Management of Through-and-Through Oromandibular Defects after Segmental Mandibulectomy with Fibula Osteocutaneous Flap

Saumya Mathews, MCh[1] Dushyant Jaiswal, MCh[1] Prabha Yadav, MCh[1] Vinay Kant Shankhdhar, MCh[1] Sumit Hadgaonkar, MCh[1] Mayur Mantri, MCh[1] Ameya Bindu, MCh[1] Vineet Pilania, MCh[1] Arbab Mohammad, MBBS[2] Joseph M. Escandón, MD[3]

[1] Department of Plastic and Reconstructive Surgery, Tata Memorial Hospital, Homi Bhabha National Institute, Mumbai, Maharashtra, India
[2] Aarupadai Veedu Medical College and Hospital, Puducherry, India
[3] Division of Plastic and Reconstructive Surgery, Strong Memorial Hospital, University of Rochester Medical Center, Rochester, New York

Address for correspondence Vinay Kant Shankhdhar, MCh, Department of Plastic and Reconstructive Surgery, Tata Memorial Hospital, Mumbai, Maharashtra, India (e-mail: vinayshankhdhar@gmail.com).

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Abstract

Background Oromandibular defects involving the external skin are a reconstructive challenge. This study aimed to evaluate the use of the fibula osteocutaneous free flap (FOCFF) for through-and-through oromandibular defects by comparing the surgical outcomes and complications of different techniques to close the external skin defect.
Methods A retrospective analysis was conducted of patients who underwent reconstruction of through-and-through oromandibular defects after oncologic segmental mandibulectomy between January 2011 and December 2014. Five groups were analyzed according to the method of external skin coverage: primary closure, locoregional flaps, deepithelialized double-skin paddle FOCFF (deEpi-FOCFF), division of the skin paddle for double-skin paddle FOCFF (div-FOCFF), and a simultaneous second free flap. Intraoperative and postoperative outcomes along with complications were analyzed between groups.
Results A total of 323 patients were included. The mean total defect area requiring a simultaneous second free flap was larger in comparison to other groups ($p < 0.001$). Reconstructions performed with div-FOCFF had a higher number of perforators per flap when compared with deEpi-FOCFF ($p < 0.001$). External defects closed with another free flap exhibited higher intraoperative time for the reconstructive segment in comparison to other groups ($p < 0.05$). The overall rate of complications was comparable between groups (24%, $p = 0.129$).
Conclusion The FFOCF is a reliable alternative to harvesting multiple simultaneous free flaps for through-and-through oromandibular defects. The authors recommend appropriate curation of the surgical plan based on individual patient characteristics and reconstructive requirements.

Keywords
- fibula
- head and neck neoplasms
- reconstructive surgical procedures
- postoperative complications
- surgical flaps

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Composite oromandibular defects after segmental mandibulectomy are regarded as a reconstructive challenge in the microsurgical community without reliable consensus on the best treatment approach as they can be problematic in terms of aesthetics, quality-of-life, and function.[1] The incorporation of free flaps in the reconstructive ladder has provided microsurgeons the ability to cover such extensive head and neck oncologic defects with relative straightness.[2] Furthermore, over the last few decades, progressive strides in reconstructive microsurgery have provided surgeons the luxury of tailoring free flaps based on recipient site requirements, which allows excellent reconstructive outcomes while limiting the level of donor site morbidity to a minimum.[2–4]

While acknowledging the reconstructive intricacies inherent to through-and-through oromandibular defects, reports from literature have demonstrated a high degree of reliability in using multiple simultaneous free flaps to address extensive head and neck defects in circumstances where a single free flap fails to provide sufficient coverage.[5,6] Despite the advantageous nature of the aforementioned approach, an additional set of anastomosis and multiple donor sites increase the overall operative time and morbidity index of the reconstructive procedure.[7]

Hidalgo's demonstration of the versatility of the fibula osteocutaneous free flap (FOCFF) for mandibular reconstruction and subsequent modifications to improve the flap configuration, have established this flap as the gold standard treatment approach.[7,8] A double-skin paddled FFOCF, either crafted after deepithelializing a central portion of the skin paddle (deEpi-FOCFF) or after dividing the skin paddle based on the perfusion of independent perforators (div-FOCFF), has further evidenced the prominent role of the FOCFF to address such composite defects in aggravated surgical settings (multiple facial subunits requiring reconstruction and/or depleted vessel region).[7] Herein, the aim of this study was to present our experience using the FOCFF for reconstruction of through-and-through oromandibular defects, and compare the surgical outcomes and complications of different techniques for external skin coverage. Additionally, we provided an algorithm to facilitate the selection of the technique for external skin coverage depending on the characteristics of the defect and the vascular infrastructure of the FOCFF.

Methods

Study Design

This study was approved by the institutional review board at a large academic medical center. A retrospective review was conducted for all patients 18 years or older who underwent immediate reconstruction of composite through-and-through oromandibular defects with FOCFFs from January 2011 to December 2014. We excluded patients without external skin defects after resection, or with incomplete data. We divided the total sample of patients in five groups according to the technique used for closure of the external skin defect: (1) primary closure, (2) regional/local flaps (e.g., rotation flap, forehead flap,[9] nasolabial + Estlander[10]), (3) deepithelialized double-skin paddle FOCFF (deEpi-FOCFF), (4) division of the skin paddle for double-skin paddle FOCFF (div-FOCFF), and (5) a simultaneous second free flap. We analyzed the intraoperative outcomes, postoperative outcomes, and complications between groups.

Surgical Technique

The surgical technique for FOCFF has been previously reported.[11] For the deEpi-FOCFF, deepithelialization of intervening fasciocutaneous tissue between the upcoming "inner" and "outer" lining is performed, resulting in a double-skin paddle FOCFF.[11] The div-FOCFF is accomplished by dividing the FOCFF's skin paddle, generating a second skin paddle either based on a distal septocutaneous perforator or on a proximal muscular perforator. One skin paddle was used for the mucosal defect while the second skin paddle was used for resurfacing the skin. When a second free flap was performed simultaneously with the FOCFF, a single skin paddle FOCFF was used to cover the mucosal defect while the other free flap covered the external defect.

Following surgery, pinprick test and Doppler examination were performed every 3 hours the first day for flap checks; afterwards, every 6 hours for the next 4 days. Ambulation was restricted until postoperative day 6, while prophylactic dose of low-molecular-weight heparin was given the first 5 postoperative days. Patients were followed every 2 weeks after discharge until removing the feeding tube or after tracheostomy was decannulated.

Variables

We extracted data on the demographics of patients (e.g., age, biologic sex); past medical history of hypertension or diabetes; active smoking (considered if smoking within 8 weeks of the day of surgery); consumption of tobacco; radiotherapy; chemotherapy; and pathologic diagnosis of the tumor.

Intraoperative variables extracted for this study included: area of the internal mucosal defect (cm^2); area of external skin defect (cm^2); total defect area (external defect + mucosal defect, cm^2); skin paddle area of the FOCFF (cm^2); defect-skin paddle relationship, which estimated if the area of the skin paddle was larger than the total defect; number of perforators per flap; distance of perforators from malleolus (0-cm), measured from distal to proximal; maximal distance between two adjacent perforators; length of the fibula bone; recipient artery; type of venous anastomosis (single vs. double venous anastomosis); and tourniquet time, ischemia time, and time of the reconstructive segment of the procedure. Postoperatively, we evaluated the rate of complications, perioperative flap reexplorations, total flap loss (complete flap loss and loss of the skin paddle), wound disruption or partial flap loss, and rate of orocutaneous fistulas. We also extracted data on the requirements of a second flap for salvage of the reconstruction and the type of flap used.

Statistical Analysis

All analyses were performed using R statistical software, version 4.0.0 (R Core Team, 2020).[12] The Shapiro–Wilk test was used to study the distributions of quantitative variables. Homogeneity of variances was evaluated with the Levene's test. The classic Fisher's one-way analysis of variance (ANOVA) or Welch's ANOVA were used according to homoscedasticity of variance. The Tukey post hoc test or Games–Howell post hoc test was used to compare all possible combinations of group differences. Data were presented as mean ± standard deviation. Chi-square was used to analyze discrete data. An α of less than 0.05 was considered statistically significant.

Results

Characteristics of Patients

Three hundred and twenty-three patients underwent reconstruction of composite oromandibular defects with FOCFFs. The method for reconstruction of the external skin defects were primary closure in 10% of cases; regional or local flaps in 2% of cases, including three cases of rotation flaps, one forehead flap, and one nasolabial and simultaneous Estlander flap; deEpi-FOCFF in 28% of cases; div-FOCFF in 47% of patients; and a second free flap in 13% of cases, including 12 peroneal perforator flaps, one sural flap, one soleal perforator flap, 22 anterolateral thigh free (ALTF) flaps, two radial forearm free flaps, one ALTF + tensor fascia lata flap, and two anteromedial thigh free flaps (►**Table 1**).

Overall, 252 males (78%) and 71 females (22%) were included. A higher proportion of male patients (89%) was evident in reconstructions performed with deEpi-FOCFFs ($p = 0.047$). The average age at the time of surgery was 57.14 ± 13.24 years. The mean age of patients among the different groups were comparable ($p = 0.059$). Overall, 10% of patients had past medical history of diabetes ($p = 0.151$), while 13% had past medical history of hypertension ($p = 0.628$). Eighteen percent of patients reported to be active smokers at the time of surgery ($p = 0.582$). The proportion of patients that actively consumed tobacco was 81, 80, 93, 93, and 76% in patients who underwent closure of the external skin defect with primary closure, regional/local flaps, deEpi-FOCFF, div-FOCFF, and a simultaneous second free flap ($p = 0.006$), respectively (►**Table 2**).

Table 1 Method for reconstruction

Reconstructive method	Frequency
Total	323 (100)
Primary closure	32 (10)
Regional/Local	5 (2)
Rotation flap	3 (1)
Forehead flap	1 (0)
Nasolabial + Estlander	1 (0)
Deepithelized	92 (28)
Division	153 (47)
Division on perforator	148 (46)
Division on branches of perforator	5 (2)
Free flap	41 (13)
Peroneal perforator	12 (4)
Sural perforator	1 (0)
Soleal perforator	1 (0)
ALTF	22 (7)
RFAFF	2 (1)
ALTF + TFL	1 (0)
AMTF	2 (1)

Abbreviations: ALTF, anterolateral thigh free flaps; AMTF, anteromedial thigh free flap; RFAFF, radial forearm free flap; TLF, tensor fascia lata.

Overall, 19% of patients required chemotherapy ($p = 0.71$). The proportion of patients that received regional radiotherapy were 91, 100, 98, 93, and 80% in patients who underwent coverage of the external skin defect with primary closure, regional/local flaps, deEpi-FOCFFs, div-FOCFFs, and a simultaneous second free flap ($p = 0.009$), respectively. Most reconstructive procedures were performed for defects resulting from resection of squamous cell carcinoma (95%, $p = 0.615$) (►**Table 2**).

Intraoperative Outcomes

The average size of the external defects after oncologic ablation was significantly different between groups (mean: 49.92 ± 29.19 cm^2; $p < 0.001$). On post hoc analysis, the average size of external defects closed with primary closure (32.03 ± 19.3 cm^2) was significantly smaller than the mean size of external skin defects closed with deEpi-FOCFF (42.93 ± 21.4 cm^2, $p = 0.046$), div-FOCFF (49.35 ± 28.81 cm^2, $p < 0.001$), and another free flap (82.93 ± 27.64 cm^2, $p < 0.001$). On the other hand, the average size of external defects closed with a simultaneous second free flap were larger than the mean external skin area closed with deEpi-FOCFF ($p < 0.001$), and div-FOCFF ($p < 0.001$) (►**Table 3**).

The average size of the mucosal defect after oncologic ablation was significantly different between groups (mean: 66.1 ± 29.95 cm^2; $p = 0.002$). On post hoc analysis, the average area of mucosal defects from reconstructions that had second free flap (82.32 ± 28.64 cm^2) was larger in comparison to reconstructions requiring primary closure (63.28 ± 26.17 cm^2, $p = 0.032$), deEpi-FOCFF (65.76 ± 28.88 cm^2, $p = 0.015$), and div-FOCFF (62.25 ± 30.36 cm^2, $p < 0.001$) for external skin coverage.

The mean size of the total defect (external skin + mucosa) after oncologic ablation was significantly different between groups (mean: 116.02 ± 50.89 cm^2; $p < 0.001$). On post hoc analysis, the mean size of the total defect requiring a simultaneous second free flap (165.24 ± 46.06 cm^2) was larger in comparison to the mean total area of reconstructions requiring primary closure (95.31 ± 34.45 cm^2, $p < 0.001$), deEpi-FOCFF (108.7 ± 43.76 cm^2, $p < 0.001$), and div-FOCFF (111.6 ± 51.54 cm^2, $p < 0.001$) for external skin defects.

The mean number of perforators per flap was significantly different between groups (mean: 2.78 ± 0.88; $p < 0.001$). On post hoc analysis, reconstructions performed with div-FOCFF (3.01 ± 0.75) had a higher number of perforators per flap when compared with deEpi-FOCFF (2.52 ± 0.93, $p < 0.001$).

Table 2 Baseline clinical and demographic variables

Variables	Primary closure	Regional/Local	Deepithelized	Division	Free flap	Total	*p*-Value
Reconstructions (%)	32 (10)	5 (2)	92 (28)	153 (47)	41 (13)	323 (100)	
Age (y)	51.16 ± 13.72 (range, 19–78)	66.4 ± 14.31 (range, 49–83)	58.21 ± 13.56 (range, 27–96)	57.16 ± 12.46 (range, 21–82)	58.24 ± 13.91 (range, 29–88)	57.14 ± 13.24 (range, 19–96)	0.059
Sex							0.047
Male (%)	24 (75)	4 (80)	82 (89)	113 (74)	29 (71)	252 (78)	
Female (%)	8 (25)	1 (20)	10 (11)	40 (26)	12 (29)	71 (22)	
Diabetes (%)	0 (0)	0 (0)	7 (8)	18 (12)	6 (15)	31 (10)	0.151
Hypertension (%)	4 (13)	1 (20)	9 (10)	21 (14)	8 (20)	43 (13)	0.628
Smoking (%)	9 (28)	1 (20)	17 (18)	25 (16)	6 (15)	58 (18)	0.582
Tobacco (%)	26 (81)	4 (80)	86 (93)	142 (93)	31 (76)	289 (89)	0.006
Chemotherapy (%)	6 (19)	0 (0)	20 (22)	29 (19)	6 (15)	61 (19)	0.71
Radiotherapy (%)	29 (91)	5 (100)	90 (98)	143 (93)	33 (80)	300 (93)	0.009
Tumor							0.615
SCC (%)	30 (94)	5 (100)	90 (98)	144 (94)	38 (93)	307 (95)	
Ossifying fibroma (%)	1 (3)	0 (0)	0 (0)	1 (1)	0 (0)	2 (1)	
PNET (%)	1 (3)	0 (0)	0 (0)	1 (1)	0 (0)	2 (1)	
Osteosarcoma (%)	0 (0)	0 (0)	1 (1)	0 (0)	2 (5)	3 (1)	
NHL (%)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	1 (0)	
Hemangioma (%)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	1 (0)	
Other/NR (%)	0 (0)	0 (0)	1 (1)	5 (3)	1 (2)	7 (2)	

Abbreviations: NHL, non-Hodgkin lymphoma; NR, not reported; PNET, primitive neuroectodermal tumor; SCC, squamous cell carcinoma.

The median maximal distance between two adjacent perforators was comparable between groups ($p = 0.9$). Remarkably, at least 3 cm between two adjacent perforators were required for reconstruction of external defects with div-FOCFF (range, 3–12 cm). The average distance of perforators from the malleolus when one, two, three, four, or five perforators were found is shown in ►**Table 4** (►**Supplementary Data S1**, available in the online version).

The mean area of the skin paddle was significantly different between groups ($194.57 \pm 59.31\ \text{cm}^2$, $p < 0.001$). On post hoc analysis, a reduced size of skin paddles for FOCFF was used when primary closure of the external skin defect was possible ($136.47 \pm 35.05\ \text{cm}^2$) in comparison to reconstructions that required an additional simultaneous free flap ($218.73 \pm 52.24\ \text{cm}^2$, $p < 0.001$), deEpi-FOCFF ($193.03 \pm 54.17\ \text{cm}^2$, $p < 0.001$), and div-FOCFF ($201.67 \pm 61.04\ \text{cm}^2$, $p < 0.001$) for external skin coverage. The proportion of reconstructions that had a larger total defect (external skin + mucosa lining) in comparison to the skin paddle area of the FOCFF were 13% for primary closure, 0% for regional/local flaps, 8% for deEpi-FOCFF, 6% for div-FOCFF, and 22% when a simultaneous second free flap was required ($p = 0.002$) (►**Table 3**).

The average length of the bone segment (fibula) was 117.5 ± 118.34, 98 ± 27.06, 100.65 ± 91.9, 95.19 ± 26.41, and 134.88 ± 26.87 mm in patients who underwent closure of the external skin defect with primary closure, regional/local flaps, deEpi-FOCFF, div-FOCFF, and another free flap ($p = 0.004$), respectively.

The most common recipient arteries were the facial artery in 80% of patients and the superior thyroid artery in 17% of patients ($p = 0.401$). The proportion of reconstructions performed with a double venous anastomosis for the FOCFF were 34% for primary closure, 40% for regional/local flaps, 57% for deEpi-FOCFF, 43% for div-FOCFF, and 27% when a second simultaneous free flap was required for closure of the external defect ($p = 0.014$).

The average tourniquet time was comparable between groups (105.69 ± 28.1 minutes; $p = 0.767$). The mean ischemia time was significantly different between groups (mean: 288.53 ± 65.44 minutes; $p < 0.001$). On post hoc analysis, external defects closed with primary closure (249.78 ± 52.6 minutes) exhibited a lower ischemia time in comparison to deEpi-FOCFF (288.1 ± 63.78 minutes, $p = 0.02$), div-FOCFF (290.57 ± 67.52 minutes, $p = 0.006$), and another free flap (312.56 ± 59.02 minutes, $p < 0.001$).

The mean reconstructive time was significantly different between groups (503.94 ± 98.16 minutes, $p < 0.001$). On post hoc analysis, external defects closed with another free flap

Table 3 Intraoperative variables

Variables	Primary closure	Regional/Local	Deepithelized	Division	Free flap	Total	*p*-Value
External skin defect (cm^2)	32.03 ± 19.3	40 ± 33.54	42.93 ± 21.4	49.35 ± 28.81	82.93 ± 27.64	49.92 ± 29.19	< 0.001
Mucosa defect (cm^2)	63.28 ± 26.17	75 ± 35.36	65.76 ± 28.88	62.25 ± 30.36	82.32 ± 28.64	66.1 ± 29.95	0.002
Total defect size (cm^2)	95.31 ± 34.45	115 ± 57.55	108.7 ± 43.76	111.6 ± 51.54	165.24 ± 46.06	116.02 ± 50.89	< 0.001
Number of perforators	2.56 ± 0.95 (range, 1–4)	2.8 ± 0.84 (range, 2–4)	2.52 ± 0.93 (range, 1–5)	3.01 ± 0.75 (range, 2–5)	2.66 ± 0.96 (range, 1–4)	2.78 ± 0.88 (range, 1–5)	< 0.001
Number of perforators							0.002
One (%)	4 (13)	0 (0)	11 (12)	0 (0)	6 (15)	21 (7)	
Two (%)	12 (38)	2 (40)	36 (39)	38 (25)	10 (24)	98 (30)	
Three (%)	10 (31)	2 (40)	34 (37)	80 (52)	17 (41)	143 (44)	
Four (%)	6 (19)	1 (20)	8 (9)	31 (20)	8 (20)	54 (17)	
Five (%)	0 (0)	0 (0)	3 (3)	4 (3)	0 (0)	7 (2)	
Max distance perforator	5.93 ± 2.09 (range, 2–11)	5.4 ± 2.19 (range, 4–9)	6.25 ± 2.73 (range, 2–15)	6.06 ± 1.99 (range, 3–12)	6.2 ± 2.26 (range, 2–11)	6.1 ± 2.24 (range, 2–15)	0.9
Distance of perforator from malleolus							
P1 (cm)	12.03 ± 3.97 (range, 4–24)	10.4 ± 1.52 (range, 8–12)	11.67 ± 3.16 (range, 6–20)	11.82 ± 3.1 (range, 7–20)	12.93 ± 3.18 (range, 8–19)	11.92 ± 3.22 (range, 4–24)	
P2 (cm)	16 ± 3.73 (range, 6–24)	15.8 ± 2.49 (range, 14–20)	16.96 ± 3.55 (range, 11–28)	16.98 ± 3.47 (range, 10–28)	17.29 ± 3.67 (range, 10–26)	16.9 ± 3.52 (range, 6–28)	
P3 (cm)	18.94 ± 3.82 (range, 10–25)	18 ± 1 (range, 17–19)	20.38 ± 3.51 (range, 14–28)	20.81 ± 3.34 (range, 13–30)	21.28 ± 4.07 (range, 14–28)	20.59 ± 3.52 (range, 10–30)	
P4 (cm)	22 ± 5.62 (range, 12–29)	21 (range, 21–21)	22.82 ± 2.44 (range, 20–28)	24.06 ± 3.14 (range, 20–36)	25.5 ± 3.85 (range, 20–32)	23.77 ± 3.47 (range, 12–36)	
P5 (cm)			28.67 ± 0.58 (range, 28–29)	30.25 ± 6.95 (range, 24–40)		29.57 ± 5 (range, 24–40)	
Skin paddle (cm^2)	136.47 ± 35.05 (range, 75–225)	179.4 ± 52.86 (range, 96–225)	193.03 ± 54.17 (range, 72–392)	201.67 ± 61.04 (range, 60–406)	218.73 ± 52.24 (range, 91–324)	194.57 ± 59.31 (range, 60–406)	< 0.001
Defect-skin paddle relationship							0.002
Total defect ≤ skin paddle	28 (88%)	5 (100%)	85 (92%)	144 (94%)	32 (78%)	294 (91%)	
Total defect > skin paddle	4 (13%)	0 (0%)	7 (8%)	9 (6%)	9 (22%)	29 (9%)	
Bone segment (cm)	117.5 ± 118.34 (range, 45–750)	98 ± 27.06 (range, 55–125)	100.65 ± 91.9 (range, 40–950)	95.19 ± 26.41 (range, 25–180)	134.88 ± 26.87 (range, 60–195)	104.04 ± 65.9 (range, 25–950)	0.004
Recipient artery							0.401
STA (%)	8 (25)	1 (20)	13 (14)	31 (20)	3 (7)	56 (17)	
FA (%)	24 (75)	4 (80)	77 (84)	118 (77)	37 (90)	260 (80)	
ECA (%)	0 (0)	0 (0)	1 (1)	4 (3)	1 (2)	6 (2)	
TCA (%)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	1 (0)	
Venous anastomosis							0.014
One (%)	21 (66)	3 (60)	40 (43)	87 (57)	30 (73)	181 (56)	
Two (%)	11 (34)	2 (40)	52 (57)	66 (43)	11 (27)	142 (44)	

Abbreviations: ECA, external carotid artery; FA, facial artery; STA, superior thyroid artery; TCA, transverse cervical artery.

Table 4 Distance of perforator from malleolus

Number of perforators per flap	Perforator 1	Perforator 2	Perforator 3	Perforator 4	Perforator 5
One	15.14 ± 3.45				
Two	13.16 ± 3.18	19.37 ± 3.6			
Three	11.24 ± 2.78	16.05 ± 2.79	21.14 ± 3.49		
Four	10.69 ± 2.68	15.15 ± 2.78	19.46 ± 3.27	23.67 ± 3.22	
Five	8.14 ± 1.57	13.29 ± 1.11	18 ± 3.21	24.57 ± 5.26	29.57 ± 5

(583.17 ± 115.96 minutes) exhibited a higher intraoperative time for the reconstructive segment in comparison to primary closure (450 ± 73.09 minutes, $p = 0.032$), deEpi-FOCFF (485.27 ± 94.23 minutes, $p = 0.015$), and div-FOCFF (505.12 ± 87.73 minutes, $p < 0.001$). Likewise, external defects closed with div-FOCFF exhibited a higher mean reconstructive time in comparison to primary closure ($p = 0.012$).

Complications

The overall morbidity was comparable between groups (24%; $p = 0.129$). The rate of reexploration was 16% for primary closure, 0% for regional/local flaps, 13% for deEpi-FOCFF, 8% for div-FOCFF, and 29% when another free flap was required for closure of the external skin defect ($p = 0.006$). The rate of total flap loss was 11% ($p = 0.311$), partial flap loss was 4% ($p = 0.967$), and orocutaneous fistula was 5% ($p = 0.561$). A second free flap was required in 11% of the cases ($p = 0.155$). Six pectoralis major myocutaneous flaps (PMMCF), 3 contralateral FOCFFs, 10 forehead flaps, 4 nasolabial flaps, 2 deltopectoral flaps, 7 scalp flaps, 3 ALTF flaps, and 1 radial forearm free flap were required for reconstruction salvage. One patient required simultaneous reconstruction with PMMCF and forehead for salvage (►**Table 5**).

Discussion

Reconstruction of through-and-through oromandibular oncologic resections remains a challenging task due to the complexity attached to these cases. In fact, this connotation for extensive composite oromandibular defects involving not only the bone framework but also the intraoral mucosal lining and the external skin, highlights the severity of associated morbidity and functional impairment patients experience even after reconstruction.[6]

While some of these defects can be reconstructed with a single free flap, the extensive soft tissue requirements and the three-dimensional configuration of these wounds usually demand in most cases two or more donor sites.[13,14] However, in this study, the versatility of a double-skin paddle FOCFF was evidenced and our results indicate that the double-skin paddle FOCFF is a reliable alternative for extensive head and neck defects involving two different soft tissue units as previously reported.[11,15–27]

A careful assessment of the defect must be conducted and discussed with the oncologic surgeon, as some external skin defects can be closed primarily after inset of the FOCFF (►**Fig. 1**). Nonetheless, defects that can be closed primarily are usually elliptical, are situated in the midline or

Table 5 Surgical outcomes

Variables	Primary closure	Regional/Local	Deepithelized	Division	Free flap	Total	*p*
Tourniquet time (min)	103.59 ± 26.02 (range, 55–150)	91.8 ± 29.98 (range, 60–135)	104.63 ± 23.99 (range, 50–160)	107.64 ± 31.16 (range, 30–267)	104.15 ± 26.66 (range, 52–150)	105.69 ± 28.13 (range, 30–267)	0.767
Ischemia time (min)	249.78 ± 52.6 (range, 150–360)	285 ± 67.08 (range, 180–360)	288.1 ± 63.78 (range, 120–420)	290.57 ± 67.52 (range, 120–480)	312.56 ± 59.02 (range, 210–450)	288.53 ± 65.44 (range, 120–480)	< 0.001
Reconstruction time (min)	450 ± 73.09 (range, 300–600)	507 ± 98.59 (range, 360–630)	485.27 ± 94.23 (range, 240–720)	505.12 ± 87.73 (range, 300–720)	583.17 ± 115.96 (range, 300–840)	503.94 ± 98.16 (range, 240–840)	< 0.001
Morbidity							
Complications (%)	9 (28)	0 (0)	26 (28)	29 (19)	14 (34)	78 (24)	0.129
Reexplore (%)	5 (16)	0 (0)	12 (13)	12 (8)	12 (29)	41 (13)	0.006
Flap loss (%)	3 (9)	0 (0)	13 (14)	12 (8)	7 (17)	35 (11)	0.311
Partial flap loss (%)	1 (3)	0 (0)	4 (4)	5 (3)	2 (5)	12 (4)	0.967
OCF (%)	3 (9)	0 (0)	3 (3)	9 (6)	1 (2)	16 (5)	0.561
Salvage flap operation							
Salvage flap (%)	3 (9)	0 (0)	14 (15)	12 (8)	8 (20)	37 (11)	0.155
Salvage flap							
PMMCF (%)	2 (6)	0 (0)	1 (1)	2 (1)	1 (2)	6 (2)	
FFOCF (%)	1 (3)	0 (0)	1 (1)	1 (1)	0 (0)	3 (1)	
Forehead[a] (%)	0 (0)	0 (0)	4 (4)	3 (2)	3 (7)	10 (3)	
Nasolabial (%)	0 (0)	0 (0)	2 (2)	1 (1)	1 (2)	4 (1)	
DP (%)	0 (0)	0 (0)	1 (1)	0 (0)	1 (2)	2 (1)	
Scalp (%)	0 (0)	0 (0)	3 (3)	4 (3)	0 (0)	7 (2)	
FALT (%)	0 (0)	0 (0)	1 (1)	1 (1)	1 (2)	3 (1)	
FRAFF (%)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	1 (0)	
PMMCF + Forehead[a] (%)	0 (0)	0 (0)	0 (0)	0 (0)	1 (2)	1 (0)	

Abbreviations: DP, deltopectoral; FALT, free anterolateral; FRAFF, free radial forearm free flap; FFOCF, free fibula osteocutaneous flap; PMMCF, pectoralis major myocutaneous flap; OCF, orocutaneous fistula.
[a]Flap based on the frontal branch of the superficial temporal artery.

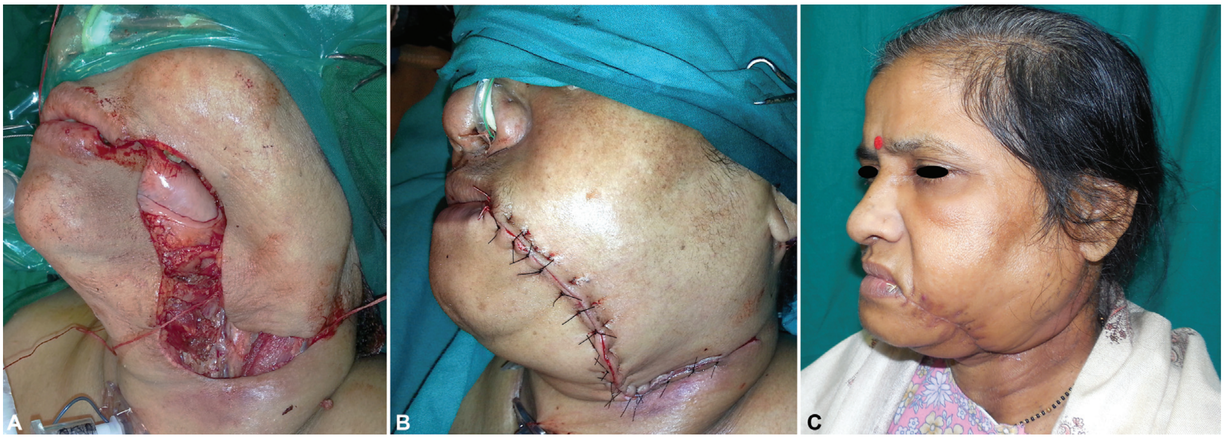

Fig. 1 Primary closure of external defect. (A) Defect after resection. (B) Immediate postoperative photo. (C) Late postoperative period.

paramedian region, and are reduced in size (< 3 cm). When the external defect cannot be closed primarily, surgeons can incorporate local flaps such as rotation flaps or a combined nasolabial and Estlander flap; a double-skin paddle FOCFF, either deepithelialized or divided based on perforators; or a second free flap like a forearm free flap or thigh fasciocutaneous free flap. Although inset is facilitated when adding an additional free flap for compound three-dimensional defects, increased morbidity of a second donor site, the requirement of a second set of anastomoses, additional intraoperative time ($p < 0.05$), and a higher risk of postoperative reexploration ($p = 0.006$) should be taken into consideration.

If defects are lateral, have an average size of 3 to 4 cm, and do not cause distortion of the lip, a fascio-cervical rotation flap can be utilized for closure of the external skin defect. Otherwise, when defects are larger, more advanced alternatives are required. As seen in our post hoc analysis, the total defect size is one of the most important determinants to incorporate a second free flap into the reconstructive plan. Once the surgeon has determined that a fascio-cervical rotation flap or a double-skin paddle FOCFF are impractical to cover the extent of the defect, selecting a second free flap depending on the characteristics of the fasciocutaneous component is the next step.

In this setting, the dilemma remains on whether to use a deEpi-FOCFF or div-FOCFF when the fasciocutaneous component of a single FOCFF can adequately cover the whole through-and-through defect area. According to our experience, a deEpi-FOCFF provides optimal internal and external coverage if the skin paddle is pliable and there are one or more perforators optimally arborizing between the "inner" and "outer" paddle. Remarkably, as the skin paddle is not divided, a single perforator or a short distance (< 3 cm) between two adjacent perforators are no limitations to using this flap configuration for composite mandibular defects (►**Fig. 2**). When selecting the deEpi-FOCFF, it must be taken into consideration that this flap usually incorporates a lower number of perforators for the skin paddle than the div-FOCFF. Therefore, marginal ischemia can occur when skin paddles are extremely large due to insufficient perfusion which can result in inadvertent fistulas and pedicle thrombosis. Alternatively, when the FOCFF is deepithelialized and folded, limitations of flow through the subdermal and subfascial plexus can also happen.

If the thickness of the skin paddle is optimal, there are at least two or more appropriate perforators, and there is a 3-cm distance or more between perforators, a div-FOCFF remains the gold standard as seen in our results. When the second skin paddle is perfused by a distal septocutaneous perforator, it is best used for coverage of the alveolar ridge or floor of the mouth.[25] In fact, a recent meta-analysis has shown superior outcomes of this technique when used for composite oromandibular defects.[7] On the other hand, the division of the skin paddle using a proximal muscular perforator provides the most convenient design for complex three-dimensional defects. The location and length of this musculocutaneous perforator allow to covering defects in different locations and an easier inset of the skin paddles without intertwining or tethering their blood supply (►**Fig. 3**).[7,19]

Even if the number and location of perforators allow for div-FOCFF, in some instances splitting the skin paddle can be complicated when a large segment of bone is needed and dissecting the perforators off the fibula can cause injury or tension of the perforators. In this setting, using a deEpi-FOCFF may be preferred. Likewise, although virtual surgical planning (VSP) has been shown to be cost-effective, reduce operative time, and may decrease recipient site morbidity,[28,29] surgeons still need to conduct a judicious intraoperative assessment of the flap and the configuration of perforators for division of FOCFF's skin paddle (div-FOCFF).[29] Of note, the incorporation of three-dimensional printing and VSP, together with the learning curve of the surgical team, will tend to improve postoperative results.[29,30]

The proximal musculocutaneous perforator may not arise from the main peroneal pedicle but from the posterior tibial, anterior tibial, popliteal artery, or as a trifurcation.[25] In these cases, the muscular perforator can be used to harvest a free-style free flap (with or without muscle) with a larger skin paddle to cover larger external defects or reconstruct other structures requiring mucosal lining (e.g., tongue, palate, sinus) (►**Supplementary Data S2**, available in the online

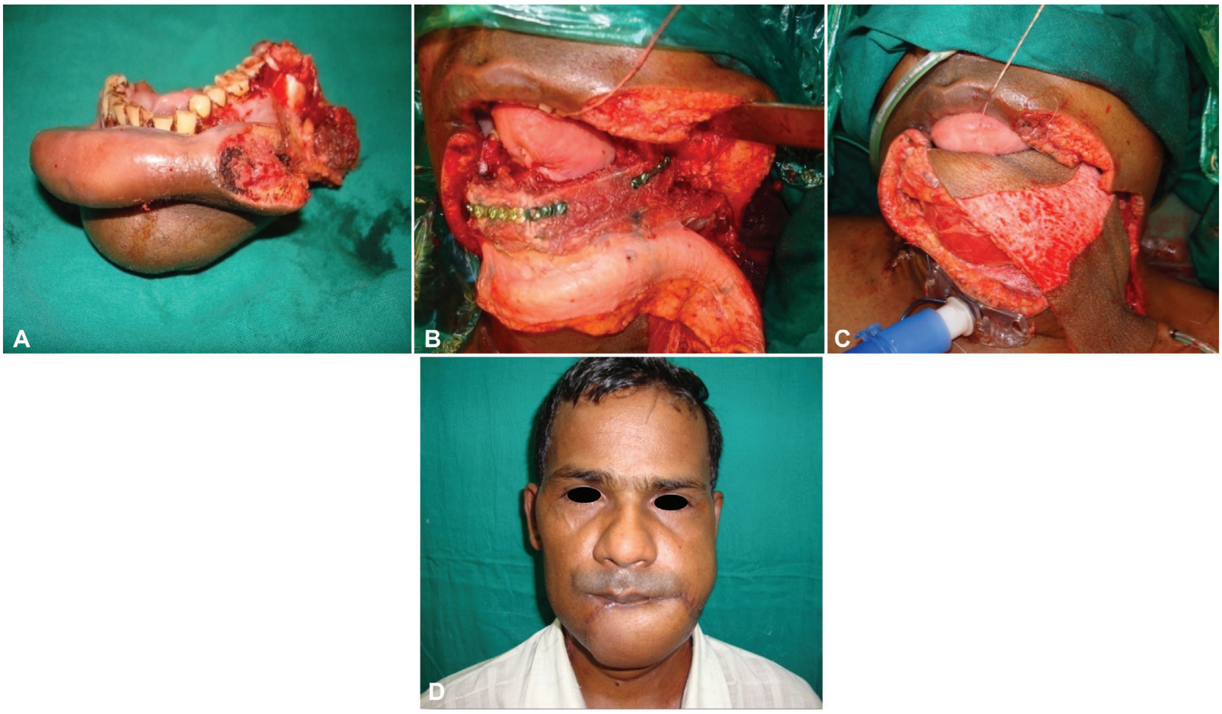

Fig. 2 Closure of external defect with deepithelialized double-skin paddle fibula osteocutaneous free flap (deEpi-FOCFF). (A) Mandibular specimen after resection; (B) deEpi-FOCFF inset; (C) deepithelialization of the intervening skin; (D) late postoperative period.

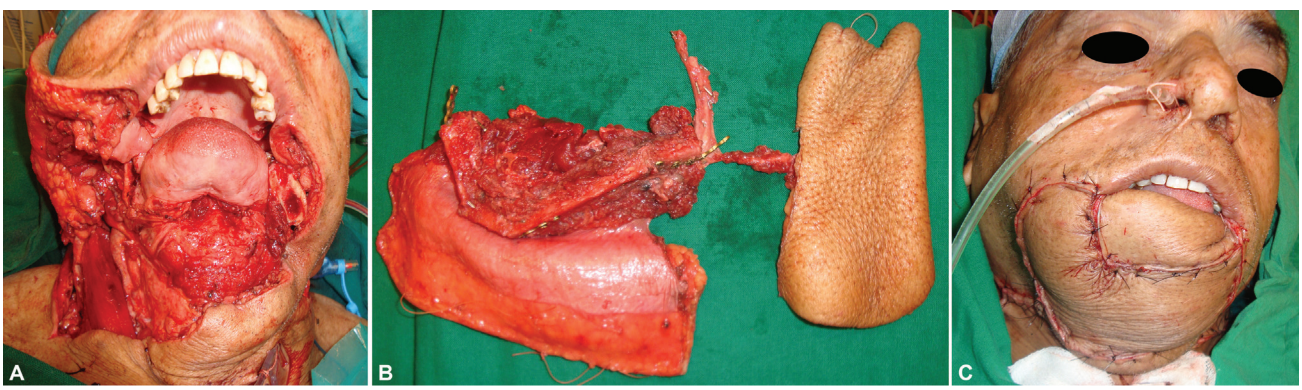

Fig. 3 Closure of external defect with division of the skin paddle for double-skin paddle fibula osteocutaneous free flap (div-FOCFF). (A) Defect after oncologic resection; (B) FOCFF after division of skin paddle; (C) Immediate postoperative photo.

version). Certainly, adding vascularized muscle to the reconstruction has been shown to increase perfusion of surrounding tissues and the bone flap, possibly decreasing the incidence of osteonecrosis or osteomyelitis when radiation is needed.[31,32] Alternatively, if adding vascularized muscle is desired but another set of anastomoses is not anticipated, a free fibula osteomyocutaneous flap with the flexor hallucis longus muscle can provide a reliable alternative for this purpose.[31] Finally, if the three-dimensional configuration of the wound has soft tissue components with different axes and the length of the perforators is not appropriate, a single paddle FOCFF with a simultaneous second free flap may provide better outcomes and should be given full consideration (►Fig. 4).

Limitations

Despite being the largest study in current literature on reconstruction of composite through-and-through oromandibular defects, the strict inclusion criteria may have led to statistically insignificant results for some associations. The retrospective nature of this investigation has an inherent risk of bias; in certain cases, surgeons may have their own preference of flap configuration instead of choosing a reconstructive approach that is most suitable for the patients (►Fig. 5). The methodological design implemented in this study can affect the quality of the results reported and constrain the use of some variables for analysis (e.g., number of osteotomies, cosmetic results, patient-reported outcomes).

Fig. 4 Closure of external defect with second free flap. (**A**) Defect after oncologic resection; (**B**) ex vivo fixation of fibula osteocutaneous free flap (FOCFF); (**C**) anterolateral thigh flap for external coverage; (**D**) inset of both free flaps; (**E**) late postoperative period.

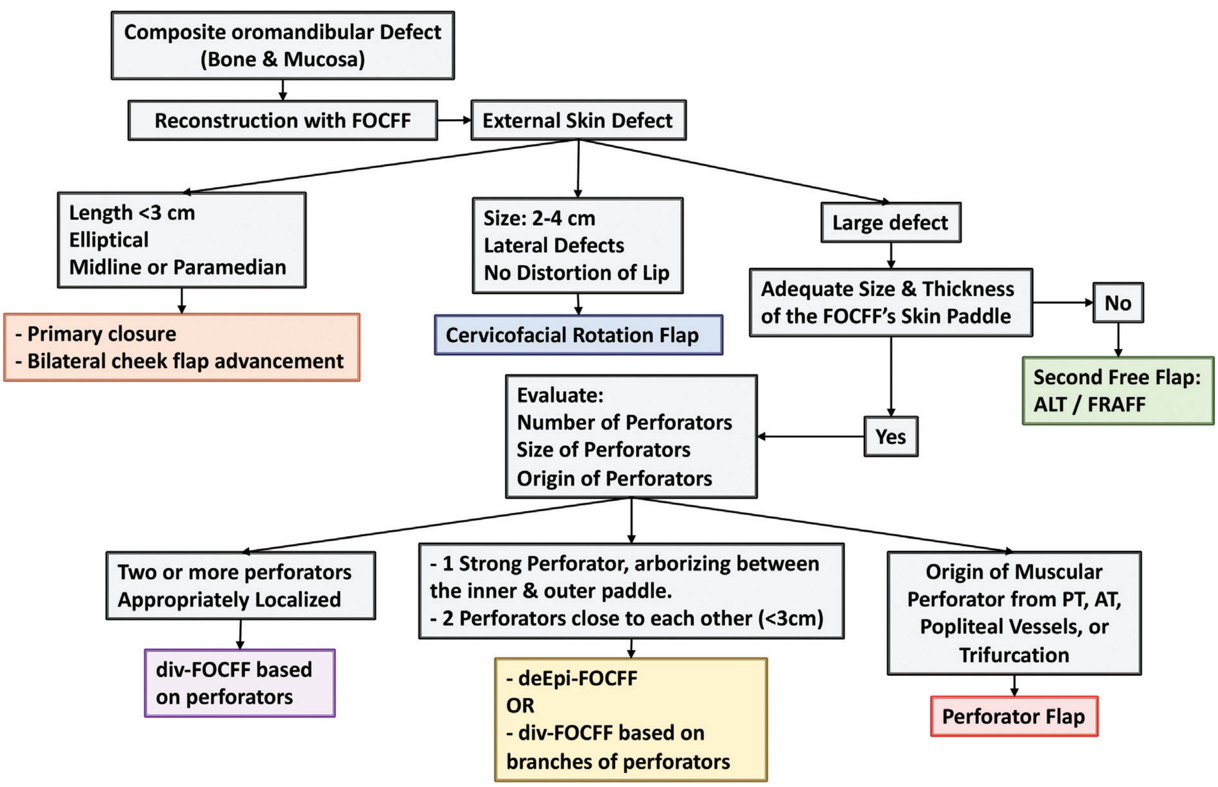

Fig. 5 Algorithm for reconstruction of composite through-and-through oromandibular defects.

Conclusion

The double-skin paddle FOCFF is a versatile and reliable option for composite through-and-through oromandibular defects. In comparison to reconstruction with a simultaneous second free flap, the double-skin paddle FOCFF decreases the rate of reexploration and surgical time. When choosing the reconstructive technique, it is always necessary to individualize according to the type and size of defects, the patient characteristics, the surgeon's personal experience, and most importantly, the intraoperative finding of the vascular organization of the FOCFF and number of perforators perfusing the skin paddle.

Thesis

The present article is not part of a thesis for a degree such as a Master's or PhD degree.

Presentation

This article has not been presented in a national or international meeting.

Authors' Contributions

(1) Conceptualization: All authors; (2) Data curation: all authors; (3) Formal analysis: all authors; (4) Funding acquisition: S.M.; (5) Investigation: all authors; (6) Methodology: all authors; (7) Project administration: all authors; (8) Resources: all authors; (9) Software: all authors; (10) Supervision: S.M.; (11) Validation: all authors; (12) Visualization: all authors; (13) Writing – original draft: all authors; (14) Writing – review and editing: all authors.

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Conflict of Interest

None declared.

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