. This provides the stable tracking sensor.
4. The pointer sensor which is the handheld sensor used intraoperatively at the surgical site.

Principle of Intraoperative Navigation

Many a times in literature, the navigation system has been compared to the Global Positioning System for the ease of understanding and the stark similarities in their principles of operation [Fig. 3]. The registration of the CT or magnetic resonance imaging (MRI) scan under navigation protocol helps in proper identification of the target area. Thereafter, the signal emitted by the infrared camera locates the handheld pointer and shows its position on the CT scan relative to the fixed patient tracker. The surgeon can thereby maneuver through

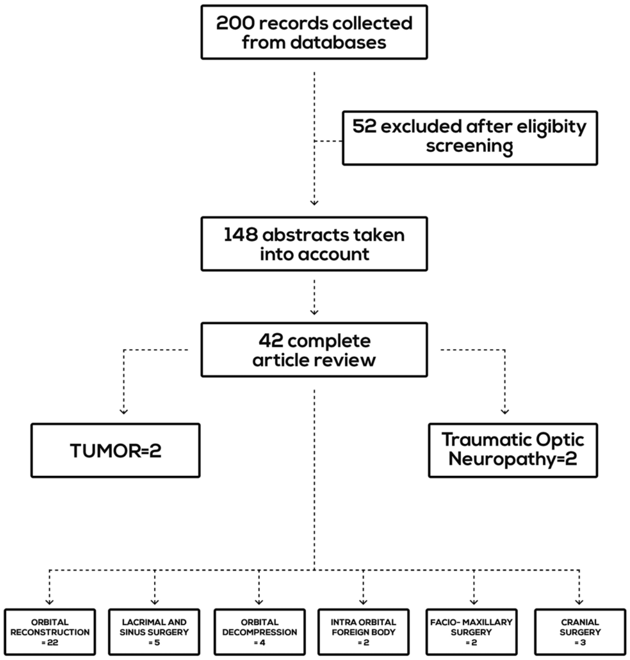

Figure 2: Flow chart

Table 1: Comparison of optical and electromagnetic tracking systems

Tracking system	Advantages	Disadvantages
Optical (infrared) (Brainlab®, Medtronic Stealth, Stryker Nav3)	1) Most accurate 2) Larger field is available 3) Most specialties can use 4) Bony as well as soft tissue registration can be done	1) Line of sight interference 2) More expensive 3) Pinning of skull post required
Electromagnetic (Medtronic, Stealth Fusion®, Brainlab)	1) Easy set up. Tracker is fixed to forehead with plaster. 2) Less expensive 3) Surface registration is adequate, hence used most by ENT and neurosurgeons where surface soft tissue movement is not much during surgery. 4) No line of sight interference	1) Narrow field, hence the reference point and trackers have to stay within a short range 2) Less accurate 3) Interference with ferromagnetic instruments; titanium instruments are needed
Combined, e.g., Medtronic Stealth station® system, Brainlab	Advantages as above	Newer technology Expensive

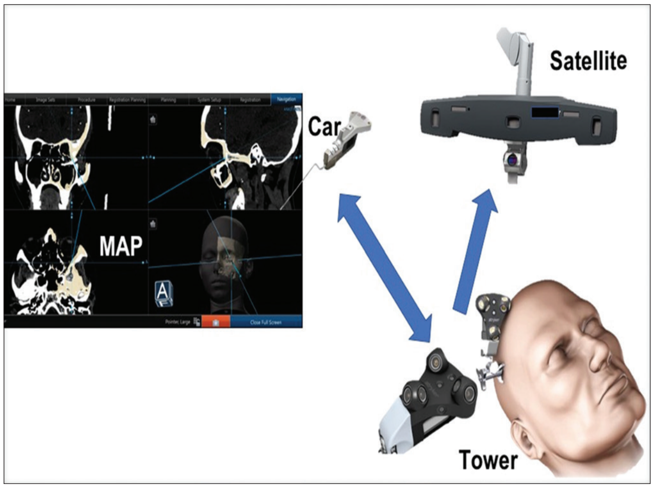

Figure 3: Analogy of the navigation system with Global Positioning System

tissues with ease without the apprehension of damaging vital structures. The end point on being reached can be confirmed through overlap between the previously fixed target and the mobile stylet placed at tissue level.

Steps in Intraoperative Navigation

There are two different levels into which the process can be divided.

The preoperative steps include the following:

1. Importing data
2. Selection of procedure
3. Registration planning
4. Procedure planning.

The intraoperative steps include the following:

5. System setup
6. Validation and calibration of the tools
7. Patient registration
8. Navigation mode activation.

Going step by step:

1. Most navigation platforms have the ability to interface and work simultaneously with numerous imaging modalities such as CT, MRI, CT and MRI angiographies, CT dacryocystography (CTDCG), fluoroscopy, and the C-arm imaging systems. Most orbital lesions are imaged with CT scans, tumors with contrast and trauma without. CT scans are performed using the standard image guidance acquisition protocols. For intraoperative navigation, contiguous thin sections (≤1 mm) are obtained from the hard palate to the vertex (for orbital fractures) and the whole face (for panfacial fractures) with zero gantry tilt and head in neutral position. Axial, reformatted coronal, sagittal, and 3D images are used for navigation. Intraoperative angiographic guidance helps the surgeon anticipate and avoid vascular or nerve injuries at crucial phases of surgery. The Digital Images and Communication in Medicine (DICOM) images are then uploaded on the workstation where preoperative image analysis is followed by treatment planning. The four-panel window of the navigation platform screen includes the chosen scans in different planes.
2. Selection of procedure – craniomaxillofacial/ENT/Neuro software.
3. Registration planning involves digitizing surface and bony landmarks on the CT. This may involve a "mask" registration which is totally automated and easy to perform or an anatomical registration mode which involves use of surface landmarks. Anatomical registration involves using surface landmarks or placement of recognizable markers like screws or dental splints which can be traced on a CT or an MRI scan. These points have to be traced on the patient physically intraoperatively and synchronized to provide the navigation guidance.
4. Procedure planning: This involves segmentation of the area of interest followed by use of "mirroring" feature that is commonly used for orbital surgery or "virtual surgery" feature which facilitates the import of computer-assisted planning data into the navigation console. Various softwares in the navigation platform are used for virtual planning before surgery. Treatment planning is typically performed by mirroring the contralateral normal orbital skeletal anatomy to the disrupted side, in unilateral fractures to guide the reconstruction and achieve symmetry [Fig. 4a]. Angiography/MRI/CTDCG can be merged with regular CT scans using the merger software. The feeder vessels to intraorbital tumors can be identified. Lesion localizer

softwares can be used to separately mark the lesion, optic nerve, and vessels using color coding. This 3D reconstruction of the tumor can be used for real-time tracking [Fig. 4b].

5. Setting up of the intraoperative navigation system is the next step. The position of the equipment has to be planned in such a way that it has free signal transfer between all the three essential components: the infrared camera, the patient tracker, and the pointer. This facilitates efficient use of the system without disturbances.
6. Validation and calibration of the patient tracker and the pointer tool enable recognition and synchronization of the sensor tools with the signal provider – in this case the infrared camera.
7. The next step is registering the patient which is the most important step in achieving accuracy in navigation. Unlike earlier navigation systems, the newer systems are "frameless" and do not require the patients head to be immobilized, although it is crucial that the eye tracker does not move during surgery. This can be performed using either soft tissue surface anatomy (surface tracking – Medtronic Stealth System, Fusion®; registration mask – Stryker Nav3® system, Brainlab) or the skeletal bony landmarks (Brainlab®) with or without markers. Markers used maybe invasive or noninvasive. The choice of registration method depends on the surgical site and possibility of soft tissue movement during surgery. Most craniofacial surgeons performing complex craniofacial surgeries prefer bony registration. This is because complex craniofacial surgery involves movement of soft tissue which will affect the accuracy of soft tissue registration. The distribution of the bony points should cover a large area and should be far from each other. Dental splints are another option. However, there is possibility of slight movement of the splint during surgery which will affect accuracy of navigation and also as we move away from the splint the accuracy reduces. Hence, for craniofacial surgery, these splints are combined with bony screws in the periorbital area. Whereas oculoplastic surgeons prefer soft tissue registration without markers using pointer or laser scanning (Z scanning in Brainlab) as oculoplastic surgeries do not involve movement of soft tissue of forehead and mid face. It is more accurate as 200 points are obtained during registration when compared to four to five points in bony registration. Registration error in periorbital area is around 1 mm which is acceptable, irrespective of the registration method. The degree of registration error is higher in posterior calvarial area. However, posttraumatic edema can result in a significant error when registering to an initial CT scan where tissues are edematous. Hence, it is important to obtain CT scan just prior to surgery.[6-8]
8. Accuracy is then verified by touching known bony landmarks like the lateral and medial canthi and orbital rim. After verification of accuracy of registration, the surgery begins with periodic verification of anatomical landmarks and reduction of orbital bony tissue. Intraoperative tracking can be performed using optical guidance (Brainlab®, Stryker, Medtronic Stealth System) or electromagnetic guidance (Fusion®, Medtronic Stealth, Brainlab®). Tracking of the patient's head is achieved with the dynamic reference frame fixed to the forehead with a plaster in case of electromagnetic tracking. For optical navigation, a skull post/reference array with tracker is fixed with screw to the skull bone. These tracking devices can be placed at a convenient location where it does not interfere with the surgical field and cause intraoperative navigation disruptions. The limitation of optical navigation is "line of sight interference" which means that the area between the infrared camera on the navigation platform and the tracker on the patient should be free of personnel to avoid disruption in navigation. The pros and cons of each system are discussed in Table 1.

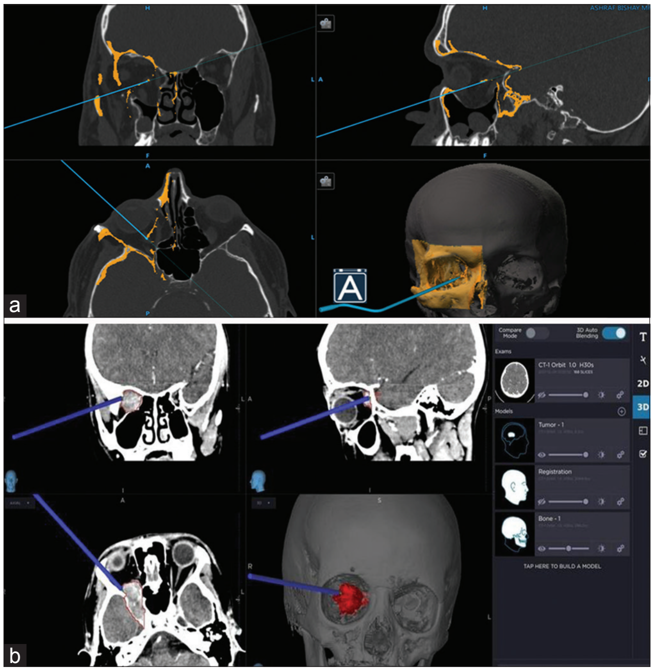

Figure 4: (a) Left normal orbit mirrored onto right affected orbit (orange outline) using mirroring software. (b) Lesion localizer software used to outline orbitocavernous tumor

When using CAS, surgical steps are performed according to standard procedures and navigation gives real-time guidance during surgery. Whenever an intraoperative CT scanner is available, an intraoperative scan should be obtained for evaluation of reduction of fractures and reconstructions. Smaller radiation doses used in intraoperative CT scans do not give adequate soft tissue details. However, the intraoperative CT scan can be fused with the virtual plan to determine the adequacy of fracture reduction. Instead of performing repeated intraoperative CT scans, radiation-free intraoperative navigation provides intraoperative guidance to the virtually planned reconstruction. Reconstruction of complex orbital wall defects may benefit from preoperative virtual insertion of STL image of the precontoured implants. Some complex reconstructions may require customized implants for reconstruction of orbital walls. This can be made by transferring virtual preoperative planning into 3D printing software to make customized implants or patient-specific implants (PSI).[9] PSI allows correction and reconstruction without additional osteotomies or bone grafts.

Application of Intraoperative Navigation in Orbital and Orbitofacial Surgery

1. Trauma
   a. Primary reconstruction
   b. Secondary corrections

2. Orbital bony decompression for thyroid orbitopathy
3. Orbital/orbitofacial tumor resection
4. OCD
5. Craniofacial deformity correction
6. Reconstructions following ablative surgery for malignant tumors
7. Exploration of foreign bodies close to bony structures
8. Endoscopic orbital surgeries
9. Endoscopic lacrimal drainage surgeries in congenital and acquired obstructions.

Navigation in orbital fractures and reconstruction

Orbital fractures may be classified into isolated or simple fractures and complex orbital and orbitofacial fractures. Challenging isolated orbital fractures include large blowout fractures without a posterior ledge and combined large orbital floor and medial wall fractures. Orbitofacial fractures include zygomaticomaxillary complex (ZMC), nasoorbitoethmoid complex fractures, orbitofacial fractures including Le Fort II and III type fractures, cranioorbital fractures, and finally panfacial fractures.

Complex orbital and orbitofacial fractures, the most common being displaced and comminuted ZMC fractures, are a real challenge even in primary trauma due to incomplete visualization of the entire zygoma through small incisions and also because the reduction of zygomatic prominence and the arch is usually performed with the soft tissue drape intact. This compromises our ability to accurately assess the reduction. Moreover, the assessment involves a comparison with the contralateral side for symmetry which is usually performed by mere "eye-balling." Inadequate primary repair can result in reduction in the anterior projection of the zygomatic body and increase in the facial width resulting from collapse and outward bowing of the zygomatic arch.[10-23]

Likewise, complex reconstructions involving more than two orbital walls with violation and disruption of the normal S-curve of the orbital floor and often the medial wall bulge are often compromised due to poor visualization of anatomical landmarks and incomplete reconstruction with sheet implants, often resulting in enophthalmos and motility limitation. In floor fractures, it is important for the surgeon to identify the posterior shelf of intact bone for proper placement of the implant. Its identification is difficult during surgery because of displaced orbital contents, intraoperative bleeding, poor lighting, and surgeon's apprehension to dissect too far posteriorly for fear of injuring the optic nerve. A common misconception is that the floor implant should cross the globe equator to support the globe. This leads to inadequate reconstruction of the posterior orbit and residual enophthalmos. The floor implant should rest on the posterior shelf and the posterior and medial bulges should be reconstructed (inadequate with sheet implants) along with symmetrization of the inferomedial strut to achieve adequate restoration. Navigation-assisted mirroring, measuring, and simulating help predictably restore the difficult-to-match posteromedial bulge and achieve successful orbital reconstruction.[24]

CAS allows virtual preoperative planning of the desired reconstruction using preoperative CT scans and appropriate software. The first step in virtual planning is autosegmentation of the unaffected orbit. This is then mirrored onto the affected side [Fig. 3]. In case of bilateral trauma, the contours of the autosegmented orbits can be virtually drawn or age- and race-matched algorithms or virtual models from standard CT datasets may be used. This virtual plan gives real-time guidance during surgery. Virtual insertion of the anatomically preformed titanium mesh can also be done which allows preoperative selection of the correct implant size, trimming of implant if needed, and correct 3D positioning of the implant. Navigation helps visualize the actual surgical outcome during surgery in relation to the preoperative plan. With this technique, insufficient orbital reconstruction can be identified and corrected during surgery, thereby reducing the need for secondary procedures [Fig. 5A-C]. It also helps avoid

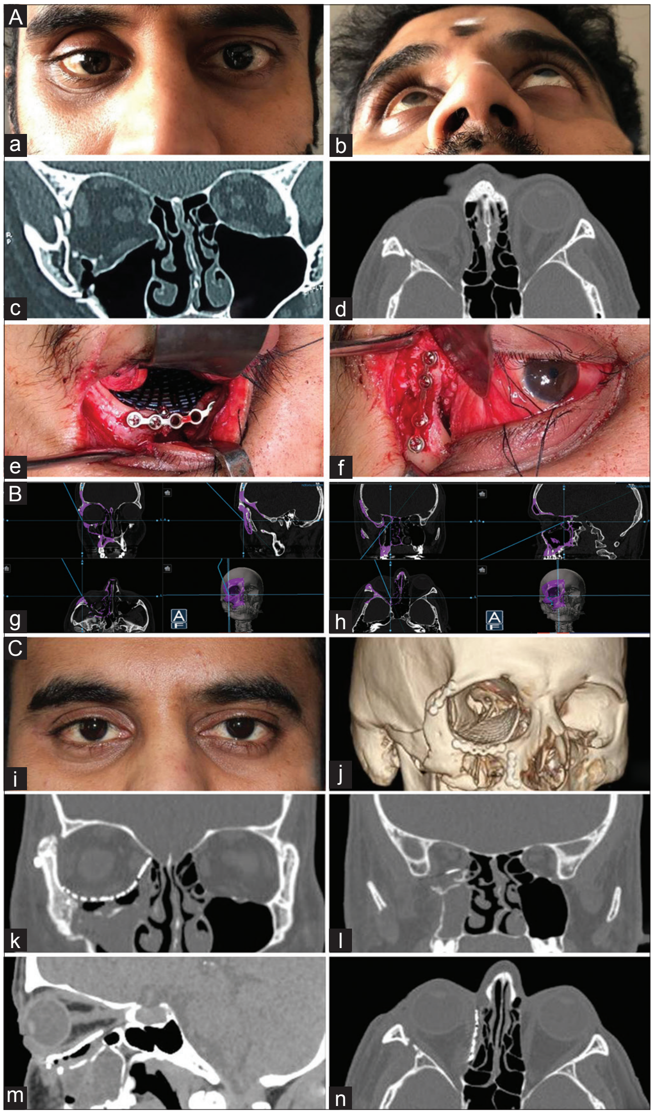

Figure 5: (A) (a and b) Clinical picture showing enophthalmos right eye and loss of malar eminence. (c and d) CT scans showing inadequately reduced zygoma and orbital floor and medial wall fractures (surgery by another surgeon). (e and f) Intraoperative pictures after reduction and fixation showing the implants used. (B) (g and h) Navigation pointer placed on the zygoma and orbital implant showing proper reduction and implant position corresponding with the mirrored image. (C) (i-n) Postop CT scans and clinical picture showing the implant position and symmetry with opposite side and significant improvement in enophthalmos and malar prominence

unnecessary surgical manipulation and dangerous dissection close to optic nerve.

Delayed reconstructions are challenging due to malunion, nonunion, bony resorption, loss of soft tissue envelope, presence of bony callouses, and scars. As a result of remodeling, no obvious fracture edges are seen that can serve as a landmark of correction. Navigation has almost become indispensable in the management of secondary deformities of the ZOC as it helps in the accurate positioning of the sites of osteotomy and facilitates removal of bony callouses which may impede proper reduction.[25,26]

A CTDCG can be used in medial wall fractures to evaluate lacrimal system and avoid its damage during reduction and fixation [Fig. 6A-C]. In patients with orbital floor and medial wall involvement, navigation can help recreate the lost inferomedial strut, recreate the posterior floor and medial wall bulges, and also identify the posterior ledge of intact bone which is of paramount importance in accurate implant placement. A precise repositioning, or reconstruction, of the orbital walls, especially of the transition area between orbital floor and medial orbital wall and ZMC, is a key procedure in orbital trauma management and contributes to a high degree to the normal function and aesthetics of the midface and computer-assisted planning is a useful tool to achieve this.

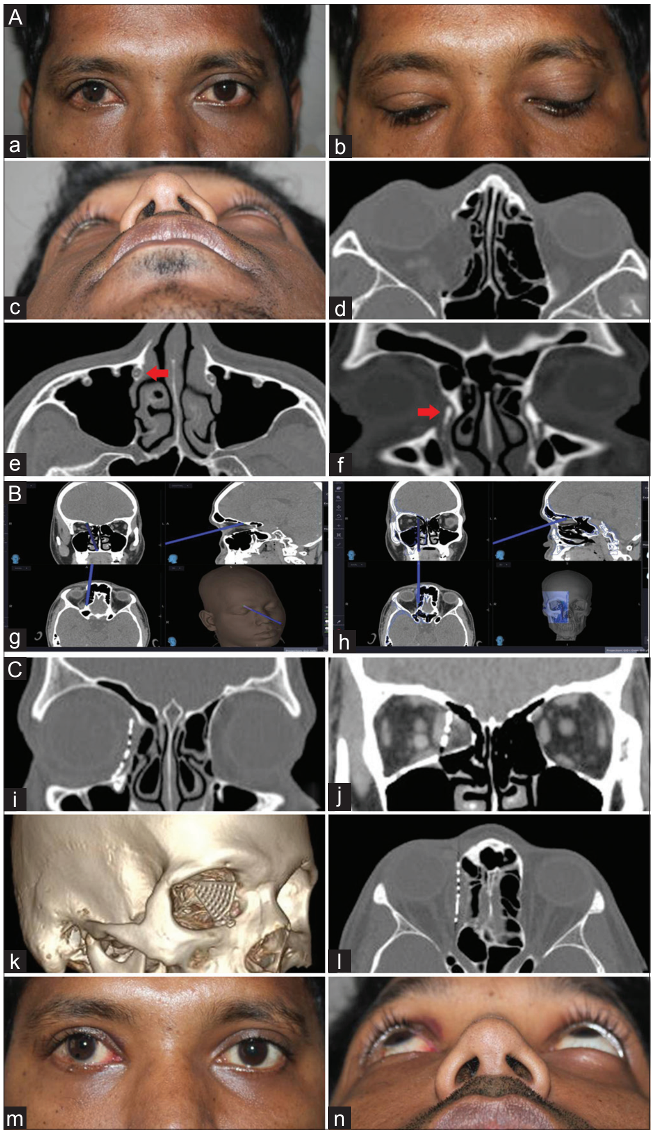

Figure 6: (A) (a-c) Clinical picture showing right enophthalmos. Patient had a ptosis correction and intraocular surgery done elsewhere. (d) CT scan showing right medial wall fracture. (e and f) CTDCG showing intact lacrimal drainage system (red arrows). (B) (g) Navigation pointer used to assess the extent of the fracture. (h) Pointer placed over the implant shows correct placement of implant coinciding with the mirrored image (blue). (C) (i-n) Postop CT scan and clinical picture showing the implant position and improvement in enophthalmos

The accuracy of navigation was demonstrated by Yu *et al*. who noted maximum deviation of less than 2 mm when comparing postoperative CT scans with the preoperative planning. They also reported accurate match between intraoperative anatomy and preoperative CT scans with an error of less than 1 mm. This degree of precision was acceptable especially when natural asymmetry is considered.[16]

It is important to note that diplopia correction does not always accompany enophthalmos correction as the soft tissue envelope of the globe with preexisting scars in extraocular muscles, and periorbita may play an important role.

Use in orbital tumors

Surgeries involving removal of orbital or complex orbitofacial tumors like sphenoid wing meningiomas with secondary hyperostosis can be challenging. Navigation helps in accurate target localization, and in establishing tumor margins for resection, CT angiographic guidance can help avoid vascular injuries during tumor excisions. Lesion localizer software can be used to separately mark the lesion, optic nerve, and vessels using color coding [Fig. 7]. Also, reconstruction of large residual bony defects after excision can be challenging due to the head position during surgery and the inability to visualize contralateral landmarks. Using navigation and mirroring

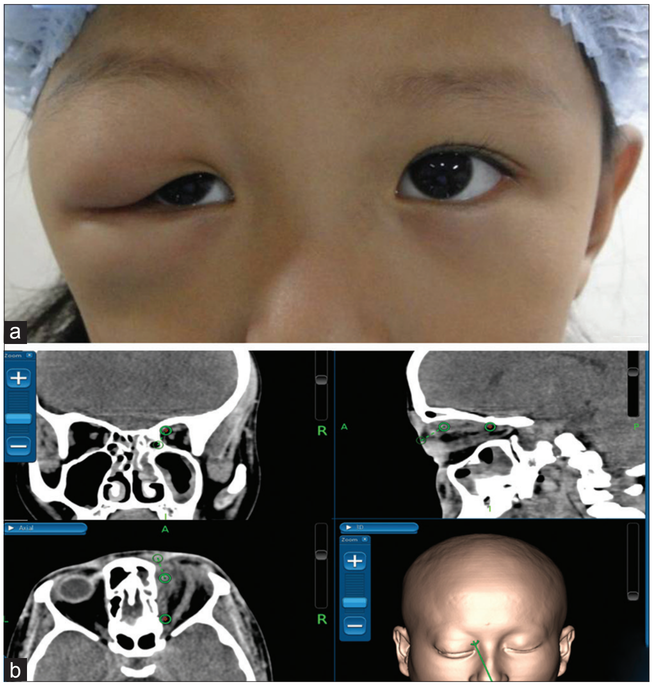

Figure 7: (a) Child with neurofibroma orbit. (b) Tumor localizer software used to outline the tumor and color coding used to mark the vessels

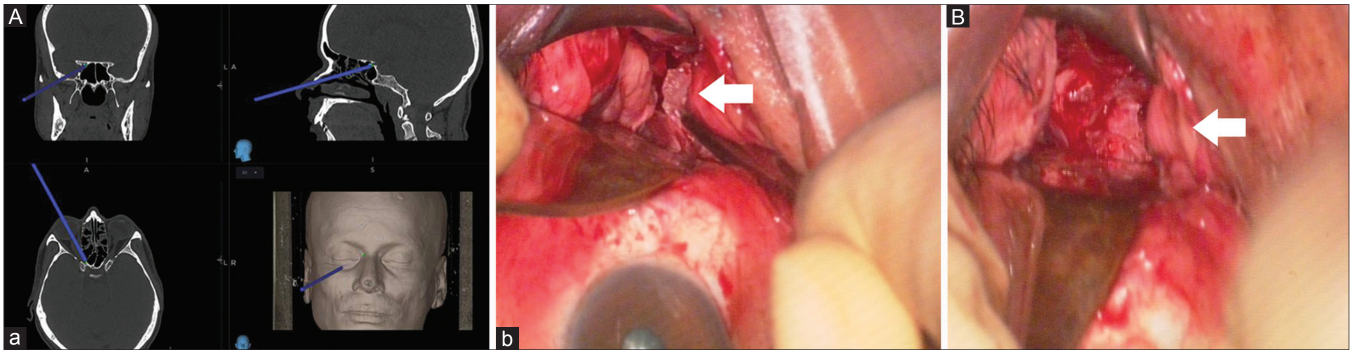

Figure 8: (A) (a) Navigation pointer used to locate the target area, i.e. the medial wall of the optic canal. (b) Intraop picture showing the fractured bony fragment impinging the optic nerve. The navigation screen used for endoscopic guidance. (B) Exposed optic nerve after decompression of the canal

technology, symmetry in reconstruction can be achieved. However, the limitation of use of navigation in soft tissue tumors is that there is a possibility that preoperative scans may not give accurate spatial information as surgical manipulation leads to massive shift in structures within the orbit. However, in surgeries involving skull base, pterygopalatine fossa, and infratemporal fossa, soft tissue displacement is minimal and navigation can be a useful adjunct to surgery.[27-32]

Use in OCD

Among the many causes of failure of surgical decompression in traumatic optic neuropathy in published reports, one common factor continues to be inaccurate intraoperative localization of the bony fragments impinging the optic nerve and inadvertent injury to the nerve causing further damage. Studies have shown that navigation-guided stereotactic technology can provide enhanced precision and safety, and intraoperative positional and spatial orientation, with minimal potential complications. High-resolution CT provides essential information regarding possible contributors to optic nerve injury, including retrobulbar hemorrhage, optic nerve edema, intraorbital emphysema, and optic canal fracture, and angiogram provides information about the location of blood vessels in the surgical area. The obtained CT angiogram is fed into the navigation platform and a 3D model is built. The software provides a scope for further planning of the surgery by deciding the entry point and target area (here medial wall of the optic canal), creating a color-coded model of the specific anatomical entity (e.g. optic nerve, optic canal, blood vessels, extraocular muscles). Medial transcaruncular incision is made to access the medial wall of the orbit. After dissection through the periorbital tissues, the anterior ethmoidal vessels are localized, approximately 24 mm posterior to the orbital rim. These vessels can be cauterized for hemostasis and better visibility. The posterior ethmoidal vessels and nerve lie further 12 mm posterior to these. Thereafter, a dissection of about 6 mm beyond helps the surgeon to reach the optic canal. The annulus of zinn and the optic nerve can be visualized after careful dissection. Once the target area is reached and confirmed using the navigation stylet, the inferior medial wall of the canal is punched out thereby deroofing the canal into the sphenoid sinus. Any impinging bone fragment is removed. The importance of the CAS in the localization of the optic canal and its role in prevention of damage to the optic nerve has been emphasized well by Bhattacharjee *et al*.[33] The navigation system provides the projection mode and the "look ahead" program mode that helps the surgeon to see what lies further ahead on the screen. This helps avoid any inadvertent damage to vital structures. OCD through the external transcaruncular approach using the navigation-guided system helps in presurgical planning, navigating to the area of interest very precisely thereby enabling a minimally invasive surgery with no accidental optic nerve injury[33,34] [Fig. 8A and B].

Endoscopic lacrimal surgery

Nasal anatomy could be severely distorted in patients post rhinectomy, hemi-maxillectomy, post radiotherapy, and post reconstruction following excision of sinonasal tumors with implants as well as in severe facial trauma. Dacryocystorhinostomy can be a challenge in these patients. Endoscopic navigation guidance is useful in these situations. The navigation platform can be used as endoscopy screen along with real-time CT guidance. CTDCG may be used to identify the lacrimal sac and its relation to the surrounding bones.[35-37]

Morley *et al*. have described use of navigation in insertion of Lester Jones tube in a patient with distorted anatomy with success.[38]

Orbital decompression

While performing deep lateral orbital wall decompressions, microdrills are used to remove bone in the deep posterior orbit. In these cases, navigation is useful in identifying exact bony landmarks for decompression, to measure the thickness and locate the areas of thick bone for drilling and to know the exact end point of decompression based on the preoperative planning. It enhances the safety of these procedures in the posterior orbit which is the target area for effective decompression.[8,39-41]

Discussion

Several recent advances have propelled precision orbital surgery to greater heights. Technology has complemented techniques in achieving more ideal outcomes than in the past. Techniques include minimally invasive surgery, tissue preservation with minimal normal tissue disruption, and so on. Technology includes the use of DICOM data to virtually plan resections and reconstructions, customize implants, precise intraoperative localization, and implant placement, sometimes with endoscopic guidance, bioresorbable implants, standard and prebent anatomical implants, and even PSIs. Intraoperative navigation is known by various terms: computer-assisted navigation surgery (CANS), image-guided orbital surgery (IGOS), and so on. Extended applications of orbital surgery are incorporated into cranioorbital and orbitofacial surgery as well. Thus, the goal of orbital reconstruction is to achieve complete and accurate restoration of the premorbid anatomy which in turn lays the foundation for functional and eventually cosmetically acceptable results, maximizing outcomes with minimizing complications.

Restoration of normal anatomy is an important component of the midfacial skeleton and soft tissues. This holds true not only for isolated orbital fractures but also for cranioorbital, orbitofacial, and panfacial fractures. The rims (frame) have to be restored before orbital wall reconstruction. Paying attention to the bony landmarks, for example, posterior, medial, lateral, superior ledges; contours of the floor, and medial wall, and using great caution to avoid damage to the vital structures, through precise intraoperative localization techniques and intraoperative verification should be the goal standard in orbital surgery, whenever and wherever possible. There is great value in preoperative analysis of the DICOM virtual data and analysis, which guides treatment planning and virtual surgery when indicated followed by intraoperative replication of treatment planning.

A study by Markiewicz *et al*.,[20] using navigation in 23 patients for reconstruction of posttraumatic and postablative orbital defects, concluded that navigation was effective in establishing normal orbital volume and globe projection.

Bly *et al.* have published a large series of 113 cases analyzing results with and without navigation guidance in unilateral complex orbital trauma.[17] They concluded improved outcomes in postoperative diplopia and orbital volume with use of navigation. Need for revision surgery was reduced from 20% in nonnavigation group to 4% in navigation group ($P = 0.03$). Similar results were seen in 15 patients by Bell.[1]

The future of orbital and orbitofacial navigation surgery includes not only intraoperative navigation but also intraoperative (low-dose radiation, high resolution) imaging, to ensure accuracy of reduction of orbital fracture fragments and confirm implant placement and posttreatment image analysis to verify and ensure high quality and good outcomes. This follows any basic surgical principle of “Get it right – the first time.” The limitations are inaccuracy in bilateral trauma cases and inadequate soft tissue guidance. It is definitely not a substitute to proper surgical technique and expertise. Another major limitation is that it assumes orbital and facial symmetry. Studies have shown that there are measurable differences in orbital volumes between the two sides for any given individual. However in most, the difference is small with no significant effect on facial appearance and function.[13] Controversy regarding the additional cost of investment and additional time incurred in preoperative planning and intraoperative navigation setup and execution may also be justified with better outcomes and minimizing the need for revision surgery. Although probably not necessary for routine use in small orbital blowout fractures, its use in shattered orbits due to high-velocity injury resulting in severe disruption of internal and external orbit shows promise.

Acknowledgement

Special thanks to Dr. Sripurna Ghosh, MS, FSSN, for her contribution in literature search.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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