Soft Tissue Management: A Critical Part of Implant Rehabilitation After Vascularized Free-Flap Reconstruction

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Purpose: Implant rehabilitation after jaw reconstruction is challenging, and postoperative peri-implantitis is common. Our aim was to present our management protocol for implant rehabilitation after vascularized free-flap reconstruction and report the outcomes of soft tissue management.

Methods: This retrospective cohort study included patients who received vascularized free-flap reconstruction, implant rehabilitation, apical reposition flaps (ARFs), and free gingival grafts (FGGs) at Peking University School and Hospital of Stomatology from January 1, 2009 to January 1, 2020. We assessed the association of age, gender, primary disease, flap choice, number and position of implants, timing of ARFs and FGGs, fixation stent use, and restoration type with the occurrence of peri-implantitis. Probing pocket depth, bleeding on probing, and marginal bone loss of the implants were measured as well. The data were analyzed by descriptive statistics, Kaplan-Meier statistics, and Cox regression analysis.

Results: In total, 19 patients with 65 implants were included. The implants were placed immediately or 7 to 44 months after reconstruction of the jaw with fibular (n = 17) or iliac flaps (n = 2). ARFs and FGGs were performed 0 to 11 months later. No implants were lost. The mean probing pocket depth, bleeding on probing, and marginal bone loss at 26.6 ± 16.8 months were 3.5 ± 0.9 mm, 70.4 ± 35.1%, and 0.6 ± 0.4 mm, respectively. The incidence of peri-implantitis was 32.3%, showing no significant associations with the gender, age, primary disease, flap choice, number and position of implants, timing of ARFs and FGGs, use of a fixation stent, and type of restoration based on the adjusted multivariate model ($P > .05$).

Conclusions: Soft tissue management helps generate firmly attached keratinized mucosa around the implants, leads to a more precise impression, and reduces peri-implant bone loss. It should be considered as a critical part of implant rehabilitation after vascularized free-flap reconstruction.

J Oral Maxillofac Surg 79:560-574, 2021

Received from Peking University School and Hospital of Stomatology, Beijing, China.

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Financial Disclosure: This work was supported by the Beijing Natural Science Foundation (L172013) and the National Key Technologies Research and Development Program of China (2017YFB1104103). The funding agencies had no role in the study design, clinical procedures, analysis of the results, or preparation of the manuscript.

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Conflict of Interest Disclosures: None of the authors have any relevant financial relationship(s) with a commercial interest.

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Received April 8 2020

Accepted November 8 2020

0278-2391/20/31333-1

https://doi.org/10.1016/j.joms.2020.11.006

Bone continuity defects of the maxillofacial region appear after treatment for tumors, cysts, trauma, or infection. It is necessary to improve the quality-of-life through vascularized free-flap reconstruction and implant restoration. However, the incidence of peri-implantitis after jaw reconstruction is high.[1,2]

The risk factors for peri-implantitis include poor oral hygiene, gingivitis, smoking, diabetes, alcohol, genetic factors,[3] and preoperative or postoperative radiotherapy or chemotherapy. However, jaw reconstruction may bring about other risk factors for subsequent sequalae, such as a shallow vestibule and a large range of movable soft tissue covering the alveolar crest. If no measures are taken to improve the soft tissue's condition, poor oral hygiene, soft tissue hyperplasia, and marginal bone loss (MBL) may occur. Studies have shown that a sufficient band of keratinized mucosa (KM) (≥2 mm) is necessary for long-term maintenance of dental implants and soft and hard tissue stability,[4,5] which suggests that soft tissue management may play a role in preventing peri-implantitis after jaw reconstruction.

Currently available methods for KM augmentation include periosteal retention procedures, split flap procedures,[6] the apically positioned flap technique,[7] and grafting procedures, among which the grafting procedures are the most widely used with the highest level of supporting evidence. Compared with other grafting procedures, such as connective tissue and soft tissue substitute grafts, free gingival grafts (FGGs) are considered to be the gold standard for KM augmentation.[8,9] FGGs have been shown to lead to less KM shrinkage and better KM quality. However, outcome data after FGGs for implant restoration after jaw reconstruction are lacking.[9-11] In addition, the existing studies have only assessed the rates of survival and success of the implants after jaw reconstruction. There is a lack of comprehensive studies involving detailed and objective metrics on the outcomes of soft tissue management in implant rehabilitation after vascularized free-flap reconstruction.

Hence, the purpose of this retrospective cohort study was to present our management protocol for implant rehabilitation after vascularized free-flap reconstruction and report the outcomes of soft tissue management. The specific aims of the study were to measure the probing pocket depth (PPD), bleeding on probing (BoP), and MBL after vascularized free-flap reconstruction with implant rehabilitation and soft tissue management and to diagnose peri-implantitis according to PPD and MBL.

Methods

The present study was performed following the criteria established by the Helsinki Declaration and has been approved by the Ethics Committee of Peking University School and Hospital of Stomatology (protocol no. PKUSSIRB-201941009). Written informed consent was obtained from all participants. The present study complied with the appropriate Enhancing the QUAlity and Transparency Of health Research (EQUATOR) guidelines.

STUDY DESIGN AND COHORT

This was a retrospective cohort study. The study population was composed of patients with benign or malignant tumors, cysts, trauma, or infections that underwent vascularized bone grafts, implant placement, and soft tissue management at Peking University School and Hospital of Stomatology from January 1, 2009 to January 1, 2020. The inclusion criteria were as follows: *1)* age of 18 years or older, *2)* maintenance of good oral hygiene, and *3)* at least 1 implant-supported fixed dental prosthesis that functioned for 6 months and greater. Patients were excluded as if they *1)* had active periodontal disease, *2)* received postoperative radiotherapy for malignant tumors, *3)* had xerostomia, *4)* had bone metabolic diseases, *5)* were immunodeficient, *6)* had uncontrolled diabetes, *7)* were heavy smokers (>10 cigarettes/day), or *8)* were pregnant or lactating.

CLINICAL PROCEDURES

First Stage: Treatment of Primary Disease and Reconstruction of the Jaw

First, simultaneous or delayed jaw reconstruction was performed according to the primary disease. Vascularized free-flap transplantation, including use of the iliac and fibula flaps as osteomuscular, osteocutaneous, or osteomyocutaneous flaps, was performed (Figs 1, 2).

Second Stage: Implant Placement

Implant placement was performed when clinical and radiographic assessments confirmed bone healing 6 months after the jaw reconstruction. Jaw reconstruction with a single-step free fibular graft and immediate dental implants was only attempted in 1 case.

After soft tissue exposure under local anesthesia, the implant sites were prepared in a standard stepwise fashion according to the manufacturers' protocols in all cases. The implants used were 10 to 15 mm long and 3.5 to 5.0 mm wide ITI (Straumann, Basel, Switzerland), Branemark, NobelActive, NobelSpeedy (Nobel Biocare, Gothenburg, Sweden), or SICace implants (SIC invent, Basel, Switzerland). The soft tissue was closed with 4-0 absorbable suture (Fig 3). All patients received oral antibiotics (cefradine + metronidazole) before and 5 days after surgery. Patients were instructed to consume soft

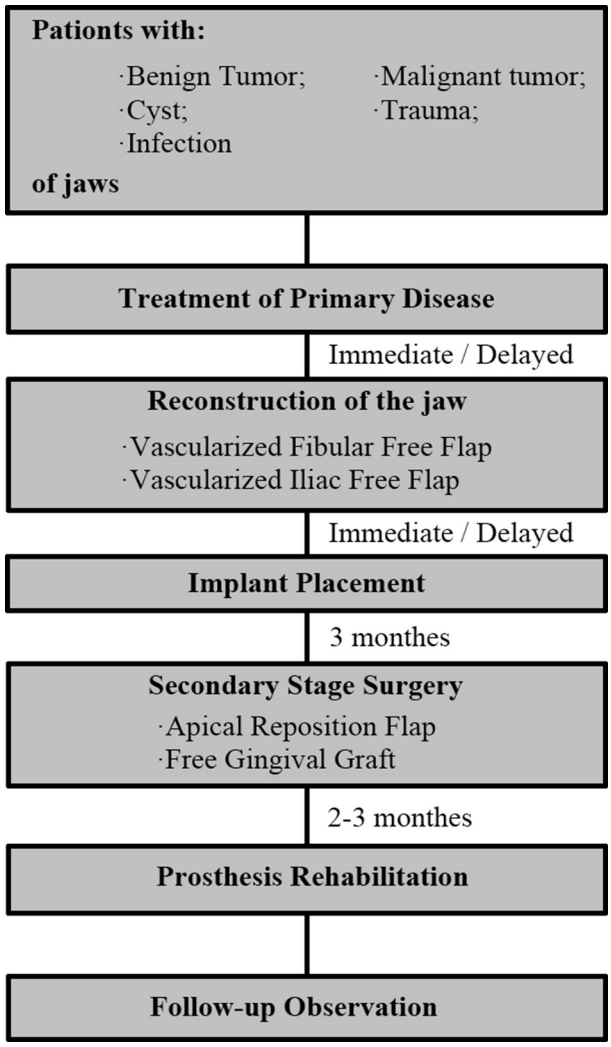

FIGURE 1. Clinical procedures performed for implant rehabilitation after jaw reconstruction.

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and cool foods, use mouthwash (a compound chlorhexidine gargle), and maintain good oral hygiene after surgery.

Third Stage: Second-Stage Surgery, Apical Repositioning Flap, and FGG

All implants were treated with delayed loading because of insufficient initial stability. Before the second-stage surgery, cone-beam computed tomography was used to assess the stability of the bone around the implants. A clinical assessment was performed to ensure that there was no infection.

The surgical technique of soft tissue management consists of 5 steps (Fig 4). The first step is recipient bed preparation. A split-thickness incision was made under local anesthesia, and the muscle attachment was carefully dissected. A 1.0- to 1.5-mm thickness

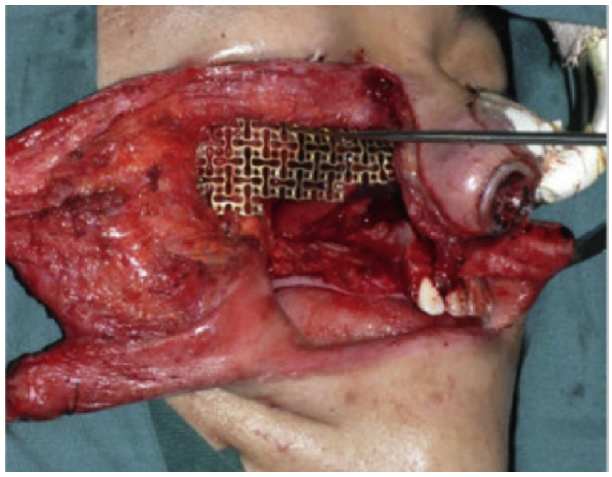

FIGURE 2. The right partial maxilla of a 19-year-old boy with ossifying fibroma was reconstructed by a fibular flap.

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of periosteum was kept attached to the bone surface. A split-thickness flap together with the muscle was raised and sutured to the more apical periosteum, and an ideal depth of vestibular sulcus was subsequently obtained. For cases involving a fibular flap, the skin paddle around the implants was removed. The second step involved replacement of the healing abutments. The healing screws were replaced with appropriately sized healing abutments. Step 3 is preparation of the keratinized mucosal graft. An area of keratinized tissue on the palatal side of the premolars and the first molar equivalent in size to the recipient bed was harvested. To obtain an accurate amount of tissue, the graft's area was marked before harvesting. A scalpel and noninvasive tissue tweezers were used to

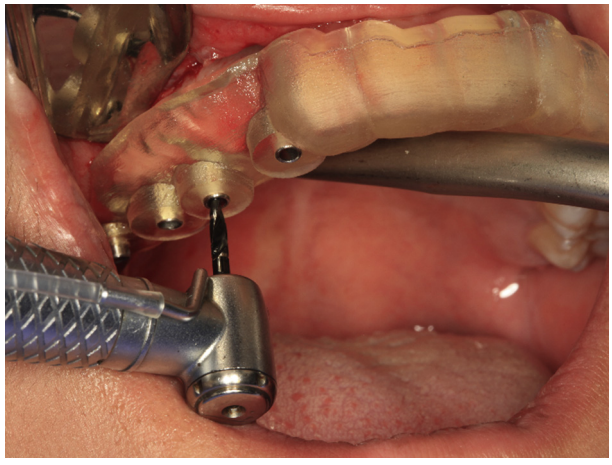

FIGURE 3. Four implants were placed during the mandibular reconstruction surgery.

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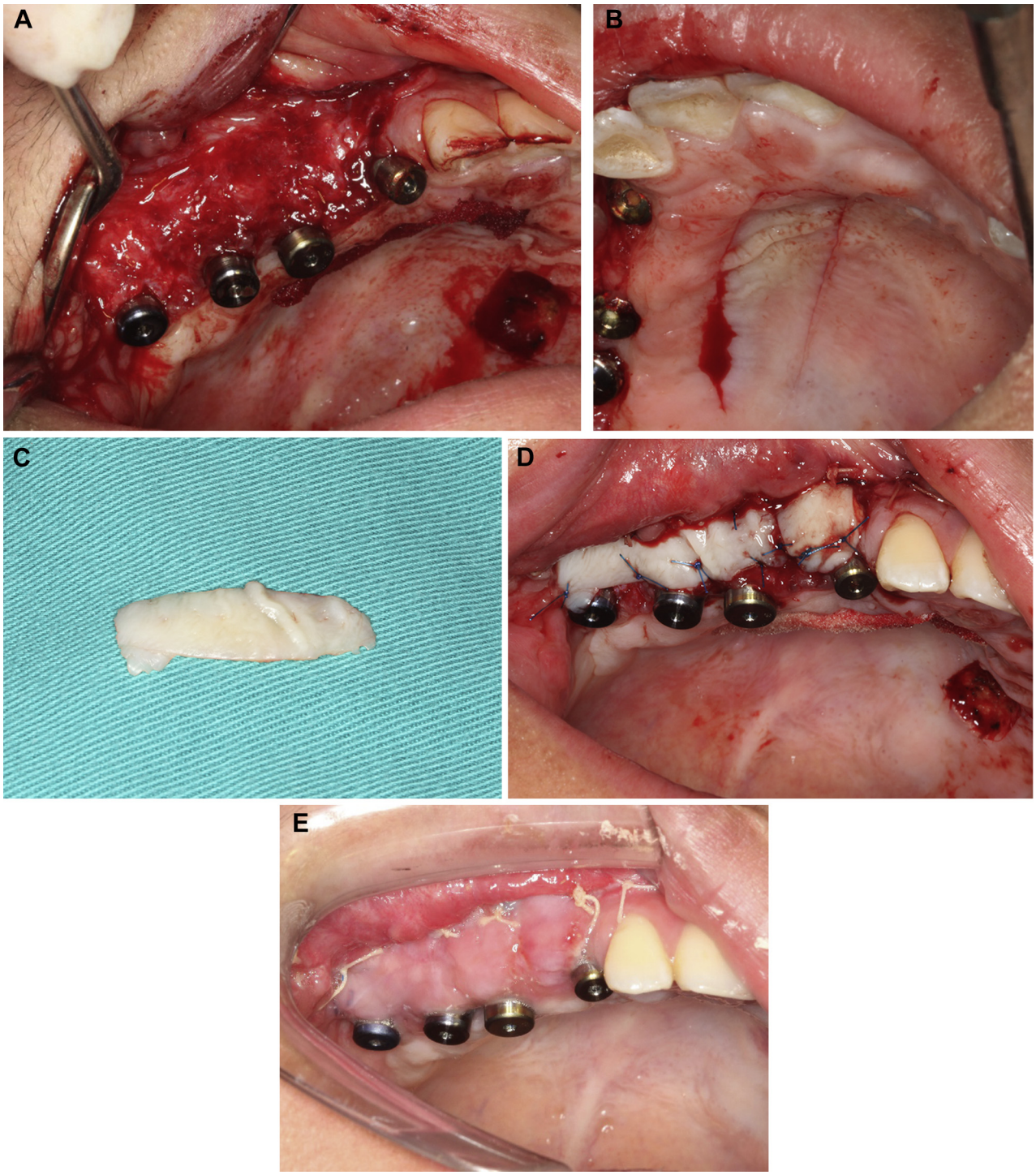

FIGURE 4. The second-stage surgery and soft tissue management. *A*, The preparation of the recipient bed. The periosteum was attached to the bone's surface. *B*, Harvesting the mucosal grafts after replacing the healing abutment. *C*, The keratinized mucosal graft was approximately 1- to 2-mm thick. *D*, The graft was sutured to the recipient bed. *E*, The mucosal graft survived 2 weeks after soft tissue management.

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carefully harvest the mucosal graft of approximately 1-mm thickness. Excess subepithelial adipose tissue was removed. A gauze was applied to exert local pressure. Step 4 is suturing of the graft to the underlying periosteum using a 4-0 absorbable suture at the 4 corners and a 6-0 absorbable suture for the remaining area. The mucosal graft was kept fixed after suturing to ensure a sufficient blood supply. After fixation, the entire mucosal graft was pressed gently with wet gauze to discharge the blood underneath and facilitate nutrient

supply and revascularization. A fixation stent was used to avoid the nonkeratinizing epithelium from the lip, cheek, or mouth floor replacing the FGG and to keep the graft fixed (Fig 5). The fifth and final step is coverage of the donor site with a collagen sponge and an acrylate resin plate for 2 weeks.

All patients received oral antibiotics (cefradine + metronidazole) before and 5 days after surgery. We instructed patients to consume only cool and soft foods in the 7 to 10 days after surgery, avoid brushing, use a mouthwash gargle (a combined chlorhexidine gargle), and maintain good oral hygiene. Patients were asked to return to the hospital at 2, 4, and 8 weeks after surgery to re-examine the healing of the peri-implant tissue.

Fourth Stage: Prosthesis Restoration

The restoration phase began after the peri-implant tissue matured, usually 2 to 3 months after the second-stage surgery. The type of prothesis was selected according to the specific patient's requirements, number of implants, restoration space, and requirement for oral hygiene (Fig 6). Removable restorations[12] were chosen when there were fewer implants and lower masticatory efficiency was required. For fixed restorations, screw-retained fixed partial denture[12] and cement-retained fixed partial denture[13] were used. A sanitary bridge was preferred in fixed partial denture cases except in patients with exacting esthetic preferences.

Fifth Stage: Follow-Up

Regular follow-up was conducted every 3 months in the first year after restoration and once a year thereafter. The outcome variables were assessed at the end of the follow-up period. The evaluation included clinical examinations and radiographic assessments.

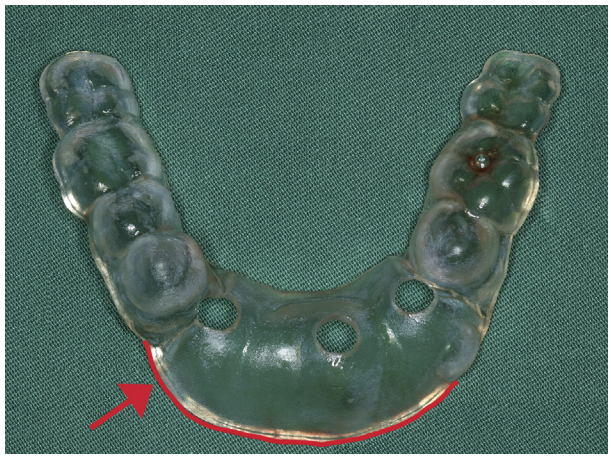

FIGURE 5. A fixation stent for protection of the graft until rehabilitation is completed. The fixation stent extends to the bottom of the sulcus.

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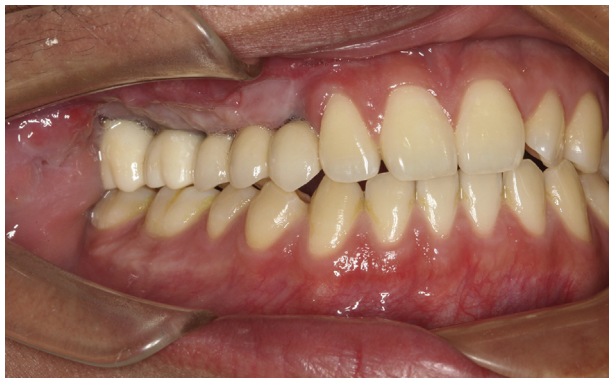

FIGURE 6. Good esthetic and oral function outcomes were obtained after reconstruction of the maxilla and implant rehabilitation.

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DATA COLLECTION METHODS

Peri-Implant Clinical Parameters

The peri-implant clinical parameters of each implant were recorded by the same examiner. A Williams probe was used to measure the PPD and BoP (in millimeters) at 4 sites (buccal, lingual, mesial, and distal) for each implant.[14]

Radiographic Examination and Measurement

Radiographic images of each implant were obtained using cone-beam computed tomography (NewTom VG, Quantitative Radiology, Verona, Italy) and analyzed by computer software (Horos, version 3.3.3, Nimble, Annapolis) calibrated based on the width of the implant abutment. The maximum marginal bone level of each implant was measured.[15] To assess the consistency of the measurements made by the examiner, all measurements were repeated after 2 days. The within-group correlation coefficient test showed a retest reliability of 93%. All measurements were performed by the same examiner.

DATA ANALYSES

Variables

We assessed the factors associated with the development of peri-implantitis, including gender, age, primary disease, flap choice, position of implants, timing of ARF and FGG, use of a fixation stent, and type of restoration.

We transferred the data to Excel (Excel for Mac, version 15.24, Microsoft, Redmond) and SPSS 24.0 software (IBM, Armonk, NY) for statistical analysis. Descriptive statistical analyses were performed for gender, age, primary disease, flap choice, number and position of implants, timing of ARF and FGG, use

of a fixation stent, type of restoration, and follow-up period. The average PPD, BoP, and MBL of all implants were described.

Peri-implantitis was defined as a PPD of 6 mm and/or greater in any of the 4 sites of an implant or a maximum MBL of greater than 3 mm together with BoP.[16,17] A patient with at least 2 implants and having more than 1 dental implant presenting peri-implant diseases was considered as presenting a cluster behavior. The adjusted multivariate model was established according to the setting.

Kaplan-Meier and Cox regression analyses were performed to analyze the impact of gender, age, primary disease, flap choice, number and position of implants, timing of ARF and FGG, use of a fixation stent, and type of restoration on peri-implantitis based on the adjusted multivariate model. Statistical significance was set at $P < .05$.

Results

A total of 19 patients were reviewed in this study, including 12 men (63.2%) and 7 women (36.8%) with an average age of 38.2 years (range, 21 to 65). Three patients (15.8%) suffered from malignant tumors, 10 (52.6%) had benign tumors, and 6 (31.6%) presented with trauma (Table 1).

Reconstruction with a fibular flap was performed in 17 patients (89.5%). Three of these subsequently only received a bone graft from the skull (n = 1) or iliac crest (n = 2), and 1 patient underwent vertical distraction osteogenesis because of insufficient height of the fibular flap. Two patients (10.5%) underwent jaw reconstruction with a vascularized iliac flap (Table 1).

A total of 65 implants (2 to 6 per person) were placed in 19 patients at 20.8 ± 10.1 months after jaw reconstruction, including 1 patient with 4 immediate implants. Among these, 25 implants (38.5%) were placed in the maxilla and 40 (61.5%) were placed in the mandible (Table 1).

Nineteen patients received ARF and FGG. Two of them underwent soft tissue management 4 months before implant placement, 2 received soft tissue management at the time of implant placement, and the remaining patients underwent soft tissue management during the second-stage surgery. The mean time interval between implant placement and soft tissue management was 5.1 ± 4.3 months. Mucosal necrosis and shedding did not occur in any of the patients.

The follow-up period was 26.6 ± 16.8 months. None of the patients dropped out of the study, and no implants were lost during follow-up. The survival rate of the implants was 100%. There were no cases of paresthesia or palsy of a nearby nerve, and none of the patients who received maxillary implants developed nasal or maxillary sinus problems.

The outcomes of ARF and FGG are shown in Table 1. The mean BoP, PPD, and MBL were 70.4 ± 35.1%, 3.5 ± 0.9 mm, and 0.6 ± 0.4 mm, respectively (Fig 7). The incidence of peri-implantitis was 32.3% (Table 1), which was relatively lower than previously reported (Table 2).[1,2,18-31] Based on the adjusted multivariate model, the Kaplan-Meier analysis and Cox regression analysis showed no significant differences among gender, age, primary disease, flap choice, number and position of implants, timing of ARF and FGG, use of a fixation stent, and type of restoration ($P < .05$) (Tables 3 and 4). The factor of using fixation stent was not reported in the Kaplan-Meier analysis because 100% survival was observed in the patients who had worn fixation stent (Table 3).

Discussion

One purpose of the present study was to report the outcomes of soft tissue management in patients who received vascularized free-flap reconstruction, implant rehabilitation, ARF, and FGG. We hypothesized that soft tissue management could improve the condition of peri-implant tissue and reduce peri-implantitis. The findings presented here illustrate the incidence rates and associate factors of peri-implantitis. The incidence of peri-implantitis in our study was lower than those of previous reports in patients who did not receive soft tissue management. Thus, our results show that ARF and FGG during implant rehabilitation can be recommended for patients undergoing jaw reconstruction.

FACTORS ASSOCIATED WITH SUCCESS AND SURVIVAL OF IMPLANTS IN THE RECONSTRUCTED JAW

The notion that oral function can be restored by implant rehabilitation after jaw reconstruction with a vascularized bone flap has been attracting wide attention. However, studies have shown that the survival and success rates of implants placed in the reconstructed jaw are low.[22,25,27,28] A major reason for implant failure is peri-implantitis, which is associated with the quality of the peri-implant soft tissue together with the height and position of the bone graft.

Inappropriate height and positioning of bone grafts are among the causes of the peri-implant bone loss. A notably insufficiently high alveolar ridge, which may result in implant fracture or prostheses destruction,[32] and an unclear border between the mucosa of the lip or cheek and that of the mouth floor or palate can be corrected by fabricating a double-barreled vascularized fibula flap or using a delayed onlay bone graft or a vertical distraction technique. However, these techniques were not applied in 13 cases because the height of alveolar bone was sufficient for placement of the

Table 1. BASELINE CHARACTERISTICS AND OUTCOME PARAMETERS

Case No.	Gender	Age (yr)	Primary Disease	Flap Choice	No. of Implants	Position of Implants	Timing of ARF & FGG (mo)	Fixation Stent	Type of Restoration	Follow-Up (mo)	Mean PPD (mm)	Mean BoP (%)	Maximum MBL (mm)	Implants With Peri-Implantitis	Cluster Patient
1	M	62	MT	FFF	3	Mandible	0	Y	RPD	44	3.7 ± 0.5	91.7 ± 14.4	0.4 ± 0.2	1	N
2	M	39	BT	IF	3	Mandible	7	N	SFPD	45	4.8 ± 1.0	58.3 ± 38.2	1.6 ± 0.3	3	Y
3	F	65	BT	IF	3	Mandible	6	Y	SFPD	34	3.3 ± 0.5	100.0 ± 0.0	0.9 ± 0.1	1	N
4	M	25	TR	FFF	4	Maxilla	0	Y	SFPD	11	3.7 ± 0.6	87.5 ± 14.4	1.3 ± 0.4	1	N
5	F	38	BT	FFF	3	Mandible	5	Y	CFPD	6	3.0 ± 0.6	8.3 ± 14.4	0.2 ± 0.1	1	N
6	M	22	BT	FFF	4	Maxilla	10	N	SFPD	42	3.9 ± 0.8	56.3 ± 12.5	0.9 ± 0.1	2	Y
7	M	34	TR	FFF	4	Mandible	6	N	RPD	33	3.0 ± 0.4	93.8 ± 12.5	0.3 ± 0.2	0	N
8	F	33	BT	FFF	2	Mandible	5	N	RPD	51	5.4 ± 0.8	100.0 ± 0.0	1.4 ± 0.4	2	Y
9	M	19	MT	FFF	3	Maxilla	9	N	SFPD	9	3.0 ± 1.0	8.3 ± 14.4	0.3 ± 0.2	0	N
10	F	35	TR	FFF	3	Mandible	−4	Y	CFPD	6	2.7 ± 0.4	83.3 ± 28.9	0.7 ± 0.1	0	N
11	F	40	BT	FFF	3	Mandible	11	N	SFPD	44	3.0 ± 0.5	91.7 ± 14.4	0.2 ± 0.2	0	N
12	M	46	TR	FFF	6	Maxilla	7	N	RPD	21	3.7 ± 0.5	75.0 ± 31.6	0.3 ± 0.2	1	N
13	M	50	MT	FFF	5	Maxilla	8	N	CFPD	23	3.7 ± 0.4	100.0 ± 0.0	0.4 ± 0.3	4	Y
14	M	31	BT	FFF	2	Mandible	5	N	SFPD	6	4.8 ± 0.0	12.5 ± 17.7	0.8 ± 0.2	2	Y
15	M	60	TR	FFF	2	Mandible	−4	N	SFPD	7	5.8 ± 0.0	75.0 ± 35.4	1.5 ± 0.3	2	Y
16	F	47	BT	FFF	4	Mandible	11	Y	RPD	6	3.2 ± 0.6	62.5 ± 43.3	0.8 ± 0.2	1	N
17	M	33	BT	FFF	3	Maxilla	5	Y	SFPD	47	2.7 ± 0.5	50.0 ± 43.3	0.6 ± 0.1	0	N
18	F	22	TR	FFF	4	Mandible	5	Y	CFPD	46	3.2 ± 0.7	68.8 ± 47.3	0.5 ± 0.3	0	N
19	M	24	BT	FFF	4	Mandible	5	Y	SFPD	25	3.1 ± 0.5	75.0 ± 20.4	0.3 ± 0.2	0	N
Average										26.6 ± 16.8	3.5 ± 0.9	70.4 ± 35.1	0.6 ± 0.4		

Abbreviations: ARF, apical repositioning flap; BoP, bleeding on probing; BT, benign tumor; CFPD, cement-retained fixed partial denture; Cluster patient, patients with at least 3 implants and more than 1 dental implant showing peri-implantitis; F, female; FFF, fibular free flap; FGG, free gingival graft; IF, iliac flap; M, male; MBL, marginal bone loss; MT, malignant tumor; N, no; PPD, probing pocket depth; RPD, removable partial denture; SFPD, screw-retained fixed partial denture; TR, trauma, Y, yes.

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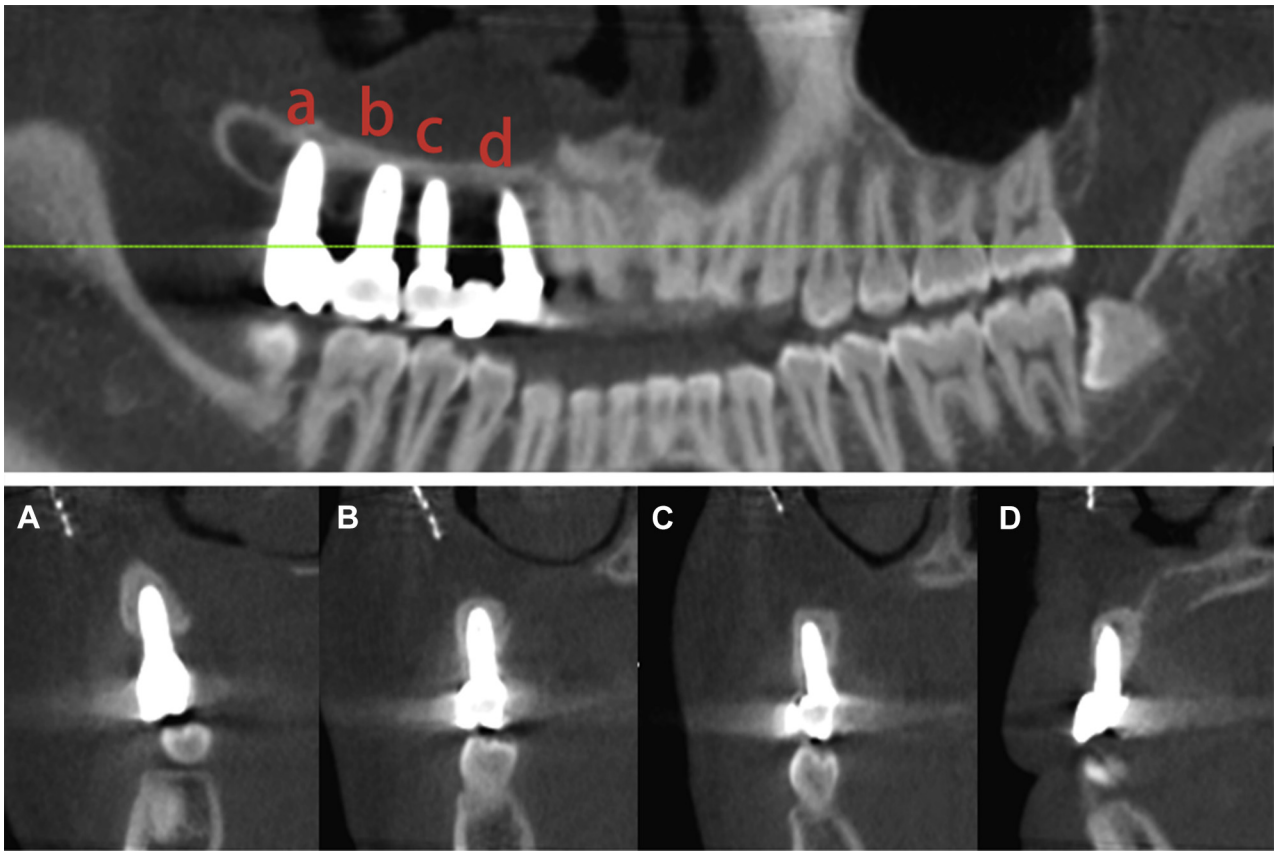

FIGURE 7. Radiographic images showing bone loss at 5 years after implant placement. *A*, *B*, *C*, and *D* represented the magnifying images of the implants *a*, *b*, *c*, and *d* in the upper image retrospectivelly.

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implants, in addition to cost factors and the patients' preferences. The FGG was spontaneously replaced by nonkeratinizing epithelium from the lip, cheek, or mouth floor soon after soft tissue management in these cases. However, peri-implantitis may be unavoidable even with multiple soft tissue management procedures. To address this problem, our current strategy includes a temporary fixation stent to protect the graft until placement of the temporary denture (Fig 5). Suboptimally placed implants or those rendered unusable because of poor positioning of the bone graft can be preoperatively corrected by digital design. Our team has accumulated a significant amount of experience with this approach.[33,34]

The lack of KM was hypothesized to be another significant factor underlying implant loss and peri-implant bone loss in patients undergoing jaw reconstruction.[35] ARF and FGG during implant rehabilitation have been recommended for effective KM augmentation, and our results further support this viewpoint. In our study, the mean MBL, which is a key index for evaluating peri-implantitis,[16,17] was 0.6 mm (±0.4 mm), notably higher than previously reported values of 0.15 to 0.21 mm.[36] However, in the previous studies, the patients had not undergone jaw reconstruction (Table 2).[1,2,18-31] In patients who received reconstruction with a double-barreled fibula flap, the average MBLs of implants surrounded by the skin paddle were 0.79 to 0.84 mm.[31] Another study from the same team[20] described the average MBL of patients who underwent mandible reconstruction as 1.8 mm after thinning of the skin paddle. Wang et al[22] reported the MBLs of patients undergoing reconstruction of a mandibular defect by a fibular flap and skin paddle thinning as 0.8 to 0.9 mm. As mentioned previously, it is clear that patients with ARF and FGG have lower MBL and better soft tissue condition around the implants than those receiving no treatment or thinning of the skin paddle (Table 2).[1,2,18-31]

TIPS FOR SOFT TISSUE MANAGEMENT

The timing of soft tissue management is controversial. According to the literature, soft tissue management can be performed during vascularized free bone grafting, implant placement, second-stage surgery, and prostheses restoration.[37] It is not

Table 2. PREVIOUS STUDIES ON SOFT TISSUE MANAGEMENT FOR VASCULARIZED BONE GRAFTS AND IMPLANT REHABILITATION

Author	Hard Tissue Reconstruction	Radiotherapy	Mean Follow-Up Period	Soft Tissue Management	Outcomes
Kumar et al[18]	Fibula-free flap	26 patients; 38.2%	12 mo	Subperiosteal dissection and denture-guided epithelial regeneration (28 patients; 53.8%) Vestibuloplasty with skin or palatal grafts (6 patients; 11.5%)	Statistically significant in the width of KM Peri-implant soft tissue hyperplasia (3%) MBL (0.5 mm; 0.2 mm)
Raoul et al[2]	Fibula-free flap	6 patients; 19.4%	76 mo	None (25 patients; 81%) Skin paddle thinning (23 patients; 74%) Palatal or skin grafts (6 patients; 19%)	Implant loss (4 implants; 3.8%) Success rate (96.2%) Fibular crest resorption (3 mm in 16 patients; 0 mm in 14 patients; bone increase in 1 patient)
Sozzi et al[19]	Fibula-free flap	6 patients; 11.1%	7.8 yr	Reshaping of irregular bone, vestibuloplasty, removal of skin paddle and preservation of subcutaneous tissues (22 patients; 100%)	Survival rate (98%); success rate (100%)
Lizio et al[1]	Fibula-free flap and DO	1 patient; 16.7%	39 mo	Skin grafts (2 patients; 33.3%) Palatal graft (1 patient; 16.7%)	Cumulative implant survival (31 of 35; 89%) Survival rate (94%) Peri-implant soft tissue hyperplasia (64%) Recurrence rate after removing the lesions (67%) Skin grafts (mediocre results) Palatal grafts (did not resolve the problem) Peri-implant bone resorption (2.5 mm)
Chang et al[20]	Fibula-free flap	5 patients; 45.5%	73 mo	Palatal grafts (4 patients; 36.4%) Skin paddle thinning (7 patients; 63.6%)	Palatal grafts: MBL (0.5 mm) Skin paddle thinning: MBL (mesial: 1.8 mm; distal: 1.7 mm) Difference is significant
Fang et al[21]	Fibula-free flap	9 patients; 7.1%	12.8 yr	Vestibuloplasty with palatal grafts (4 patients; 5.4%) Vestibuloplasty with skin grafts (22 patients; 29.7%)	Implant failure (18 implants; 9.3%) Survival rate (5 yr: 90.1%; 10 yr: 83.1%; and 20 yr: 69.3%) PPD (2-3 mm: 152 implants; greater than 5 mm: 31 implants; and greater than 7 mm: 9 implants)

Fang et al[22]	Fibula-free flap	None	42.1 mo	Skin paddle thinning (12 patients; 100%)	Cumulative survival rate (100%) Cumulative success rate (84.8%) MBL (1 yr: 0.8 ± 0.3 mm; 3 yr: 0.9 ± 0.4 mm) Plaque score (<20%)
Hessling et al[23]	None (39 patients; 66.2%) Free iliac crest graft (12 patients; 20.3%) Microvascular fibular graft (4 patients; 6.7%) Microvascular scapula graft (2 patients; 3.4%) Distraction osteogenesis (2 patients; 3.4%) Microvascular iliac crest graft (1 patient; 1.7%) Calvarial bone graft (1 patient; 1.7%)	49 patients, 83.1%	30.9 mo	Ventriculoplasty with skin grafts (22 patients; 37%)	Implant loss (10 implants; 3.7%) Survival rate (2 yr: 98.9%; 5 yr: 97.1%) Peri-implantitis (182 implants; 67%).
Meloni et al[24]	Fibula-free flap	4 patients, 40.0%	4 yr	Vestibuloplasty (5 patients; 41.7%) Concomitant palate fibromucosal grafting (3 patients; 25.0%) Customized acrylic template (2 patients; 16.7%) Skin and fibromucosal grafts (1 patient; 8.3%) Palatal graft (1 patient; 8.3%) Palatal fibromucosal grafts (2 patients; 16.7%) Prosthetic shaping of soft tissues (6 patients; 50.0%)	Implant loss (3 implants; 5.4%) Overall survival rate (94.6%) Prostheses survival rate (100%) Peri-implant soft tissue hyperplasia (4 mo: 2 patients; 14 mo: 2 patients) MBL (palatal/lingual site: 1.43 mm; vestibular site: 1.48 mm) PPD (12 mo: 4.70 mm; 24 mo: 4.85 mm; and 48 mo: 4.93 mm) BoP (12 mo: 16%; 24 mo: 13%; and 48 mo: 12%)
Bodard et al[25]	Fibula-free flap	Unknown	77.85 mo	Carbon dioxide laser surgery (3 patients; 11.5%) Epithelial grafts (2 patients; 7.7%)	Peri-implant soft tissue hyperplasia (5 patients; 19.2%)
Fenlon et al[26]	Fibula-free flap	None (29 patients; 79.7%) Radiotherapy (12 patients; 29.3%)	30 mo	None	Implant failure (10 patients, 24.4%; 18 implants, 12.4%)
Jaquiéry et al[27]	Fibula-free flap	Unknown	12 mo	Skin graft and Gore-Tex membrane (8 patients; 100%)	Implant failure (2 patients; 4.9%) Vertical bone loss (12 mo: 0.5 mm)

Table 2. Cont'd

Author	Hard Tissue Reconstruction	Radiotherapy	Mean Follow-Up Period	Soft Tissue Management	Outcomes
Wang et al[28]	Fibula-free flap	Unknown	42.5 mo	Palatal grafts (2 patients; 22.2%) Skin paddle thinning (6 patients; 60.0%)	Peri-implant bone resorption after DBF (1 yr: 0.42 mm; 2 yr: 0.58 mm; and 3 yr: 0.68 mm) Peri-implant bone resorption after VDOF (1 yr: 0.51 mm; 2 yr: 0.65 mm; and 3 yr: 0.71 mm)
Kumar et al[29]	Fibula-free flap	4 patients, 40.0%	42.7 mo	Subperiosteal dissection with denture-guided epithelial regeneration (10 patients; 100%)	Survival rate (100%)
Chang et al[30]	Fibula-free flap	None	22.2 mo	Palatal grafts (7 patients; 70%) Skin grafts (3 patients; 30%)	MBL (mesial: 0.18 mm; distal: 0.25 mm) MBL after palatal grafts (mesial: 0.11 mm; distal: 0.19 mm) MBL after skin grafts (mesial: 0.29 mm; distal: 0.35 mm) PPD (mesial: 2.84 mm; distal: 3.12 mm; buccal: 2.7 mm; and lingual: 3.08 mm) PPD after palatal grafts (2.56 mm) PPD after skin grafts (3.50 mm)
Chang et al[31]	Fibula-free flap	Unknown	Patients with VDO (68.4 mo) Patients with DB (63.7 mo)	Palatal grafts (17 patients; 73.9%) None (6 patients; 26.1%)	MBL after VDO (mesial: 0.44 mm; distal: 0.48 mm) MBL after DB (mesial: 0.50 mm; distal: 0.56 mm) MBL after DB and without palatal grafts (mesial: 0.79 mm; distal: 0.84 mm) MBL after DB with palatal grafts (mesial: 0.21 mm; distal: 0.28 mm)

Abbreviations: BoP, bleeding on probing; DB, double-barreling; DBF, double-barrel fibula; DO, distraction osteogenesis; KM, keratinized mucosa; MBL, marginal bone loss; PPD, probing pocket depth; VDO, vertical distraction osteogenesis; VDOF, vertical distraction osteogenesis of fibula.

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Table 3. KAPLAN-MEIER ANALYSIS OF FACTORS ASSOCIATED WITH PERI-IMPLANTITIS

Variable	Number	Mean	Lower Limit of 95% CI	Upper Limit of 95% CI	χ^2	*P*
Gender						
Male	12	35.964	27.009	44.920	3.217	.073
Female	7	51.000	51.000	51.000		
Primary disease						
MT	10	43.440	33.778	53.102	0.198	.906
BT	3	33.500	18.948	48.052		
TR	6	38.200	24.526	51.874		
Flap choice						
FFF	17	41.306	31.732	50.880	0.052	.819
IF	2	45.000	45.000	45.000		
Position of implants						
Maxilla	13	41.385	29.775	52.995	0.216	.642
Mandible	6	37.333	25.634	49.033		
Type of restoration						
RPD	4	34.500	18.562	50.438	0.466	.495
SFPD	5	51.000	51.000	51.000		
CFPD	10	37.300	27.622	46.978		

Abbreviations: BT, benign tumor; 95% CI, 95% confidence interval; CFPD, cement-retained fixed partial denture; FFF, fibular free flap; IF, iliac flap; MT, malignant tumor; RPD, removable partial denture; SFPD, screw-retained fixed partial denture; TR, trauma.

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recommended during jaw reconstruction. Unpredictable KM shrinkage would necessitate a second FGG procedure, which may lower the compliance of patients with subsequent treatments. We do not advocate implant placement with simultaneous abutment exposure and soft tissue management because premature exposure of implants is associated with a lower survival rate.[35] We do not recommend soft tissue management after completion of the prosthetic restoration either as the prostheses would interfere with KM augmentation on their lingual side. Despite the increased surgical difficulty because of the interference of implants and abutments, we recommend performing soft tissue management during the second-stage surgery because the implant bed can be evaluated during surgery, a free mucosal flap of an ideal size and shape can be obtained, and a stable peri-implant KM can ultimately be obtained.

Our experience in soft tissue management has revealed the following insights. First, advanced

Table 4. COX REGRESSION ANALYSIS OF FACTORS ASSOCIATED WITH PERI-IMPLANTITIS

			The 95% CI of Exp(*B*)	
Metrics	*P*	Exp(*B*)	Lower Limit	Upper Limit
Gender	.617	0.535	0.046	6.222
Age	.636	1.019	0.941	1.104
Primary disease	.301			
Primary disease = MT	.125	0.151	0.013	1.688
Primary disease = TR	.572	0.469	0.034	6.473
Flap choice	.507	2.972	0.119	74.052
Position of implants	.998	1.003	0.125	8.034
Timing of ARF and FGG	.364	1.137	0.861	1.501
Fixation stent	.137	3.705	0.66	20.805
Type of restoration	.645			
Type of restoration = RPD	.356	0.215	0.008	5.642
Type of restoration = SFPD	.629	0.605	0.079	4.632

Abbreviations: ARF, apical repositioning flap; 95% CI, 95% confidence interval; FGG, free gingival graft; MT, malignant tumor; RPD, removable partial denture; SFPD, screw-retained fixed partial denture; TR, trauma.

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preparation of the implant bed can minimize the in vitro time of the mucosal graft in vitro and prevent necrosis. When preparing the implant bed, only the periosteum and a thin layer of muscle fiber tissue (1.0 to 1.5 mm) are preserved to ensure that the soft tissue is fixed in place after surgery. Second, a thicker mucosal graft (1 mm) is necessary for KM augmentation. Although thicker grafts exhibit greater contraction immediately after transplantation, which can result in vasoconstriction and delayed revascularization, they can protect newly formed capillaries and are more resistant to functional stress. Thus, it is believed that when the size of the mucosal graft is insufficient to cover a large KM defect, a thick graft is preferred to prevent further graft absorption. In addition, the biological width of implants is greater than that of natural teeth because of the weaker connection between the implants and bone; therefore, a thicker graft is necessary. Third, the size and shape of the mucosal graft should be matched to the implant bed to ensure good connection at its edges and facilitate revascularization. It should be noted that shrinkage of the graft is inevitable, with rates ranging from 37 to 70%.[38] Therefore, attention should be paid to fix the edge of the mucosal graft more than 6 mm above the edge of the implant's neck to ensure a sufficient width of KM around the implants after graft shrinkage. Fourth, a meticulous suturing technique is beneficial for stabilization of the mucosal graft and obtaining sufficient blood supply. It is believed that suture fixation can help avoid excessive graft shrinkage and be beneficial for taking care of the mucosal graft at any time. Finally, prostheses restoration is usually performed 2 to 3 months after soft tissue management to ensure complete reconstruction and stabilization of the mucosal graft.

HOW SOFT TISSUE MANAGEMENT MAY AFFECT OUTCOMES

The condition of soft tissue on vascularized bone grafts is much poorer than that on a general edentulous jaw. An alveolar ridge defect makes the vestibular groove disappear, and its KM is replaced by non-KM or a skin paddle. These extensive soft tissues are excessively mobile to be resistant to friction, and thus, the peri-implant mucosa cannot form a seal to protect the underlying bone during osseointegration.[35] In addition, the lack of cementum leads the connective tissue to be arranged parallel to the implant surface; thus, the mucosal seal at the cuff of the implants may be destroyed by the traction of the muscles and ligaments attached to the peri-implant mucosa because of the lack of KM around the implants. Destruction of the seal gives rise to the accumulation of plaque around the implants,[39] which is prone to cause serious peri-implant bone loss. Moreover, the lack of KM around the implant results in the epithelial tissue being unable to resist mechanical damage during implant rehabilitation.[40] Native tissue can be injured by pressure or decubitus ulcers after wearing of the removal partial denture. The difficulty of maintaining oral hygiene and the pain experienced during brushing because of the lack of KM is one of the reasons for peri-implant mucositis. The formation of granulation tissue and pain or bleeding during brushing will further increase the difficulty of oral care, creating a vicious circle. Finally, the soft tissues around the implant are excessively flexible to enable a precise impression to be acquired in the prosthodontic stage. Therefore, soft tissue management is essential.

A particular strength of this study is that it is the first to comprehensively analyze and report the outcomes of soft tissue management in implant rehabilitation after vascularized free-flap reconstruction. Although a large number of studies involving implants after vascularized bone graft have been reported, there have invariably been case reports involving a few cases. None have specifically focused on comprehensively analyzing soft tissue management. Furthermore, we used detailed and objective metrics to describe the outcomes of this study. In contrast, only the survival and success rates of the implants had been assessed in previous studies. The present study also reported the BoP, PPD, and MBL of implants after vascularized bone grafting and soft tissue management, evaluated the incidence of peri-implantitis, and determined the relationship between gender, age, primary disease, flap choice, number and position of implants, timing of ARF and FGG, use of a fixation stent, type of restoration and peri-implantitis. Finally, our experience with soft tissue management was described in detail, which may be of significant benefit to practicing clinicians.

However, implant rehabilitation after jaw reconstruction is a complex and challenging endeavor that requires significant time, effort, and financial resources. Thus, many patients did not complete all treatment procedures in our study. Although the sample size of 19 patients was larger than previous reports of implants after vascularized bone graft, it is insufficient for drawing definitive conclusions. In addition, the prosthodontists found it difficult to take impressions and provide long-term care of the prostheses, meaning that almost all patients with jaw reconstruction and implant rehabilitation required FGG and ARF. A cohort study was difficult to conduct because patients who did not undergo soft tissue management were lacking. In addition, most of the patients involved were young and middle aged with benign tumors or trauma; this led to bias, ultimately resulting in the statistical differences observed according to the primary disease.

In conclusion, our results show that soft tissue management is essential to good outcomes. Although soft tissue management cannot eradicate peri-implantitis in patients with implant rehabilitation and vascularized bone grafts, ARF can deepen the vestibular sulcus as well as prevent the muscles and ligaments from pulling, thus leading to less plaque accumulation. FGG helps to rebuild the KM around the implant and prevent peri-implantitis. Contrary to edentulous jaw, implant rehabilitation after jaw resection has the extra challenges of a wide range of KM defects. Without ARF and FGG, rehabilitation would be difficult to complete, and peri-implantitis is inevitable.

ARF and FGG during implant rehabilitation for patients with jaw reconstruction are recommended according to our experience. However, drawbacks such as limited amount of palatal mucosa obtained and high donor site morbidity rates cannot be overlooked. Soft tissue graft substitutes appear to be a promising option for addressing these problems. Our future efforts will focus on developing tissue-engineered human oral mucosa for clinical applications.

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