



Navigation-guided orbital medial wall fracture reconstruction

Jae Hyung Jeon, Hong Bae Jeon, Hyonsurk Kim, Dong Hee Kang

Department of Plastic and Reconstructive Surgery, Dankook University Hospital, Cheonan, Korea

Background: Orbital medial wall fractures, which are more common than inferior wall fractures, have traditionally been difficult to diagnose with conventional radiography. As the fracture extends deep into the bony orbit, accurately visualizing internal structures becomes challenging, increasing the risk of optic nerve compression. In a previous study, the author introduced a technique for treating medial orbital wall fractures using a combined transethmoidal and transcaruncular approach. In this study, the authors hypothesized that the use of surgical navigation could enhance precision, safety, and anatomical reconstruction in this approach and employed navigation during surgery for medial orbital wall fractures and evaluated whether it improved postoperative functional and anatomical outcomes while minimizing complications.

Methods: From September 2021 to November 2023, 48 patients with isolated medial wall fractures underwent surgical treatment using a combined transcaruncular approach and transethmoidal packing to repair the orbital fracture. Of these patients, 23 underwent surgery with the use of intraoperative navigation, while the other 25 did not. Intraoperative navigation was employed to facilitate precise fracture reduction and reduce the risk of optic nerve injury. The outcomes were compared by dividing the patients into two groups. Preoperative and postoperative assessments included ophthalmologic evaluations, Hertel exophthalmometry, and computed tomography-based orbital volume measurements.

Results: The surgical approach with intraoperative navigation was successfully performed in all patients. Postoperative outcomes showed full recovery without residual symptoms or complications. Orbital volume measurements indicated a significant reduction in the preoperative orbital volume ratio from 109.03% to 104.80% postoperatively ($p < 0.001$). However, changes in the Hertel scale were not statistically significant ($p = 0.086$).

Conclusion: The integration of intraoperative navigation in medial orbital wall fracture surgery enhances the precision of medial orbital wall restoration and minimizes postoperative complications, supporting its use in the surgical management of medial orbital fractures.

Abbreviations: CT, computed tomography; OVR, orbital volume ratio

Keywords: Blowout fractures / Orbital fractures / Surgical navigation systems

INTRODUCTION

A blowout fracture is a bony defect deep within the orbit, classi-

fied by its location as a medial wall, inferior wall, or combined inferior-medial wall fracture. Since the medial orbital wall is thinner than the inferior orbital wall, fractures of the medial orbital wall are more common than those of the inferior orbital wall. However, medial orbital wall fractures are more challenging to diagnose using conventional radiography compared to floor fractures [1]. The introduction of facial bone computed tomography (CT) has significantly improved the detection of medial orbital fractures, resulting in a higher rate of surgical interventions. The primary goal of surgery for blowout fractures

Correspondence: Dong Hee Kang
Department of Plastic and Reconstructive Surgery, Dankook University Hospital,
201 Manghyang-ro, Dongnam-gu, Cheonan 31116, Korea
E-mail: dhkcool@daum.net

How to cite this article:
Jeon JH, Jeon HB, Kim H, Kang DH. Navigation-guided orbital medial wall fracture reconstruction. Arch Craniofac Surg 2025;26(1):5-12. <https://doi.org/10.7181/acfs.2024.00542>

Received November 1, 2024 / Revised December 7, 2024 / Accepted January 23, 2025

is to restore ocular motility and the original orbital shape, preventing enophthalmos [2,3]. Achieving this requires careful repositioning of the herniated orbital contents and fractured orbital wall, with precise implant placement being a key challenge. When the fracture extends deep into the bony orbit, accurately visualizing the internal structures becomes difficult, increasing the risk of optic nerve compression [4]. Fractures near the optic canal pose particular challenges, such as ensuring the complete repositioning of orbital contents, properly bridging the posterior fracture margin, and maintaining a safe distance between the implant and the optic nerve [5]. In a previous study, the author introduced a technique for treating medial orbital wall fractures using a combined transthemoidal and transcaruncular approach [6]. This method involves restoring the medial orbital wall from the ethmoid sinus using its primary bone fragments and placing temporary support within the sinus. During the ethmoid packing process, precise exploration and restoration are crucial, as the ethmoid sinus is located medial to the optic canal and inferior to the cranial base [6].

In this study, it is hypothesized that the use of surgical navigation could improve outcomes by enhancing precision, safety, and anatomical reconstruction in the senior author's combined transthemoidal restoration and transcaruncular approach. The authors employed navigation during surgery for medial orbital wall fractures to verify the accurate restoration of the fractured orbital wall to its original anatomical position and to ensure the proper insertion of the orbital implant at the anteroposterior, superior, and inferior edges [7]. Navigation was also used to confirm the accuracy of ethmoid packing through the transthem-

oidal approach. Additionally, the study evaluated whether using navigation could improve postoperative functional and anatomical outcomes while minimizing complications.

METHODS

Patient and injury characteristics

In Korea, government approval for new health technologies utilizing navigation in the treatment of orbital wall fractures was granted in August 2022, along with insurance coverage for its use. As a result, navigation technology has only recently become available for clinical application. We compared the outcomes between two groups of patients: those who underwent surgery for orbital wall fractures prior to the use of navigation and those who had surgery after its introduction. This study was approved by the Institutional Review Board of our institution and conducted in accordance with the Declaration of Helsinki.

From September 2021 to November 2023, 228 patients underwent surgical treatment for orbital fractures. Medial wall involvement was identified in 87 cases (38.2%), with 48 patients (21.1%) presenting with isolated medial wall fractures and 39 (17.1%) exhibiting concomitant orbital floor fractures (Fig. 1). Among the 48 patients with isolated medial wall fractures, 38 were men and 10 were women, ranging in age from 12 to 74 years, with a mean age of 43.3 years. 23 cases involved the right orbit, while the remaining affected the left orbit. CT scans confirmed the diagnosis in all cases, with six patients exhibiting limited eye movement and 30 presenting with enophthalmos before surgery.

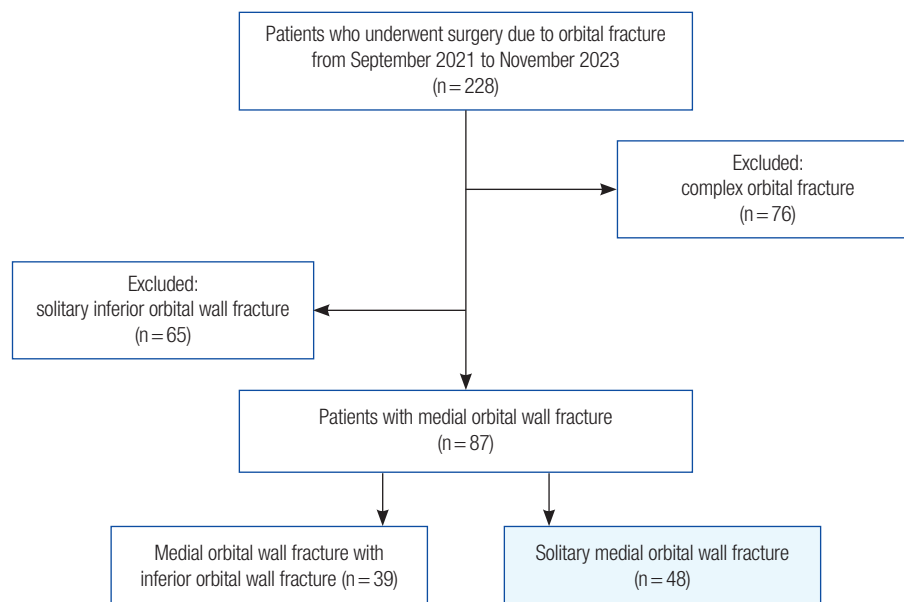


Fig. 1. Flowchart of patient selection.

Surgical intervention was indicated in 48 cases. The surgery was performed using a combined transcaruncular approach and transthmoidal packing to repair the orbital fracture. Since January 2023, we have been utilizing navigation system (Navio; Mega Medical) in orbital fracture reconstruction. Among these patients, 23 cases utilized navigation during surgery, while 25 cases did not. The outcomes were compared by dividing the patients into two groups.

Ophthalmic examination

All surgical candidates underwent a preoperative ophthalmologic evaluation to assess diplopia and extraocular motility. The severity of enophthalmos was measured using a Hertel exophthalmometer (Inami), with initial measurements taken 1 day before surgery. Patients returned for follow-up visits at our outpatient clinic at 2 weeks, 1 month, and 6 months after surgery. Hertel measurements were reassessed at the 6-month follow-up, coinciding with the completion of orbital soft tissue atrophy and scar formation.

CT scans and orbital volume measurements

Three-dimensional CT images were obtained using a GE Lightspeed VCT scanner (GE Healthcare), with 1 mm thick in axial and coronal slices. CT scans were conducted both preoperatively and postoperatively, with the postoperative scans performed during the outpatient follow-up period, at least 6 months after surgery. The Rapidia Image Post-processing System (Infinit) was used to measure orbital volume by delineating the orbital boundary on each CT image. The volume of the unaffected orbit was used as a reference to account for individual variations in orbital volume. The orbital volume ratio (OVR) was calculated by dividing the volume of the affected orbit by that of the normal side, with postoperative OVR determined using the same method.

Surgical techniques

The decision to proceed with surgical intervention was based on the criteria, including absolute indications such as restricted ocular motility and persistent diplopia, as well as relative indications like a fracture area exceeding 2 cm². Under general anesthesia, pledgets soaked in a solution of 1:100,000 epinephrine and 2% lidocaine were applied to the caruncle. A curvilinear incision measuring 10 to 12 mm was made through the lateral aspect of the caruncle, after retracting it medially and laterally with a 6-0 Prolene suture along the semilunar fold. This incision was extended superiorly and inferiorly into the fornices. Stevens tenotomy scissors were then used for spreading dissection, allowing incision of the periosteum and access to the me-

dial orbital wall. Dissection was carried out between the medial orbital septum and Horner's muscle. The posterior lacrimal crest was initially palpated with a blunt instrument, and a blade was used to vertically incise the periorbita along the lamina papyracea. Subperiosteal dissection was then performed using a periosteal elevator, exposing the entire medial orbital wall. To improve visualization, the globe was retracted laterally with an orbital retractor, and further subperiosteal dissection was carried out posteriorly to fully identify the fracture.

Medial wall restoration

During the procedure under general anesthesia, nasal congestion was relieved by applying epinephrine-soaked pledgets, and 2% lidocaine with 1:100,000 epinephrine was injected into the anterior root of the middle turbinate. Once the medial wall fracture was exposed through a transcaruncular incision, a straight Freer elevator was carefully introduced into the nasal cavity, navigating the ethmoid air cells without performing an ethmoidectomy to reach the medial aspect of the orbital wall fracture. A Freer elevator was used intraethmoidally to assist in lateralizing the fracture through a transnasal approach, carefully repositioning the medial wall bone fragments to their prior anatomical position, which was directly visualized through a transcaruncular approach. The herniated orbital contents that had protruded into ethmoid sinuses were relocated back into the orbit. The medial wall fracture was reconstructed by conserving the primary orbital wall fragment and returning it to its original position. To support the reconstructed orbital wall, Nasopore (Polyganics B.V.) was introduced into the ethmoid sinus via a transnasal approach, adjacent to the reconstructed medial orbital wall fragment. This material gradually dissolved over several weeks, eliminating the need for packing removal (Fig. 2G and H). A 0.5 mm thickness resorbable plate (Rapid-Sorb; DePuy Synthes) was trimmed and placed at the fracture site through transcaruncular approach, with the size determined intraoperatively using real-time measurements obtained with a navigation probe (Fig. 2E and F). Following reduction of the orbital fracture, the periosteum and conjunctival incisions were closed with absorbable sutures.

Intraoperative guide with navigation

Before implementing the navigation system, anatomical landmarks of the patient were carefully correlated with corresponding reference points on CT images, and the accuracy of registration points was thoroughly verified. The navigation system enabled transnasal access to the ethmoid sinus for the restoration of the medial orbital wall. A navigational probe was inserted through the nasal passage to evaluate the ethmoidal air cells

and facilitate precise transnasal reduction of the medial orbital wall fracture (Fig. 2B). Additionally, navigation was employed via a transcaruncular incision to confirm the dimensions and anteroposterior, superior and inferior extent of the orbital wall fracture (Fig. 2A). This system provided visualization of the deep posterior aspect of the medial orbital wall fracture, particularly near the optic nerve during dissection (Fig. 2C and D).

Real-time assessment of the orbital fracture's extent was conducted using the navigational probe.

Following the reduction of the medial wall fracture through the transnasal approach, the navigation system ensured the accurate restoration of the posterior margin of the medial wall fracture. After restoring the medial wall with ethmoidal packing and implants placement through transcaruncular approach,

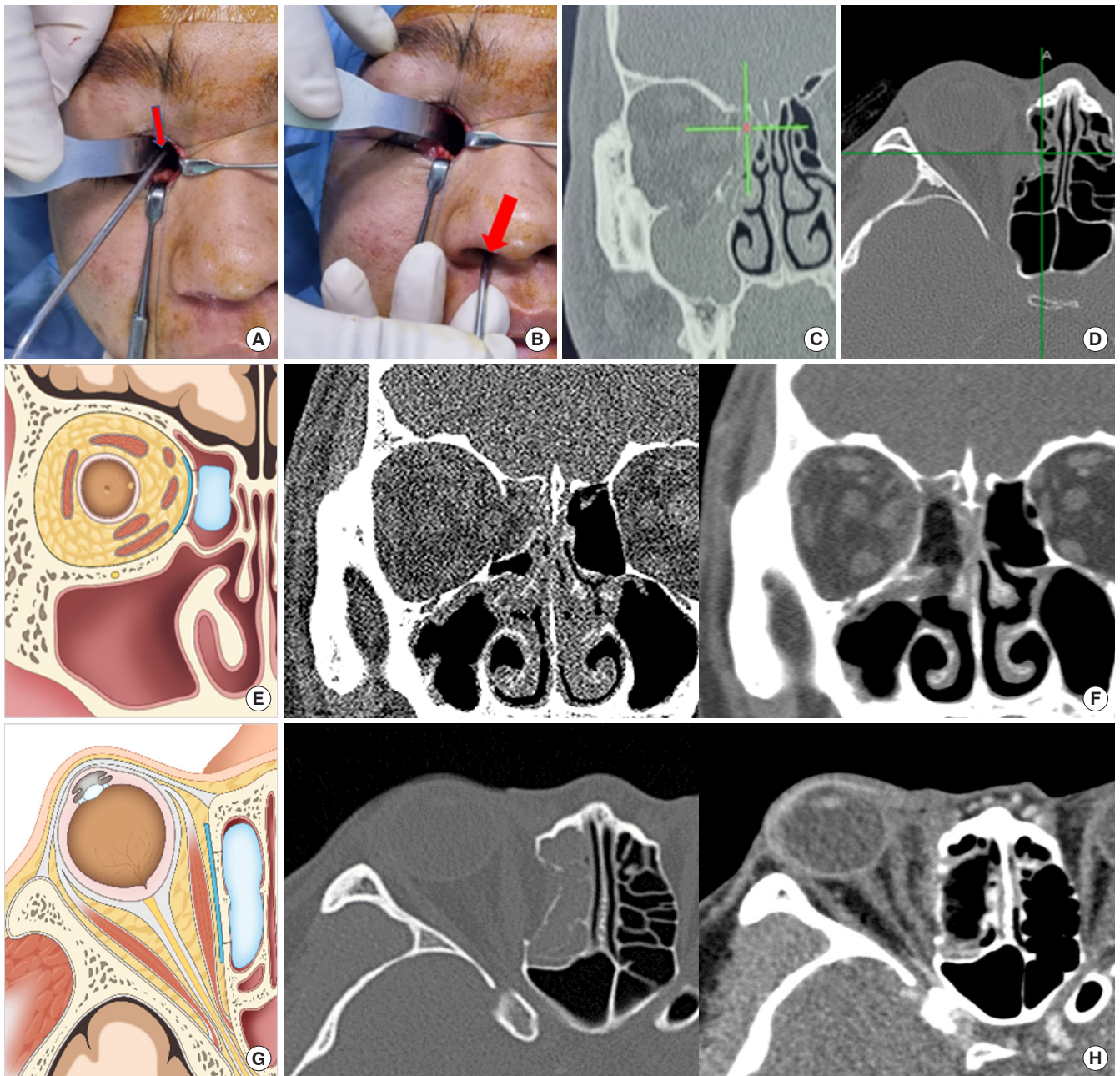


Fig. 2. Navigation-guided medial orbital wall restoration. (A) A transcaruncular incision was used to navigate (red arrow) and confirm the dimensions of the orbital wall fracture. (B-D) A navigational probe (red arrow) was introduced through the nasal passage to assess the ethmoid sinus. (E) Navigation-guided ethmoid packing was performed. (F) Preoperative and postoperative coronal views of the medial wall blowout fracture. (G) Orbital wall reconstruction was carried out to the posterior edge of the fracture, adjacent to the optic canal, with the guidance of navigation. (H) Preoperative and postoperative axial views of the medial wall blowout fracture.

verification was carried out to ensure there was no compression on the optic nerve. The navigation system also facilitated continuous monitoring of the alignment between the repositioned wall and the preoperative plan.

Orbital volume measurement and statistical analysis

At the 6-month postoperative follow-up, evaluations included CT scans to assess orbital volumes and OVR. These assessments were conducted using semi-automatic segmentation with specialized software. Orbital volume, a widely recognized parameter for evaluating outcomes of orbital fracture treatment, was analyzed quantitatively and compared. Measurements of OVR and Hertel scale were analyzed for statistically significant differences between groups using the Mann-Whitney test or Wilcoxon signed-rank test. Statistical analyses were performed using SPSS version 20.0 for Windows (IBM Corp.), with a significance level of $p < 0.05$ considered statistically significant.

RESULTS

Orbital assessment

Among the 48 patients (25 control group A and 23 experimental group B) who underwent orbital reconstruction for medial blowout fractures, 30 patients experienced enophthalmos (14 in group A and 16 in group B), and six patients had limited extraocular movement (5 in group A and 1 in group B) preoperatively. After surgery, all patients fully recovered from ocular symptoms, including diplopia and limited extraocular movement. The mean Hertel exophthalmometer measurements were -0.76 mm in group A and -0.65 mm in group B preoperatively, and -0.52 mm in group A and -0.22 mm in group B postoperatively.

In the control and experimental groups, the Hertel scale changed by 0.24 mm and 0.43 mm, respectively. The perioperative changes in the Hertel scale within each group, as well as the differences in preoperative and postoperative values between the two groups, were statistically nonsignificant ($p > 0.05$) (Table 1).

Measurements of orbital volume

The preoperative difference in the OVR between the control and experimental groups (-2.45%) was not significant (106.58% in group A vs. 109.03% in group B). However, 6 months postoperatively, CT imaging showed a significant decrease in the OVR in both groups based on volumetric analysis (104.01% in group A vs. 104.80% in group B). The experimental group exhibited a more substantial decrease in OVR (4.23%) compared to the control group (2.57%) ($p < 0.05$) (Table 2).

DISCUSSION

Orbital medial wall fractures, which are more common than inferior wall fractures, have traditionally been challenging to diagnose using conventional radiography. However, the advent of CT has greatly improved diagnostic accuracy and increased the rates of surgical intervention. The most common symptoms of a medial orbital fracture include periorbital edema, ocular discomfort and orbital emphysema following nasal insufflation [2]. Although less frequent than inferior wall fractures, medial wall fractures can lead to pain during eye movements and movement restrictions if the extraocular muscles become entrapped [1,6]. Additionally, because the medial wall normally protrudes convexly into the orbit, a fracture that results in a loss of this convexity may cause enophthalmos after the initial swelling subsides.

Table 1. Preoperative and postoperative Hertel scale in each group

	No. of patients	Mean preoperative Hertel scale (mm)	Mean postoperative Hertel scale (mm)	Δ Hertel scale	p -value ^{a)}
Control group	25	-0.76	-0.52	0.24	0.353
Experimental group	23	-0.65	-0.22	0.43	0.086

^{a)} $p > 0.05$, no significant difference.

Table 2. Preoperative and postoperative orbital volume expansion in each group

	No. of patients	Orbit volume ratio (%)				<i>p</i> -value
		Unaffected orbit	Affected orbit (mean)		Volume change	
			Preoperative	Postoperative		
Control group	25	100	106.58	104.01	2.57 ^{a)}	< 0.001
Experimental group	23	100	109.03	104.80	4.23 ^{a)}	< 0.001
ΔGroups			−2.45	−0.79	−1.66 ^{b)}	0.020

^{a)}Significant difference, $p < 0.05$ Wilcoxon signed-rank test; ^{b)}Significant difference, $p < 0.05$ Mann-Whitney test.

Surgical indications for orbital fractures include restricted ocular motility, persistent diplopia, and the presence of a bone defect larger than 2 cm² detected on CT imaging, due to the risk of developing enophthalmos [2]. The primary surgical procedure involves repositioning herniated orbital tissue and restoring the fractured orbital wall to its original configuration, with the goal of preserving the eye's anatomical and functional integrity. However, the optimal surgical approach and technique remain subjects of ongoing debate among orbital surgeons [2].

In a previous study, our team used a combined transnasal and orbital approach to restore fractured medial orbital walls extending into the ethmoid sinus. This method offered advantages over the transorbital technique by facilitating the smooth recovery of herniated orbital tissue by applying pressure from the ethmoid sinus [6]. When using a transorbital approach, the orbital tissues must be pulled and repositioned back into the orbit, which can exacerbate traction damage to the tissues and potentially increase separation damage to the orbital wall fracture fragments [2]. However, accessing the ethmoid sinus via a transnasal approach allows for simultaneous pressure application to the fractured orbital wall and ethmoidal mucosa, reducing traction-induced damage and minimizing fracture fragment separation [2]. Temporary support with absorbable foam inserted into the ethmoid sinus helped maintain the restored medial wall for several weeks post-surgery. Ethmoid packing was crucial in providing support, preventing reherniation, and promoting optimal healing [2,6].

The ethmoid sinus is situated between the superior aspect of the nasal cavity and the medial aspect of the orbit, separated from the cranial base by a thin skull base and positioned anatomically close to the optic canal posteriorly. Applying pressure to the medial orbital wall from the ethmoid sinus to restore a fractured orbital wall through a transnasal approach, or performing packing in the ethmoid sinus to support the restored medial orbital wall, may risk damaging the skull base or the optic canal [4,8]. Therefore, meticulous attention is essential during the surgical correction of a medial orbital wall fracture using a transethmoidal approach to minimize the risk of optic nerve damage and ensure accurate restoration of the fractured orbital wall.

Key challenges in orbital fracture surgery include restoring the orbital wall and accurately positioning the implant. Medial orbital wall fractures near the optic canal are particularly difficult due to the narrow operative field and the risk of postoperative complications, such as optic nerve injury and blindness. Intraoperative navigation addresses these challenges by providing real-time assessment of the orbital cavity's geometry, especially its posterior extent. This capability allows the surgeon to continuously monitor the device's position within the orbit, ensuring safety during restoration and minimizing the risk to the optic nerve [9,10].

Navigation guidance enhances the accuracy of implant placement and supports the customization and adjustment of malleable implants during surgery. It facilitates the precise execu-



Fig. 3. Case of left medial wall restoration. (A) Preoperative, (B) postoperative, and (C) 6-month postoperative computed tomography scans (axial and coronal views) of a 54-year-old woman with a left medial orbital wall fracture. Orbital wall reconstruction was performed to the posterior edge of the blowout fracture, adjacent to the optic canal, with the guidance of navigation.

tion of pre-planned restoration procedures, reducing the need for subsequent corrections [10,11]. Additionally, the navigation system enables multiple evaluations of orbital wall reconstruction and plate positioning throughout the procedure, improving overall accuracy and outcomes [11]. In severe fractures, particularly those involving multiple regions, determining

whether the orbital contents have been fully repositioned, if the posterior edge of the fracture has been bridged, and whether the implant is safely distanced from the optic nerve can be particularly challenging [11,12]. Once an orbital implant is in place, navigation should be used to confirm its position and shape, making any necessary adjustments to achieve the desired



Fig. 4. Case of right medial wall restoration. (A) Preoperative, (B) postoperative, and (C) 6-month postoperative facial computed tomography scans (axial and coronal views) of a 24-year-old woman with a right medial orbital wall fracture. Orbital wall reconstruction was performed to the posterior edge of the blowout fracture, adjacent to the optic canal, with the guidance of navigation.

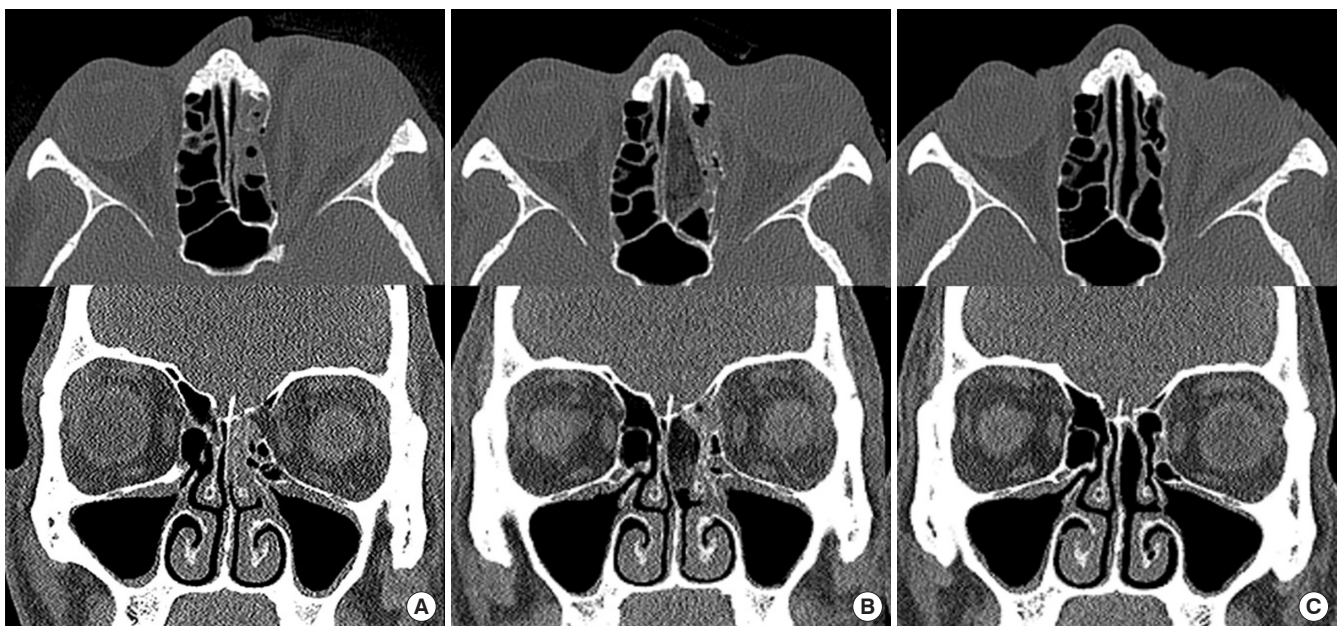


Fig. 5. Case of left medial wall restoration. (A) Preoperative, (B) postoperative, and (C) 6-month postoperative facial computed tomography scans (axial and coronal views) of a 28-year-old man with a left medial orbital wall fracture. Orbital wall reconstruction was performed to the posterior edge of the blowout fracture, adjacent to the optic canal, with the guidance of navigation.

contouring. Navigation addresses crucial concerns in orbital wall restoration by allowing real-time verification of proper wall restoration and prevention of optic nerve damage.

In summary, incorporating navigation into surgery for orbital medial wall fractures enhances surgical precision and minimizes the risk of optic nerve damage, both of which are essential for achieving successful outcomes in orbital fracture surgery (Figs. 3-5).

NOTES

Conflict of interest

Dong Hee Kang is an editorial board member of the journal but was not involved in the peer reviewer selection, evaluation, or decision process of this article. No other potential conflicts of interest relevant to this article were reported.

Funding

None.

Ethical approval

The study was approved by the Institutional Review Board of Dankook University Hospital (IRB No. 2024-09-012) and performed in accordance with the principles of the Declaration of Helsinki.

Patient consent

The patients and their guardians provided written informed consent for the publication and use of their images.

ORCID

Jae Hyung Jeon	https://orcid.org/0009-0007-3228-5783
Hong Bae Jeon	https://orcid.org/0000-0003-2412-4537
Hyonsurk Kim	https://orcid.org/0000-0001-6576-8035
Dong Hee Kang	https://orcid.org/0000-0002-6673-9655

Author contributions

Conceptualization; Formal analysis: Dong Hee Kang. Methodology: Jae Hyung Jeon, Dong Hee Kang. Writing - original draft: Jae Hyung Jeon. Writing - review & editing: Dong Hee Kang. Investigation; Resources: Dong Hee Kang. Supervision: Hong Bae Jeon, Dong Hee Kang. Validation: Hong Bae Jeon, Hyonsurk Kim, Dong Hee Kang. All authors read and approved the final manuscript.

REFERENCES

1. Copelli C, Manfuso A, d'Ecclesia A, Catanzaro S, Cassano L, Pederneschi N, et al. Endoscopic transnasal approach and intraoperative navigation for the treatment of isolated blowout fractures of the medial orbital wall. *J Craniomaxillofac Surg* 2015;43:1974-8.
2. Kang DH. Orbital wall restoring surgery with primary orbital wall fragments in blowout fracture. *Arch Craniofac Surg* 2019; 20:347-53.
3. Oh SA, Aum JH, Kang DH, Gu JH. Change of the orbital volume ratio in pure blow-out fractures depending on fracture location. *J Craniofac Surg* 2013;24:1083-7.
4. Kim YH, Jung DW, Kim TG, Lee JH, Kim IK. Correction of orbital wall fracture close to the optic canal using computer-assisted navigation surgery. *J Craniofac Surg* 2013;24:1118-22.
5. Schmelzeisen R, Gellrich NC, Schoen R, Gutwald R, Zizelmann C, Schramm A. Navigation-aided reconstruction of medial orbital wall and floor contour in cranio-maxillofacial reconstruction. *Injury* 2004;35:955-62.
6. Choi WK, Kang DH, Oh SA. Anatomical reconstruction of the medial orbital wall fracture. *Arch Craniofac Surg* 2012;13:29-35.
7. Cai EZ, Koh YP, Hing EC, Low JR, Shen JY, Wong HC, et al. Computer-assisted navigational surgery improves outcomes in orbital reconstructive surgery. *J Craniofac Surg* 2012;23:1567-73.
8. Shin HS, Kim SY, Cha HG, Han BL, Nam SM. Real time navigation-assisted orbital wall reconstruction in blowout fractures. *J Craniofac Surg* 2016;27:370-3.
9. DeLong MR, Gandolfi BM, Barr ML, Datta N, Willson TD, Jarrahy R. Intraoperative image-guided navigation in craniofacial surgery: review and grading of the current literature. *J Craniofac Surg* 2019;30:465-72.
10. Choi SH, Kang DH. Prediction of late enophthalmos using preoperative orbital volume and fracture area measurements in blowout fracture. *J Craniofac Surg* 2017;28:1717-20.
11. Park TH. The usefulness of the navigation system to reconstruct orbital wall fractures involving inferomedial orbital strut. *J Clin Med* 2023;12:4968.
12. Yang JR, Liao HT. Functional and aesthetic outcome of extensive orbital floor and medial wall fracture via navigation and endoscope-assisted reconstruction. *Ann Plast Surg* 2019;82(1S Suppl 1):S77-S85.