

Anatomical Basis and Clinical Application of the Ulnar Forearm Free Flap for Head and Neck Reconstruction

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Objectives/Hypothesis: This study was designed to investigate the anatomical features and applications of the ulnar forearm flap in head and neck reconstructive surgery.

Study Design: A prospective study was designed to include 50 ulnar forearm free flap transplants in 50 patients. Patient defects requiring reconstructive surgery involved the buccal mucosa, tongue, floor of the mouth, upper or lower gums, lips, soft palate, and scalp. Twenty ulnar forearm flaps were analyzed along the entire ulnar artery to determine the anatomy and distribution of the ulnar artery septocutaneous perforators.

Results: All 50 flaps were successfully transplanted into their respective sites. The mean diameters of the ulnar artery and vein were 2.3 ± 0.6 mm and 1.7 ± 0.6 mm, respectively. Arterial and venous size mismatch was experienced in 12 and 33 flaps, respectively. The mean number of sizable perforators was 4.3 ± 1.2 , and most of the first perforators were located within 5 cm of the proximal wrist crease. None of the patients experienced long-term complications concerning the ulnar nerve.

Conclusions: The ulnar forearm flap is a reliably consistent source of free flap transfer because it harbors constant septocutaneous perforators and produces minimal donor site morbidities for head and neck reconstructive surgery.

Key Words: Ulnar forearm flap, radial forearm flap, head and neck reconstruction, anatomical study.

Level of Evidence: 4.

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INTRODUCTION

Since its introduction in 1982,¹ the radial forearm free flap (RFFF) has been the gold standard for head and neck reconstructive surgeries. The advantages of the RFFF have been previously described, and much of its use stems from its thin and pliable nature, making it ideal for reconstructing defects in enclosed locations.^{2–3}

The counterpart of RFFF, the ulnar forearm free flap (UFFF), is seldom used as a donor tissue because of the long-held belief that the ulnar artery is crucial for hand circulation. Introduced 2 years after RFFF,⁴ UFFF transfer had been dismissed by many physicians due to concerns that the dissection of the ulnar nerve would be required and that the sacrifice of the ulnar artery might compromise the blood flow to the hand.^{5–6}

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In 2003, Haerle et al. conducted a detailed review of the forearm and hand blood supply from the brachial artery to the fingertips. Using color Doppler sonography and plethysmography, they showed that the ulnar artery was the dominant artery immediately after the bifurcation of the brachial artery, but soon ceased to be the dominant artery after giving rise to multiple branches distal to the bifurcation, notably the common interosseous artery.⁷ Of interest, these results suggested that each artery appeared to selectively nourish different parts of the upper limb. From this study, the ulnar artery was shown to provide more blood supply to the proximal forearm, and supplied a minor amount of blood to the hand after branching off into the common interosseous artery. In contrast, the radial artery was found to carry the main vascular load to the distal forearm and hand.

Given the findings of Haerle et al., the long-held beliefs regarding the safety of the UFFF appear to be unfounded, and the clinical application of the UFFF has since resumed. Despite being more popular, one of the major drawbacks of the RFFF is the conspicuous donor scar, which is often a subject of complaint among RFFF transplant patients.^{8–9}

With a donor site located on the medial aspect of the forearm, the UFFF offers a more concealable donor site. This study was designed to investigate the anatomy of the septocutaneous perforators of the ulnar forearm flap, and its clinical applications in head and neck reconstructive surgery.

MATERIALS AND METHODS

From September 2008 to December 2009, a total of 50 ulnar forearm free flap transfer were performed in 50 patients for head and neck defect reconstructive surgery. Of the 50 subjects, 45 were male and 5 were female, with an average age of 49.6 ± 12 years (range, 28–86 years). The different indications for reconstructive surgery and the anatomical locations of defects are listed in Table I. Forty-nine patients underwent ablation surgery for head and neck cancer treatment. One patient needed reconstruction of a scalp defect following repeated craniotomies and radiotherapy for glioblastoma multiforme, which had resulted in osteoradionecrosis of the central scalp and skull bone. The flap size, pedicle length, pedicle diameter, re-exploration rate, and complications were recorded for each transfer. The number of all sizable septocutaneous perforators and their locations relative to the proximal wrist crease were intraoperatively recorded, in which there was a longer pedicle length required for reaching the recipient site (20 patients).

Surgical Technique

A preoperative Allen's test was conducted in the nondominant forearm. Either radial or ulnar arterial dominance was confirmed, based on the rate of return of color to the limb upon occlusion and release of the respective artery. All patients with radial arterial dominance were selected for ulnar forearm free flap harvest.

Preoperatively, the flexor carpi ulnaris (FCU) tendon was marked on the forearm. The ulnar neurovascular bundle is usually located immediately on the radial side or beneath the FCU. A Doppler pencil was used to map the septocutaneous perforators to ensure at least one perforator was included in the flap.

After the dimensions of the flap were determined, a tourniquet was applied, and an incision was made from the radial side of the flap. The dissection continued in the suprafascial plane until the ulnar aspect of the flexor digitorum superficialis (FDS) tendon was reached. At this point, the superficial fascia was incised, and the dissection was continued in the subfascial plane to expose the neurovascular pedicle underneath the FCU tendon (Fig. 1A). After the initial incisions, multiple septocutaneous perforators were identified arising from the ulnar artery to the overlying skin (Fig 1B). Next, a proximal forearm incision was made, and the FCU and the FDS muscles were separated to expose the vascular pedicle for retrograde dissection (Fig. 1C). Following division of the distal end of the ulnar artery and its associated venous component, the pedicle was dissected from the neighboring ulnar nerve along its length. Then, the incision was completed on the ulnar side of the flap on a suprafascial plane, and the skin flap was removed (Fig. 1D). The tourniquet was released for 15 minutes to ensure adequate perfusion of the hand and the flap before dividing the vascular pedicle.

RESULTS

The patients were followed for a mean period of 12.6 ± 4.6 months (range, 6–21 months). All of the flaps survived, yielding a success rate of 100%. Figures 2 and 3 illustrate examples of buccal mucosa and tongue reconstructive surgeries using ulnar forearm free flaps. Six patients required a re-exploration surgery postoperatively for various reasons. Four patients had well-perfused flaps that required the removal of hematomas from the neck. One flap required a revision of the venous anastomosis due to a large size difference between the ulnar vein and external jugular vein. The flap transfer of one patient was re-explored for arterial

TABLE I.
The Indications and Recipient Sites of 50 Patients Underwent Free Ulnar Forearm Flaps for Head and Neck Reconstruction.

Diagnosis	Location of Defect	Patient Numbers	Age y/o \pm SD (rang)	BMI mean \pm SD (rang)	Risk Factor						
					Smoking n (%)	Alcohol n (%)	Betel Nut n (%)	HTN n (%)	DM n (%)		
Squamous Cell Carcinoma	Buccal mucosa	19	45.6 \pm 10 (32–70)	27.2 \pm 4.7 (17–37)	16 (84.2)	13 (68.4)	15 (79)	2 (10.5)	1 (5.3)		
	Tongue	8	44.1 \pm 8 (28–50)	23.4 \pm 3.6 (18–29)	7 (87.5)	5 (62.5)	5 (62.5)	—	—		
	Mouth floor	6	53.2 \pm 15 (40–73)	22.3 \pm 4.2 (15–27)	5 (83.3)	4 (66.7)	4 (66.7)	2 (33.3)	1 (16.7)		
	Lower gum	5	48 \pm 10 (37–57)	28 \pm 2.7 (25–30)	3 (60.0)	2 (40.0)	3 (60.0)	2 (40.0)	—		
	Upper gum	2	57 \pm 1.4 (56–58)	29 (29.3)	1 (50.0)	1 (50.0)	1 (50.0)	—	—		
	Retromolar	5	63.4 \pm 20 (46–86)	24.1 \pm 0.8 (24–25)	2 (40.0)	2 (40.0)	1 (20.0)	1 (20.0)	—		
Scalp Necrosis	Lip	3	54.7 \pm 7.2 (50–63)	23.8 \pm 1.7 (23–25)	2 (66.7)	2 (66.7)	1 (33.3)	1 (33.3)	1 (33.3)		
	Soft palate	1	62 (62)	—	—	—	1 (100)	—	—		
Total	Scalp	1	44 (44)	24 (24)	—	—	—	—	—		
		50			36 (72)	29 (58)	31 (62)	8 (16)	3 (6)		

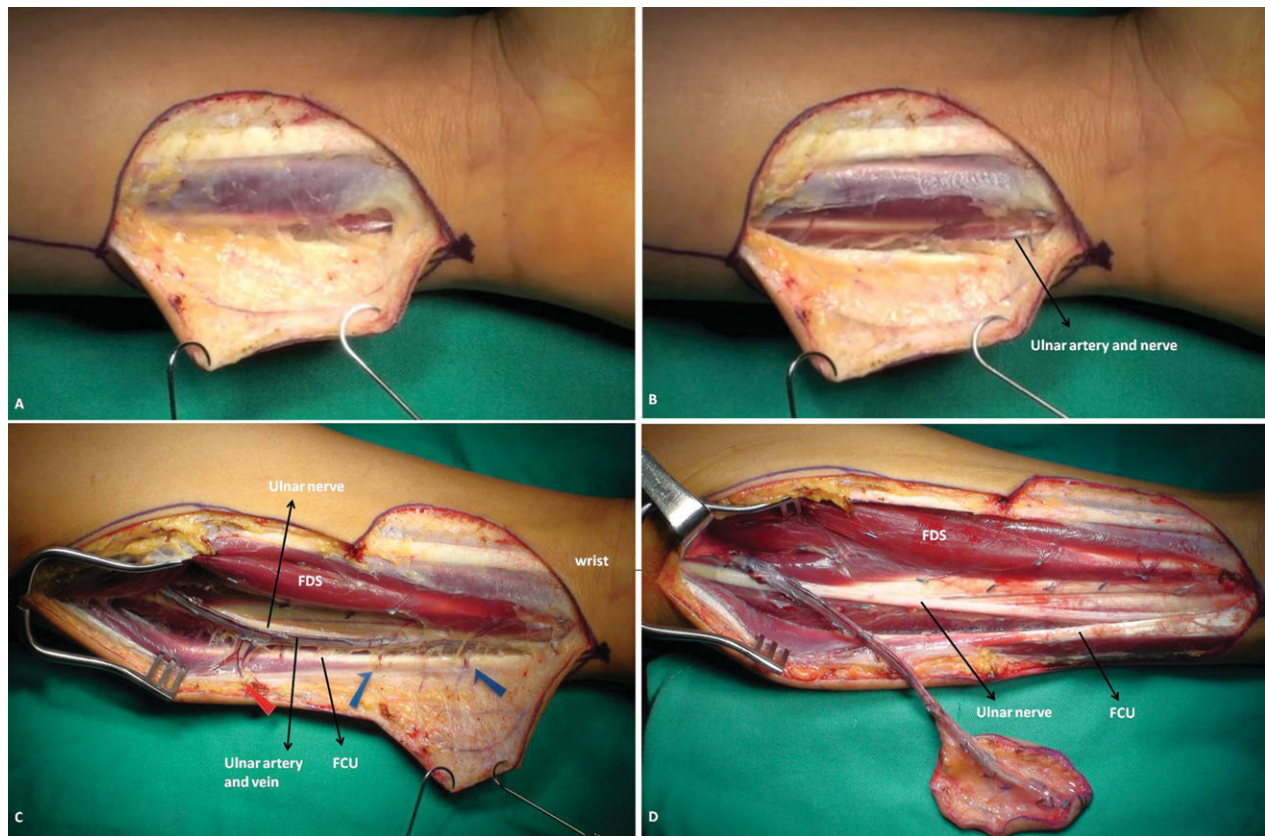


Fig. 1. (A) Demonstration of the surgical technique used in ulnar flap harvesting. The initial incision was made in the suprafascial plane until after the flexor digitorum superficialis (FDS) muscle. (B) A subfascial incision was made at which point the ulnar pedicle and nerve were exposed. (C) The incision was then continued proximally to explore the pedicle, and the ulnar pedicle was dissected from the ulnar nerve. (D) After the ulnar pedicle was separated from the ulnar nerve, the distal end of the pedicle was ligated and ulnar incision was performed to complete the flap harvest.



Fig. 2. (A) A 36-year-old male patient with a stage T1N2bM0 tumor in the right buccal mucosa. After tumor resection, a 3.5×7 cm buccal defect was present over the right buccal area. (B) An ulnar forearm flap was harvested from the nondominant hand of the patient for buccal reconstruction. (C) Twelve months post-reconstructive surgery, (D) The flap showed good resurfacing over the buccal defect, and the patient presented with good facial structure. The general appearance of the donor site was relatively normal over the medial aspect of the forearm (E), and was well concealed when the patient stands in a neutral position (F).

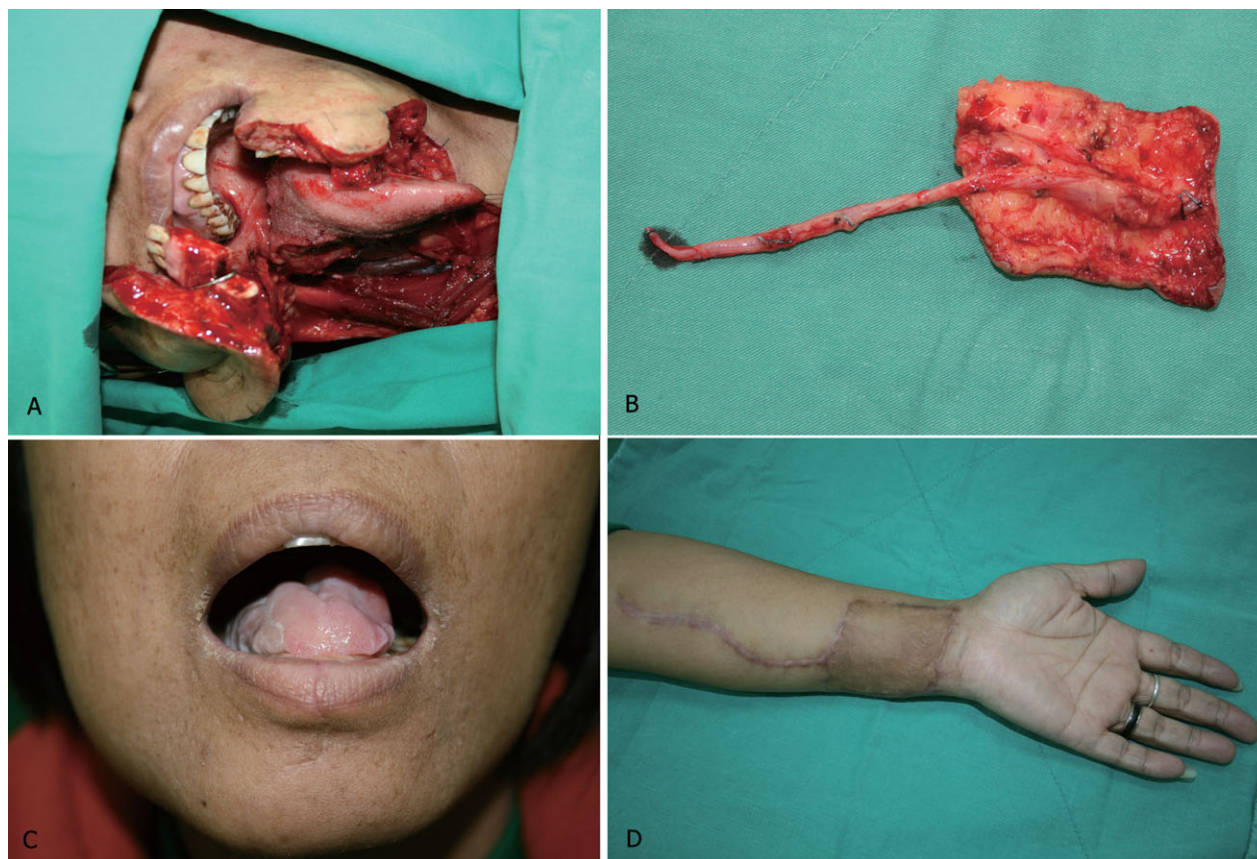


Fig. 3. A 44-year-old female patient was diagnosed with a stage T2N0M0 tumor on the right side of the tongue. (A) After tumor resection, there was a defect present in the right third of the tongue. (B) An ulnar forearm free flap was harvested from the left arm of the patient. (C) After reconstructive surgery, the patient presented with a satisfactory lingual appearance and function (D) and an acceptable donor site scar over the medial forearm.

insufficiency due to compression by scar tissue through the narrow subcutaneous tunnel. An incision was made to release the pressure from the scar tissue, which successfully restored blood flow to the flap.

One flap was harvested along with the palmaris longus tendon, which was used as a sling for suspension of the lower lip. One patient had two separate defects on the buccal mucosa that were reconstructed with a chimeric flap comprised of two skin paddles from a single pedicle. The average flap size was $5.0 \pm 1.1 \times 7.8 \pm 1.9$ cm (range, 3.5×7.0 cm to 7.0×13.0 cm). The mean pedicle length was 10.1 ± 2.0 cm (range, 6–15 cm). The ulnar artery and one concomitant vein were used as the donor vessels. For the recipient vessels, the ipsilateral superior thyroid artery was most commonly used ($n = 41$), followed by the ipsilateral facial artery ($n = 2$), the ipsilateral superficial temporal artery ($n = 6$), and the contralateral superior thyroid artery ($n = 1$). Branches from the internal jugular vein were selected as the recipient vein in 39 flap transfers. The facial vein was selected as the recipient vein in one flap transfer, and the superficial temporal vein was selected in the six flap transfers. Of the remaining flap transfers, two were anastomosed to the external jugular vein, one flap transfer used a stump of the internal jugular vein via an end-to-end venous anastomosis, due to the lack of branches

from the internal jugular vein after neck dissection; and one flap transfer was anastomosed to the internal jugular vein in an end-to-side fashion. The average ischemic time was 94.6 ± 45.4 min (range, 46–240 min).

In the patient who underwent scalp reconstructive surgery, a vein graft from the cephalic vein was used for vascular anastomosis because the closest superficial temporal vessels were damaged due to the repeated craniectomies.

Topographical Study

The mean diameters of the ulnar artery and concomitant vein were 2.3 ± 0.6 mm (range, 1–4 mm), and 1.7 ± 0.6 mm (range, 1–4 mm), respectively. Overall, arterial size mismatch was experienced in 12 flaps (24.0 %) with a mean recipient arterial diameter of 1.30 ± 0.7 mm (range, 1–3 mm). Size discrepancies for venous anastomoses were encountered in 33 flaps (66.0 %) with a mean recipient vein of 1.5 ± 1.1 mm in diameter (range, 1–5 mm), excluding the end-to-side anastomosis (Table II).

For the anatomical study, the entire length of 20 ulnar forearm flaps was explored. Sizable septocutaneous perforators were defined as having a diameter greater than 0.5 mm in size. Figure 4 demonstrates a

TABLE II.
 Sizes of the Donor and Recipient Vessels in 50 Patients Who Underwent Free Ulnar Forearm Flaps for Head and Neck Reconstruction.

	Diameter (mm)	
	Average	Range
Flap (Donor)		
Artery	2.3 ± 0.6	1–4
Vein	1.7 ± 0.6	1–4
Recipient		
Artery	1.3 ± 0.7	1–3
Vein	1.5 ± 1.1	1–5

septocutaneous perforator exploration. At least three sizable perforators could be identified in each forearm. A total of 85 sizable septocutaneous perforators from the ulnar pedicles were identified in the 20 forearms. The number of sizable perforators ranged from three to seven in each patient, with a mean of 4.3 ± 1.2 sizable perforators (range, 3–7).

The distances between the perforator and the proximal wrist crease were recorded in 20 patients (Fig. 5). The locations where the perforators were identified were divided into four distinct areas according to the distance from the proximal wrist crease: area I, 0–5 cm; area II, 5–10 cm; area III, 10–15 cm; and area IV, 15–20 cm. Based on our previous experience, a pedicle length of at least 5 cm was considered safe to transfer a free flap to the buccal mucosa using the facial artery and vein as recipient vessels.³ The distribution of the perforators was variable and ranged from 1–20 cm away from the proximal palmar crease. Among the 85 total perforators, 35 were located in area I, 23 were in area II, 20 were in area III, and 9 were in area IV. The first septocutaneous perforator in all but one flap transfer was located within

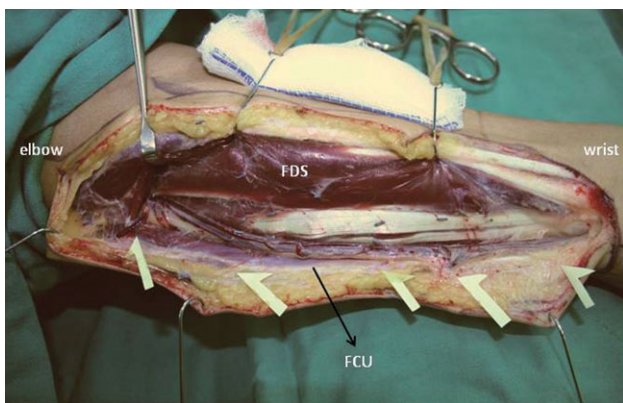


Fig. 4. Depicted is the FDS muscle, which has been retracted laterally using a hook to explore the ulnar pedicle and nerve located between the FDS muscle and the FCU tendon. Also depicted is an intraoperative view showing multiple septocutaneous perforators (yellow arrow) attached to the skin from the distal forearm proximal to the wrist to the proximal forearm near the elbow, which were consistent and compatible with the preoperative Doppler mappings.

5 cm of the proximal wrist crease (Fig. 5). A 5-cm distance was considered as a section for the measurement of pedicle, which is easy to understand and remember. Perforators were identified in two or more different regions in every patient examined. The distance between the first and last perforator ranged from 3 to 16.5 cm (mean, 10.9 cm).

Donor Site Morbidity

One of the 50 donor sites was primarily closed, whereas the other 49 donor sites required a skin graft for resurfacing. One patient presented with severe liver cirrhosis and hypoalbuminemia, and experienced total graft loss and accompanying poor intraoral wound healing. Another patient had partial graft loss due to poor compliance regarding immobilization. Both patients were treated with dressings until their wounds healed satisfactorily via secondary intention.

The patients were followed for a minimum period of 6 months. None of the patients suffered from cold intolerance in the hand. Two patients complained of transient numbness over the ulnar nerve distribution (ring and little fingers) postoperatively, which subsided after 1 month. Another patient complained of weakness while making a fist, but the symptoms subsided spontaneously within 3 months. All these patients subsequently underwent nerve conduction and electromyography studies of their ulnar nerve function revealing completely normal results at 6 months. All patients expressed satisfaction with the cosmetic appearance of their donor site.

DISCUSSION

Refinements in reconstructive microsurgery have shifted the expectations of patients and surgeons alike in terms of the desired outcome. One of the increasingly important aspects is the postsurgical donor site morbidity and appearance. The radial forearm flap is considerably preferred over the ulnar forearm flap based on clinical experiences, popularity, and related publications. Although its usefulness remains unchallenged, the radial forearm flap has associated with it hair follicles. Furthermore, the donor site remains difficult to conceal when the forearm is in the resting position at midsupination.

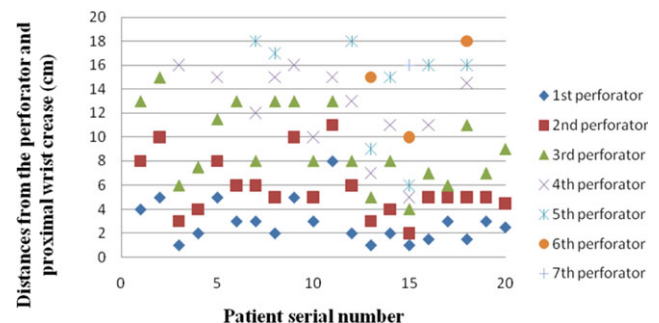


Fig. 5. Topographical study of the number of septocutaneous perforators and their distribution on 20 ulnar forearm flaps. The measurements began from the transverse wrist crease.

Since its introduction, the ulnar forearm flap has been used in tongue, oromandibular, extremity, and penile reconstructive surgeries.^{10–14} Rodriguez et al. prospectively studied hand function following ulnar forearm flap-harvesting, and reported comparable results between the hands with and without operation in terms of two-point discrimination, grip strength, and digital perfusion, despite a mean increase in the radial blood flow of 17.5% following ulnar artery sacrifice.¹⁵ From this report, the authors concluded that the ulnar forearm flap represented a safe donor site without the risk of additional morbidity when compared with the radial forearm flap. Furthermore, the authors suggested the superiority of the ulnar forearm flap in terms of postsurgical cosmetics.¹⁵ None of the patients included in the Rodriguez et al. study complained of cold intolerance or showed any signs of ischemia.

Another concern regarding the use of UFFF relates to the discomfort in dissecting a pedicle from a major nerve. The two patients included in our study who reported transient sensory or motor weakness most likely encountered neuropraxia upon dissection of the pedicle. In our study, we frequently observed small branches from the pedicle that nourished the ulnar nerve. These were vasomotor branches that could be divided without causing any neurological deficit. Separating the vessels from the nerve should be a relatively straightforward procedure when performed by an experienced surgeon.

The ulnar forearm was often less hirsute than the radial forearm. Thus, the ulnar forearm presents as a good donor site for head and neck reconstructive surgery as it avoids the presence of hair in the oral cavity or cheek after reconstruction. Most of the patients in our study required a skin graft to close the donor site. During dissection, a suprafascial dissection technique ensures the preservation of the paratenon and better skin graft success rate following the flap harvest. After flap dissection, the ulnar nerve should be occluded underneath the FCU tendon. This is often accomplished with two or three sutures using absorbable suture material to close the space between the FCU and FDS tendons. We also routinely run a continuous suture between the skin and the fascia to reduce the amount of area requiring skin graft, and to obtain a smoother transition from the skin to the base of the wound, thus preventing a ‘punched-out’ appearance. In our experience, the final aesthetic results of the donor sites have been more satisfactory, allowing better concealment of the scar during daily activities, such as eating, sitting, and shaking hands (Figure 2E, 2F, 3D).

In our topographical study of 20 patients, we have found a relatively constant anatomy of the location of sizeable perforators. Based on our experience, these perforators are also larger than perforators from the radial artery, and are sufficiently sizable to perfuse a single flap on its own.¹⁶ Therefore, the dissection of the ulnar flap is more straightforward and less time-consuming than the dissection of a radial forearm flap. Separation of the main pedicle from the skin paddle is a safe procedure, provided that at least one sizable perforator

remains attached. Because of the anatomical features, the ulnar forearm flap can be designed and transplanted similar to a true perforator flap. Axial flaps, like free radial forearm flap, have been transferred along with the attached vascular pedicle to prevent damage to the blood supply. The segmental-attached vascular pedicle limits the flap positioning when compared with a perforator flap. The ulnar forearm flap has the advantages of a perforator flap and provides better versatility in three-dimensional reconstructive surgery. The presence of multiple, distant, sizable perforators also allows a more versatile flap design, like chimeric flaps allowing the simultaneous reconstruction of two adjacent defects with the same vascular pedicle. The ulnar forearm flap can also be designed as two independent, small flaps with their own respective vascular pedicles for the reconstruction of separate defects.

Our study also revealed a consistent localization and size of the perforators associated with the ulnar forearm flap, which allows predictability as far as locating the perforators. However, the use of a preoperative Doppler is still recommended, especially when a chimeric flap or more than one flap will be designed and harvested from a single donor site. The Doppler can also be used to facilitate a more versatile flap design and to accommodate different reconstructive needs.

There are a few disadvantages of using the ulnar forearm flap. The pedicle length of the ulnar forearm flap has been reported to be 1–2 cm shorter than that of the radial forearm flap;¹² however, this did not cause any major problems in reaching the recipient vessels in our study. In addition, there were a high percentage of patients who presented with size discrepancies during venous anastomoses with frequent small-caliber veins (approximately 66%). These small-caliber veins may render venous anastomosis more technically demanding. However, as demonstrated, the size discrepancy between the ulnar veins and the recipient veins did not increase the incidence of re-exploration for venous problems.

CONCLUSION

The ulnar forearm flap is a reliable and pliable flap with constant septocutaneous perforators with minimal donor site morbidity. The size and location of the perforators allow a more versatile flap design, as well as double flaps harvesting from the same donor site for the simultaneous reconstruction of two defects. One disadvantage of using the ulnar forearm flap is the discrepancy in the size of venous pedicle.

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