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ORIGINAL RESEARCH

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Modified individualized titanium mesh in orbital floor reconstruction for preventing exposure

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Abstract

Objective: To describe a novel method of medial fixation of titanium mesh with a right-angled screwdriver for orbital floor and maxillary reconstruction and to compare the reconstruction outcome of orbital floor reconstruction with modified and traditional methods.

Methods: The data of 23 patients who underwent maxillectomy and orbital floor defect reconstruction by individualized titanium mesh in Peking University School and Hospital of Stomatology between 2018 and 2021 were retrospectively reviewed. While eight patients received modified orbital floor reconstruction with titanium mesh and angled screwdriver (group A), 15 patients received traditional orbital floor reconstruction (group B). The contact area with buccal flap for titanium mesh in groups A and B was calculated. Titanium mesh deformation, fracture or exposure was recorded. Postoperative ophthalmic function and success of esthetic restoration were assessed.

Results: Mean follow-up was for 15.7 months (range, 9–22 months). The contact area with buccal flap for the modified titanium mesh in group A (13.11 ± 1.41 cm^2) was significantly less than that of the traditional titanium mesh in group B (21.83 ± 1.23 cm^2; $p < .05$). The exposure of titanium mesh occurred in two patients in group B. The self-evaluation of facial symmetry for 23 patients showed no significant difference between group A (7.75 ± 0.71) and group B (6.68 ± 1.30; $p > .05$). No specific complications were reported.

Conclusion: We propose a novel method of zygomatic medial fixation of titanium mesh with a right-angled screwdriver for orbital floor and maxillary reconstruction, which has the potential to prevent the postoperative exposure of titanium mesh.

Level of Evidence: Level III (Retrospective comparative study).

KEYWORDS
free flap, level of evidence, maxillary reconstruction, orbit floor reconstruction, right-angled screwdriver, titanium mesh

INTRODUCTION

The maxillary and orbital floor defects resulting from tumors and trauma can cause larger oronasal and oromaxillary fistulas; loss of lip, cheek, and eye support; and loss of midface projection and significant tooth-bearing segments.[1,2] Correction of these defects presents a great challenge for oral and maxillofacial surgeons. Individualized titanium mesh combined with free flap is widely used for the maxillary

and orbital floor defects.[3–5] The titanium mesh can be prebent to simulate orbital bone structure and the shape of the orbital floor. The mesh is covered with a tissue flap for preventing exposure. However, the exposure and infection of titanium mesh have been reported, which seriously affects the postoperative appearance and quality of life.[6–8]

Currently, virtual surgical planning and computer-aided design/computer-aided manufacture are well-developed tools that help to prebend individual titanium mesh.[9,10] The right-angled screwdriver has been designed for predrilling and insertion of screws, which allows procedures to be minimally invasive. It has also been recommended for maxillofacial surgery including the transoral management of condylar fractures with endoscopic assistance, fixation of segments in bilateral sagittal split osteotomies, and repair of fractures of the orbital floor and anterior cranial fossa.[11,12]

The purpose of this study was to describe a novel method of medial fixation of titanium mesh with a right-angled screwdriver for orbital floor and maxillary reconstruction and to compare the reconstruction outcome of orbital floor reconstruction with modified and traditional methods.

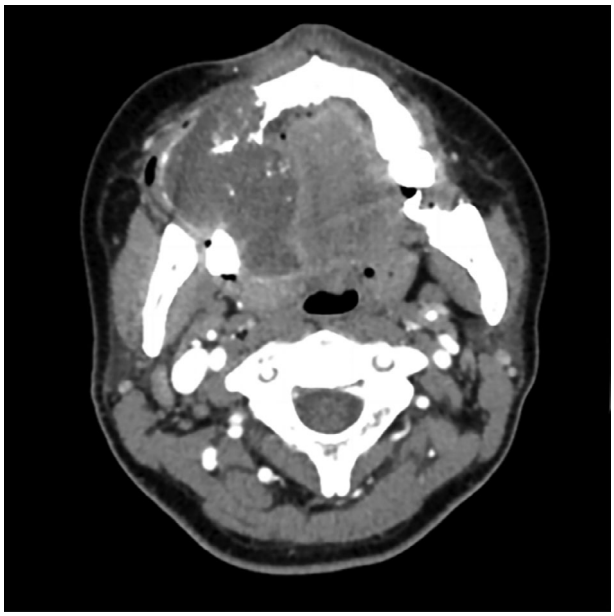

FIGURE 1 Computerized tomography showed an extensive, radiolucent, multilocular, expansile lesion.

1 | PATIENT AND METHODS

1.1 | Study design

This retrospective cohort study enrolled patients who underwent maxillectomy and orbital floor defect reconstruction by individualized titanium mesh in Peking University School and Hospital of Stomatology between 2018 and 2021. Inclusion criteria for this study were (1) patients diagnosed with primary maxillary neoplasm; and (2) defects including Brown class III maxillary defects with orbital retention preserved.[13] Of the 23 patients who satisfied the eligibility criteria, 8 patients received modified orbital floor reconstruction with individual titanium mesh and angled screwdriver (group A), and 15 patients received traditional orbital floor reconstruction (group B). The preoperative and postoperative data of the patients were collected from the hospital records for analysis. We received informed consent for this study. This study was approved by the Ethical Review Board of Peking University School and Hospital of Stomatology (No. PKUSSIRB-201522051). All procedures conformed to the tenets of the Helsinki Declaration.

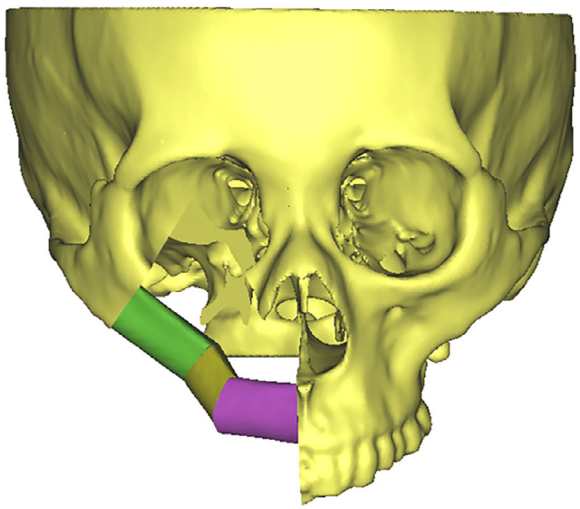

FIGURE 2 3D fibular segments were inserted into the maxillary defect in its desired orientation according to the ideal maxillary contour.

1.2 | Virtual planning

ProPlan CMF software (ProPlan CMF, Materialize NV, Leuven, Belgium) was used for virtual plan. According to Preoperative maxillofacial enhanced CT data, the contour of the right maxilla was destroyed by the tumor (Figure 1). Next, we performed a virtual maxillectomy with ProPlan CMF according to the clinical and 3D radiological findings. The maxillary defect for this patient involved the orbital floor (Brown class III). Mirroring tools were used to form the ideal maxillary contour, following which, we superimposed the 3D fibular image on the maxillary defect in its desired orientation according to the ideal maxillary contour (Figure 2). For patients in group A, the gap (width: 1.5 cm) between the residual zygoma and mirrored maxilla was made by cutting (Figure 3).

For group A, reconstructed maxillary stereomodels with the gap were manufactured by the bioengineer, with 3D printing technology. The modified titanium mesh was bent from maxillary processes and infraorbital region to the medial surface of the zygoma along the gap (Figure 4). The modified titanium mesh used for reconstruction of the

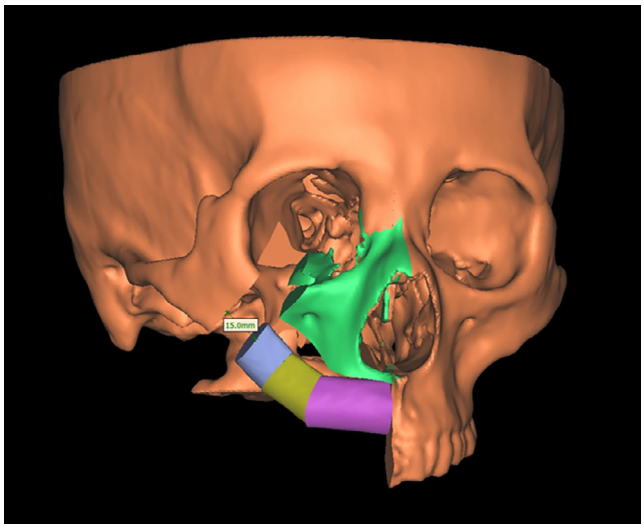

FIGURE 3 The gap (width: 1.5 cm) between the residual zygoma and mirrored maxilla was made by cutting.

FIGURE 4 The modified titanium mesh was bent to the medial surface of the zygoma along the gap.

infraorbital region and medial fixation with maxillary processes would come into contact with the buccal flap. The contact area with the buccal flap for group A was calculated.

For group B, traditional titanium mesh was prebent according to the maxillary 3D model without a gap. The traditional titanium mesh was bent from maxillary processes and infraorbital region to the lateral surface of the zygoma along the gap (Figure 5). The titanium mesh used for reconstruction of the infraorbital region and bilateral fixations would come into contact with the buccal flap. The contact area with the buccal flap for group B was calculated.

The data for virtual maxillectomy and reconstruction with a free flap was imported to the intraoperative navigation system (iPlan 3.0, Brainlab, Feldkirchen, Germany). Reconstructed maxillary stereolithic

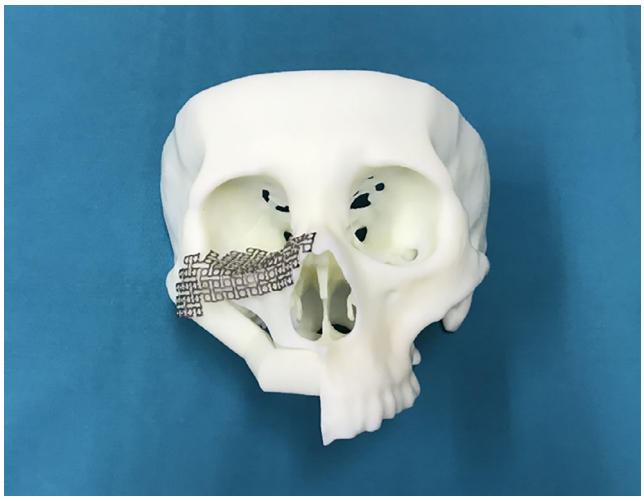

FIGURE 5 The traditional titanium mesh was prebent according to the maxillary 3D model without a gap.

models and modified titanium mesh were sterilized preoperatively for the surgery.

1.3 | Navigation surgery

All surgeries and reconstructions were performed by the same surgeon. A Weber–Ferguson incision was used to raise the upper cheek flap to expose the tumor. According to the virtual plan, a total maxillectomy including orbital floor resection with preservation of the orbital contents was carried out under the guidance of a computerized navigation system. The navigation system used in this study was iPlan 3.0. Intraoperative navigation was used to implement the virtual plan for our patient undergoing maxillectomy, orbital floor reconstruction with titanium mesh, and maxillary reconstruction with free flap. The three-dimensional images displayed by the navigation system were used during surgery to mark the osteotomy line and transfer the virtual maxillectomy to real-time surgery (Figure 6).

For group A, the medial surface of the zygoma and the maxillary processes were exposed for bilateral fixation of the modified titanium mesh. The right-angled screwdriver was used for predrilling and insertion of screws, which eliminates the need for straight-line access and allows screws to be inserted perpendicular to the bony surface (Figure 7). The titanium plate was used for fixation between the zygoma and fibula (Figure 8). For group B, the lateral surface of the zygoma and the maxillary processes were exposed for bilateral fixation of the traditional titanium mesh (Figure 9).

Compared to the traditional surgery, the differences of the novel technique (group A) include the preoperative preparation and intraoperative implementation. Before the surgery, reconstructed maxillary stereolithic models with the gap were manufactured with 3D printing technology, which was used to prebend the modified titanium mesh. During the surgery, the medial surface of the zygoma was exposed for medial fixation with the modified titanium mesh.

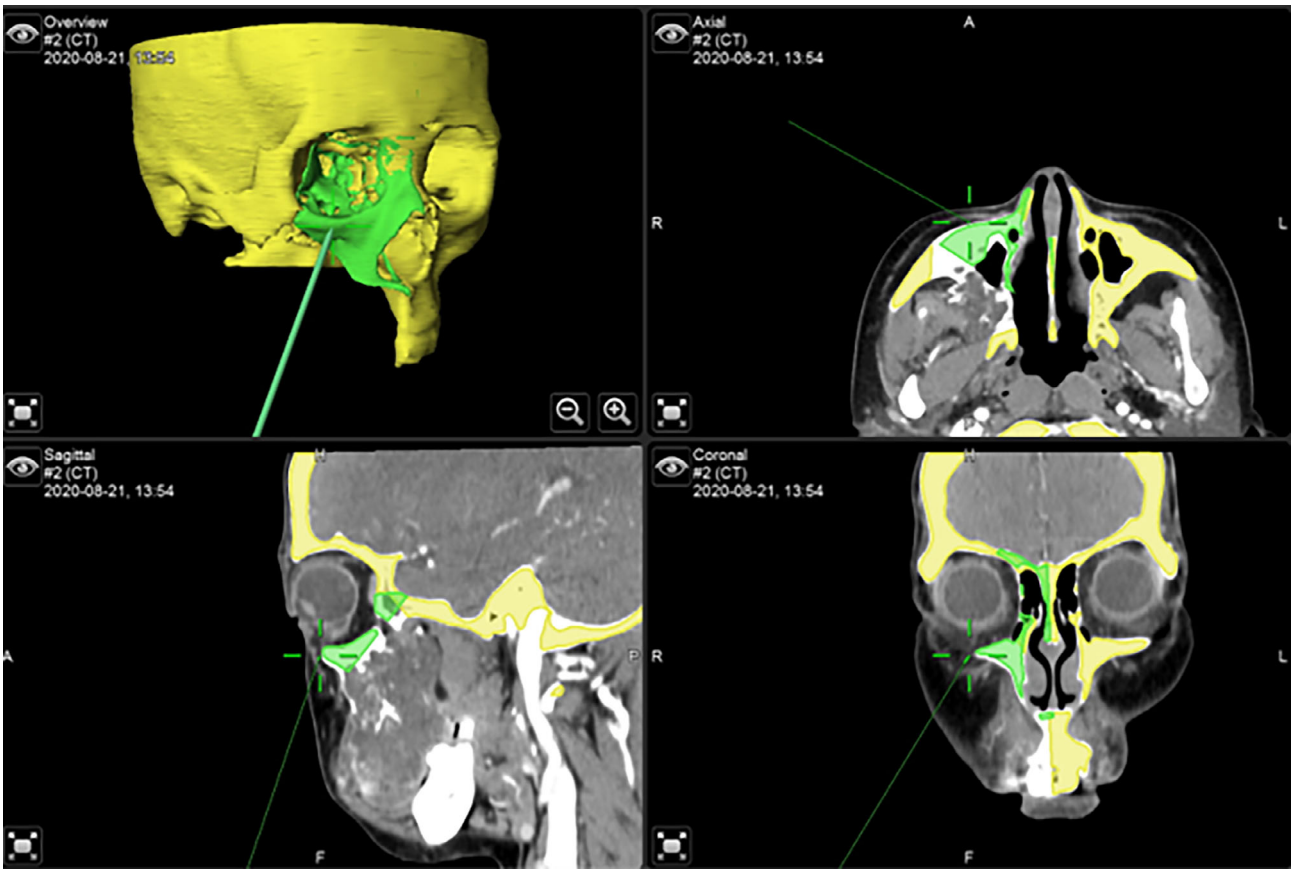

FIGURE 6 Under the guidance of a surgical probe, the osteotomy line was marked and the virtual maxillectomy was transferred to real-time surgery.

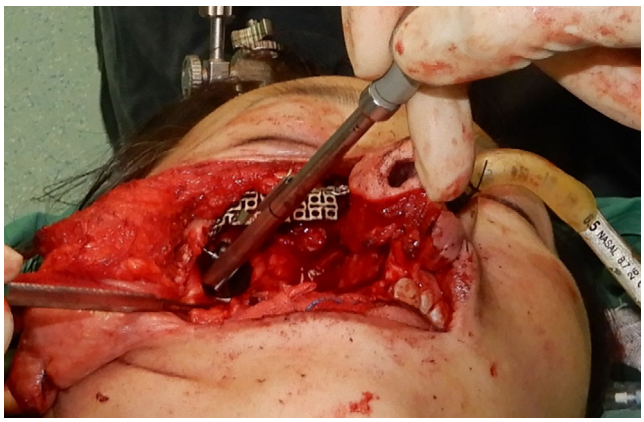

FIGURE 7 The right-angled screwdriver was used for predrilling and insertion of screws, which eliminates the need for straight-line access, and allows screws to be inserted perpendicular to the bony surface.

1.4 | Outcome evaluation

All patients were followed up for at least 9 months. Postoperative complications including titanium deformation, fracture or exposure, diplopia and flap necrosis were reviewed according to the clinical record. The self-evaluation of facial symmetry by patients was classified as poor (0–3), fair (4–7), and satisfactory (8–10).

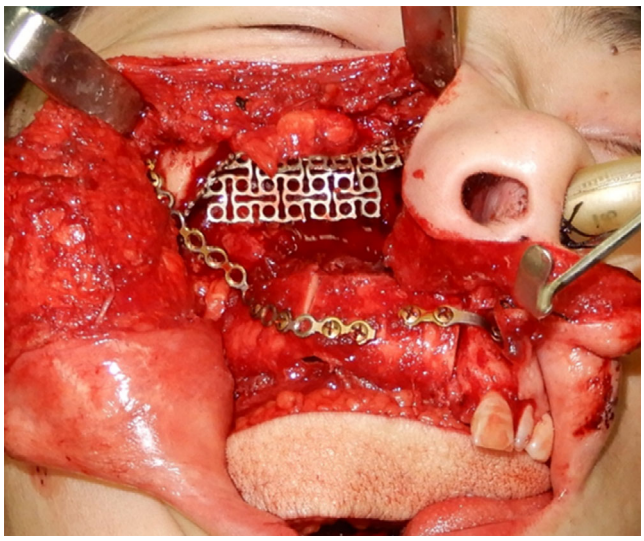

FIGURE 8 The titanium palate was used for fixation between the zygoma and fibula.

2 | RESULTS

Of the 23 patients, 14 were diagnosed with benign tumors and 9 were diagnosed with malignant tumors. Mean follow-up was for 15.7 months

(range, 9–22 months). During the follow-up period, none of the 14 patients with benign tumors presented with local recurrence, while local recurrence was reported in 2 patients diagnosed with malignant tumors.

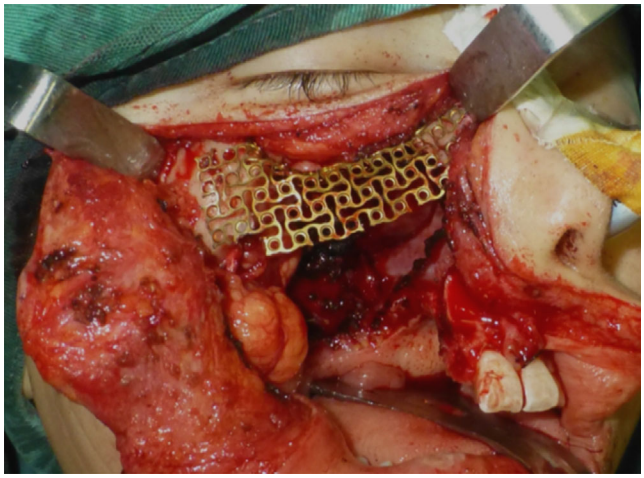

FIGURE 9 The lateral surface of the zygoma and the maxillary processes were exposed for bilateral fixation of the traditional titanium mesh.

A total of 8 patients received modified orbital floor reconstruction with titanium mesh and angled screwdriver (group A), and 15 patients received traditional orbital floor reconstruction (group B). The mean contact area with the buccal flap for group A (13.11 ± 1.41 cm^2) was significantly less than that of group B (21.83 ± 1.23 cm^2) ($p < .05$). There was no titanium mesh deformation or fracture in groups A and B. However, the exposure of titanium mesh occurred in group B (2/15) (Table 1). One of these two patients had malignant disease, had a history of previous surgery, and had received preoperative radiotherapy, while another one was diagnosed with a benign tumor. For these two patients, the regions exposed was the zygomatic part, and secondary surgery was used to recover titanium mesh exposure. No other specific complications were reported. The 12-month postoperative photo of the patient with this new technique showed a good surface contour of face (Figure 10). The self-evaluation of facial symmetry showed no significant difference between group A (7.75 ± 0.71) and group B (6.68 ± 1.30; $p > .05$).

3 | DISCUSSION

Severe functional and esthetic disturbances could be caused by maxillary defects due to trauma or tumor resection. Extensive maxillectomy

TABLE 1 Comparison of different variables between patients who received modified titanium mesh (group A) and traditional titanium mesh (group B).

Group	*N*	Age (years)	Diagnosis Benigh: Malignant	Mean contact area with the buccal flap	Titanium mesh exposure	Self-evaluation scores of facial symmetry
Group A	8	39.7 ± 12.7	5:3	13.11 ± 1.41 cm^2	0/8	7.75 ± 0.71
Group B	15	45.4 ± 14.4	9:6	21.83 ± 1.23 cm^2	2/15	6.68 ± 1.30
p-value				$p < .05$	$p > .05$	$p > .05$

FIGURE 10 The 12-months postoperative photo of the patient with this new technique showed a good surface contour of face.

for midfacial tumors usually includes orbital floor which forms the roof of the maxilla. The orbital floor is very important to support the eye globe, midfacial projection, and facial symmetry in the midfacial region. Defects of the maxilla combined with the orbital floor resulting from tumor ablative surgery can severely affect patients' facial function and appearance.[14–16] It may also cause enophthalmos, exophthalmos, diplopia, and impaired visual acuity, thereby severely affecting patients' quality of life. Titanium mesh is mostly applied to maxillofacial reconstruction, prosthodontics, and cranioplasty.[17,18] Nakayama et al.[7] reported titanium mesh exposure occurred in 5/18 patients undergoing maxillary reconstruction with titanium mesh plate and soft-tissue free flap. Sun et al.[5] reported titanium mesh exposure in 2/19 patients who performed reconstruction with the fibula flap and titanium mesh. Our previous study reviewed 66 patients who underwent maxillectomy and orbital floor defect reconstruction by individualized titanium mesh and demonstrated that titanium mesh exposure occurred in six patients (exposure rate, 9.1%). For these six patients, the region of titanium mesh exposure included the medial canthus, the suborbital region, and the zygomatic region, which confirmed that titanium mesh exposure may occur in the region that comes into contact with the buccal flap.[19] Kang et al.[20] believed that flaps raised using the Weber–Fergusson approach are usually too thin and thus carry the risk of titanium mesh exposure and wound dehiscence. Many studies reported that sufficient soft tissue coverage of titanium mesh could prevent from titanium mesh exposure.[5,7,19] According to our previous study,[19] the region with a high risk of titanium mesh exposure could be divided into three zones: the suborbital region, angulus oculi medialis, and zygomatic region. For the angulus oculi medialis and the zygomatic region, it was difficult to accomplish coverage of the titanium mesh with sufficient soft tissue. Because of the existence of bone foundation including zygoma and maxillary process, the space between the titanium mesh and buccal flap was too small to put sufficient soft tissue in. For these two patients with titanium mesh exposure in our study, the regions exposed were both the zygomatic part, which confirmed this region had a high risk of titanium mesh exposure. Our methods could solve the problem in the zygomatic region. With the medial fixation of the titanium mesh with a right-angled screwdriver, the titanium mesh in the zygomatic region had sufficient tissue coverage including the zygoma and the buccal flap. The mean contact area with the buccal flap for the modified titanium mesh (13.11 ± 1.41 cm^2) was significantly less than that for the traditional titanium mesh (21.83 ± 1.23 cm^2), which could possibly reduce the risk of the titanium mesh exposure in zygomatic region. However, our method could not be used in the medial canthus, because the width of the maxillary process was too thin to manage medial fixation of the titanium mesh. The sufficient soft tissue coverage of the titanium mesh in the suborbital region was feasible. By the step-back of the titanium mesh in the sagittal position, the soft tissue had enough space to cover the titanium mesh. However, atrophy of the soft tissue over the titanium mesh could affect the long-time stability of the appearance. The appearance in the suborbital region was maintained by a balance between the adjusted distance of titanium mesh in the sagittal position and the atrophy of the soft tissue; this could likely be a direction for future research.

There are two key points to remember in the application of medial fixation of titanium mesh with a right-angled screwdriver. First, there should be no gap between the residual zygoma and titanium mesh, in order to support the stability of the titanium mesh and ensure the symmetric appearance of the suborbital region. Preoperative virtual surgical planning, pre-bending of the titanium mesh upon the 3D model of the maxilla, and intraoperative navigation provide a useful solution to achieve the appropriate position and stability of the titanium mesh. Second, wide, clear, and multiple angles in the operative field are important aspects for the success of this procedure. The right-angled screwdriver with endoscope has been used for many maxillofacial surgeries.[21,22] Through endoscope, direct visualization of a magnified and illuminated operative field was offered to the surgeon and unobstructed views for the assistant.[23] In our study, because of the tumor resection, a visible and limited operative field could be used for application of medial fixation of titanium mesh with a right-angled screwdriver.

4 | CONCLUSION

We provided a new method of zygomatic medial fixation of titanium mesh with a right-angled screwdriver for orbital floor and maxillary reconstruction, which has the potential to prevent postoperative exposure of the titanium mesh.

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CONFLICT OF INTEREST STATEMENT

None of the authors has a financial interest in any of the products, devices, or drugs mentioned in this manuscript.

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