The Lateral Proximal Phalanx Flap for Contractures and Soft Tissue Defects in the Proximal Interphalangeal Joint: An Anatomical and Clinical Study

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Abstract

Background: The management of contractures and soft tissue defects in the proximal interphalangeal (PIP) finger joint remains a challenge. We report a transposition flap from the lateral skin of the proximal phalanx that is based on perforating branches of the digital arteries and can be used safely for both palmar and dorsal cover defects. **Methods:** We first completed an anatomic study, dissecting 20 fingers in fresh cadavers with arterial injections and made the new flap in patients with dorsal or palmar defects in PIP joints. **Results:** In cadavers, we can reveal 4 constant branches from each digital artery in the proximal phalanx, with the more distal just in the PIP joint constituting the flap pedicle. Between February 2010 and February 2015, we designed 33 flaps in 29 patients, 7 for dorsal and 26 for palmar defects, with no instances of flap necrosis and 4 distal epidermolysis. The patients were between 4 and 69 years with no major complications, and all of the skin defects in the PIP joint were resolved satisfactorily without any relevant sequelae at the donor site. **Conclusions:** This flap procedure is an easy, reliable, versatile, and safe technique, and could be an important tool for the management of difficult skin defects and contractures at the PIP joint level.

Keywords: flap, proximal interphalangeal joint, proximal phalanx, perforator, contracture, digital artery, joint coverage

Introduction

Skin contractures in fingers can cause significant skin shortening, leading to major defects at contracture release. This problem often affects the proximal interphalangeal (PIP) joints in both the dorsal and palmar skin, and at present, there is no ideal method to replace the lost skin. The same principle applies to traumatic skin losses in this area. Total skin grafts can tend to contract, and thus could not be the best choice for tendon or neurovascular bundle exposition.^{1,5} For Dupuytren disease, some surgeons use the McCash technique waiting for secondary intention closures; however, this approach requires a long splinting time in extension. We have found descriptions of rotation flaps, homodigital and heterodigital flaps, and combinations of lateral transposition flaps taken from the proximal and middle phalanges that have been used to achieve the complete closure of defects in the PIP joint.^{1,7} Such approaches, although successful, are usually complex, require multiple surgeries, and demand large incisions in the injured finger and/or healthy areas in other fingers, increasing regional morbidity. The lateral regions of fingers are very rich in arterial anastomosis⁶; they are usually protected from burns

and able to retain healthy skin and subcutaneous tissues. Furthermore, the relative skin excess in this area allows for primary closure if used as a donor site.^{1,5,7} With this in mind, we have designed a new surgical technique calling for a flap to be taken from the lateral side of the proximal phalanx with a distal pivot point in the PIP joint. This approach can be easily modified for either the dorsum or the palm to cover any defects in this location within a single surgery without harming the adjacent fingers while still achieving a reliable vascular pedicle and minimal sequelae in the donor area.

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Figure 1. Vascular injection studies in the cadavers. (A) Branch numbers 3 and 4 painted in blue with the proximal interphalangeal joint skin crease marked in black dots with a pin. The yellow pin indicates branch number 3. (B) In black are branches 2, 3 and 4, with the projected proximal interphalangeal joint skin crease appearing in black dots. (C) In red are branches 2, 3, and 4 with a ruler marking 6.5 mm between the origins of branches 3 and 4, in lateral view. (D) dorsolateral view of C. (E) Branch 4 enters at the base of the flap. Note. Red arrow = metacarpophalangeal palmar skin. Yellow star = distal phalanx.

Materials and Methods

After consulting many excellent studies detailing the vascular anatomy of the fingers, such as those published by Strauch and Moura,⁶ Voche and Merle,⁸ Braga Silva,⁴ and Bertelli,³ we decided to practice our vascular injection studies on fresh cadavers (see Figure 1). We dissected 20 fingers in 8 hands previously injected with a mixed fast setting acrylic and Chinese ink in the radial artery at the distal third of the forearm. At loupes magnification $\times 4.0$ and $\times 6.0$, we searched for branches of digital artery in the proximal phalanx and found that all of the fingers had 4 branches of digital artery in proximal phalanx; these we numbered 1 to 4, from proximal to distal. These branches create a rich anastomotic network that perfuses the lateral skin of the proximal phalanx. After beginning the flap dissection, we located branch numbers 1 and 2, which were sacrificed to continue the distal dissection. Branch number 3, also known as the “dorsal branch” for dorsal island flap described for Bertelli,³ arises from the digital artery, 6 or 7 mm proximal to the PIP joint palmar skin crease. Branch

number 4 is our main flap pedicle and arises just at the level of the PIP joint. Next, we created a flap using the entire length of the proximal phalanx lateral skin (almost 4 cm in length and up to 6 mm in width), until we reached the subcutaneous tissue at the PIP joint palmar skin crease. Our study demonstrated an axial vessel piercing the fascia that entered at the base of the flap and remained in the proximal two-thirds.

Surgical Technique

We begin by noting the dimensions of the defect and drawing the flap at the donor site. We chose the most hidden side, which was the ulnar side in the second finger and the radial side in the fifth finger, unless there were any previous scars or an exposure incision was necessary on the preferred side (see Figures 2 and 3). The more proximal point of the flap can include some web skin to extend its length up to 4 cm, depending on each patient proximal phalanx length and ensuring no future scar retractions. This procedure was performed under regional or general anesthesia and using an arm tourniquet without

Figure 2. Index finger proximal interphalangeal joint postburn palmar contracture, case 12. (A) Preoperative view of the palmar contracture. (B) Skin defect in the proximal interphalangeal joint after contracture release. (C) Flap raised with the pivot point at the level of the proximal interphalangeal joint. (D) Detail of the previous photo showing arterial branch number 4 entering at the flap base and following the flap axis, with the collateral artery at the left top corner. (E) Flap in the projected position covering all skin defects. (F) The tourniquet was deflated with the flap in final position with good arterial inflow. (G) Fifty-five postoperative days passed before the complete healing and release of the contracture, and the flap stayed in good condition.

compressive exsanguination for the easy visualization of the digital artery and its branches. All flaps were dissected by the senior author (Aldo Beltrán) using loupes $\times 6.0$ magnification. We begin by raising the flap at the more proximal point of finger, using the midline of the lateral side of the finger as an axis. We calculate the flap width pinching lateral skin until we were able to close the primary donor defect, allowing an average of 6 mm of flap width. In some cases, requiring a greater flap width, we made a partial closure and left heal donor site for secondary intention. We used as much of the subcutaneous tissue as possible, cutting in this process branch numbers 1 and 2 and taking care not to harm the collateral artery or nerve. We

preserved all of the fat tissue under the flap and over the collateral neurovascular bundle and stopped dissection 7 mm proximal to the interphalangeal joint to ensure that the two more distal branches of the digital artery were included. If the flap needed to be pivoted more distally, we cut branch number 3 and accordingly dissect the flap more distally, reaching the PIP joint. At this juncture, the more distal branch, our branch number 4, is able to perfuse the flap alone. We were able to see the arterial branches at the undersurface of the flap in only some of the clinical cases and anatomic specimens. When incision was close to the palmar skin crease of PIP joint, we stopped dissection to attempt to bring the flap to the defect.

Figure 3. Dupuytren contracture of the little finger, case 13. (A) Preoperative view. (B) Intraoperative view of the resultant palmar skin defect in the proximal phalanx after contracture release. (C) Flap design in the radial aspect of the proximal phalanx. (D) Flap in the projected position covering the skin defect. After tourniquet release, the flap was sutured in a position with good perfusion, (E) a palmar view and (F) a palmar lateral view that showed the primary closure of the donor site. After 42 postoperative days, (G) the flap had completely healed, and (H) the contracture had resolved.

Next, we closed the donor area using continuous sutures, leaving the flap in its original position and releasing tourniquet. We waited 3 to 5 minutes for flap reperfusion and fixed the flap in the receptor area using very few stitches. In the process of transposition, we can observe a transitory slow arterial perfusion in the flaps, many of which improved spontaneously in 4

to 5 minutes. We left the subcutaneous tissue exposed because the flaps are normally thicker than the skin in the receptor area. Although initially we believed that this partial closure can cause an irregular contour, the healing and reepithelialization process moved quickly to repair all significant defects in the contouring. All of our patients were previously informed about

Table 1. Clinical Cases of Lateral Phalanx Flap for PIP joint.

Patient	Surgery date	Age	Diagnostic	Hand	Finger	Defect localization	Donor side	Complication	Follow days
1	February 23, 2010	58	Burn sequelae	Right	III	Dorsal	Ulnar	No	476
2	April 7, 2010	27	Motorcycle chain injury, flexor tendons injury	Right	III	Dorsal	Radial	No	272
3	April 20, 2010	64	Dupuytren disease	Right	IV	Palmar	Radial	No	45
4	May 4, 2010	56	Tenosynovitis sequelae	Right	II	Palmar	Radial	Epidermolysis distal 1/4	61
5	May 26, 2010	41	Old flexor tendon injury, retraction	Left	V	Palmar	Ulnar	Delay 3 weeks	567
6	October 14, 2010	16	Gunshot, hiperextensión arthrodesis	Left	III	Dorsal	Radial	No	40
7	October 28, 2010	27	Knife injury, flexor tendon nontreated injury	Right	II	Palmar	Ulnar	No	64
					III	Palmar	Ulnar	No	
					IV	Palmar	Ulnar	Epidermolysis distal 2/3	
					IV	Palmar	Radial	No	
8	December 16, 2010	4	Postsurgical scar contracture	Right	V	Palmar	Radial	No	166
9	February 3, 2011	44	Posttraumatic arthrosis	Left	IV	Palmar	Radial	No	54
10	April 28, 2011	22	Extensor tendon injury	Left	II	Dorsal	Radial	No	40
11	June 9, 2011	51	Dupuytren disease	Right	V	Palmar	Radial	No	42
12	June 17, 2011	36	Electric burn sequelae	Right	II	Palmar	Ulnar	No	55
13	September 20, 2011	62	Dupuytren disease	Left	V	Palmar	Radial	No	15
14	September 23, 2011	69	Crushing trauma II—III-IV fingers	Left	III	Dorsal	Ulnar	No	14
15	March 15, 2012	26	Chainsaw injury III-IV fingers	Right	III	Dorsal	Radial	No	24
16	March 21, 2012	23	Dupuytren disease	Left	V	Palmar	Radial	Distal epidermolysis	55
17	April 10, 2012	30	Fan blade injury	Left	II	Palmar	Radial	No	20
18	July 12, 2012	17	Post flexor tendon repair contracture III-IV fingers	Right	IV	Palmar	Ulnar	No	49
	July 19, 2012				III	Palmar	Ulnar	No	42
19	September 8, 2012	56	Dupuytren disease	Right	IV	Palmar	Radial	No	101
20	November 12, 2012	62	Dupuytren disease	Right	V	Palmar	Radial	No	36
21	January 11, 2013	24	Tenolysis post saw injury	Right	V	Palmar	Ulnar	No	218
22	October 3, 2013	12	Scar and flexor contracture, tenolysis	Right	IV	Palmar	Ulnar	Distal epidermolysis	28
23	November 20, 2013	16	Sequelae knife injury, amputation V, tenolysis	Right	IV	Palmar	Radial	No	69
24	January 15, 2014	60	Dupuytren disease	Left	IV	Palmar	Radial	No	35
25	May 8, 2014	21	Saw injury dorsum III, IV, V	Right	IV	Dorsal	Radial	No	14
26	July 31, 2014	59	Dupuytren disease	Left	V	Palmar	Ulnar	No	21
27	August 6, 2014	33	PIP joint trauma, capsulotomy	Right	V	Palmar	Radial	No	364
28	September 10, 2014	19	Flexor tendon injury, skin defect	Right	III	Palmar	Radial	No	140
29	February 13, 2015	36	PIP joint trauma, capsulotomy	Left	V	Palmar	Radial	No	80

Note. Twenty-nine patients, 33 flaps with date of surgery, diagnostic, hand, finger, defect location, donor side, complications, and days of clinical following. PIP = proximal interphalangeal joint.

the surgical technique, risks and benefits, and we obtained informed consent from each. Our institutions do not require board approval for use of different or new surgical techniques with reasonable risks; it is requested for pure experimental purposes only.

Results

Between February 2010 and February 2015, we performed 33 flaps in 29 patients, 7 for dorsal and 26 for palmar defects. The patient's ages ranged between 4 and 69 years (average 34.3). All patients with a contracture or skin defect at the PIP joint were included. A previous suspected collateral pedicle injury was considered a relative contraindication that could be solved by approaching the flap from the contralateral side. We did not exclude patients for other pathologies, such as diabetes, atherosclerosis, or smoking, and there were no age limits. Only one patient was excluded for no possibility of clinical follow-up; a big number of our patients come from very far towns, circumstance that made difficult the postoperative appointments.

We encountered no cases of total flap necrosis. Distal epidermolysis that resolved spontaneously developed in 3 flaps: 1 in a patient with several fibroses secondary to an old tenosynovitis, 1 in a young patient with severe Dupuytren disease, and 1 in the only finger that was subjected to 2 simultaneous flaps. In another case, we had to delay the flap for 3 weeks due to a large scar on the finger from a previous flexor tendon injury. Clinical follow-up was completed for an average of 121.6 days, although we considered patients ranging between 14 and 476 days after the procedure. However, complete healing and full movement took close to 3 weeks in all patients (see Table 1).

Discussion

Lateral proximal phalanx flaps with proximal bases have been described by Green⁵ as a good alternative for contractures or defects on the palmar side of the metacarpophalangeal joints. The authors mention the previously described advantages of the lateral phalanx as a donor site, such as the skin redundancy that allows for primary donor site closure; however, their description resembled that of a random flap, designed on a base : length ratio between 1:1.5 and 1:2. Indeed, a high risk of tip necrosis may emerge if the flap exceeds these dimensions.⁵ However, analyzing the vascular anatomy of the fingers,^{3,4,6,8} we can suppose that branches 1 and 2 are the real vascular pedicles of this flap, which makes it possible for Green's limits to be exceeded.

The currently described flap approach is very safe. Acikel¹ published a cases series with 11 patients (37 fingers) undergoing PIP joint contractures managed with 2 lateral flaps of the proximal base, one from the proximal

phalanx and another from the contralateral side of the middle phalanx. Ülkür⁷ described 8 cases of combined usage of the lateral proximal phalanx flap with a proximal base and cross-finger flap for severe contractures of the PIP joint. Bertelli² designed an island dorsal flap in severe flexion contractures, preserving a 5-mm pedicle proximal to the PIP joint. We believe that this pedicle was included in our study as the number 3 branch, which allowed for an island design. The donor defect was closed primarily because the flexion contracture caused a dorsal skin expansion. However, all these previous techniques have significant limitations as only availability for palmar defects (Bertelli's flap), middle phalanx is smaller and gives us small flaps (Acikel) harming both sides of the injured finger, or using an adjacent healthy finger (Ülkür).

Using our technique, we were able to take advantage of all properties of the lateral skin of the proximal phalanx as donor site, including that is the longest phalanx, skin redundancy, protection of lateral side of the finger in burns, and the constant presence of arterial branches that allow the flap to be pivoted at a distal base, easily reaching either dorsal or palmar defects at the PIP joint. Our flaps were not random; based on our anatomic study, we were able to demonstrate the branching of an arterial perforator at the level of the PIP joint, which is constant and allows large flaps to be created, exceeding the ratio base-length of 1:2. Such dissections are not complex and, using loupes magnification and the appropriate instruments, the surgical time is quite short (5 minutes or less). Morbidity at the donor site is minimal, and the clinical results are very satisfying.

We consider the proximal phalanx flap with distal base to be a versatile (can reach dorsal and palmar defects), safe (constant vascular pedicle), easy, and reliable alternative technique for the management of challenging soft tissue defects in the PIP joint.

Institutions

We made this flap in multiple centers in Bogotá, Colombia, where we develop our institutional and private practice, but our principal center is Hospital Central Policía Nacional de Colombia (Bogotá, Colombia).

Meeting Presentations and Awards

- Oral Presentation, XIX Meeting Iberolatinoamerican Federation of Plastic Surgery FILACP, Medellín, Colombia. May 22-26, 2012.
- FIRST PLACE, PRIZE "Abraham Cupperman," to Best Research Work
 - VIII International Symposium, Colombian Association for Hand Surgery. August 23-25, 2012.
- E-poster, Abstract 119, 67th Meeting American Society for Surgery of the Hand, Chicago, Illinois, USA. September 6-8, 2012.

- Oral Presentation, American Association of Hand Surgery, 2013 Meeting. Naples, Florida, USA, January 9-12, 2013.

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Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This study takes care of respect all humans rights in clinical research; our institutions do not require approval from a review board if the study does not involve any experimental technique or unusual surgical or medical risks; all patients know the nature of procedure, other treatment choices, and sign an informed consent. The clinical study do not require any funding, and anatomical study was all covered for authors' own funding resources; any institution or company gives us money for financing this project.

Statement of Informed Consent

Informed consent was obtained when necessary.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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