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ORIGINAL ARTICLE

Reconstructive

A Unifying Algorithm in Microvascular Reconstruction of Oral Cavity Defects Using the Trilaminar Concept

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Background: Although many algorithms exist to classify oral cavity defects, they are limited by either considering a single subsite or failing to provide a concise reconstructive algorithm for the breadth of defects. Based upon our experience as a tertiary referral center, a unifying algorithm is presented that guides free flap selection in this heterogenous population.

Methods: All intraoral defects requiring microvascular reconstruction from February 2012 to August 2018 were reviewed. Defects were classified according to their depth as unilaminar (type U = mucosa only), bilaminar (type B = mucosa and bone), or trilaminar (type T = mucosa, bone, and skin) and the number and side of mucosal zones involved (from 1 to 5). Hard palate defects were considered separately and excluded if part of a wider maxillectomy defect.

Results: A total of 118 patients were eligible for inclusion in the study. Of type U defects involving 1 mucosal zone, 98% were reconstructed with a radial forearm free flap. Ninety-two percentage of type U defects involving ≥2 mucosal zones were reconstructed with an anterolateral thigh flap. Among type B defects, 86% were reconstructed with a fibula osseocutaneous free flap if less than 4 mucosal zones were involved and 100% reconstructed with an ALT if ≥4 mucosal zones were involved. The algorithm presented was accurate for 93% of the cases. Ninety-eight percentage of patients achieved intelligible speech and 72% returned to a normal diet. Flap success rate was 100%.

Conclusions: The algorithm presented provides a simple system to guide the reconstruction of oral cavity defects. *(Plast Reconstr Surg Glob Open 2019;7:e2267; doi: 10.1097/GOX.0000000000002267; Published online 24 July 2019.)*

INTRODUCTION

The incidence of malignant oral cavity tumors in the United Kingdom has increased 30% since 1990 with over 2,000 major head and neck cases performed per annum in the United Kingdom alone.[1,2] Unlike other head and neck sites, surgery remains the preferred treatment option in managing oral cavity malignancies due to the short- and long-term sequelae of external beam radiotherapy.[3,4]

Reconstruction in the oral cavity should aim to restore integrity, function, and form.[5] As the entry point to the aerodigestive tract, the oral cavity mucosa lies in close proximity to the nasal cavity, the mandible, facial, and cervical integument, and the major vessels of the neck. Restoring integrity of the oral cavity to "separate" the oral cavity from the neck is, therefore, a paramount objective in all reconstructive procedures. Furthermore, the oral cavity serves a number of important functions which include speech and mastication and, thus, reconstruction should aim to optimize these. Finally, the form and appearance of the lower third of the face is intimately related to the oral cavity with composite mucosal and bony mandibular defects compromising the contour and appearance of the lower third of the face.

Free tissue transfer has enhanced the capacity to replace like-with-like to best restore integrity, function, and form in oral cavity reconstruction. Currently, a number of algorithms aimed at classifying defects and reconstructive options for the oral cavity subsites have been reported.[6–16] However, none have gained widespread acceptance. The laminar concept is well established in eyelid and nasal reconstruction[17,18] and we have applied the trilaminar

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concept in oral cavity reconstruction based upon the pattern of tumor growth and spread. The vast majority of malignant oral cavity tumors arise from the mucosa and are squamous cell carcinomas in origin.[2] The tumor can then infiltrate the local bone (intermediate layer) and in very advanced cases involve the integument (external layer; Fig. 1). We have developed an algorithm based upon the trilaminar concept that guides the reconstructive surgeon despite a heterogeneous group of potential defects. A recent study presented a classification system that considered both the horizontal and vertical extensions of defects affecting the lateral and lower aspects of the oral cavity.[16] Although useful in stratifying oral cavity defects as a whole, the system presented by Liu et al.[16] fails to generate a concise reconstructive algorithm.

We believe this article presents an algorithm that focuses primarily on the flap characteristics required to reconstruct the full breadth of oral cavity defects that necessitate microvascular reconstruction. With the ultimate objective being to replace like-with-like, the oral cavity can be considered a trilaminar structure with the internal mucosa, middle bony mandible, and outer skin forming the 3 layers. From this, a simple yet concise approach to oral cavity defect classification and flap selection is presented.

METHODS

A retrospective analysis of the prospectively maintained departmental database at Charing Cross Hospital, a tertiary referral center in London, United Kingdom, was performed between February 2012 and August 2018. All free flap reconstructions of tumors involving the oral cavity mucosa were included. Hard palate defects were excluded if they were part of a maxillectomy defect, or did not necessitate microvascular reconstruction. Any patient records with incomplete data were also excluded from further analysis.

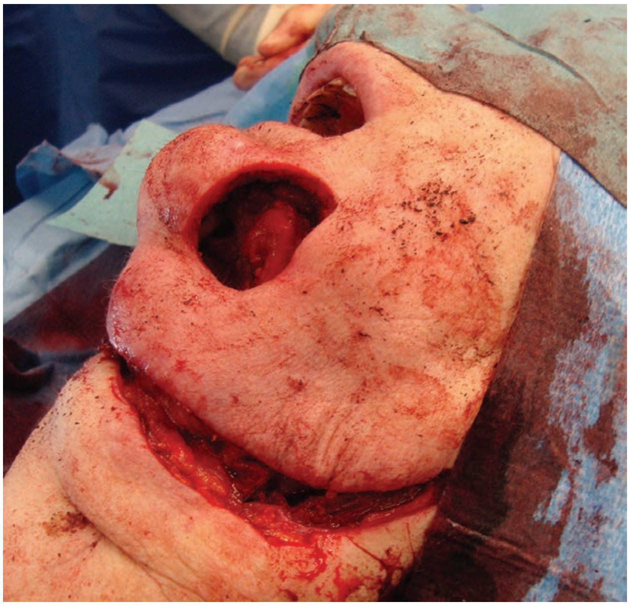

Fig. 1. An example of a through-and-through type T defect resulting from a left floor of mouth squamous cell carcinoma.

Defects were classified according to their depth and mucosal extent. Using a trilaminar approach, the depth could be type U (unilaminar, ie, mucosa only), type B (bilaminar, ie, mucosa and full thickness of bone), or type T (trilaminar, ie, mucosa, full thickness of bone if nonbuccal area and skin). In the case of an isolated hard palate defect, the 3-layer concept would constitute oral mucosa (unilaminar), bone (bilaminar), and nasal mucosa (trilaminar). As a result, hard palate defect classification and reconstructive approach is considered separately to the rest of the oral cavity to allow for the different flap characteristics necessary.

With the hard palate considered separately, each side of the oral cavity was split into 5 mucosal zones moving from lateral to medial (Fig. 2). This allowed for the mucosal extent of a defect to be established for the full breadth of oral cavity defects. Using this system, each defect could be classified as either type U, B, or T with an associated left ("L") or right ("R") to establish the side of the defect and a number denoting the number of mucosal zones involved. For example, a L.B.1,2,3 defect would describe a left-sided oral cavity defect involving 3 mucosal zones (buccal, gingiva, and floor of mouth) and the full thickness of the mandible. In contrast, a R.U.3 defect would describe a mucosa-only defect involving the right floor of mouth.

RESULTS

Demographics

A total of 118 patients were eligible for inclusion in the study with a mean age of 62 years (range 29–86 years). The mean follow-up time was 43 months (range 4–77 months).

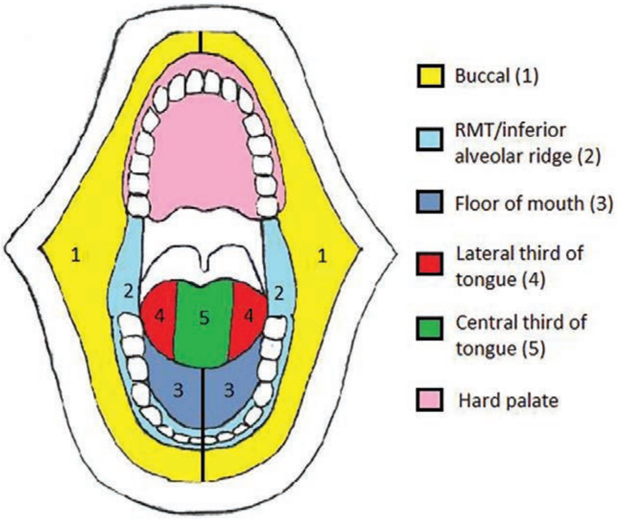

Fig. 2. The 5 possible mucosal zones for each side of the oral cavity. The numbering system moves from lateral to medial, with zone 5 denoting the central third of the tongue. Using this system, a unilaminar defect involving 2 mucosal zones (right floor of mouth and lateral tongue) would be coded as R.U.3,4. A bilaminar defect involving 3 mucosal zones (left gingival mucosa, floor of mouth, and buccal mucosa would be coded as L.B.1,2,3). Note: the reconstructive approach to the hard palate is considered separately to the rest of the oral cavity and it is, therefore, not considered as 1 of the 10 mucosal zones. RMT, retromolar trigone.

Table 1. The Location of the Primary Lesion Resulting in an Oral Cavity Mucosal Defect

Location of Primary Lesion	No. Patients
Tongue	41
Floor of mouth	36
Retromolar trigone	10
Inferior alveolar ridge	9
Buccal	8
Mandible	8
Hard palate	6

Table 2. The Extent of Defects Among the Study Population with Isolated Hard Palate Defects Excluded

	No. Mucosal Zones Involved				
Depth	1	2	3	4	5
U	45	32	4	1	—
B	0	11	11	4	—
T	1	—	2	1	—

B, mucosa and full-thickness mandible; T, mucosa, mandible (if nonbuccal area) and skin; U, mucosa only.

The location of the primary lesion is shown in Table 1. Of these, 6 were isolated hard palate defects which were all trilaminar, T1-type defects. Among the remaining 112 patients the spectrum of defects is shown in Table 2. Causes of the defects included mucosal squamous cell carcinoma (n = 102), mandibular osteoradionecrosis (n = 6), other malignant tumor (n = 4), oronasal fistula (n = 4), benign tumor (n = 1), and infection (n = 1). Twelve percentage of patients underwent neoadjuvant and 41% received adjuvant radiotherapy. Eight percentage of patients underwent neoadjuvant and 12% received adjuvant chemotherapy.

Flap Selection

The reconstructive approach to the defects of differing depth and mucosal extent are shown in Figures 3–5. The approach to hard palate defects is shown in Figure 6. Based upon this, a unifying algorithm to guide flap selection according to the oral cavity defect was created (Fig. 7) and an example of its application to defects involving different subsites of the oral cavity is shown in Table 3. Among this series, the compliance with the algorithm was 93%.

Surgical and Functional Outcomes

All operations were performed with a dual team approach involving head and neck extirpative surgeons and reconstructive plastic surgery teams with the average length of the procedure 6.6 hours (range 2.5–10 hours). The flap success rate was 100%. The donor and recipient site outcomes are shown in Table 4. Within the patient cohort, 98% achieved intelligible speech and all patients maintained their own airway. Seventy-two percentage of patients returned to a normal diet, 18% to a soft diet, 8% to a liquid diet, and 2% required percutaneous feeding.

DISCUSSION

The algorithm presented is primarily aimed at the reconstructive surgeon and acts as a guide for flap selection in a multitude of different oral cavity defects, while also providing a classification system to aid communication between healthcare professionals. This is in contrast to other classification systems for the oral cavity and associated subsites, which primarily focus upon classifying the defect or the reconstruction of a specific subsite in isolation.[6–16]

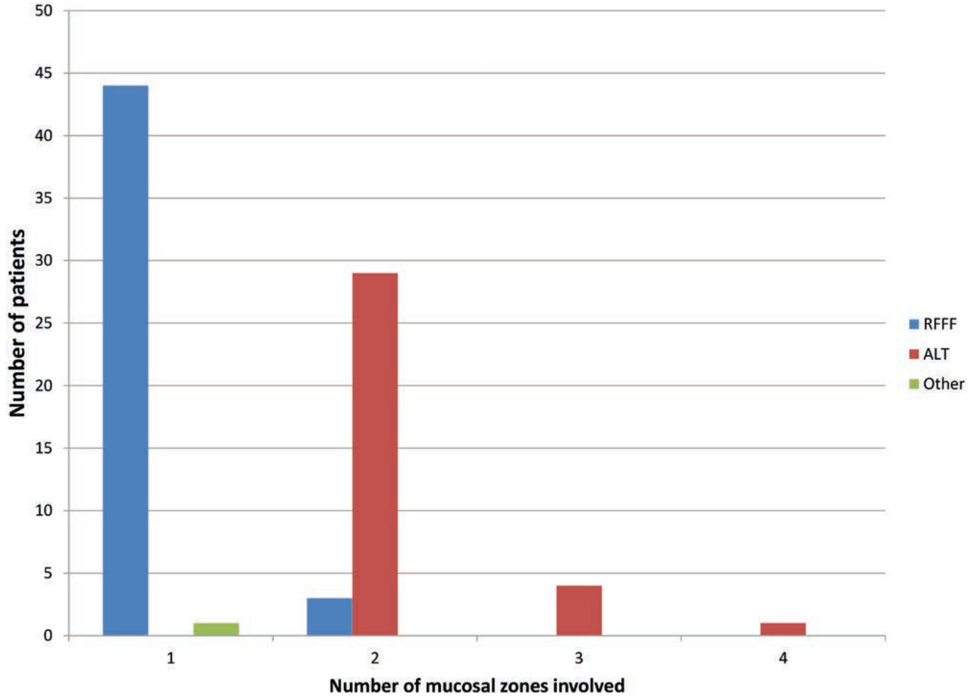

Fig. 3. Flap selection in patients with a mucosa only (type U defect) according to the number of mucosal zones resected. ALT, anterolateral thigh free flap; RFFF, radial forearm free flap.

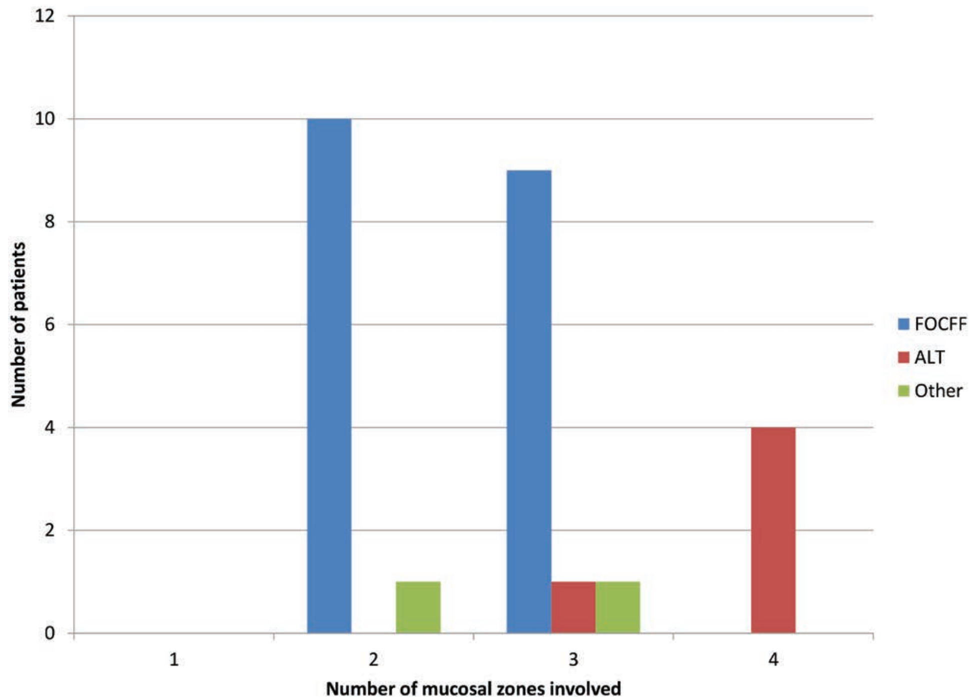

Fig. 4. Flap selection in patients with mucosa and bony defects (type B defect) according to the number of mucosal zones resected. ALT, anterolateral thigh free flap; FOCFF, fibula osseocutaneous free flap.

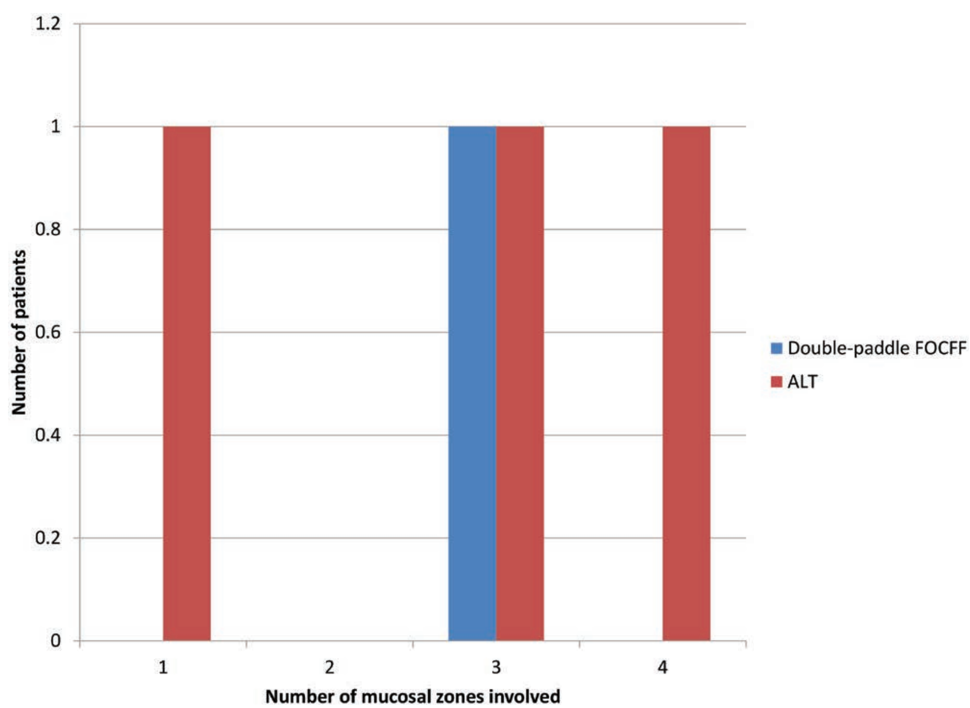

Fig. 5. Flap selection in patients with mucosa, bony, and skin defects (type T defect) according to the number of mucosal zones resected. ALT, anterolateral thigh free flap; FOCFF, fibula osseocutaneous free flap.

The trilaminar approach to head and neck defects is widely accepted. Nasal and eyelid defects are often considered in this way.[17,18] Within the oral cavity, the internal laminar is the mucosa and its restoration is vital for maintaining tongue mobility and restoring the integrity of the oral cavity thus preventing leakage of saliva into the cervical region. The middle laminar is the bony framework, that is, the mandible and, in the case of the hard palate, the maxillary and palatine bones. Mandibular reconstruction helps restore the contour of the lower third of the

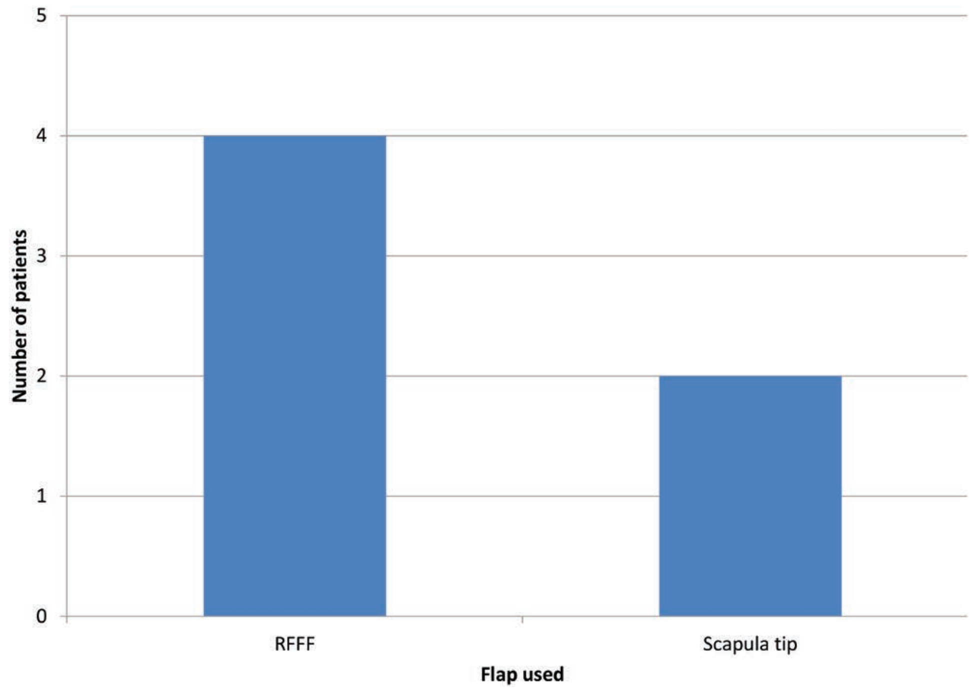

Fig. 6. Flap selection in patients with isolated hard palate defects: all type C1 defects. RFFF, radial forearm free flap.

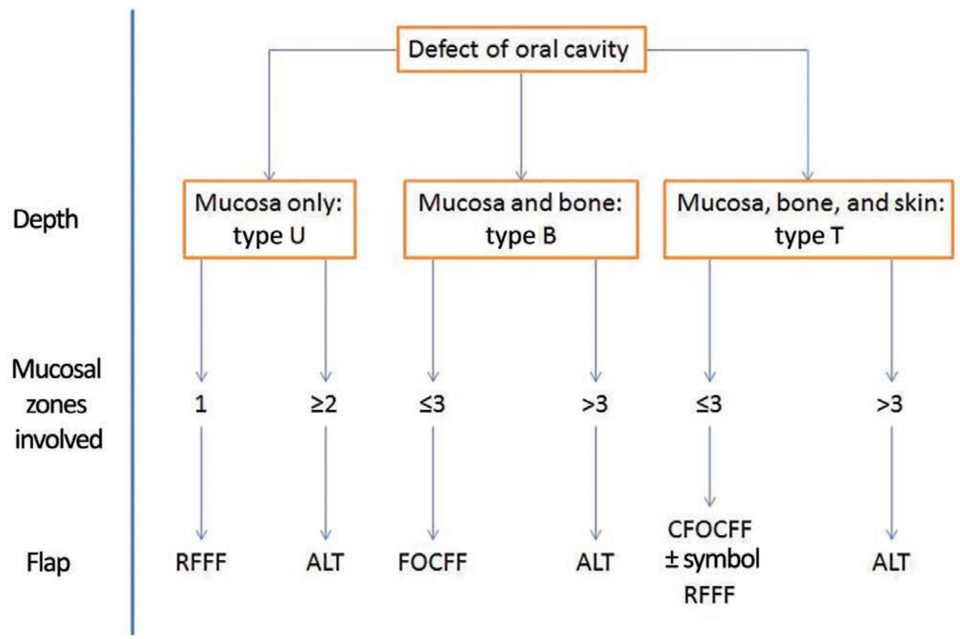

Fig. 7. A unifying algorithm guiding flap selection and applicable to all oral cavity defects apart from those affecting the hard palate. ALT, anterolateral thigh free flap; B, bilaminar; CFOCFF, chimeric fibula osseocutaneous free flap; FOCFF, fibula osseocutaneous free flap; RFFF, radial forearm free flap; T, trilaminar; U, unilaminar.

face, aids in mastication, and offers the potential for dental rehabilitation. The final outer laminar is that of the integument and its reconstruction is of upmost importance in expediting wound closure to facilitate adjuvant radiotherapy, preventing infection of metal work, and playing an essential role in determining the final aesthetic appearance. The trilaminar concept is, thus, useful as it guides the reconstructive surgeon to the surgical options and is also a marker of the complexity of the reconstructive procedure.

Table 3. Application of the Unifying Algorithm to a Variety of Defects within Certain Oral Cavity Subsites

Depth	Mucosal Zones Involved	Tongue	Floor of Mouth	Retromolar Trigone	Hard Palate
Type U	1	First – RFFF Second – lateral arm flap	First – RFFF Second – lateral arm flap	First – RFFF* Second – lateral arm flap	Secondary intention
	≥2	ALT	ALT	ALT	N/A
Type B	≤3	FOCFF	FOCFF	FOCFF	Secondary intention
	>3	ALT	ALT	ALT	N/A
Type T	≤3	First – bipaddled FOCFF Second – FOCFF + RFFF or PPMF	First – bipaddled FOCFF Second – FOCFF + RFFF or PPMF	First – bipaddled FOCFF Second – FOCFF + RFFF or PPMF	First – scapula tip flap Second – RFFF
	>3	ALT	ALT	ALT	N/A

In addition, an algorithm to address isolated hard palate defects using a trilaminar approach.
*Rarely involves single mucosal zone, as resection usually extends onto buccal mucosa or oropharynx, thus necessitating an ALT.
ALT, anterolateral thigh free flap; FOCFF, fibula osseocutaneous free flap; PPMF, pedicled pectoralis major myocutaneous flap; RFFF, radial forearm free flap.

Table 4. Recipient and Donor Site Complications

Complications	No. Patients (%)
Recipient site	
Total flap loss	0 (0%)
Partial flap loss	7 (5.9%)
Venous anastomotic revision	4 (3.4%)
Arterial anastomotic revision	0 (0%)
Hematoma	7 (5.9%)
Infection	6 (5.1%)
Donor site	
Dehiscence	12 (10.2%)
Infection	4 (3.4%)
Seroma	4 (3.4%)

Fig. 8. The radial forearm free flap donor site scar at 1-year postsurgery.

With the majority of oral cavity defects resulting from an intraoral squamous cell carcinoma, the extent of mucosal resection plays an important role in flap selection. The concept of considering the size of the mucosal defect has recently been presented in an algorithm for mandibular reconstruction.[7] In the algorithm from Cordeiro et al.,[7] a mucosal defect involving 3 or more intraoral soft-tissue zones would be considered for a nonosseous reconstruction despite the underlying bony defect. The fibula osseocutaneous free flap (FOCFF) has been shown to provide an average of 231 cm^2 of viable skin, which would be sufficient to restore mucosal integrity in the vast majority of oral cavity defects.[19] However, the transition toward a nonosseous reconstruction in situations involving more than 3 mucosal zones with an underlying full-thickness mandibular defect is based upon the need for soft-tissue bulk outweighing the requirement to restore bony continuity. A further consideration is the perforator anatomy of the lower leg. If the cutaneous paddle of the fibula is not suitable (inadequate perforator) or large enough for the defect, a second soft-tissue flap may be required. We have not found this to be the case in this series, but do routinely perform computerized tomography angiography of the lower limb to aid surgical planning in FOCFF.

In addition to type B oral cavity defects, the extent of the mucosal defect is central to flap selection in reconstructing type U defects. For defects involving a single mucosal zone, the radial forearm free flap (RFFF) remains our flap of choice. Within the oral cavity, a defect involving a single mucosal zone necessitates a flap that is very thin and pliable so that it does not restrict the movement of the tongue or obstruct the teeth during mastication. The RFFF achieves these reconstructive criteria. Furthermore, the long vascular pedicle facilitates easier microvascular anastomoses in the setting of a vessel-depleted neck, or when insetting the flap in the hard palate.[20–22] Despite these advantages, many now look toward other donor sites for smaller intraoral defects, often emphasizing concerns regarding the donor site morbidity associated with the RFFF.[23–27] Our technique to raising the RFFF involves a suprafascial dissection of the skin island and reconstruction of the donor defect with a full-thickness skin graft elevated from the proximal forearm and closed in a V-Y fashion.[28,29] This approach generates a donor site with an acceptable appearance with no revisions required in our patient series (Fig. 8). Furthermore, the RFFF has a consistently thin skin island across a broad spectrum of patient body habitus. The mean thickness of superficial circumflex iliac artery perforator flap has been reported as 5.0 mm[26] and the medial sural artery perforator flap at 8.4 mm.[23] As a result, the thickness of tissue within these 2 areas may preclude their use in a single mucosal zone defect reconstruction, particularly in overweight patients. Although primary thinning of the anterolateral thigh (ALT) flap is able to achieve a mean thickness of 4 mm,[27] this can increase the risk of partial flap loss in a Western population.[30] In the setting of an oral cavity reconstruction, the implications of this would potentially include a salivary leak and delayed oral rehabilitation and discharge.

Once beyond a single mucosal zone, the ALT becomes our flap of choice in reconstructing a mucosa-only defect. In this situation, the necessity for bulk and a larger skin island preclude the use of the RFFF. The mean thickness of the ALT has been shown to be 17.1 mm when measured radiologically in a Caucasian population.[23] In combination with the long vascular pedicle and extensive skin island that can be elevated on a single perforator,[31] the ALT is extremely versatile in reconstructing type U oral cavity defects involving 2 or more mucosal zones.

Our primary option for a type T defect is a chimeric FOCFF (Figs. 9, 10), where a skin paddle can be used to reconstruct the oral defect, the bone to reconstruct the mandible, and a separate skin paddle to reconstruct the external skin defect. However, if the perforator topography is inadequate, we would advocate a FOCFF for the mucosa and bone and either a second cutaneous free flap or a pedicled pectoralis major flap for the skin. It should, however, be noted that many patients presenting with such extensive disease may not be candidates for a prolonged procedure or have extensive mucosal disease. In these circumstances, an ALT flap is utilized.

It should be emphasized that our algorithm has been designed as a guide to the reconstructive surgeon with limited experience in head and neck reconstruction. Although the approach has allowed us to achieve good surgical and functional results and was followed in 93% of cases, we acknowledge that surgeons in other high-volume units may prefer to adopt a more bespoke approach to flap selection according to the defect in question and the availability of recipient vessels in the neck. Furthermore, there are occasions when the optimal flap is unavailable and alternative donor sites should be sought. For example, in our series a patient with a mucosa-only defect involving 1 mucosal zone but no RFFF donor site available underwent a lateral arm flap instead.

The algorithm presented does not attempt to guide the reconstructive surgeon on the size and shape of flap harvest. The nuances of designing the skin island depend on evaluation of the resulting defect and, therefore, decisions should be made on a case-by-case basis. Although a partial glossectomy simply requires a RFFF designed to fit the defect, the approach to designing the skin island for more extensive tongue defects have been discussed extensively elsewhere.[14,15,32,33] Our algorithm simply affirms

Fig. 9. The use of a double-paddled fibula osseocutaneous free flap to reconstruct a trilaminar defect. A, Preoperative photograph of squamous cell carcinoma arising from floor of mouth and eroding through skin overlying left jawline. B, Resulting through-and-through defect after tumor extirpation. C, Bipaddled osseocutaneous fibula flap elevated.

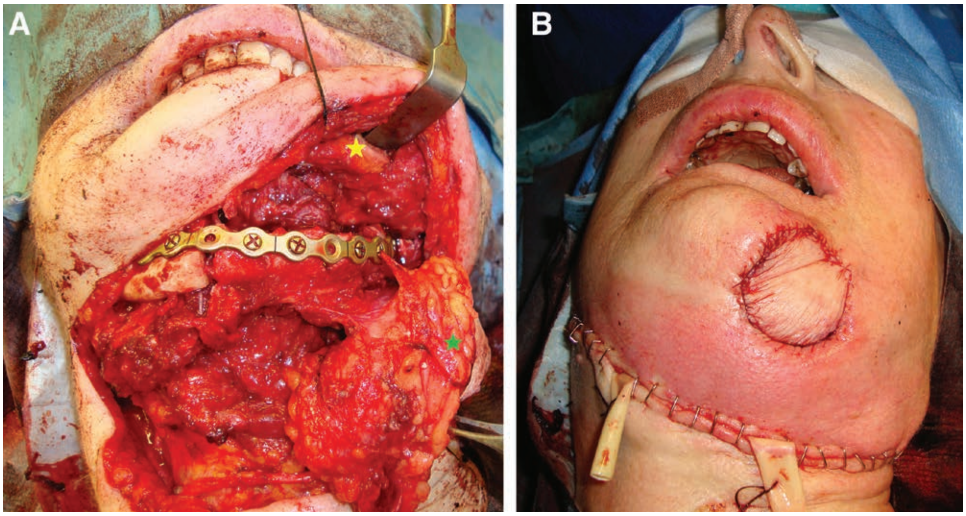

Fig. 10. A, Flap inset with yellow star denoting skin island used for mucosa reconstruction and green star demonstrating skin island to be used for skin reconstruction. B, Final skin inset.

Fig. 11. Scapula tip flap used to reconstruct left-sided full-thickness hard palate defect. A, Full-thickness defect of left hard palate. B, Inset of scapula tip flap seen at 3 weeks. C, Inset of scapula tip flap at 3 months following complete mucosalization.

the opinion that the optimal flap for a tongue defect involving more than one third of the tongue bulk is best reconstructed with an ALT and, thus, guides the initial flap selection.[14,34,35]

In our experience, flap selection can be made according to the depth and mucosal extent of the defect irrespective of the exact location within the oral cavity. We have, however, extended this concept further to develop a classification system that describes the exact location, mucosal extent, and resection depth (Fig. 2). The adoption of the classification system will aid in communication among reconstructive surgeons, data collection, and future outcomes-based research. It should, however, be emphasized that it is simply the number of mucosal zones and lamina excised that will dictate flap selection.

Finally, the approach to isolated hard palate defects is different and so cannot be included in the unifying algorithm applicable to the rest of the oral cavity. Many postcancer resection palatal defects extend into maxillectomy-type defects and so would not be addressed using our algorithm. On the occasions that the defect is isolated to the hard palate, most would be treated with obturation alone. In the cases where an obturator fails to prevent oronasal leakage and hypernasality, or is poorly tolerated by the patient, microvascular reconstruction is an option for defects not amenable to local tissue transfer techniques. Both the RFFF[21,22,36] or the scapula tip flap[37,38] are good options. The RFFF provides a long pedicle that can reach the branches of the external carotid artery but does not restore bony integrity. It also necessitates either raising local palatal mucosal flaps or folding skin or fascia of the RFFF to restore the nasal lining.[21] We, therefore, prefer the scapula tip flap where possible (Fig. 11). When using the scapula tip for an isolated hard palate defect, our approach is to raise the bone flap with the subscapularis and infraspinatus muscles and use the muscle layers to line the oral and nasal mucosal defects. As these subsequently remucosalize, mucosal integrity is restored. It should be noted that previous reports on the use of the scapula tip flap primarily focus upon defects that extend into the maxilla.[37,38]

CONCLUSION

The algorithm presented is aimed at providing a simple system to classify oral cavity defects and to guide the reconstructive procedure rather than focusing upon the anatomical location of the defect. This is based upon the knowledge that, in 93% of the cases, the application of the algorithm guided the reconstruction of the breadth of oral cavity defects. This approach can be used by reconstructive microsurgeons with varying levels of experience and has been demonstrated to generate excellent surgical and functional outcomes.

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