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ORIGINAL ARTICLE
Reconstructive

Osteocutaneous Radial Forearm Flap: Harvest Technique and Prophylactic Volar Locked Plating

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Background: The osteocutaneous radial forearm (OCRF) flap is a variation of the traditional radial forearm flap with incorporation of an anterolateral segment of corticocancellous bone of the radius, periosteum, and overlying skin. The OCRF flap is indicated in traumatic injuries or extirpation defects with segmental bone loss and is well suited to foot and ankle reconstruction due to its thin pliable skin.
Methods: In this single-center case series, a retrospective review was conducted to identify patients who underwent OCRF free flap for foot and ankle reconstruction that required harvest of more than 50% of the cross-sectional area of the radius with prophylactic volar locked plating of the donor site. Outcome measures included flap failure rates, postoperative fracture, thrombotic events, time to follow-up, and time to full weightbearing. Flap harvest technique is extensively discussed.
Results: Six cases were included in this series. There were no flap failures or thrombotic events. Recipient site healing was confirmed in all patients, with partial distal skin paddle loss in one patient requiring operative debridement. No patients sustained donor site complications or functional impairment. Full lower extremity weightbearing was achieved at 12.4 ± 3.3 weeks after surgery.
Conclusions: The OCRF free flap transfer provides a reliable means of obtaining thin, supple soft tissue coverage with a large, vascularized segment of bone for reconstruction in the foot and ankle. Here, we describe use of more than 50% of the cross-sectional area of the radius with volar locked prophylactic plating. These updates expand use of this reconstructive technique. *(Plast Reconstr Surg Glob Open 2023; 11:e5449; doi: 10.1097/GOX.0000000000005449; Published online 27 November 2023.)*

INTRODUCTION

The osteocutaneous radial forearm (OCRF) flap is a variation of the traditional radial forearm flap with incorporation of an anterolateral segment of corticocancellous bone of the radius, including the periosteum and overlying skin.[1] The flap can be harvested with the addition of a tendon graft (palmaris longus) as well as incorporation of branches of the lateral antebrachial cutaneous (LABC) nerve for tendon reconstruction or neurotization to allow for a sensate reconstruction. The bony portion of the flap is supplied by deep perforating vessels of the radial artery. The OCRF flap has a theoretical maximum harvest length of 10 cm of bone, with width and depth determined by the donor radius dimensions but typically approximately 1 cm deep × 1 cm wide. The associated skin paddle may be sized dependent on reconstructive needs, with small skin paddles allowing for primary closure of the donor site and large paddle dimensions limited only by the dimensions of the donor arm. The majority of periosteal and fasciocutaneous perforators are located at the distal portion of the flap, allowing for harvest with a long vascular pedicle. Prophylactic plating of the donor site is indicated for early unrestricted weightbearing and defects beyond 40% of the donor radius cross-sectional area.[2]

Indications for the OCRF flap include traumatic injuries or extirpation defects with segmental bone loss. Vascular bone flaps are typically recommended for defect size of more than 6 cm.[3–5] The flap can also be used for any cortical bone construct due to bone loss from osteomyelitis, nonunion, or trauma.[6,7] Specific applications

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Related Digital Media are available in the full-text version of the article on wwwPRSGlobalOpencom include head and neck reconstruction for segmental loss of the mandible; upper extremity reconstruction of the hand and thumb; and more frequently, for foot and ankle reconstruction.[8–11] The purpose of this retrospective case series is to describe harvest technique and assess donor site morbidity in patients after OCRF harvest for foot and ankle reconstruction. The authors aimed to establish that harvest of more than 50% of the cross-sectional area of the radius can be safely performed when coupled with volar locked, prophylactic plating.

Takeaways

Question: How can we expand upon traditional radial forearm flaps, especially for large defects requiring vascularized bone.

Findings: No flap failure was seen in any of the six osteocutaneous radial forearm free flaps in this study where more than 50% of the radius was harvested and an anatomic volar locked plate was placed prophylactically. All but one patient achieved full range of motion of the donor limb. Donor site bone healing was confirmed in all patients, and full weightbearing was achieved within 12 weeks.

Meaning: These updates to the osteocutaneous radial forearm free flap allow for expanded use of this technique in the foot and ankle.

MATERIALS AND METHODS

In this single-center case series, a retrospective review of patients who underwent OCRF free flap harvest with more than 50% the cross-sectional area of the radius and prophylactic volar locked plating for foot and ankle reconstruction from January 2015 to January 2023 was performed, identifying six cases. The following variables were then recorded: patient demographics (age, sex, and race), mechanism, laterality and size of defect, cross-sectional bone harvest percentage, postoperative complications (defined as flap failures, postoperative fractures, donor site morbidities, and thrombotic events), time to postoperative follow-up, and time to full lower extremity weightbearing. IRB approval was granted by Carilion Clinic IRB (IRB-23-1897).

Technique

Standard plastic surgery and microsurgical instruments are used. Bone harvest requires the use of a sagittal saw and osteotomes and is aided by a powered wire driver for templating the bony cuts. Prophylactic plating requires an anatomic curved distal radius plate and combination of locking and nonlocking screws, as well as intraoperative fluoroscopy for bone harvest and plate positioning.

A preoperative Allen's test is performed to assess adequacy of superficial palmar arch perfusion of all digits of the donor limb via the ulnar artery. This may be confirmed with occlusion of the radial artery and Doppler assessment of the digital artery to the thumb. The patient is positioned to allow access to the recipient flap site, and the donor arm is placed in an abducted and externally rotated position. Selection of the donor arm is dependent on the defect to be reconstructed; however the septum between bone and skin allows for significant flexibility. Patient hand dominance is a consideration as well, with preference for the nondominant extremity. For foot and ankle reconstruction, the use of the contralateral arm is often preferred for ease of access with multiple surgical teams. The inclusion of additional skin paddle length proximally overlying the flap pedicle may improve ability of close lower extremity wounds without tension overlying the pedicle (Fig. 1). A nonsterile tourniquet is placed high on the upper arm, and the arm is prepared to the mid-humerus. The recipient site is prepared to the surgeon's preference; for foot and ankle reconstruction, the use of a sterile tourniquet on the thigh may improve visualization during recipient site preparation and recipient vessel dissection.

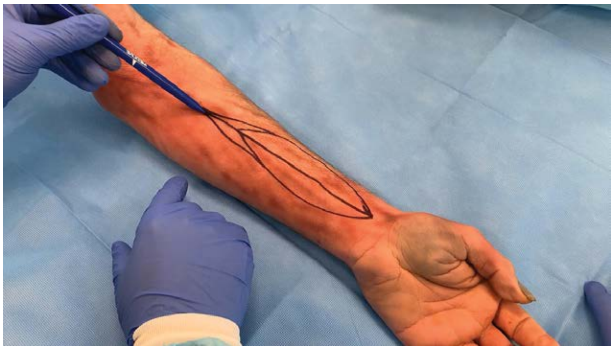

Fig. 1. A photographic illustration of sample flap design for OCRF harvest.

Operative Steps

After drawing the planned skin paddle dimensions based on the donor defect, the upper extremity is exsanguinated, and tourniquet control is used during dissection. We prefer to begin dissection on the ulnar side of the flap, using primarily a scalpel for dissection with bipolar cautery to control exposed vessels. (**See Video 1 [online],** which shows OCRF flap harvest planning steps and initial flap elevation in a cadaveric model, as well as introduction to a patient example.) The dissection proceeds in the suprafascial plane to the lateral edge of the flexor carpi radialis muscle and tendon, at which point the fascia is incised over the flexor carpi radialis, allowing for ulnar retraction of the tendon. This preserves the anterolateral intramuscular septum containing the perforating vessels off the radial artery. The muscle bellies of the flexor pollicis longus and pronator quadratus are divided longitudinally over the midportion of the radius and elevated to expose the periosteum of the radius. The dissection may be modified to a deep plane if inclusion of the palmaris longus tendon is needed within the flap; alternatively, the palmaris longus may be harvested simultaneously as a free tendon graft for reconstruction.

Attention is then turned to the radial side of the flap. The flap is elevated in a suprafascial plane to the brachioradialis, at which point the fascia is incised longitudinally and dissection carried subfascial to the radius. Pronation of the forearm and radial retraction of the brachioradialis serve to both protect the superficial branch of the radial sensory nerve and improve exposure to the dorsal side of the distal radius. The dissection is more radial and dorsal than the typical radial forearm flap harvest. The brachioradialis may be partially elevated off the distal radius, if needed, for additional exposure. Once dissection of the radial and ulnar portions of the flap is complete, distal dissection is completed with exposure of the radial artery and venae commitants and control with vessel clips before transection). (**See Video 2 [online],** which shows continuation of flap elevation steps in a cadaveric model.) The cephalic vein may be included on the distal radial side if anatomy and flap design allow. The LABC nerve is identified proximally, lying approximately 5 mm ulnar to the cephalic vein in the suprafascial adipose tissue. The LABC nerve and cephalic vein may also be easily harvested through this exposure, if needed, for vein graft or nerve graft during reconstruction.

During dissection of the pedicle, pronation of the forearm and lateral retraction of the brachioradialis muscle allows for dissection of the fascia off the deep surface of the muscle and protection of the fasciocutaneous perforating vessels. Dissection may be carried to the level of the bifurcation of the brachial artery, approximately 1 cm distal to the antecubital crease. The venae commitantes are of sufficient caliber at this level to allow for primary venous outflow from the flap; alternatively, the cephalic vein may be preserved and used as described previously. Ligation and division of the pedicle is reserved until the bone harvest is completed to allow for assessment of cancellous perfusion.

Once the soft tissue dissection is complete, the dimensions for distal radius harvest are plotted. (**See Video 3 [online],** which shows final steps of OCRF flap elevation, including osteotomy and prophylactic volar plating technique using both a cadaveric and a Sawbones model, as well as patient example wrap-up.) Angled cuts are planned proximally and distally to prevent formation of a stress riser (Fig. 2). Kirschner wires are placed at the proximal and distal extents of the planned harvest, and location and dimensions are confirmed with fluoroscopy.

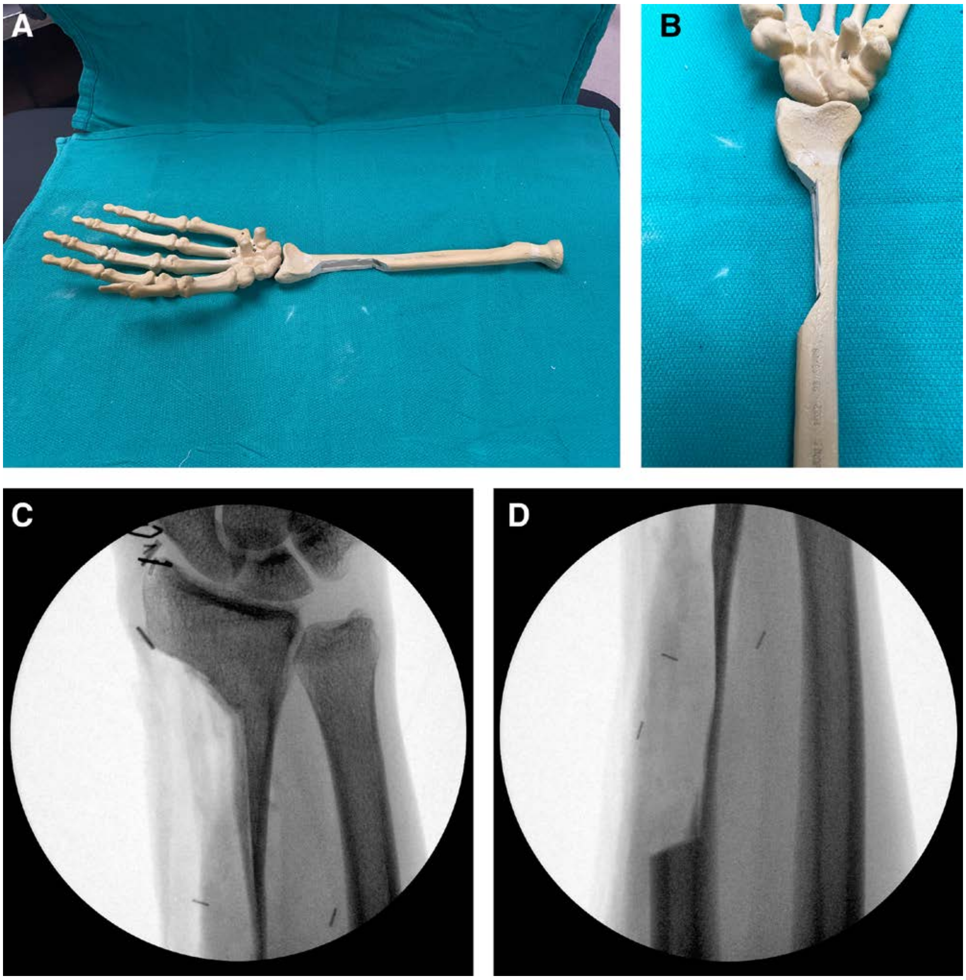

Fig. 2. Sawbones model and fluorographic images showing appropriately angled cuts for bone harvest on a distal radius. A, Lateral view. B, AP view. C, Fluorographic distal view. D, Fluorographic proximal view.

The proximal and distal cuts are made first, with the longitudinal cortical cuts made either as a plunge cut from the volar or dorsal aspect of the forearm or as separate volar and dorsal corticotomies with the osteotomies completed with the use of small osteotomes. The flap is then elevated from the arm, and tourniquet released to confirm perfusion of both the skin paddle and cancellous bone. The radial artery and venae commitantes are then controlled proximally, and the pedicle is transected to complete flap harvest.

Donor Site Prophylactic Plating

An anatomically precontoured long diaphyseal-metaphyseal distal radius plate is selected (Fig. 3), with length determined by the osseous defect. In this case series, a DePuy Synthes VA distal radius plate was used. Plate length should allow placement of a minimum of four nonlocking 2.7-mm bicortical screws proximally. Additional proximal exposure of the radius may be needed. For exposure of the radial shaft, the forearm can be pronated, and the pronator teres insertion is elevated from the dorsal aspect of the radius. Remember to "pronate to release the pronator" from is most dorsal insertion. The pronator teres may be partially released without repair. If extensile proximal exposure is needed, the pronator can be released in a Z fashion, leaving a cuff for later repair. Releasing the pronator teres will expose the middle one-third of the radius. Further proximal dissection can be performed by elevating the supinator from the proximal radius. The forearm should be supinated to minimize risk to the posterior interosseous nerve. Remember to "supinate to release the supinator" to release it from its origin. Most vendors' long volar radius plates have a proximal bow to accommodate the bow of the radius. With the above maneuvers, proximal exposure can be performed up to the biceps tuberosity.

Fig. 3. A photograph of the anatomically precontoured long diaphyseal-metaphyseal distal radius plate.

For plate fixation, a nonlocking screw is placed in the oblong hole in the mid-portion to allow fine adjustment to plate position, and the plate is then fixed to the volar forearm. The distal portion of the plate may be provisionally positioned with a Kirschner wire, if needed. The plate should be positioned proximal to the watershed line of the distal radius to limit risk of flexor tendon irritation/ rupture. Plate positioning is confirmed with fluoroscopy; locking screws are placed distally, and nonlocking screws are placed proximally. Final plate placement is verified with fluoroscopy (Fig. 4).

Donor Site Closure and Dressing

The wound is copiously irrigated, and meticulous hemostasis is achieved with bipolar cautery. The flexor pollicis longus and PQ muscle bellies are closed over the plate distally with absorbable suture. The proximal incision should be closed primarily in layers. If the distal donor site is unable to be closed primarily, the site may be covered with a split-thickness unmeshed skin graft, with small perforations made for fluid egress. Alternatively, it is our preference to place a skin substitute over the donor site for planned staged reconstruction with a split-thickness unmeshed graft. There is not an indication for closed suction drain placement.

If a skin graft or skin substitute are placed, a negative pressure dressing, or bolster dressing are placed with planned removal and dressing change on postoperative days 5–7. The arm is covered with sterile gauze, sterile cast padding, and an elastic bandage. A splint for immobilization is usually used to allow for skin graft or skin substitute take but is not required from a bone perspective when prophylactic plating is performed. Light weightbearing of the extremity is allowed immediately postoperatively and no restrictions once the splint is removed after soft tissue healing is sufficient. Platform weightbearing with crutches or a walker is allowed to permit lower extremity non-weightbearing requirements.

RESULTS

Six osteocutaneous radial forearm free flaps successfully reconstructed foot and ankle defects on limbs otherwise unsalvageable by conventional methods (Table 1). Each of the cases involved bone harvest exceeding 50% of the radius. Average cross-sectional harvest area was 67.5% (distal mean 70%, range 66%–81%; proximal mean 65%, range 53%–82%) (Table 2). All cases were prophylactically plated with no fractures, hardware complications, or osteolysis at final follow-up. The mean follow-up period was 9.5 months (range 6–12 months) with a mean patient age of 44.7 years (range 31–61). There was no bone flap failure or thrombotic events. Bone healing was confirmed in

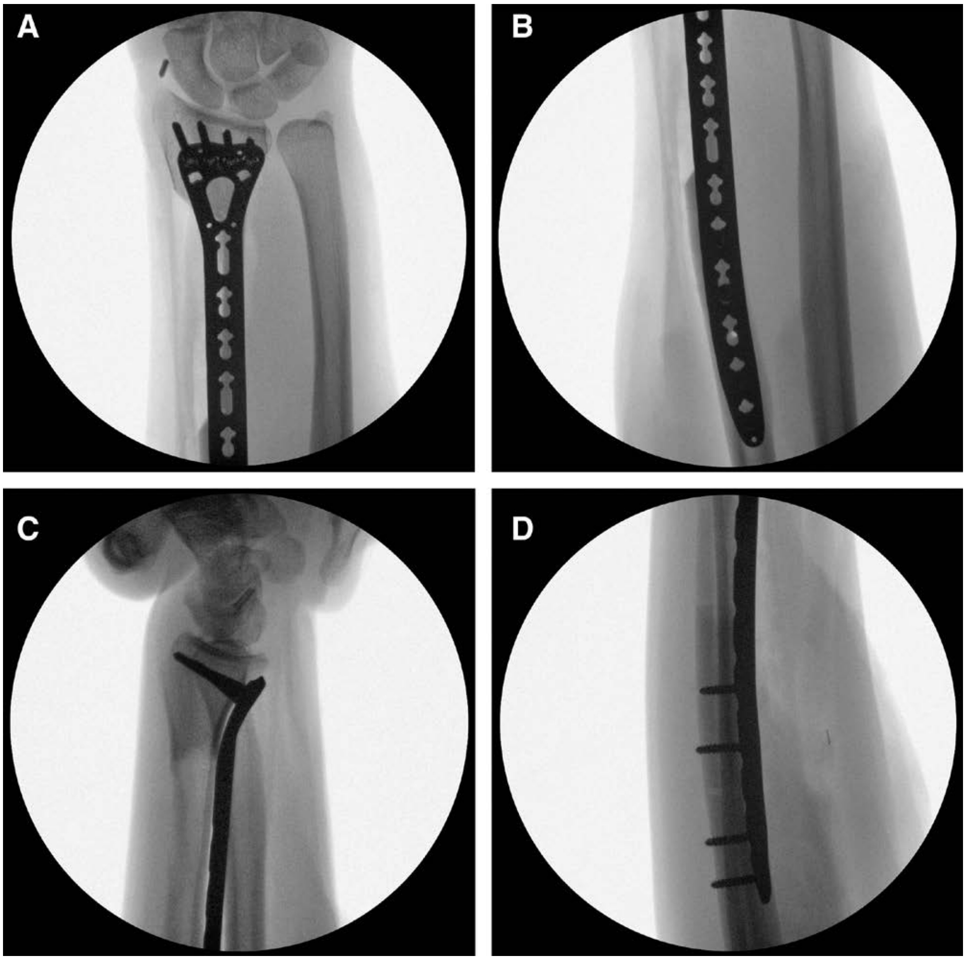

Fig. 4. A fluoroscopic image showing final placement of the volar plate. A, AP distal radius view. B, AP proximal radius view. C, Lateral distal radius view. D, Lateral proximal radius view.

Table 1. Subject Demographics

Subject	Age	Sex	Race	Location of Defect	Indication for Bony Reconstruction	Donor Site
1	57	M	White	L first metatarsal	Osteomyelitis	R UE
2	54	M	White	R second metatarsal	GSW	L UE
3	31	F	White	L bimalleolar fracture	Trauma; open ankle	L UE
4	41	F	Black	R open calcaneus	MVA; pedestrian	L UE
5	37	M	Black	L first metatarsal	GSW	L UE
6	61	M	White	R metatarsal/cuneiform	Osteomyelitis	R UE

GSW, gun shot wound; MVA, motor vehicle accident; UE, upper extremity.

all patients (6), with partial skin paddle loss in one patient requiring operative debridement. Full lower extremity weightbearing was achieved at 12.4±3.3 weeks after surgery. All but one patient achieved full range of motion of the donor limb at the time of final follow-up visit.

DISCUSSION

The osteocutaneous radial forearm flap is a well-established option for head and neck reconstruction. The OCRF flap has a thin, pliable skin paddle, long vascular pedicle, and bony segment, which make it ideal for reconstructing mandibular and maxillary defects. These characteristics also make it an excellent option for dorsal foot and ankle reconstruction, but it is often overlooked due to the limited bone stock available and early studies showing high donor site morbidity (ie, distal radius fractures).[12]. However, modifications to the surgical technique and implementation of prophylactic locked plating of the distal radius has reduced donor site morbidity significantly, with a 2013 study showing one radius fracture (0.5%) out of 218 patients who underwent OCRF flap harvest and equivalent Disabilities of the Arm, Shoulder, and Hand Questionnaire scores between osteocutaneous

Table 2. Surgical Characteristics and Outcomes

Subject	Size of Bony Defect (cm)	Size of Soft Tissue Defect (cm)	Graft Size Proximal	Graft Size Distal	Full Weightbearing (d)	Follow-up (mo)	Elbow Flexion-extension Arc*	Supination-pronation Arc*	Wrist Flexion-extension Arc*	Complications
1	7	10×5	55%	66%	91	12	135	90	120	None
2	5	15×5	70%	69%	71	12	135	90	120	None
3	4	8×5	54%	69%	80	7	135	NR	120	None
4	4	10×4	75%	81%	131	8	135	90	120	None
5	6	15×5	82%	71%	76	6	115	NR	90	Partial flap loss
6	5	15×5	53%	61%	71	12	135	90	120	None
Average	52		65%	69%	867	95	1317	90	110	

*Range of motion at final follow-up visit.
NR, not recorded.

and fasciocutaneous harvest patient groups.[13]. The volar locked plate used in the current study is widely available and offers high quality short segment fixation for the distal metaphyseal segment. The locking plate has greater resistance to axial shear forces than nonlocked plates and allows for immediate finger range of motion and platform weightbearing.[14]. In addition, the current case series suggests that thicker bone segments (>50% circumference of the radius) can be safely harvested with prophylactic locked plating of the radius, and this is not associated with increased donor site morbidity. This finding expands the utility of this technique for both head and neck and foot and ankle reconstruction.

There are other osteocutaneous flaps described for foot and ankle reconstruction, including the superficial circumflex iliac perforator, fibular, and scapular flaps. The superficial circumflex iliac perforator flap can be used for small- to moderate-sized bony defects and has a large potential skin paddle harvest area.[15]. However, dissection of this flap requires microsurgical expertise in perforator dissection, and the vascular pedicle length is short (2–5 cm) when compared with the OCRF flap pedicle (14–22 cm).[16,17] The fibular flap has the advantage of a large bone harvest, but has limited utility in the foot and ankle because of its bulkiness. The scapular flap is useful in that the circumflex scapular artery has a propensity to avoid vascular intimal disease, and should be considered in older patients with a history peripheral vascular disease.[18] However, the scapular flap has the added burden of intraoperative patient reposition after harvest and does not allow for a two-team approach, which adds to total operative time.

The OCRF flap is not without limitations. The main limitation is the cosmetic impact to the upper extremity. Although functional results have been shown to be excellent, both here and in other studies,[13] the cosmetic impact is clinically obvious. Patient expectations must be clearly delineated regarding the cosmesis of the donor site. The authors have found that placement of a dermal substitution matrix and nonmeshed split-thickness skin grafting give the best cosmetic results, but these require staged reconstruction of the donor site and a skin graft donor site from the thigh. An additional limitation of the osteocutaneous radial forearm flap is the inability to disassociate the skin paddle from the bone. Other chimeric flaps allow for separation between the bone and the skin paddle, and may be better suited for complex, irregular defects.[19] The osteocutaneous radial forearm flap requires that the skin paddle be directly overlying the bone, which is useful in reconstruction of foot and ankle defects where the subcutaneous fat is thin. Lastly, the placement of the distal radius plate for stabilization of the bone after harvest of the osteocutaneous radial forearm flap may be unfamiliar to plastic surgeons or head and neck surgeons. Although this is a familiar technique for orthopedic surgeons, the relative lack of familiarity with these plating techniques may be a barrier to adaptation by plastic surgeons and head and neck surgeons. We find that this plating technique is relatively straightforward and is easily learned by plastic surgeons and head and neck surgeons. As an alternative, collaboration with an orthopedic surgeon for placement of the distal radius plate is generally possible, as these techniques are routine to orthopedic surgeons and most institutions have access to orthopedic surgeons familiar with the placement of distal radius plates.

This study demonstrates that the OCRF flap is a safe and reliable option for reconstruction of the foot and ankle. For larger defects, OCRF flaps with more than 50% the circumferential area of the radius can be harvested and demonstrate minimal donor site and functional morbidity. This flap also has low failure rates, rapid bone incorporation, and allows for full weightbearing of the lower extremity at about 3 months. Limitations of this study include the small size, retrospective nature of the review, limited follow-up time, and lack of patient-reported outcomes.

CONCLUSIONS

The osteocutaneous radial forearm flap is an ideal flap for reconstruction of foot and ankle defects. The thin pliable skin of the volar forearm is an ideal match for the foot and ankle region, and the corticocancellous bone of the radius is excellent for stability and amenable to internal fixation. The vascularized bone flap allows for bone incorporation into large defects (>6 cm) and allows weightbearing once fully incorporated. Thick bone flaps (>50% circumference) can be safely harvested with prophylactic plating of the radius.

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DISCLOSURE

The authors have no financial interests to declare in relation to the content of this article.

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