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Long-term Effect of Individualized Titanium Mesh in Orbital Floor Reconstruction After Maxillectomy

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Objective: The aim of this study was to determine the clinical outcomes and long-term stability of individualized titanium mesh combined with free flap for orbital floor reconstruction after maxillectomy and to identify the risk factors for titanium mesh exposure.

Material and Methods: The data of 66 patients who underwent maxillectomy and orbital floor defect reconstruction by individualized titanium mesh in Peking University School and Hospital of Stomatology between 2011 and 2019 were retrospectively reviewed. Postoperative ophthalmic function and success of aesthetic restoration were assessed. Titanium mesh exposure was recorded and the risk factors were identified.

Results: Mean follow-up was for 24.8 months (range, 6–92 months). Ophthalmic function was successfully restored in 63/66 patients. Aesthetic restoration was not considered satisfactory by 10 patients. Titanium mesh exposure occurred in six patients (exposure rate, 9.1%). Preoperative radiotherapy was identified as an independent risk factor for mesh exposure (OR = 28.8, P = 0.006). Previous surgery, postoperative radiotherapy, pathological type of the primary lesion, the type of tissue flap applied, and the use of intraoperative navigation were not significant risk factors. Six patients with titanium mesh exposure underwent second surgery, but mesh exposure recurred in two patients due to insufficient soft tissue coverage.

Conclusion: Individualized titanium mesh with free flap can effectively restore maxilla–orbital defects. Preoperative radiotherapy is an independent predictor of postoperative titanium mesh exposure. Adequate soft tissue coverage of the mesh may reduce the risk of mesh exposure.

Key Words: Titanium mesh, maxillectomy, orbit floor defect, reconstruction, titanium mesh exposure.

Level of Evidence: 4 (case–control study)

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INTRODUCTION

A maxillectomy defect that involves the orbital floor (Brown class III) can cause severe aesthetic and functional problems. The loss of cheek, eye support, and midface projection results in facial asymmetry, globe malposition, diplopia, and disturbance of extraocular muscle function.[1] Reconstruction of orbital floor defects is performed in many institutions, but aesthetic and functional restoration remains a challenge.

Various strategies are used for reconstruction of orbital defects. Free bone grafts, alloplastic materials, tensor fascia lata, pedicle flap, free vascularized flap with or without titanium meshes, hydroxyapatite, polyether ether ketone, or porous high-density polyethylene (Medpor®) have all been used for reconstruction. A popular choice is individualized titanium mesh combined with free flap[2–6]; the titanium mesh provides sturdy support to prevent ophthalmic complications and helps restore midface projection, and the tissue flap is used to cover the mesh, close the wound, and separate the oral and sinonasal cavities. However, complications have been reported. The irregular morphology of the area makes it hard to achieve the ideal titanium mesh shape, and early tissue flap edema and later muscle atrophy—especially in patients who have received adjuvant radiotherapy for malignant disease—can lead to several complications. Stability of the reconstruction is also known to be poor in patients undergoing secondary reconstruction and in those who develop tumor recurrence. There has been little research on the clinical outcomes of individualized titanium mesh orbital reconstruction and the factors predisposing to titanium mesh exposure.[7–10] This study aimed to determine the clinical outcomes and long-term stability of individualized titanium mesh combined with free flap for orbital floor reconstruction after maxillectomy and to identify the risk factors for titanium mesh exposure.

PATIENTS AND METHODS

Patients

This retrospective study included 66 patients (42 men, 24 women) who underwent orbital floor defect reconstruction by individualized titanium mesh plus free flap after maxillectomy at the Department of Oral and

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Maxillofacial Surgery, Peking University School and Hospital of Stomatology, China, between February 2009 and November 2019. All patients had pathologically confirmed diagnosis by the criteria of the World Health Organization (WHO) Classification of Tumors, 4th edition.[11] The classification of maxillectomy defects using the Brown classification system was initially described in October 2010.[12] The defect is classified according to the vertical and horizontal dimensions or palatal aspect of the maxillectomy. We used the vertical classification, as follows: I—maxillectomy not causing an oronasal fistula; II—not involving the orbit; III—involving the orbital adnexae with orbital retention; IV—with orbital enucleation or exenteration; V—orbitomaxillary defect; and VI—nasomaxillary defect. Only patients with primary neoplasm of the maxilla and Brown class III maxillary defects were eligible for inclusion.

This study was performed in accordance with the principles of the Declaration of Helsinki and was approved by the institutional ethics committee and review board. Written informed consent was obtained from all patients before surgery.

Surgical Procedure

All patients underwent preoperative computed tomography (CT) scan of the head and neck region to evaluate the extent of the tumor resection for those needing immediate reconstruction after maxillectomy or to evaluate the extent of the defect for those due to undergo secondary reconstruction. The mirroring technique was used for unilateral orbital floor reconstruction and database matching for bilateral reconstructions. Individualized titanium meshes (0.6 or 0.4 mm; AO CMF; Synthes, Switzerland) were fabricated with the help of three-dimensional (3D)-printed skull models (Fig. 1). Maxillectomies and reconstructions were performed through the Webber–Ferguson incision. The titanium mesh was trimmed and stabilized in position at the orbital floor. The maxillary defects were rehabilitated with bony or soft tissue flaps. The soft tissue of the flaps was used to fill the dead space of the orbital floor, to completely cover the mesh surface, and to separate the oral and nasal cavities (Fig. 2).

Follow-up and Outcome Evaluation

Patients were followed up for at least 6 months. Postoperative stability was evaluated by clinical examination and CT scan. Ophthalmic function was self-evaluated by the patients and also separately by surgeons and ophthalmologists. Aesthetic outcome was self-evaluated by patients and were graded on a scale of 0 to 10; the scores were classified as satisfactory (8–10), fair (4–7), or poor (0–3).

Statistical Analysis

Statistical analysis was performed using SPSS 19.0 (IBM Corp., Armonk, NY, USA). Univariate analysis was performed using the chi-square test or Fisher's exact test to identify factors significantly associated with mesh exposure. Multivariate logistic regression analysis was performed to identify the independent risk factors for mesh exposure. $P \leq .05$ was considered statistically significant.

RESULTS

Mean follow-up was for 24.8 months (range, 6–92 months). Normal ophthalmic function was achieved in 63/66 (95.5%) patients; diplopia, ocular mobility disorder, and incomplete eye closure occurred in one patient each (Table 1). Facial symmetry was graded as unsatisfactory (score 0–3) by 10 patients (Table 1); 4 of these 10 patients also had mesh exposure. Local recurrence was reported in eight patients during follow-up. In three patients, the recurrence did not affect the orbit floor, and so only local excision was performed; another three patients with recurrence involving the orbit floor underwent local excision plus mesh trimming, and the remaining two patients underwent chemoradiotherapy without surgery (Table 1).

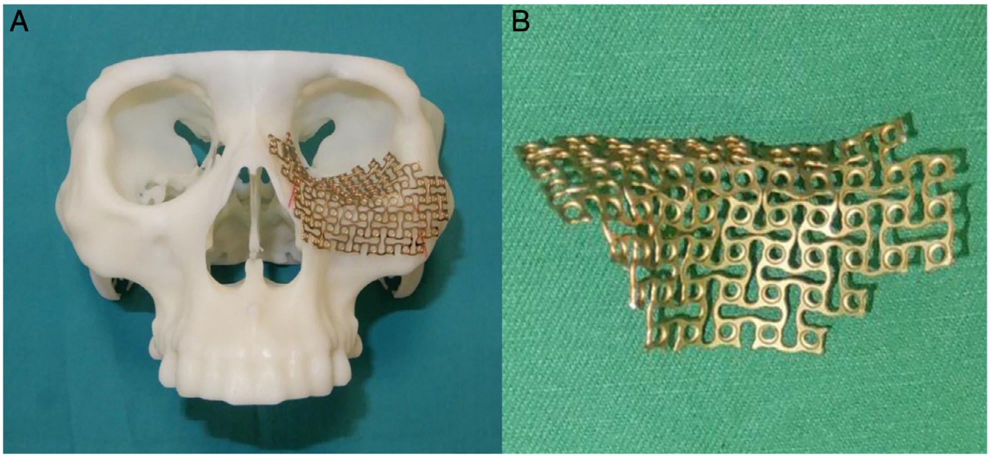

Fig. 1. The prefabricated titanium mesh. Three-dimensional (3D)-printed skull model (A) was used for fabricating the individualized titanium mesh (B).

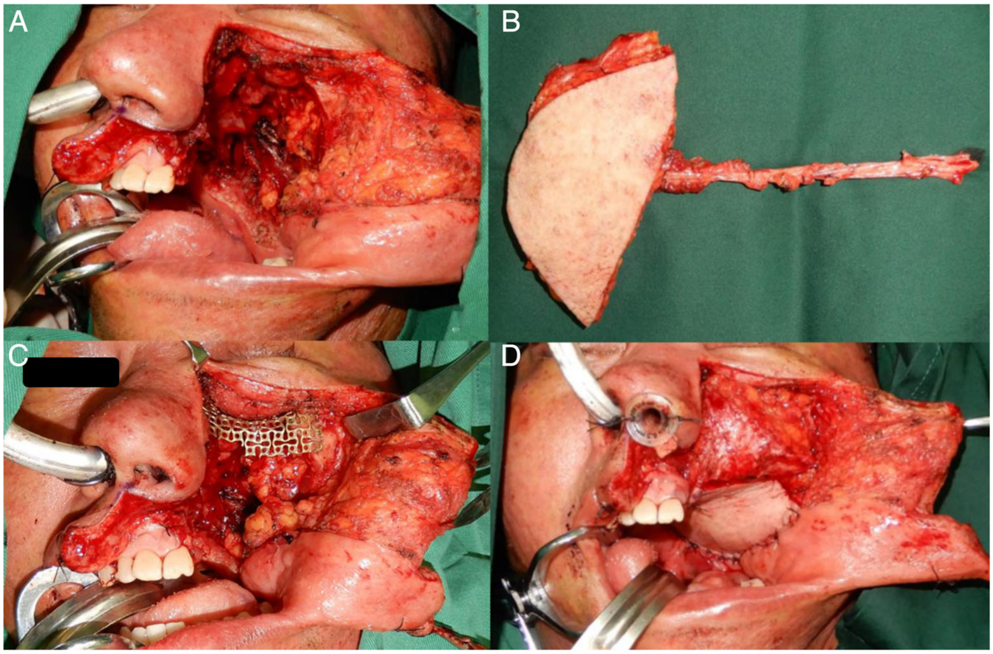

Fig. 2. Intraoperative reconstruction. (A) The Webber–Ferguson incision and the maxillectomy; (B) the anterolateral thigh flap; (C) placement of the titanium mesh; (D) soft tissue used to cover the mesh surface and to separate the oral and nasal cavities.

TABLE 1.
Follow-up Outcome of the Patients

Follow-up Outcome	No. of Cases
Long-term complications	
Diplopia	1
Ocular mobility disorder	1
Incomplete eye closure	1
Titanium mesh deformation or fracture	0
Titanium mesh exposure	6
Poor facial symmetry*	10
Local recurrence	
With local excision	3
With local excision and titanium mesh trimming	3
With no surgery	2

*Aesthetic assessment score 0–3.

No patient had titanium mesh deformation or fracture on clinical and CT evaluation. However, titanium mesh exposure occurred in 6/66 (9.1%) patients (Table 1). Among the six patients exposed to titanium mesh, the common clinical features were male, malignant tumor, previous surgical history, preoperative radiotherapy, and surgery without intraoperative navigation assistance. The time to titanium mesh exposure varied from 1 month to more than 2 years after reconstruction surgery, with most cases occurring within 2 months of the surgery. The suborbital part, the angulus oculi medialis, and the zygomatic part were the regions exposed (Table 2). All six patients with titanium mesh exposure underwent secondary salvage surgery; however, mesh exposure recurred in two of the six patients due to insufficient soft tissue coverage (Table 2, Fig. 3). The area of titanium mesh exposure was relatively minor and the exposure site did not affect the functions significantly, the patients refused for secondary surgery for repair or removal.

In univariate analysis, preoperative radiotherapy and history of previous surgery were the factors significantly associated with mesh exposure. In multivariate logistic regression analysis, only preoperative radiotherapy was an independent risk factor for mesh exposure (P = .006). Previous surgery, pathological type of the primary lesion, the type of tissue flap applied, and the use of intraoperative navigation were not significantly associated with risk of titanium mesh exposure (Table 3).

DISCUSSION

The goal of orbital reconstruction is to provide support for the orbital contents, to maintain the position of the eye globe, and to minimize facial deformity. Many types of tissue flaps, with and without artificial material, have been reported. Pryor et al.[2] used a coronoid–temporalis sling, without a titanium mesh, whereas Jung et al.[3] reconstructed the orbital floor using only a tensor fascia lata sling. Ophthalmic function was successfully restored with both techniques, but the patients were not satisfied with the aesthetic outcomes. Titanium meshes are commonly used for reconstruction in the head and neck region, in prosthodontics, and for cranioplasty.[7,13,14] In orbital floor reconstruction, the titanium mesh provides sturdy support for the orbital contents and helps restore midface projection. Stability, flexibility, and

TABLE 2.
Characteristics of the Patients With Titanium Mesh Exposure (n = 6).

Number	1	2	3	4*	5	6
Sex	M	M	M	M	M	F
Age (yr)	46	47	65	67	43	45
Pathology	Malignant	Malignant	Malignant	Benign	Malignant	Malignant
Previous surgery	Yes	Yes	Yes	Yes	No	Yes
Tissue flaps	FFF	FFF	ALFT	ALFT	SMAF	ALFT
Radiotherapy	No	Pre-Op	Pre-Op	Pre-Op	Post-Op	Pre-Op
Navigation	Yes	Yes	No	No	No	No
Exposure time (mo)	1	1	2	1	10	27
Exposure region	Angulus oculi medialis	Suborbital	Angulus oculi medialis	Zygomatic	Suborbital	Zygomatic
Salvage procedure	Debridement and suture	ALFT	RFFF	ALFT	ALFT	RFFF
Long-term outcome	Healed well	Healed well	Healed well	Exposure again (23 mo)	Exposure again (41 mo)	Healed well

*Figure 3.
ALTF = anterolateral thigh flap; FFF = free fibular flap; RFFF = radial forearm free flap; SMAF = submental artery island flaps.

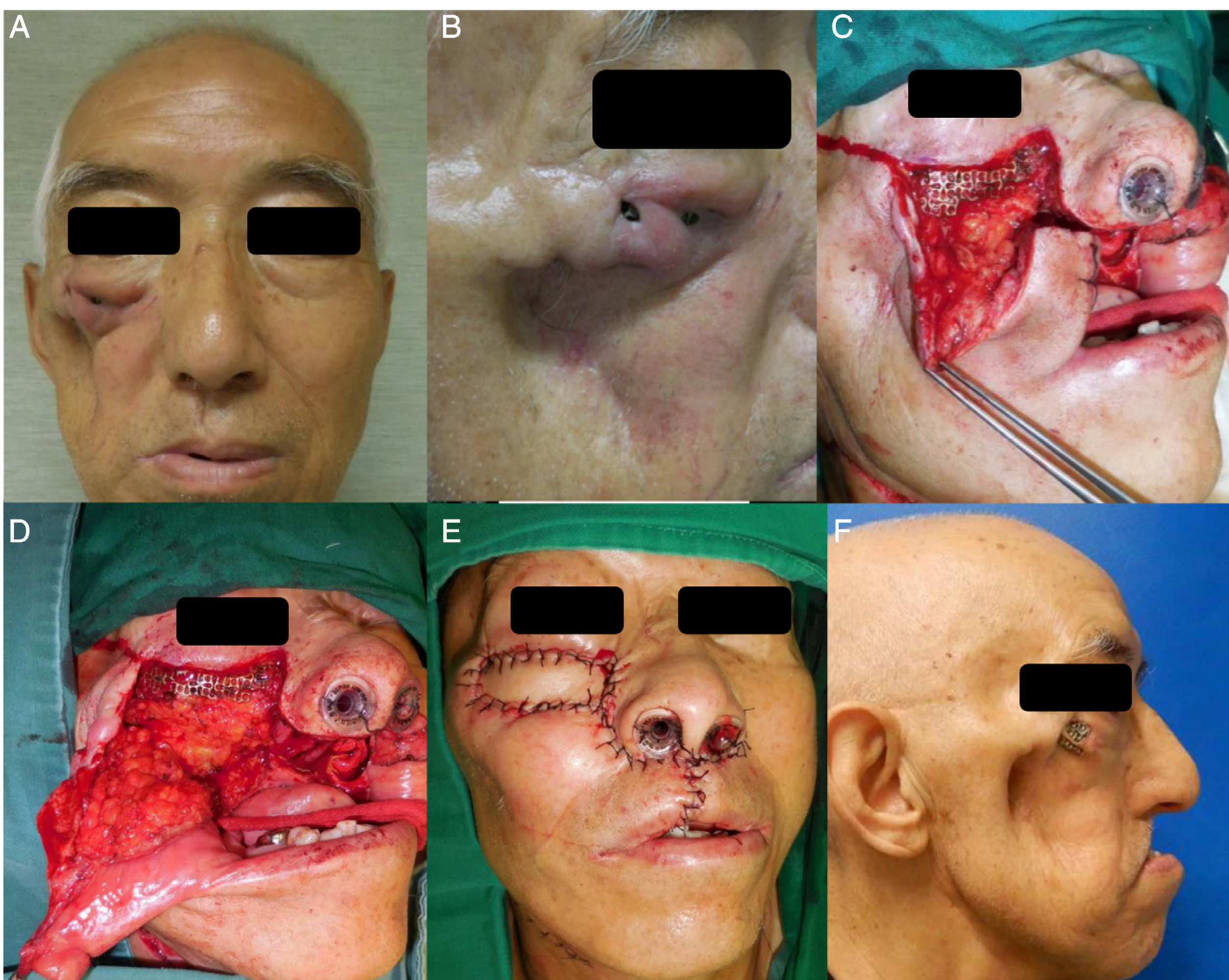

Fig. 3. Secondary salvage surgery in a patient with titanium mesh exposure (No. 4). (A,B) Mesh exposure was at the zygomatic region; (C,D) the meshes were trimmed to remove redundant material and the wound was debrided thoroughly; (E) the mesh surface was covered by the anterolateral thigh flap; (F) titanium mesh exposure recurred at the zygomatic region 23 months later due to soft tissue atrophy.

TABLE 3.
Risk Factors for Titanium Mesh Exposure

Factors	No. of Cases	Exposure (%)	Chi-square or Fisher *P* Value	Logistic *P* Value	Adjusted OR (95% CI)
Pathology			.207		
Malignant	39	5 (12.8)			
Benign	27	1 (3.7)			
Previous treatment			.003*	.057	20.000 (2.133–187.544)
Yes	17	5 (29.4)			
No	49	1 (2.0)			
Radiotherapy			<.001*		
Preoperative	9	4 (44.4)		.006*	28.800 (2.659-311.944)
Postoperative	20	1 (5.0)		.658	1.895 (0.112–32.010)
No	37	1 (2.7)		1	0 (0)
Reconstruction flaps			.815		
FFF	20	2 (10.0)			
DCIA	1	0 (0.0)			
ALFT	40	3 (7.5)			
RFFF	1	0 (0.0)			
SMAF	4	1 (25.0)			
Navigation			.474		
Yes	18	2 (11.1)			
No	48	4 (8.3)			

*Statistically significant.
ALTF = anterolateral thigh flap; DCIA = deep circumflex iliac artery bone flap; FFF = free fibular flap; RFFF = radial forearm free flap; SMAF = submental artery island flaps.

ability to osseointegrate are the main advantages of titanium mesh; their use also helps decrease operation time.[3,15]

In the present study, the rate of ophthalmic complications was low, and there were no cases of titanium mesh deformation or fracture. Previous studies have also demonstrated the physical and chemical stability of titanium mesh and its ability to provide long-term stable support.[4,5,10,13] However, complications and mesh exposure are not uncommon.[2,5,8,10]

Nakayama et al.[8] performed reconstruction using titanium mesh and soft-tissue flap and reported mesh exposure in 5 of their 18 patients (exposure rate, 27.8%). They did not evaluate the risk factors for mesh exposure, but postulated that the risk of exposure is inherent because the mesh is an artificial material. Sun et al.[4] used the fibula flap in combination with titanium mesh for high maxillectomy reconstruction in 19 patients and reported mesh exposure in 2 patients (exposure rate, 10.5%); both of these patients had undergone secondary reconstruction. Dediol et al.[5] used soft tissue flap in combination with titanium mesh and reported an exposure rate of 14.3% (1/7), whereas Samuel et al.[16] used bone flap with titanium mesh and reported an exposure rate of 16.7% (2/12). Both groups considered adjuvant radiotherapy to be the cause of mesh exposure in their patients. The mesh exposure rate in our study was markedly lower than in the above reports, indicating the effectiveness of our technique.

Several studies have reported preoperative radiotherapy to be a risk factor for mesh exposure, but the risk has not been adequately evaluated in the context of orbital floor reconstruction. Our study confirmed that preoperative radiotherapy is an independent risk factor for mesh exposure. Maqbool et al.[7] identified preoperative radiotherapy as one of the significant risk factors for mesh exposure following cranioplasty. There are several reports on the impact of preoperative radiotherapy on the stability of reconstruction with flaps in the head and neck region. Benatar et al.[17] found that preoperative radiotherapy (irrespective of irradiation dose) was a significant risk factor for fistula formation and wound infection. A systematic review and meta-analysis by Mijiti et al.[18] showed that preoperative external radiotherapy significantly increased the risk of plate exposure at the tumor site.

Radiation affects the microenvironment at the operation site and delays healing via various mechanisms: inhibition of neovascularization, and local infection with repetitive inflammatory responses. The long-term effects of radiation therapy include skin and tissue atrophy, fibrosis, and ulceration.[19–23] However, free tissue transfer during reconstruction may partly overcome some of these adverse effects of radiation.[22] Thus, individualized titanium mesh combined with free flap is the preferred reconstruction solution for patients receiving preoperative radiotherapy. The key to successful reconstruction is sufficient soft tissue coverage of the titanium mesh.

Postoperative radiotherapy may also adversely affect the long-term stability of orbital floor reconstruction with titanium mesh.[5,16,24,25] However, this was not found to be a significant factor in our study. The risk of poor wound healing decreases with adequate soft tissue coverage of the titanium mesh and good postoperative care. In our cohort, the impact of the postoperative radiotherapy was limited as care was taken to ensure adequate coverage of the titanium mesh.

The influence of previous surgery on orbital floor reconstruction has not been previously reported. Mücke et al.[26] found previous neck dissection to be significantly associated with postoperative wound infection, need for microsurgical revision, and free flap loss. This is not unexpected as the previous neck dissection may have resulted in inadvertent vascular injury and wound infection. The scarring and fibrosis that follow wound healing can restrict local blood flow and also increase mechanical tension in the wound. All of these increase the possibility of wound breakdown and exposure of the mesh.[26–29] In the present study, although the mesh exposure rate was higher in patients with history of previous surgery, the difference was not statistically significant. Surgery in the maxillary region is much more complicated than in the neck, and resection results in complex defects. In the present study, previous surgery was not a significant risk factor for mesh exposure; however, the failure to demonstrate a significant association was most likely due to the limited sample size.

Titanium mesh needs to be combined with a free flap for effective orbital floor reconstruction.[4,5,8] The flap is used to cover the mesh, close the wound, and fill the dead space. High success rate has been reported with the use of free flaps for orbital reconstruction. Our study also showed lower exposure rate with the free flap than with the pedicle flap (submental artery island flap), although the difference was not statistically significant. The free flaps provided sufficient tissue volume to cover the mesh and fill the dead space. The shape and the three-dimensional position of free flaps are easy to identify and adjust[15]; this helps decrease the mechanical tension in the wound and to promote healing.

In this study, the mesh exposure rate was higher in patients with malignant disease than in those with benign disease. One possible explanation is that patients with malignant disease had received adjuvant radiotherapy. Our study also showed lower exposure rate when a navigation system was used. The advantages of intraoperative navigation in orbital floor reconstruction have been highlighted in several previous studies.[15,30] Further research is needed to improve and standardize the technique.

In the present study, the time to titanium mesh exposure varied from 1 month to more than 2 years, with most cases occurring within 2 months of surgery. Mesh exposure mostly occurred in the suborbital region, the angulus oculi medialis, and the zygomatic region. Poor wound healing and insufficient soft tissue coverage of the titanium mesh are known to increase the risk of mesh exposure.[10,23] When titanium mesh exposure occurs, revision procedures are necessary. Redundant mesh material must be trimmed and the wound must be debrided thoroughly.[8,16] In our patients, locoregional flaps or secondary free flaps were used to close the exposed area, ensuring adequate soft tissue coverage of the titanium meshes. Unfortunately, mesh exposure recurred in two patients (Fig. 3) more than 3 years after the revision surgery due to atrophy of the flaps.

The limitations of this study are those inherent to retrospective reports. In our study, patients were followed up for at least 6 months because of the atrophy of the flaps, which mainly occurs within 6 months postoperatively,[30] and the previous literature reported that most cases occur within 6 months after surgery.[8] But we also noticed that one patient who demonstrated exposure at 2 years, which may lead to a lower exposure rate. Longer follow-up periods should be necessary to evaluate the reconstruction outcome.

In conclusion, individualized titanium mesh combined with free flaps can effectively restore maxilla–orbital defects with good ophthalmic function and long-term stability. Preoperative radiotherapy is a risk factor for titanium mesh exposure. Adequate soft tissue coverage of the titanium mesh can reduce the risk of mesh exposure.

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