U-Turn Design Metatarsal Artery Flap

Reliable Solution in Distal Forefoot Defect

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Background: In distal forefoot defect, finding wound closure is challenging because of the distal site and small blood vessels involved. One possible resolution is the utilization of a metatarsal artery flap in a 'U-turn' design. This method offers several advantages, including its long length and a viable option for distal forefoot defect.

Methods: Thirty-six patients with forefoot injuries from metatarsophalangeal (MTP) joint to distal interphalangeal (DIP) joint due to trauma were consecutively recruited and completed the study. Outcomes were analyzed descriptively, and risk prediction modeling for edge necrosis was performed.

Results: The mean ± SD follow-up time was 27.3 months ±1.9. The median (IQR) MTP-to-DIP joint wound width and length were 1.8 (1.4, 3.0) and 3.2 cm (2.9, 6.2), respectively. The median (IQR) width, length, and width-to-length ratio flap dimensions were 3.6 (2.8, 6.0), 4.7 cm (4.3, 9.3), and 1.5 (1.2, 1.7), respectively. The mean ± SD operative time was 32.9 min ± 5.7. The median (IQR) intraoperative blood loss was 5.0 mL (4.0, 5.0). The mean ± SD hospital length of stay postoperatively was 4.0 days ±1.0. The mean ± SD Foot and Ankle Outcome Score and Foot Function Index were 64.1 ± 2.5 and 7.8% ± 3.3, respectively. All patients had good or excellent aesthetic satisfaction. Spontaneously resolving edge necrosis occurred in 13.9%. The mean ± SD time-to-start-ambulation was 1.7 weeks ±0.5. At the 2-year follow-up visit, all patients had reduced U-turn flap pivot point redundancy without shoe size impact, needing reoperation, or donor site morbidity. Edge necrosis was significantly associated with length-to-width ratio (P = 0.014) but not with Foot and Ankle Outcome Score or Foot Function Index.

Conclusions: Metatarsal artery flap of U-turn design was reliable and was associated with a short recovery time, alternative resolution for forefoot area due to short operation time, minimal blood loss, short hospital length of stay, and excellent availability.

Key Words: forefoot defect, MTP joint, toe, metatarsal artery flap, U-turn design

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Severe distal forefoot injury may not be closable with primary repair, requiring a split-thickness skin graft (STSG) or flap coverage. STSG may cause toe deformities by scar contracture and is not recommended if bone or tendon are exposed. Studies on local flap are scarce, especially about coverage extending to the toe or plantar side of forefoot. In the general practice, although free flap coverage has favorable outcome but it has disadvantage with technical demanding, prolong operative time, and access to equipment. As a result, leading to toe loss.

The metatarsal artery is constant in the region with two to five perforator branches, linking the plantar metatarsal artery at the metatarsal head.[1,2] Frequently seen at the distal web space, it is formed by linking the plantar and dorsal metatarsal arteries to a retrograde long flap in Figure 1. Because of perfusion from both the dorsalis pedis and tibialis posterior tibial artery, it is reliable and useful. This enables the use of the U-turn flap for coverage from MTP joint to the toe tips or plantar surface by rotating the metatarsal perforator's artery 180 degrees while keeping some skin bridge for increased survival rate. Flap coverage can be achieved without identifying vessel compatibility with all of the web space to cover both the plantar and distal dorsum in a manner similar to a car U-turning on a road. Therefore, we named it a 'U-turn' flap. The advantages may be reliability, reproducibility, ease of technique, and shortness of operative time. Skin edge necrosis and redundancies may be disadvantages correlated to flap length to width ratio.[3–5] Thus, we report the outcomes and complications of the use of the U-turn flap for treating the distal dorsum or plantar forefoot from the metatarsophalangeal joint (MTP) to distal interphalangeal joint (DIP) joint area to minimize the chance of toe loss.

PATIENTS AND METHODS

Study Design

We performed a retrospective, uncontrolled case series of 36 consecutives patients treated with the U-turn flap on the distal forefoot performed by one surgeon (PR) between the 2018 and 2021 at one tertiary referral center. The eligibility criteria were as follows: 1) the forefoot region has not undergone any surgical interventions, according to the medical records; 2) no concurrent injuries to the dorsum or plantar of the feet; 3) the nonexistence of a neurovascular injury; 4) an ambulatory status showing capability to move; 5) absence of any skin lesion or chronic wound at the wound site; and 6) traumatic injury by a road traffic accident. Data on severity of the injury, size of the wound and flap, cause of the injury, characteristics of the operation, hospital length of stay, reoperation rate, skin redundancy, the Foot and Ankle Outcome Score (FOQ),[6] and the Foot Function Index (FFI)[7,8] were collected. The protocol was reviewed and approved by the institutional review board and ethics committee (HREC No.085/2565). All patients gave written informed consent to participate. The study was performed in accordance with the Declaration of Helsinki.

Surgical Technique

The patient was placed in supine position and administered anesthetics after wrapping and draping the skin according to aseptic protocol. Next, tourniquet and debridement were performed. After that, the length and the width of the wound were measured to draw the flap edge by a simple ruler method.[9] An adequate size was defined as 1.5–3 times to the size of the wound. In the patient with a fracture or dislocation of

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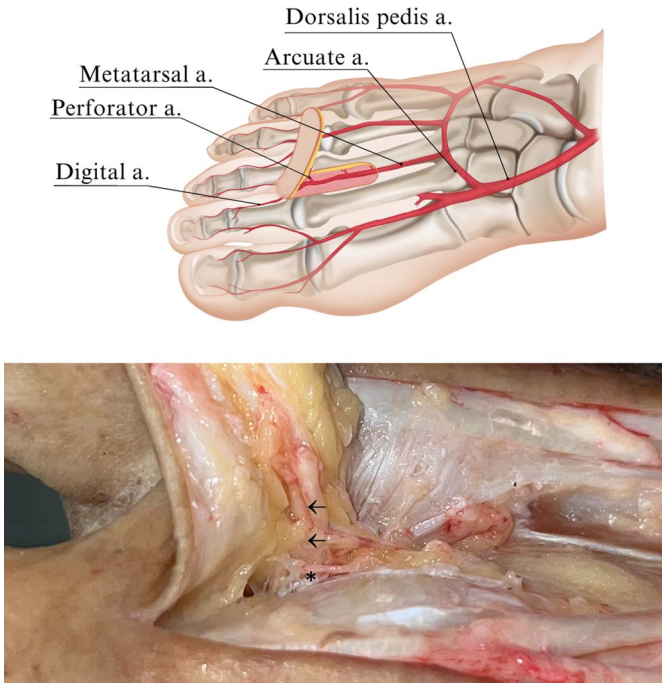

FIGURE 1. The picture shows the characteristics of the blood vessels. An asterisk mask(*) at the line of the digital artery is shown. The double arrow marks the line of the perforator artery from the metatarsal artery that supplies the U-turn flap.

the bone, bone fixation by K-wire for immobilization was performed before flap mark drawing. The base of the flap was in direct apposition to the location of the wound defect. Place the center of the flap between the metatarsal bones to align the artery centered in the flap. Dissection near the metatarsal head should be approached with caution, considering the last perforator branch situated between the metatarsal heads. This method does not necessarily identify the blood supply that is the perforator of the metatarsal artery, but it may be necessary to ligate the proximal branch artery away from the wound because of the need for a good pivot point. Next, an incision was made with no. 15 blade down to the fascia to preserve subdermal plexus nourishment by keeping the adiposfascial globule undamaged. The tourniquet was deflated and flap was revascularized using warm saline for 10–15 minutes. After deflating the tourniquet, we test by using forceps to expel blood along the lines at the small blood vessel and then observe for capillary refill. If blood cannot flow in the vessel within 3 seconds, it may be a sign that the blood circulation is not acceptable. Furthermore, we also observe edge bleeding during evaluation for planning postoperative care. It was then turned 180 degrees and was sutured with 3-0 nylon. The surgical procedure is depicted in Figure 2.

Postoperative Management

The surgical site was check at postoperative 24 hours. If any wound did not close completely with a surviving flap, the patient was taken for STSG at the donor site. All patients were followed-up after 1 week to re-evaluate flap condition. After that, all patients were followed-up at 2, 6, and 12 weeks, followed by every 6 months thereafter. Visual analog scale (VAS), FOQ, FFI, and satisfaction level were collected at 2 years or just over 2 years of follow-up.

Definitions, Assessments, and Measurements

The primary outcome was flap survival rate. Secondary outcomes included wound and flap size, rate of necrosis, revision rate, length of hospital stay, operative time, complications with resolution, change in footwear size, and functional outcomes.

Skin necrosis was defined as edge, partial, or complete necrosis. Superficial or partial thickness could not be achieved due to flap thinness. Edge necrosis was defined as necrosis at the flap edges narrower than 3 mm. A partially necrotic flap appeared discolored, but it did not extend to the pivot point. Complete necrosis extended to the pivot point.

The FOQ includes 11 questions assessing current functional ability with domains including daily living, symptom control, aesthetic appeal, overall flap rating, and quality of life.[6] The FFI is used to evaluate pain, disability, and activity limitations in patients with foot and ankle issues[7,8] and is valid and reliable.[8,10] Visual analog scale was used as a pain scale. The patient marked the box corresponding to pain level on a scale from 1 to 10.

Statistical Analysis

Data were analyzed descriptively. Continuous data are reported as mean (SD) or median (interquartile range) (IQR) for parametrically and nonparametrically distributed data, respectively. Categorical data are reported as frequency (%). Continuous data were tested by the

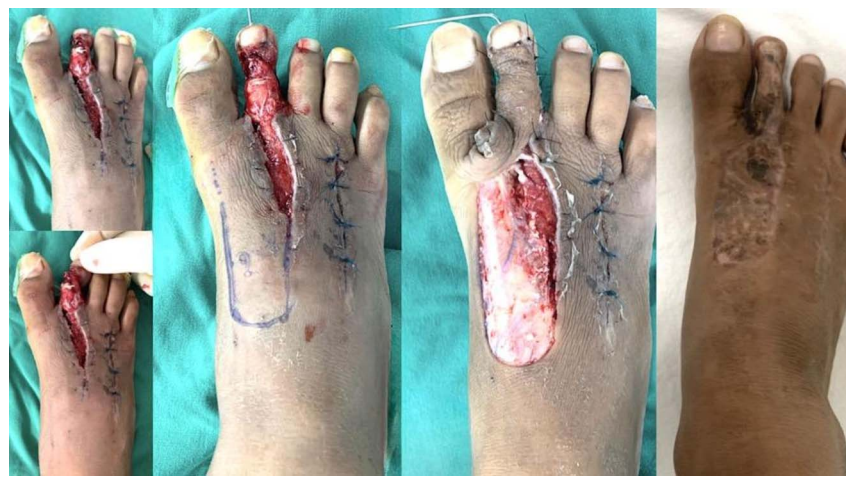

FIGURE 2. Utilization of the U-turn flap positioned at the second toe with K-wire fixation to enhance the stability of the DIP dislocation. Redundancy at the pivot point was spontaneously resolved during the last few follow-up times.

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TABLE 1. Demographic Data, Operation Characteristics, and Clinical Outcomes Data (N = 36)

Variable	Total (N = 36)	No Edge Necrosis (n = 30)	Edge Necrosis (n = 6)	*P*
Age, mean ± SD [range] (years)	37.5 ± 18.2 [3.0, 67.0]	37.3 ± 19.1 [3.0, 67.0]	38.5 ± 14.5 [19.0, 60.0]	0.89
Male	22 (61.1)	19 (63.3)	3 (50.0)	0.66
Comorbidity‡	9 (25.0)	23 (76.7)	4 (66.7)	0.63
Hypertension	7 (19.4)	6 (20.0)	1 (16.7)	1.00
Dyslipidemia	4 (11.1)	3 (10.0)	1 (16.7)	0.54
Diabetes mellitus	4 (11.1)	3 (10.0)	1 (16.7)	0.54
Old CVA	1 (2.8)	1 (3.3)	0 (0.0)	1.00
Chronic kidney disease	1 (2.8)	0 (0.0)	1 (16.7)	0.17
Current smoker	3 (8.3)	2 (6.7)	1 (16.7)	0.43
Location				0.02*
Metatarsophalangeal joint	18 (50.0)	12 (40.0)	6 (100)	
Toe	18 (50.0)	18 (60.0)	0 (0.0)	
Aspect of foot				1.00
Dorsum	34 (94.4)	28 (93.3)	6 (100)	
Plantar	2 (5.6)	2 (6.7)	0 (0.0)	
Wound dimensions				
Width, median (IQR) [range] (cm)	1.8 (1.4, 3.0) [1.0, 6.4]	1.7 (1.4, 3.0) [1.0, 6.4]	2.7 (2.0, 4.0) [1.0, 6.0]	0.22
Length, median (IQR) [range] (cm)	3.2 (2.9, 6.2) [2.2, 12.0]	3.1 (2.8, 5.5) [2.2, 8.9]	8.2 (4.0, 10.0) [3.0, 12.0]	0.01*
Flap dimensions				
Width, median (IQR) [range] (cm)	3.6 (2.8, 6.0) [2.0, 12.8]	3.4 (2.8, 6.0) [2.0, 12.8]	5.4 (4.0, 8.0) [2.0, 12.0]	0.22
Length, median (IQR) [range] (cm)	4.7 (4.3, 9.2) [3.3, 18.0]	4.6 (4.2, 8.3) [3.3, 13.4]	12.2 (6.0, 15.0) [4.5, 18.0]	0.01*
Length-to-width ratio, mean ± SD (cm)	1.5 ± 0.4 [0.9 2.5]	1.4 ± 0.4 [0.9, 2.4]	2.0 ± 0.5 [1.3, 2.5]	0.004†
Intraoperative blood loss, median (IQR) [range] (ml)	5.0 (4.0, 5.0) [2.0, 10.0]	5.0 (4.0, 5.0) [2.0, 10.0]	5.0 (5.0, 10.0) [2.0, 10.0]	0.09
Operative time, mean ± SD [range] (min)	32.9 ± 5.7 [22.0, 43.0]	33.1 ± 5.8 [22.0, 43.0]	32.2 ± 5.5 [25.0, 38.0]	0.72
Hospital length of stay, mean ± SD [range] (days)	4.0 ± 1.0 [2.0, 6.0]	4.0 ± 1.0 [2.0, 5.0]	4.3 ± 1.4 [2.0, 6.0]	0.43
Length of follow-up, mean ± SD (months)	27.3 ± 1.9 [24.0, 31.0]	27.3 ± 1.7 [24.0, 31.0]	27.2 ± 2.9 [24.0, 31.0]	0.91
Satisfaction level				1.00
Excellent	6 (16.7)	25 (83.3)	5 (83.3)	
Good	30 (83.3)	5 (16.7)	1 (16.7)	
Impaired	0 (0.0)	0 (0.0)	0 (0.0)	
Poor	0 (0.0)	0 (0.0)	0 (0.0)	
Pivot point resolution	100 (36)	30 (100)	6 (100)	
Time to ambulation, mean ± SD [range] (weeks)	1.7 ± 0.5 [1.0, 2.0]	1.7 ± 0.5 [1.0, 2.0]	1.5 ± 0.5 [1.0, 2.0]	0.36
FOQ, mean ± SD [range]	64.1 ± 2.5 [59.0, 68.0]	64.3 ± 2.5 [59.0, 68.0]	64.2 ± 1.8 [62.0, 66.0]	0.88
Total FFI, mean ± SD (%) [range]	7.6 ± 3.4 [2.0, 15]	8.0 ± 2.9 [2.0, 15]	5.8 ± 5.2 [2.0, 15]	0.16
FFI for pain, median (IQR) [range]	2.0 (2.0, 4.0) [2.0, 8.0]	2.0 (2.0, 4.0) [2.0, 8.0]	2.0 (2.0, 2.0) [2.0, 6.0]	0.29
FFI for disability, mean ± SD [range]	12.4 ± 5.8 [2.0, 26.0]	13.0 ± 5.0 [2.0, 26.0]	9.3 ± 8.8 [2.0, 24.0]	0.16
FFI for limitation, median (IQR) [range]	0 (0, 0) [0, 0]	0 (0, 0) [0, 0]	0 (0, 0) [0, 0]	
Footwear size increase	6 (16.7)	5 (16.7)	1 (16.7)	1.00
Footwear size before, mean ± SD [range]	40.2 ± 3.2 [30, 47]	40.0 ± 3.2 [30, 45]	41.2 ± 3.4 [38, 47]	0.42
Footwear size after, mean ± SD [range]	40.4 ± 3.2 [30, 47]	40.2 ± 3.2 [30, 45]	41.3 ± 3.4 [38, 47]	0.45
Pre-post difference in footwear size, mean ± SD [range]	0.2 ± 0.5 [0.0, 2.0]	0.2 ± 0.6 [0.0, 2.0]	0.2 ± 0.4 [0.0, 1.0]	0.78
Donor site morbidity rate	0 (0.0)	0 (0.0)	0 (0.0)	
Ulcer complication rate	0 (0.0)	0 (0.0)	0 (0.0)	
Reoperation rate	0 (0.0)	0 (0.0)	0 (0.0)	

Data are presented as frequency (%), unless stated otherwise.

*Significant at the <0.05 level.

†Significant at the <0.01 level.

‡Includes all comorbidities list in the table.

CVA, cerebrovascular accident.

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TABLE 2. Univariate Odds Ratios of Factors Associated With Edge Necrosis (N = 36)

	Main Analysis		Sensitivity Analysis	
Variable	**Crude Odds Ratio (95%CI)**	***P***	**Crude Odds Ratio (95%CI)**	***P***
Length-to-width ratio	1.36 (1.06, 1.74)	0.014*	1.32 (1.07, 1.70)	0.008†
Diabetes mellitus	1.80 (0.15, 21.0)	0.639	2.14 (0.18, 16.6)	0.497
Age	1.004 (0.96, 1.05)	0.885	1.003 (0.96, 1.05)	0.909
Current smoker	2.80 (0.21, 37.0)	0.434	3.11 (0.25, 28.7)	0.338

The main analysis was performed using unconditional binary logistic regression. The sensitivity analysis was performed using Firth's logistic regression; a penalized logistic regression method. *Significant at the <0.05 level. †Significant at the <0.01 level.

independent *t* test or Mann-Whitney *U* test as appropriate, and categorical data were tested by the chi-squared test or Fisher's exact test as appropriate. Baseline and last follow-up footwear size was compared by dependent t-test. Normal distribution was assessed by histograms, quantile-quantile plots, and the Shapiro-Wilk test.

We performed a univariate conventional logistic regression to identify factors descriptively associated with adverse outcomes. Because of the low sample size, we also perform a sensitivity analysis by penalized logistic regression by Firth's logistic regression to estimate descriptive risk difference. Firth's logistic regression is a penalized form of regression that provides correction for small sample size bias,[11] and trades bias for variance, thereby giving more generalizable risk estimates. Confidence intervals for the sensitivity analysis were profile likelihood, which are appropriately asymmetric at low sample sizes.[12] We estimated the final model-based descriptive risk difference of edge necrosis in rescaled and centered length-to-volume ratio that was rescaled to 0.1 intervals and mean centered for interpretation. Modeling for descriptive risk difference estimation in sensitivity analysis was performed by Firth's logistic regression with intercept correction to provide valid estimates predicted probability from Firth's logistic regression models.[13,14] We performed descriptive linear regression to investigate the association with flap dimensions and pre-post change in footwear size along with edge necrosis or any increase in footwear size with functional outcome scores.

Analyses were performed using R version 4.2.0. [R Core Team (2023). R Foundation for Statistical Computing, Vienna, Austria] using the glmtoolbox, lmtest, and logistf package. A *P* value of <0.05 was considered significant.

RESULTS

Between 2018 and 2021, there were 36 eligible patients that were recruited, completed the study, and were included in the final analysis. The characteristics of patients are shown in Table 1.

The mean ± SD follow-up time was 27.3 months ±1.9 (range 24, 31). The cause of the injury was trauma in all cases, and the affected area was from the MIP to DIP joint in all cases. The median (IQR) wound size was 1.8 cm wide (1.4, 3.0) (range 1.0, 6.4) by 3.15 cm long (2.85, 6.15) (range 2.2, 12.0). The median (IQR) flap size was 3.60 cm wide (2.80, 6.00) (range 2.0, 12.8) by 4.73 cm long (4.28, 9.23) (range 3.3, 18.0), the median (IQR) width-to-length ratio was 1.47 (1.19, 1.67) (range 0.9, 2.5). The mean ± SD operative time was 32.9 minutes ±5.67 (range 22.0, 43.0), the median (IQR) intraoperative blood loss was 5.0 mL (4.0, 5.0) (range 2, 10), the mean ± SD hospital length of stay at hospital after flap coverage was 4.09 days ±1.03 (range 2, 6). The mean ± SD FOQ and FFI were 64.1 ± 2.46 (range 62, 69) and 7.6% ± 3.4 (range 2, 15). The aesthetic satisfaction level was excellent in 16.9% (95%CI 6.4, 32.8) (6 of 36) and good in 83.3% (95%CI 67.2, 93.6) (30 of 36); no cases reported either impaired or poor satisfaction level categories of aesthetic satisfaction. Edge necrosis was found in 16.7% (95%CI 6.3, 32.8) (6 of 36), but all cases resolved spontaneously in 12 weeks. Mean ± SD time to start ambulation was 1.67 weeks ±0.48 (range 1, 2). At the final follow-up visit, by resolving the redundancy at the pivot point of the U-turn flap, the size of the shoe could remain unchanged. The availability at the final follow-up was 100% (95%CI 90.3, 100). No case needed reoperation or had donor site morbidity.

We performed descriptive univariate logistic regression analysis of factors associated with edge necrosis. Length-to-width ratio was significantly associated with edge necrosis [crude odds ratio 1.36 (95%CI 1.06, 1.74); $P = 0.014$] while diabetes mellitus, age, and smoking were not significant (Table 2). Sensitivity analysis results were similar (Table 2).

A univariate descriptive model of length-to-width ratio and edge necrosis was estimated. We report the descriptive crude risk difference in Table 3 for the relationship between length-to-width ratio and edge necrosis with length-to-width ratio rescaled to 0.1-unit intervals and mean centered. In the main analysis, the model estimated a descriptive crude risk difference of 3.4% (95%CI 0.6, 6.8; $P = 0.014$) per 0.1-unit increase in length-to-width ratio above the mean of all 36 patients (Table 3). In the sensitivity analysis, the model estimated a descriptive crude risk difference of 3.2% (95%CI 0.8, 6.8; $P = 0.008$) per 0.1-unit increase in length-to-width ratio above the mean of all 36 patients (Table 3).

There was a significant mean ± SD pre-post change in footwear size of a of 0.22 size ±0.9, range 0, 2) ($P = 0.02$), but no patients reported problems walking in their shoes at the last follow-up visit. Univariate linear regression analysis showed that increasing flap length and flap width were negatively correlated with increased shoe size, but both results were nonsignificant (Table 4).

We performed univariate linear regression of the associations of the factors of edge necrosis and any increase in footwear size with functional outcomes. There were no significant differences in functional outcome scores between patients experiencing edge necrosis compared

TABLE 3. Risk Differences for the Association Between Length-to-Width Ratio and Edge Necrosis (N = 36)

	Main Analysis		Sensitivity Analysis	
Parameter	**Intercept**	**β**	**Intercept**	**β**
Length-to-width ratio	−2.07	0.309	−1.99	0.275

Notes: The main analysis was performed using unconditional binary logistic regression. The sensitivity analysis was performed using Firth's logistic regression; a penalized logistic regression method. The Firth's logistic regression was performed with intercept correction to obtain valid estimates of average predicted probability. Confidence intervals are profile likelihood. Length-to-width ratio was rescaled to units of 0.1 and mean centered for interpretation.

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to those who did not or in those experiencing any increased footwear size and those who did not (Table 5).

DISCUSSION

We have performed an uncontrolled case series of metatarsal artery flap to develop the U-turn design use in the distal forefoot among 36 patients. The current surgical techniques for this area can be treated using various methods.[15–23] Each technique having advantages and disadvantages. Furthermore, a few studies stated using other toe positions, and there are limited data on the functional outcome postoperatively when the distal dorsum or plantar forefoot was utilized. The U-turn flap can be done without microsurgery expertise, and no major blood vessel is sacrificed using it, thereby allowing it to have an adequate blood supply. Conversely, a free flap requires microsurgery, and is technically demanding. Additionally, the rotation flap and the U-turn flap differ in that a rotation flap provides an artery at random whereas U-turn flap uses an artery that is reliable from the metatarsal artery.

In the present study, a total of 36 cases were performed (n = 34 dorsal vs. n = 2 plantar cases and n = 15 toe defects vs. n = 21 MTP defects). The toe area cases were divided into 8 cases at the big toe, 4 cases at the second toe, 1 case at the third toe, 1 case at the fourth toe, and 1 case at the fifth toe, which means it can be applied to all toes as previous studies have shown that the metatarsal artery exists on each toe.[1,2,15,16,24,25] An advantage of the U-turn flap is the length. However, the 1:2.3 ratio result in a small base, and the availability may be affected. Nonetheless, while edge necrosis occurred in 13.9%, all flaps survived until the final follow-up visit and reoperation was never needed. The largest flap in this study was 13.4 cm wide at the base and 12.8 cm long. As the forefoot is not a big area, the U-turn technique can provide adequate coverage. The width-to-length ratio is greater than 1:2.3, which is dissimilar to other studies because a longer flap can cover down to the distal phalanx. Although there were cases of edge necrosis, they recovered spontaneously, which may be explained edge flap research claiming that the osmotic system allows for self-recovery[26] resulting in no reoperations because there was no total necrosis. The outcomes were excellent, and no reoperation or amputation was needed. Another factor that has an effect is the tension of stretched flap, causing reduced lumen size.[27] An appropriate length-to-width ratio will ease the tension on the flap. In the present study, the length-to-width ratio was a risk factor for edge necrosis, and there was around a 3–4% increase in risk of edge necrosis of each 0.1 unit increase above the group mean length-to-width ratio of 1.52.

In terms of operation time, less time was required in comparison to free flap usage, for which anastomosis is needed. In addition, the period of hospitalization was shorter as there was no need for reoperation. Perfusion observation of the flap required less complicated monitoring as opposed to that of the free flap. To the best our knowledge, the present study is the first study of the U-flap design to report functional outcomes. The results of functional outcomes were favorable because of this reconstruction. The patients could resume ambulation quickly within 2 weeks despite some cases of edge necrosis. However, in cases in which the bone fixation is performed, the bone must be union first.

TABLE 4. Linear Regression of the Association Flap Dimensions and Pre-Post Change in Footwear Size (N = 36)

Parameter	β (95%CI)	*P*
Pre-post change in footwear size		
Flap width	−0.05 (−0.11, 0.01)	0.130
Flap length	−0.04 (−0.09, 0.004)	0.074

TABLE 5. Linear Regression of the Association of Edge Necrosis or Any Increase in Footwear Size With Functional Outcome Scores (N = 36)

Outcome	β (95%CI)	*P*
Edge necrosis		
FFI		
Total	−2.13 (−5.19, 0.92)	0.17
Pain	−0.80 (−2.54, 0.94)	0.36
Limitation	−3.70 (−8.91, 1.51)	0.16
FOQ	−0.17 (−2.35, 2.01)	0.88
Any increase in footwear size		
FFI		
Total	0.67 (−2.33, 3.66)	0.654
Pain	2.13 (−1.50, 5.77)	0.241
Disability	−0.80 (−4.68, 3.08)	0.678
Limitation	−0.63 (−1.96, 0.70)	0.341
FOQ	−0.33 (−2.60, 1.93)	0.767

Satisfaction should come from solving the cosmetic problem and being satisfied with keeping all the toes of the foot.

Previous studies have claimed that the footwear was another concern.[28–30] In the present study, there was a slight pre-post increase in footwear size. Nevertheless, no patients report any problems walking in their shoes, and there were no differences in functional outcome scores between patients with and without increased footwear size. We found that larger flap dimensions were negative correlated with increased footwear size in point estimators although results were nonsignificant possibly due to small sample size. These negative correlations may be because the shorter flap is used to close the web space, increasing the distance between the metatarsal head and the forefoot area. Despite this, the functional outcome remained unaffected in the present study. The only concern was the redundancy at the pivot point. However, it could self-resolve after a very long period of time. Donor site morbidity was undisputed as primary closure was possible in this position, or immediate STSG could have been performed, resulting in no side effects and no scar contracture after 2 years of follow-up.

The present study has strengths and limitations. The strengths are the length of follow-up, which was greater or equal to 2 years, and the performance of all operations by a single surgeon. The limitations of this study are its retrospective and uncontrolled case series design. As a retrospective study, the condition of the toe before the injury, such as the blood vessel network at the area and the sensation of the nerve were not recorded. Further studies for this are needed. As an uncontrolled case series, there is no group to which to compare the outcomes.

CONCLUSIONS

Metatarsal artery flap of U-turn design was reliable and was associated with a short recovery time, alternative resolution for forefoot area due to short operation time, minimal blood loss, short hospital length of stay and excellent availability.

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