Bone regeneration after pedicled periosteal dorsal metacarpal flap. Reconstructive technique

Ann. Ital. Chir., 2020 91, 5: 534-537
pii: S0003469X20033308

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The dorsal metacarpal artery (DMCA) flap is considered as one of the working horses to cover exposed extensor tendon or bone of dorsal digits. The periosteal composite DMCA reverse flap (pcDMCAr flap) is described as a fast and safe solution to manage this kind of trauma.
A 35-year-old male had a trauma to his left hand from a circular saw. The resultant injury was localized to the proximal middle finger with a dorsal bone loss. A vascularized composite flap, including 3th metacarpal periosteum, was elected as the most appropriate option. Postoperative follow-up at 6 months confirmed bony regeneration.
There are no documented cases to the best of our knowledge demonstrating the use of pcDMCAr flap to treat fractures with bone loss in the proximal digits. This report suggests that technique may be employed as regenerative bone flap in reconstructive surgery for proximal fingers trauma with bone loss and open fracture.

KEY WORDS: Bone regeneration, Dorsal metacarpal flap, Periosteum

Introduction

The dorsal metacarpal artery (DMCA) flap in its standard or extended version is considered as a reliable option to cover digital dorsal exposed extensor tendon or bone[1]. We present a clinical case of hand trauma with a soft tissue and partial bone defect of the proximal dorsal aspect of middle finger and the postoperative outcome employing a modified DMCA flap. Assumed the osteogenic potential of periosteum as widely recognized, the periosteal composite DMCA reverse flap (pcDMCAr flap) presents as a fast and safe solution to cover and to repair small bone defects. To the best of our knowledge, this is the first report of a DMCA flap including bone periosteum to restore soft and bone defects in the proximal digits.

Case Report

A 35-year-old gentleman presented to the emergency department having sustained a trauma to his non-dominant left hand from a circular saw. The trajectory of the injury was transversal and hit all the fingers at different level (Fig. 1A). The resultant injury was predominantly to the proximal middle finger with a substantial soft tissue and bone loss (Fig. 1B).
After 3-weeks from initial washout, fractures k-wires stabilization and skin closure, the x-ray confirm the dorsal bony loss and dorsal skin necrosis over the fracture was noted (Fig. 2 A-B). Treatment options were discussed with the patient, including terminalization versus reconstruction with either non-vascularized bone graft or vascularized composite flap. Because of the traumatic nature of the injury and the extent of contamination, vascu-

Pervenuto in Redazione Maggio 2020. Accettato per la pubblicazione Giugno 2020
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larized composite flap including metacarpal periosteum was elected as the most appropriate option for a hypotetical regenerative potential. We decided to postpone the tendon reconstruction to a third procedure on the base of the high risk of infection. The procedure was programmed as elective surgery under brachial plexus anesthesia.

Under tourniquet control, the proximal phalanx skin defect was explored and wash out from non-viable soft tissue. Both extensor tendon and partial dorsal bone were missing. The defect was templated and then the pcDMCAr flap was performed. Longitudinal skin incisions were made along the length of the third metacarpal bone, as seen in Fig. 3 A. With retraction and preservation of the common extensor tendons to the middle finger and sensory branches of the radial nerve, identification and dissection of the 3° dorsal metacarpal artery (DMA) and its comitant veins was performed from proximal to distal according to Maryuama technique. The DMA was ligated proximally and a composite flap measuring 8x2 cm was elevated including a strip of interosseus muscle and dorsal aspect of the third metacarpal periosteum. The flap was dissected until the level of the distal anastomoses between the palmar and dorsal metacarpal arteries in the web space and then rotated of 180° on its DMA pedicle as a reverse flap. Tourniquet was released to confirm vascularity of the flap. Fig. 3 B-D shows the pcDMCAr flap raised and resultant donor defect in the third metacarpal space.

Fig. 3 D illustrates the dimension and the arch of rotation of the vascularized composite flap. The skin island covered almost the fifth percent of the gap while all around the wound was left for secondary intention healing. There was uncomplicated direct closure of the recipient site. The position of the k-wires inside the fracture previously treated was confirmed by intraoperative imaging. The patient was splinted with metacarpo-phalangeal and interphalangeal joints in extension to limit tension on the vascular pedicle.

Fig. 1: (A) Hand trauma at admission: THUMB with exposed interphalangeal joint; INDEX FINGER with amputation at middle phalanx head, artery and nerve not adequate for replantation; MIDDLE FINGER with critically dorsal flap wound and exposed P1 fracture with bone dorsal loss; RING FINGER with exposed unstable distal interphalngeal joint luxation unstable. (B) Radiography at admission shows the fracture at proximal phalanx level of the middle finger with a dorsal bone loss

Fig. 2: Radiography series checked at 21-days shows a good axiality of P1 of the middle finger with a moderate bone dorsal loss (A) Posteroanterior projection (B) Lateral projection

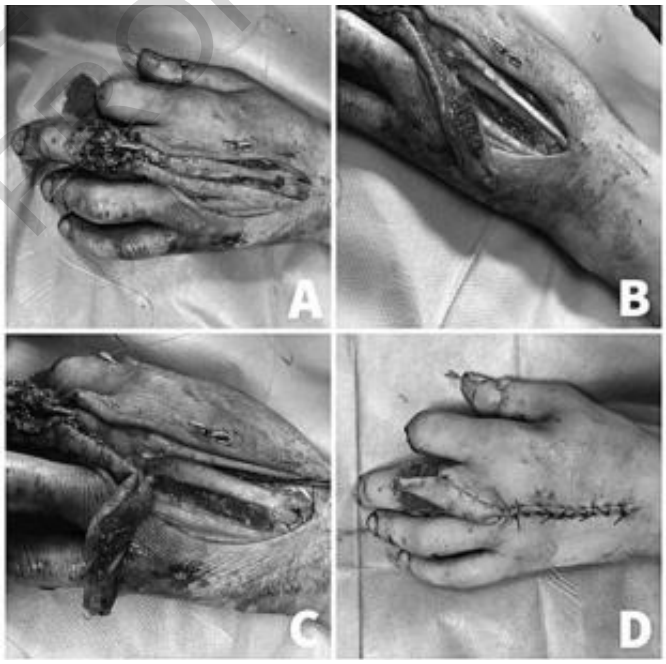

Fig. 3: (A) K-wires exposition at the fracture level after dorsal skin necrosis debridement. (B) Periosteal composite dorsal metacarpal artery reverse flap (pcDMCAr) harvesting. (C) Proximal section of DMCA detail. (D) pcDMCAr insetting and final result

Fig. 4: Radiography series at 30-days since admission (A-C) and 180-days after reconstruction surgery (B-D)

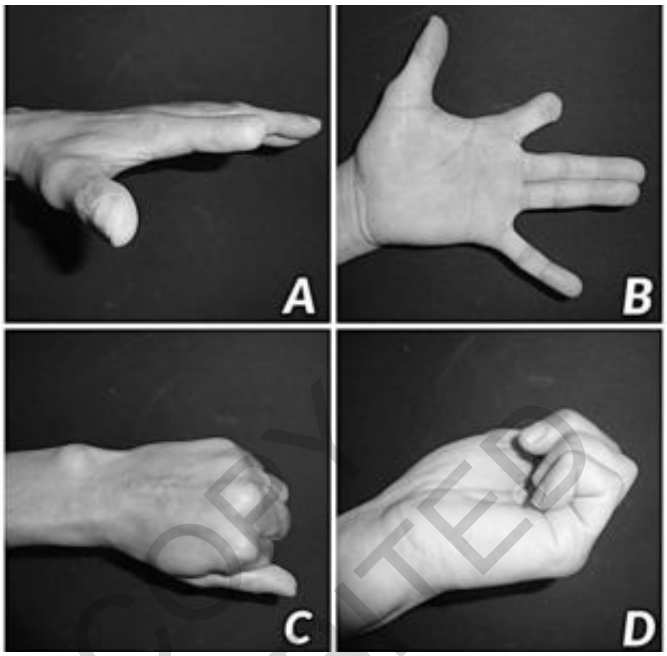

Fig. 5: 6-months follow-up (A) Lateral view in complete extension. (B) Posterior view in complete extension. (C) Anterior view in complete flexion. (D) Lateral view in complete flexion.

The patient was kept in hospital with hand elevated and discharged home after 4 days with close follow-up. Postoperative immobilization was planned for four weeks. Soft-tissue healing was obtained after 45 days from surgery. Two months after surgery, bone regeneration was assessed with x ray and the K-wires were removed. Mobilization was begun immediately after, performed by our hand therapists. Postoperative clinical follow-up for 6 months confirmed bone stability and good alignment. Functionally, the patient regained the ability to flex the middle finger to 100° but was unabled to extend completely the proximal interphalangeal joint (lag of 45°) for the loss of the extensor tendon apparatus (Fig. 4). Nevertheless he achieved forceful and stable distal pinch grip with a ready back to work. For this reason the patient do not accept the tendon reconstruction procedure proposed.

Discussion

Soft tissue defects of the fingers with exposed tendons, bones or joints are frequently encountered in reconstructive hand surgery. Numerous techniques of soft tissue reconstruction of the hand have been described in the literature and a wide selection of traditional local, regional and distant pedicle flaps is available so that the hand surgeon can choose from several techniques. The DMCA flaps, in particular, have gained in popularity and are well-established in reconstructive hand surgery.
The cutaneous vascular supply of the dorsum of the hand arises from perforators of the DMCA most commonly branching off the dorsal carpal arch and less commonly from the radial artery. Anastomotic networks between the dorsal and palmar metacarpal artery systems are also well described, found in most abundance distal to the conjoint tendon in the intermetacarpal space. The basis for reverse flow DMCA flaps is formed by the relationship between the DMCA and the palmar metacarpal arteries and their intermetacarpal anastomoses at the level of the metacarpal heads.
In 1990 Maryuama introduced the reverse DMCA flap, based on the dorsal metacarpal arteries II-IV [2], while Quaba and Davison described the 'distally based dorsal artery flap' based on the main palmar-dorsal perforator in the web space [3].
Since the initial publications, several modifications of the dorsal metacarpal artery flaps have been developed [4]. The extended distally based dorsal metacarpal artery flap introduced by Pelissier [5] is based on the first dorso-palmar perforator at the level of the web spaces in the proximal third of the proximal phalanges.
A procedure that allows reconstruction of complex defects with all vascularised components as segments of the extensor tendons or a metacarpal bone is described in the review of Gregory et al [1].
Bony defects are often managed in conjunction with overlying soft-tissue injury, aiming to maintain maximal viable length. Non-vascularized bone graft is a common method of reconstructing bony loss, harvested from iliac crest, distal radius, or olecranon. Vascularized bone graft may offer greater mechanical strength, reduced

resorption and infection rates, and early bony union [6]. DMCA flaps have progressed towards composite flap harvest with bone and tendon raised with the pedicle to assist more complex defect reconstruction, with these structures supplied by collaterals from the four DMCAs. The use vascularized bone grafts have been widely described for carpal reconstruction, but less for distal bony defects based on a reverse-flow system [7].
However there are no documented cases to the best of our knowledge demonstrating the use of periosteum for the coverage of small phalanx bone loss at the dorsum of the hand. During development, periosteum plays a prominent role in the radial growth of long bones and similarly, it has a key role in the consolidation of fractures. Its detachment from the bone surface reactivates its potential for fibrogenic and osteochondrogenic regeneration. The findings of several in vivo and in vitro experiments indicate that the maintenance of the periosteum's vascularization stimulates its quantitative potential [8]. The prefabrication technique is one of the most exciting areas in plastic surgery because of its bridging role between conventional reconstructive surgery and tissue engineering. A typical prefabrication procedure begins with the implantation of a vascular pedicled flap to an avascular receipt territory/construct. After a period of in vivo cultivation, the vascular pedicled flap will revascularize and even regenerate new tissue in the receipt territory/construct, allowing the prefabricated new flap to be transferred to any specified recipient site [9]. Therefore, we hypothesized that a functional bone graft could be favorited by using a pedicled periosteal flap.

Conclusions

This case showed that the pcDMCAr flap may be undertaken to reconstruct small bony loss in the distal phalanx. Although this case illustrates the use of this technique in the setting of trauma, its use could be translated to reconstruction of pathological defects in the distal digits.

Riassunto

Il lembo intermetacarpale basato su una delle arterie intermetacarpali dorsali, nella sua versione standard o estesa, è considerato una scelta affidabile e sicura per la copertura di perdite di sostanza complesse a livello dorsale delle dita lunghe della mani in presenza di esposizione tendinea e/o articolare e/o ossea. Obiettivo del lavoro è presentare una variante di questa tecnica chirurgica descrivendo il lembo intermetacarpale dorsale composito di tipo periostale (lembo pcDMCAr - periosteal composite DMCA reverse flap) particolarmente utile nelle situazioni in cui la frattura falangea conseguente al trauma risulti instabile e di difficile guarigione per mancanza di sostanza.
Un maschio di 35 anni riportò accidentalmente un trauma pluridigitale alla mano sinistra mediante l'utilizzo di una sega circolare. La lesione predominante più grave, dopo il primo intervento di stabilizzazione in urgenza, risultò essere a livello dorsale sulla falange prossimale con esposizione del focolaio di frattura, perdita ossea anteriore e presenza dei mezzi di sintesi esposti nella ferita. La nuova variante del lembo intermetacarpale nella sua versione estesa comprendente il periostio del terzo osso metacarpale aveva l'obiettivo di dare copertura alla frattura ossea con esposizione dei mezzi di sintesi e nello stesso tempo di creare un ambiente favorevole all'osteogenesi, alla rigenerazione ossea e quindi alla stabilizzazione. Il follow-up postoperatorio a 6 mesi dal trauma ha confermato la rigenerazione ossea e la buona stabilità e assialità del raggio.
Il lembo intermetacarpale dorsale nella sua variante periostea è una tecnica chirurgica semplice, breve e versatile che ben si adatta alla variabilità dei traumi della mano e che consente la copertura di difetti dorsali delle dita lunghe di tipo complesso in un unico tempo, con un buon risultato estetico e funzionale e con una minima morbidità del sito donatore.

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