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Clinical Paper
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Clinical outcomes of keratinized mucosa augmentation in jaws reconstructed with fibula or iliac bone flaps

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Abstract. This prospective study was undertaken to evaluate the treatment outcomes of keratinized mucosa augmentation (KMA) on the buccal and palatal/lingual sides of implants in jaws reconstructed after oncological surgery. Forty-two implants in 12 patients whose jaws had been reconstructed with a fibula or iliac bone flap were included. KMA was performed at 3 months after implant placement; this included an apically displaced partial-thickness flap and a free gingival graft (FGG) around the implants to increase the keratinized mucosa width (KMW). Patients were followed up for at least 6 months post-surgery. KMW, shrinkage, and patient pain and discomfort measured on a visual analogue scale were analysed. A histological analysis was performed of tissue epithelium from two patients. The results showed that KMW was >2 mm on both the buccal and palatal/lingual sides during follow-up. Before surgery, histological analysis showed epithelium with no epithelial spikes; normal keratinized epithelial spikes were observed at 8 weeks after KMA. Greater KMW was observed around implants in reconstructed maxillae than around those in reconstructed mandibles ($P < 0.001$). Patients felt more pain at the donor site than at the recipient site during the first 3 days post-surgery. KMA with FGG was predictable in reconstructed jaws and may help maintain the long-term stability of implants.

Key words: dental implant; mucosa; fibula; ilium; epithelium; surgical flap.

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Maxillofacial reconstruction to restore the form and function of patients has progressed in recent decades[1,2]. With the development of implantology, microsurgery, and digital techniques, implant restoration has become an effective way to restore masticatory and speech function[3] and improve quality of life[4], and good long-term implant survival rates have been reported after maxillofacial reconstruction[5–7]. However, in extensive bony defects repaired with fibula or iliac bone flaps, the soft tissue imported with the reconstruction does not adequately replicate the unique properties of keratinized mucosa[8,9]. The unattached soft tissue combined with compromised flat bone morphology increases the difficulty of oral

hygiene procedures and the risk of peri-implantitis. In such cases, high peri-implantitis or mucositis rates of 20.3% to 32.3% have been identified, and a high prevalence of granulation tissue around the implants has been reported[1,10]. Surgical excision of soft tissue hyperplasia is sometimes required [8,11], therefore indicating that additional procedures are necessary to improve the soft tissue situation around implants prior to prosthetic rehabilitation[4,6].

Adequate peri-implant keratinized mucosa width (KMW) facilitates oral hygiene and increases the predictability of implant therapy over time, and has been well documented in non-tumour patients[12,13]. However, there have been limited reports on KMW around implants in jaws reconstructed after oncological surgery. In such cases it is difficult to achieve whole recipient site coverage with free gingiva due to the extensive keratinized mucosa deficiency and limited palatal keratinized mucosa, particularly in reconstructed maxillae where usually less than half of the palatal tissue is available. Studies performing a histological analysis before and after keratinized mucosa augmentation (KMA) with a free gingiva graft (FGG) in jaws reconstructed with free fibula or iliac bone flaps are lacking. Thus, the aim of this study was to evaluate the clinical outcomes of KMA around implants placed in reconstructed maxillae and mandibles after oncological surgery and to find histological evidence of epithelium changes before and after KMA.

Materials and methods

This was a prospective case series that was completed with the cooperation of reconstructive surgeons, periodontists, and prosthetists. Enrolled patients underwent oral and maxillofacial reconstruction with a free fibula or iliac bone flap for the repair of tumour-related jaw defects in the Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology. Implants with TiUnite (NobelActive; Nobel Biocare, Göteborg, Sweden) or Ti modSLA (SLActive; Straumann, Basel, Switzerland) surfaces, with lengths of 10 mm to 14 mm and widths of 3.5 mm to 5 mm, were placed in the reconstructed jaws by reconstructive surgeons using an occlusion-driven surgical guide. All surgeries were performed between February 2017 and January 2020. A fixed or removable implant-supported restoration was planned based on bone quality, restoration space, and patient requirements. KMA was performed at 3 to 4 months after implant placement (Fig. 1). This study was approved by the Institutional Review Board of Peking University Hospital of Stomatology (approval number PKUSSIRB-202059164). All patients signed an informed consent form.

Inclusion criteria for participants were age between 18 and 70 years and oral and maxillofacial reconstruction performed with a free fibula or iliac bone flap to repair a bone defect resulting from tumour surgery. Implants were placed in the reconstructed jaws at least 3 months before KMA, and the KMW before augmentation was less than 2 mm.

Patients were excluded if they smoked more than 10 cigarettes per day, had any uncontrolled oral and maxillofacial disease or major systemic health condition, had received radiotherapy or chemotherapy during the previous 12 months, or were unable or unwilling to follow the instructions provided during follow-up.

Keratinized mucosa augmentation procedures

Initial periodontal therapy, including oral hygiene instructions, scaling, and root planing, were performed as needed. A panoramic radiograph was obtained to evaluate the osseointegration and position of each implant. One experienced periodontal specialist (R.L.) performed the KMA procedures.

Recipient site preparation was performed as follows. In the maxilla, a horizontal incision was made 1 mm palatal to the healthy keratinized gingiva (Fig. 2B). In the mandible, a horizontal incision was made at least 3 mm lingual to the implants (Fig. 3B). Vertical incisions were made at both ends of the horizontal incision as best as possible in the healthy tissue and extended apically. A partial-thickness flap was made from the horizontal incision using a 15c blade; this flap was elevated to the most apical part similar to the healthy vestibular groove to deepen the vestibule. The flaps were trimmed to remove excess muscle fibres and abundant epithelium tissue, to form a relatively thin adaptable flap, which was apically positioned to create a vestibular groove and stabilized with horizontal mattress and interrupted sutures to the periosteum. The recipient site was carefully trimmed to provide a firm bed (Figs. 2 and 3).

At the donor site, a strip of free gingiva was harvested from the healthy palate. The length of the palatal gingiva was required to be sufficient to cover all implants at the recipient site; the graft width was 8–10 mm and the thickness was 1–1.5 mm. The donor site was covered with a collagen sponge and sutured.

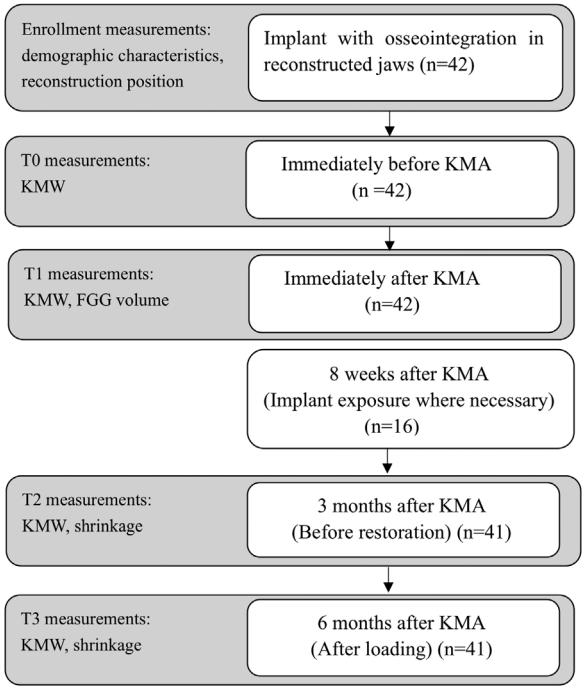

Fig. 1. Diagrammatic representation of the study protocol.
Note: FGG = free gingival graft; KMA = keratinized mucosa augmentation; KMW = keratinized mucosa width.

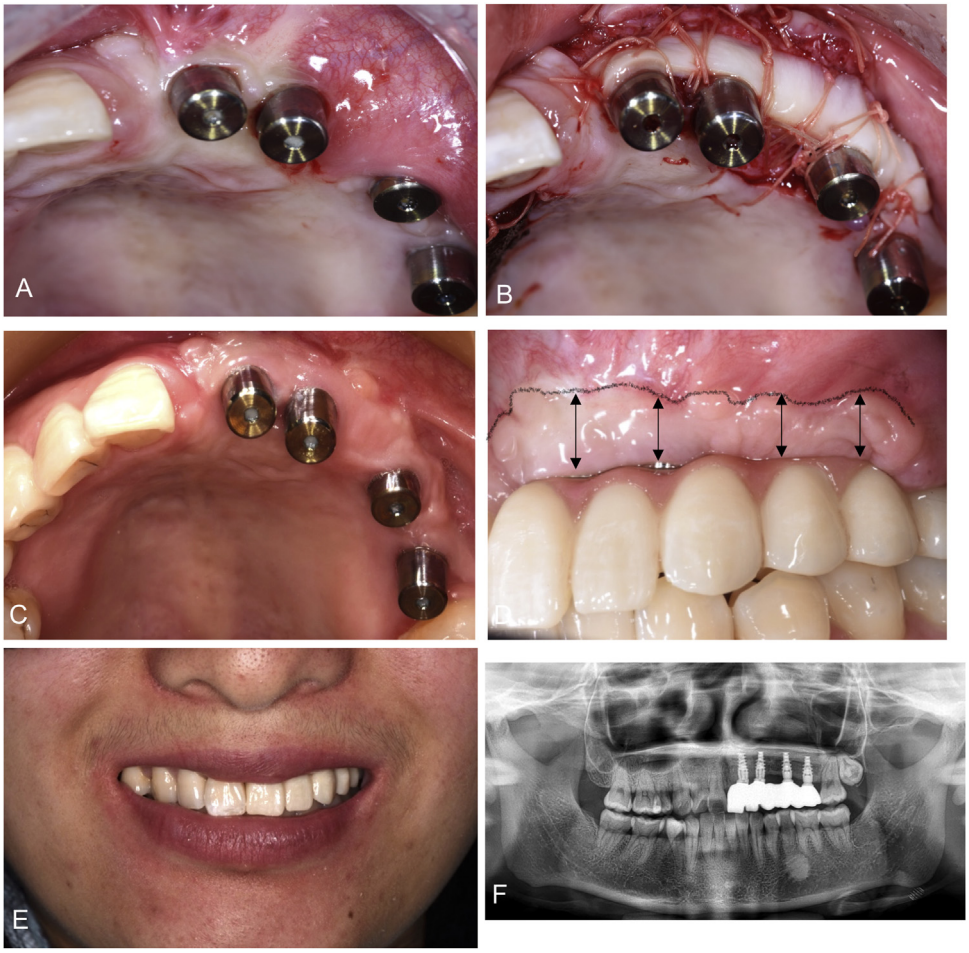

Fig. 2. Keratinized mucosa augmentation (KMA) in a left maxilla reconstructed with a fibula graft. (A) Clinical view of the left maxilla reconstructed with a free fibula graft before KMA, showing scarce keratinized mucosa around the implants. (B) Partial-thickness flaps were elevated from the healthy palatal mucosa; a free gingiva graft was placed on the buccal side of the implants. (C) Keratinized mucosa on the buccal and palatal sides of the implants before restoration. (D) Keratinized mucosa width on the buccal side, with the final restoration. (E) Appearance of the patient's smile. (F) Panoramic radiograph showing the fibula graft and implant osseointegration.

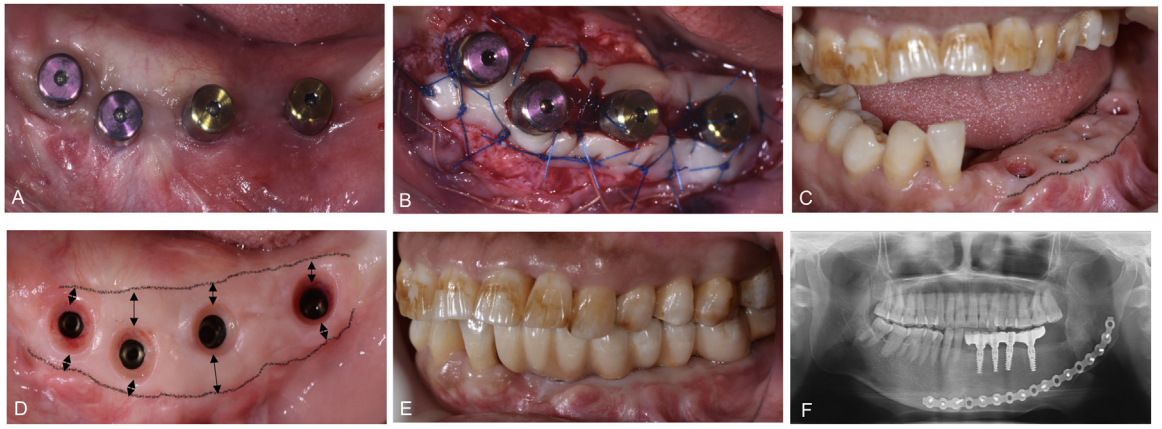

Fig. 3. Keratinized mucosa augmentation (KMA) in a left mandible reconstructed with an iliac bone flap. (A) The mucosa was quite thin, with no keratinized mucosa around the implants. (B) A partial-thickness flap was elevated from the lingual side of the implants and stabilized to the periosteum apically to form a vestibular groove; a free gingival graft (FGG) was placed on the buccal and lingual sides of the implants. (C) Healthy keratinized mucosa around the implants. (D) The width of keratinized mucosa on the buccal and lingual sides of the implants. (E) At 6 months after surgery with the final restoration. (F) Panoramic radiograph showing implant osseointegration.

The free gingiva was adapted and stabilized around the implants at the recipient site. Further exposed areas of the recipient site were covered by a collagen sponge or collagen matrix where necessary. Single interrupted sutures were placed at the lateral border of the graft and periosteum to stabilize the free gingiva. Cross-mattress sutures were placed over the graft to immobilize and compress the graft against the underlying vascular bed. Finally, moist gauze was used to compress the graft to ensure close adaptation to the bed and develop a minimal clot.

In some patients, the healing abutment was exposed before or during KMA. Some patients underwent a second-stage procedure, when the healing abutment was transferred to replace the cover screw at 6 to 8 weeks after KMA. The method was chosen based on the status of the implants and the possibility of achieving graft stability. Biopsy samples of the soft tissue epithelium measuring 3 mm × 1 mm were obtained from two patients with a sufficient KMW who needed stage 2 surgery to uncover the implants at 8 weeks after KMA.

Patients were instructed to keep a soft diet after surgery. Postoperative antibiotics were provided: amoxicillin and clavulanate potassium at a dosage of 0.457 g, twice per day, for 6 days. Pain relief medication and chlorhexidine digluconate 0.12% oral rinse were also prescribed.

Clinical and histological examination and follow-up

A single calibrated examiner performed all clinical examinations. T0 was defined as the time immediately before KMA surgery and T1 was immediately after surgery. The patients were recalled for clinical follow-up at 2 weeks for suture removal, at 8 weeks (stage 2 surgery where necessary), at 3 months (before restoration; defined as T2), and at 6 months after the surgery (after loading; defined as T3). Reinforced individualized oral hygiene instructions were provided at every patient visit.

The following clinical parameters were evaluated centrally for each implant: (1) KMW, measured using a UNC-15 periodontal probe, defined as the distance of the keratinized mucosa at the centre point of each implant. This was determined by the colour difference between keratinized mucosa and alveolar mucosa. Measurements were obtained at T0, T1, T2, and T3, on both the central buccal and central palatal/lingual sides (Figs. 2D and 3D). On the palatal side of the maxilla, if all soft tissue was covered by keratinized mucosa, the KMW was defined as 6 mm. (2) Shrinkage of the KMW, defined as (1 − KMW at the follow-up time point)/KMW at T1, as a percentage (%), which was analysed based on the central buccal side of the implant. (3) Pain and discomfort (measured using a visual analogue scale, VAS) and bleeding at the recipient and donor sites, evaluated by the patient at T1 and on days 1, 3, 7, and 14 after surgery. (4) The results of the histological analysis of soft tissue epithelium in reconstructed jaws before and 8 weeks after KMA; this was performed in two patients.

Statistical analysis

Data were analysed with IBM SPSS Statistics version 20 software (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated (mean and standard deviation (SD) for continuous data with a normal distribution, and median and interquartile range (IQR) for continuous data with a non-normal distribution).

KMW values were compared between each follow-up time point and T0 at the implant level, using the paired *t*-test. The comparisons of KMW were subdivided into buccal and palatal/lingual sides, and the differences between the maxilla and mandible were also compared. KMW values were also categorized into anterior/posterior position, and possible differences were compared (anterior was defined as the region corresponding to tooth position canine to canine). Statistical significance was set at $P < 0.05$ (two-tailed).

Results

Patient characteristics

Forty-two implants in 12 patients were included in this study. The average age of the patients was 38.7 ± 11.8 years. No patient received radiotherapy. One patient had controlled diabetes and one patient was a smoker. Three patients received a free fibula graft and nine patients received an iliac bone flap. Seven reconstructions were performed in the maxilla and five in the mandible. For two patients, the primary disease was a malignant tumour in the maxilla; the other patients had benign tumours. There was no clinical or radiographic evidence of failure during the osseointegration process of the 42 implants. One implant in the posterior maxilla was not used and was left unexposed; the final restoration was changed so that removable implant-supported prostheses were used instead of fixed ones. All of the other fixed or removable implant-supported prostheses were loaded as planned. Details of the patients' age, sex, and location of the reconstruction are shown in Table 1.

Clinical outcomes of keratinized mucosa augmentation on the buccal side of the implants

There was a statistically significant increase in KMW on the buccal side of the maxilla and of the mandible at all follow-up time points when compared to T0 ($P < 0.001$). The average KMW at T3 (6 months after surgery) was 3.24 mm, with a mean and median shrinkage of 26.6% and 33.3%, respectively. On the buccal side, the KMW was greater in the maxilla than in the mandible, and greater in the anterior area than in the

Table 1. Demographic and clinical characteristics of the patients.

Variables	Values
Age (years)	
Mean ± SD (range)	38.7 ± 11.8 (26–56)
Sex, *n* (%)	
Male	7 (58.3)
Female	5 (41.7)
Reconstruction origin, *n* (%)	
Fibula flap	3 (25)
Iliac bone flap	9 (75)
Reconstruction location, *n* (%)	
Maxilla	7 (58.3)
Mandible	5 (41.7)
Implant position, *n* (%)	
Anterior	24 (58.5)
Posterior	17 (41.5)

SD, standard deviation.

Table 2. Comparison of keratinized mucosa width on the buccal side at the different time points and according to implant-related variables; mean ± SD values in millimetres.

Variables	T0	T1	*P*-value	T2	*P*-value	T3	*P*-value
KMW (n = 41)	0.10 ± 0.30	4.43 ± 1.82[a]	<0.001	3.49 ± 1.05[a]	<0.001	3.24 ± 1.02[a]	<0.001
Shrinkage							
Mean ± SD %				21.7 ± 21.5		26.6 ± 22.2	
Median (IQR) %				25 (0.0–35.4)		33.3 (10–40)	
Implant position							
Anterior (n = 24)	0.08 ± 0.28	4.69 ± 2.13[a]	<0.001	3.83 ± 1.09[a]	<0.001	3.54 ± 1.10[a]	<0.001
Posterior (n = 17)	0.12 ± 0.33	4.06 ± 1.20[a]	<0.001	3.00 ± 0.79[a,b]	<0.001	2.82 ± 0.73[a,b]	<0.001
P-value	0.723	0.280		0.011		0.024	
Reconstruction position							
Maxilla (n = 24)	0.08 ± 0.28	4.79 ± 2.04[a]	<0.001	3.96 ± 0.96[a]	<0.001	3.63 ± 1.06[a]	<0.001
Mandible (n = 17)	0.12 ± 0.33	3.91 ± 1.33[a]	<0.001	2.82 ± 0.81[a,c]	<0.001	2.71 ± 0.69[a,c]	<0.001
P-value	0.723	0.128		<0.001		0.003	

IQR, interquartile range; KMW, keratinized mucosa width; SD, standard deviation; T0, immediately before surgery; T1, immediately after surgery; T2, 3 months after surgery; T3, 6 months after surgery.
[a] $P < 0.05$, compared to T0.
[b] $P < 0.05$, compared to anterior implant.
[c] $P < 0.05$, compared to maxilla implant.

posterior area at the T2 and T3 follow-up time points ($P < 0.001$) (Table 2).

Clinical outcomes of keratinized mucosa augmentation on the palatal/lingual side of the implants

Due to the extensive keratinized mucosa deficiency in these patients, the average palatal and lingual mean KMW was <1 mm at T0. There was no obvious difference at T0 or T1 between maxilla and mandible ($P = 0.311$ and $P = 0.414$, respectively). Palatal KMW showed a much better improvement at follow-up, and reached a mean value of 5.92 mm at T3. The mean KMW was 2.41 mm on the lingual side of the mandible at T3 and showed great improvement compared to T0 ($P < 0.001$) (Table 3).

Patient evaluation of pain and discomfort (VAS) and bleeding

The free gingiva obtained from the palate was a mean 31.17 ± 7.00 mm in length and 8.42 ± 1.83 mm in width, with a thickness of 1–1.5 mm. The donor site healed uneventfully. Bleeding was reported by two patients at 5 to 7 days after surgery. Patients felt more pain and discomfort at the donor site than at the recipient site during the first 3 days after surgery (T1, $P = 0.007$; day 1, $P = 0.002$; day 3, $P = 0.047$). The discomfort was usually relieved from then on, and there was no statistically significant difference between the donor and recipient sites at 7 days and 14 days after surgery (Table 4).

Histological analysis of soft tissue epithelium before and after KMA

The three fibula graft patients had no skin paddle. The soft tissue epithelium biopsy obtained before surgery demonstrated that keratinized epithelium and epithelial spikes were rare before KMA, in both the free fibula graft and iliac bone flap reconstruction areas (Fig. 4A and B). At 8 weeks after surgery, keratinized epithelium with epithelial spikes was observed, which was similar in appearance to the normal attached gingiva (Fig. 4C).

Discussion

Compared with healthy patients with tooth loss, the reconstructed jaw has more complicated surroundings for implants because of the surgical alterations to the oral cavity. The results of this study demonstrated good clinical outcomes of KMA around implants in reconstructed jaws with an apically positioned partial-thickness flap to rebuild the vestibular groove and the placement of a FGG around the implants. The mean KMW was 3.24 mm on the buccal side and >2 mm on the palatal or lingual side of the implants at 6 months after surgery. Increased KMW with the formation of epithelial spikes after surgery may help maintain the long-term stability of implants in the reconstructed jaw.

Maxillofacial defects affect the patient's appearance, mastication, nutrition[14], psychological well-being, and quality of life[15]. Successful oral and maxillofacial reconstruction is influenced by multidisciplinary treatment planning, proper patient selection, and patient motivation to perform optimal oral hygiene. Furthermore, placing the fibula or iliac bone flap in the correct maxillomandibular anteroposterior position, inserting the appropriate number of implants in the correct locations, and soft tissue management[11,16] are vital for rehabilitation. In this study, three free fibula grafts

Table 3. Comparison of keratinized mucosa width on the palatal/lingual side at the different time points; mean ± SD values in millimetres.

Variables	T0	T1	*P*-value	T2	*P*-value	T3	*P*-value
Palatal/lingual KMW (n = 41)							
Maxilla (n = 24)	0.75 ± 2.02	2.67 ± 2.62[a]	0.001	5.83 ± 0.56[a]	<0.001	5.92 ± 0.41[a]	<0.001
Mandible (n = 17)	0.24 ± 0.44	3.24 ± 1.30[a]	<0.001	2.47 ± 0.62[a,b]	<0.001	2.41 ± 0.62[a,b]	<0.001
P-value	0.311	0.414		<0.001		<0.001	

KMW, keratinized mucosa width; SD, standard deviation; T0, immediately before surgery; T1, immediately after surgery; T2, 3 months after surgery; T3, 6 months after surgery.
[a] $P < 0.05$, compared with T0.
[b] $P < 0.05$, compared with maxilla.

Table 4. Pain on a VAS for the donor and recipient sites during the first 2 weeks postoperative; mean ± SD scores.

Variables	T1	1 day	*P*-value	3 days	*P*-value	7 days	*P*-value	14 days	*P*-value
Donor site	7.42 ± 1.67	7.50 ± 1.57	0.339	6.17 ± 2.29[a]	0.017	3.25 ± 2.26[a]	<0.001	1.17 ± 1.53[a]	<0.001
Recipient site	5.33 ± 1.78[b]	5.17 ± 1.75[b]	0.438	4.42 ± 2.15[a,b]	0.005	2.50 ± 1.57[a]	<0.001	1.08 ± 1.08[a]	<0.001
P-value	0.007	0.002		0.047		0.335		0.897	

SD, standard deviation; T1, immediately after surgery; VAS, visual analogue scale.
[a] $P < 0.05$, compared with T1.
[b] $P < 0.05$, compared with the donor site.

and nine iliac bone flaps were used; both are effective for repairing maxillofacial defects[17]. The free fibula can be relatively longer and is better for achieving primary stability of the implants[18,19], while the iliac bone flap is better for rebuilding the bone height and width, is rich in cancellous bone, and vascularization and osseous formation is faster. There was no significant difference between the two methods in the recovery of facial apperance and diet, or in donor and recipient site complications[15,20].

All implants achieved osseointegration; no implant was lost during follow-up in this study. A pooled 5-year survival rate of 94% for implants in fibula and iliac crest has been reported, with no difference between the groups[5]. The extent of the reconstructed area, the number of teeth lost, bone quality, the local anatomy, and the force transferred to the reconstructed jaws should be considered when fixed or removable implant-supported prostheses are selected[6]. Although there was no skin paddle in the patients included in this study, the fibula osteoseptocutaneous flap usually has a thin and pliable skin paddle, whereas more bulky soft tissues are associated with the iliac flap. The mobile nature of these tissues is not suitable for implant emergence. The histological analysis in this study showed a lack of normal epithelial spikes before KMA, which is different from the healthy attached gingiva. Several methods of handling the soft tissue around implants have been reported, including the FGG[19,21,22], skin grafting[6,23], debulking of the flap[8,24], and vestibuloplasty[6]. Vestibuloplasty along with split-thickness apically positioned flap often fails to prevent periimplantitis[25]. More bleeding on probing, soft tissue hyperplasia, and bone loss have been reported around the skin island than around the mucosa graft[10,19]. However, the KMW values, which are significant in the evaluation of the results of the palatal mucosa graft, have rarely been reported. Kumar et al.[10] reported the attached tissue width measured on the mesial and distal sides of implants; however, these could not be compared with that reported in healthy patients with tooth loss, where KMW was taken at a midbuccal site. In the present study, KMW was 3.54 ± 1.10 mm in the buccal anterior region and 2.82 ± 0.73 mm in the buccal posterior region at T3, similar to the KMW values reported by Wang et al.[26] around implants in a group of healthy Chinese patients: KMW was greatest in the upper buccal anterior region (4.97 ± 1.72 mm) and lowest in the lower buccal molar region (2.22 ± 1.38 mm).

In the reconstructed jaw, the fixation of an apically positioned partial-thickness flap to rebuild or expand the vestibula and provide space for a FGG has been thought to be critical to the success of KMA. Some studies have tried using dentures or stents to stabilize the mucosa and shape the graft to the periosteum[21,23,24]. However, in the present study, due to the necessity to perform oral hygiene, stabilization of the mucosa was provided by fixing the partial-thickness flap to the periosteum, which was predictable if properly trimmed, and the patients were able to perform oral hygiene easily with mouth rinse during healing. In the shallow vestibule, most of the soft tissue epithelium was preserved with the buccal partial-thickness flap. In this study, more KMW was found in the anterior area. A possible reason for this may be that the apically positioned flap is easier to handle in this region.

According to previous studies, a donor strip of more than 14 mm in length may cause discomfort to the patient, and the incidence of infection increases[27]. As patients usually require a FGG to cover both the buccal and palatal/lingual regions, and taking into consideration possible shrinkage, a large section of the palatal mucosa with a mean length of 31.17 mm and a mean width of 8.42 mm was harvested in the present study. This may explain why the patients felt more pain at the donor site than at the recipient site during the first 3 days after surgery.

The palatal KMW showed great improvement in this study. The non-keratinized palatal soft tissue was dissected to within at least 1mm of the healthy palatal keratinized mucosa, and the exposed palatal area was covered with collagen matrix or left exposed if not large enough to stabilize the collagen. The tissue appeared keratinized in this area during follow-up, possibly because the surrounding keratinized epithelium covered the exposed area; however, to what extent the exposed palatal area can be covered by keratinized mucosa is not clear. Due to the lack of histological analysis, and because most soft tissue management has been reported in the mandible[19,28], the long-term stability of this apparent keratinized palatal mucosa requires further study. Nevertheless, the study results provide some clues that could help simplify the surgical procedures by using narrow FGG around implants or using alternatives on the reconstructed palatal side of the maxilla.

Graft tissue shrinkage is an important factor in the long-term stability of KMA. A mean shrinkage of 26.6% and median shrinkage of 33.3% was observed on the buccal side at T3 (6 months after surgery), which is similar to that reported previously in healthy patients with tooth loss[29,30]. It should be mentioned that the shrinkage is non-normally distributed, and the variance in relapse of KMW may be influenced by the size and thickness of the FGG, preparation of the recipient site, adaptation of the graft, and stabilization of the apically positioned flap.

Limitations of this study should be acknowledged, such as the small sample size, the inclusion of both free fibula and iliac bone flap reconstruction cases, variations in the types of prostheses, all procedures performed at a single centre, and the lack of long-term observation. The number of biopsy samples might have been too small to achieve distinct results. The strengths of this study include that the recipient sites were prepared in the same manner and the reporting of results of KMA in the reconstructed maxilla. In particular, the better clinical outcome of palatal KMW may provide clues to simplifying the surgical procedures in this area.

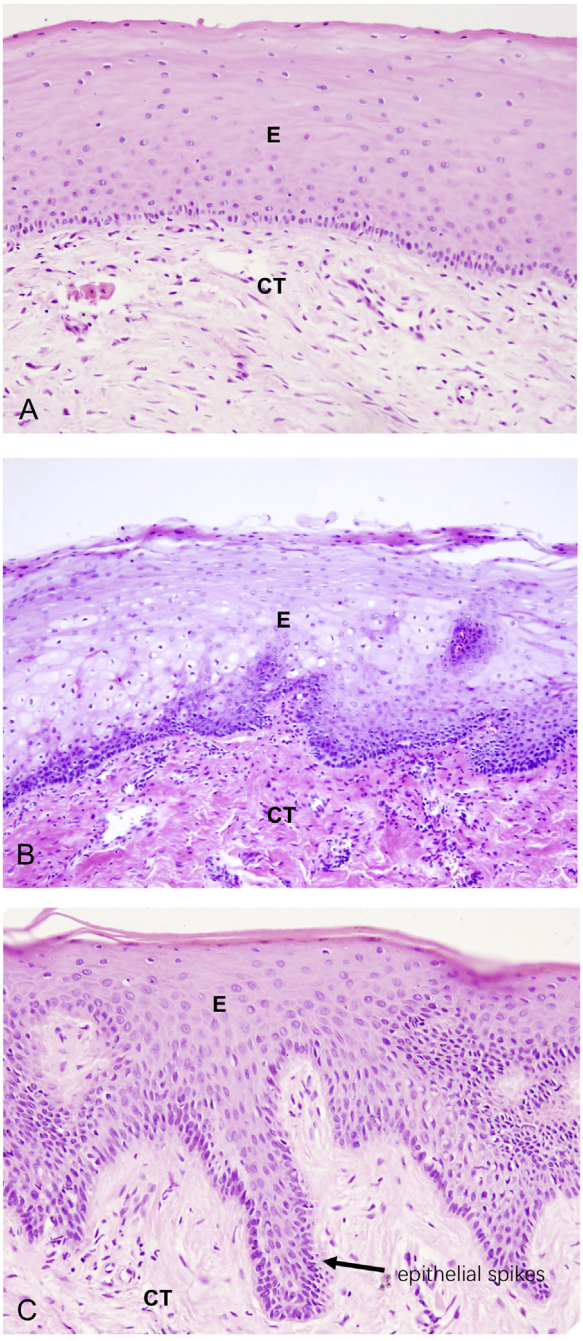

Fig. 4. Soft tissue epithelium biopsy before and after KMA (×200), with haematoxylin and eosin (H&E) staining. Haematoxylin stains the epithelium predominantly blue, while eosin stains the connective tissue predominantly pink. (A) The epithelium from a patient with an iliac bone flap reconstruction before KMA. (B) The epithelium from a patient with a fibula graft before KMA; similar to image A, there are no epithelium spikes. (C) The epithelium obtained at 8 weeks after KMA from the same patient as in image B; the formation of epithelium spikes indicates an improvement in the epithelium similar to healthy keratinized mucosa (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

The results of this study indicate that good clinical outcomes can be expected with KMA for patients with reconstructed jaws when using an apically placed partial-thickness flap with a FGG around the implants. An increased KMW of >2 mm on the buccal and palatal/lingual sides in the reconstructed jaws and the formation of keratinized epithelial spikes around implants may help maintain the long-term stability of the implants.

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Competing interests

None.

Ethical approval

This study was approved by the Institutional Review Board of Peking University Hospital of Stomatology (approval number PKUSSIRB-202059164).

Patient consent

Informed consent was obtained from all individual participants included in the study.

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