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Original Research Article

Soft tissue reconstruction of low voltage electric burn injuries of the thumb and first web space by the first dorsal metacarpal artery island flap: a three-year study from Eastern India

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ABSTRACT

Background: Complex soft tissue defects of thumb and first web space are a reconstructive challenge. Low voltage electric burns of the hand commonly result in localised and deep soft tissue destruction. The first dorsal metacarpal artery flap (FDMA) is an attractive local flap option to reconstruct these. This study illustrates our experience with the same.
Methods: Between March 2014 and February 2017, 16 patients with complex soft tissue defects of thumb and first web space resulting from low voltage electric burns underwent reconstruction with the FDMA flap and subsequent structured hand therapy. In the follow up visits objective assessment of hand function included tests of mobility using Kapandji Score, sensory evaluation with static 2 point discrimination and cortical reorientation. The Subjective Satisfaction Score was used to ascertain the patient's overall perception of aesthetic and functional outcome.
Results: Majority (43.75%) of the patients had defects involving the thumb IP joint. No case of complete flap failure was noted. In a mean follow-up of 11.5 months the reconstructed thumb showed return of good protective sensation as well as mobility. Though cortical reorientation was complete in only 18.75 %, it did not substantially impede hand functioning. All patients were satisfied with the functional and aesthetic result.
Conclusions: In cases of low voltage electric burn injuries the FDMA flap is a reliable reconstructive option for small to moderate sized complex defects of thumb and first web space. It has minimal donor site morbidity and can be accomplished in a relatively simple single stage procedure.

Keywords: Electric burn, First web, Flap, Thumb

INTRODUCTION

Soft tissue injuries of the thumb can be significantly disabling and seriously impede activities of daily living. 40% of the total hand function is attributed to the thumb.[1] This requires an opposable thumb with stable, sensate soft tissue cover.[2] Moreover, to facilitate the full range of thumb opposition the first web space should be adequately spanned and have a stable, thin and pliable skin cover. Low voltage (<1000 Kv) electric burn injuries are usually sustained accidentally while handling household or workplace wires and cables with faulty insulation. These almost exclusively involve either the hands or oral cavity and result in very deep but localised burns which can result in exposure of tendons, joints or bones in case of thumb or severe adduction contracture in case of first web space.[3] Prompt resurfacing of the defect following excision of all necrotic tissue is essential to allow early mobilisation and optimum recovery of hand function.[4] But reconstruction should also not be too early

as it can cause insufficient excision of non-viable tissue due to ongoing microvascular damage or can lead to unwarranted removal of potentially salvageable tissue.[5] A couple of important factors dictating optimal reconstructive option are the exposure of deeper structures and availability of healthy local or regional tissue. If the resulting defect is limited to superficial soft tissue loss, a skin graft for coverage may suffice. Local tissue rearrangements like Z-plasty and its modifications are only applicable in case of availability of healthy, pliable surrounding skin. However, if there is exposure of the deeper structures or extensive damage to local tissue, as in cases of low voltage electric burn injuries, the defect must be resurfaced with vascularised flaps.[6]

Various such flap options include the Moberg advancement flap, sensate cross-finger flap, Littler's neurovascular island flap, first dorsal metacarpal artery flap (FDMA), reversed radial forearm flap, distant flaps and free flaps from the first and second toes and web space of the foot.[7-13] The cross-finger and distant flaps are two-staged procedures and can result in significant hand stiffness. The Moberg flap, described in 1964, is only useful to cover small (up to 1.5 cm) thumb tip defects. Littler's neurovascular island flap, described in 1953, is harvested from the ulnar aspect of the ring or middle finger and hence, involve more extensive and complicated dissection across the digits and palm. Reversed radial forearm flap sacrifices one of the two main arteries of the hand. Free flap reconstruction using tissue from the foot was first described in 1978-'79.It is best reserved for defects not amenable to local or regional flap coverage as it requires prolonged surgery and expertise in microsurgical techniques.

The FDMA flap was first reported by Hilgenfeldt in 1961 and Hollevich in 1963 as a heterodigital peninsular flap with preservation of the skin bridge over the pedicle. The islanded flap, proximally based on a pedicle containing the first dorsal metacarpal artery and accompanying veins was described by Foucher and Braun in 1979.[13,14] This flap was rendered sensate by incorporating a branch of radial sensory nerve. This is a reliable, simple regional flap option which can potentially circumvent all the disadvantages mentioned earlier with the alternative techniques. The first dorsal metacarpal artery has a relatively constant anatomy originating from the radial artery in the first intermetacarpal space just proximal to the point where it plunges between the two heads of the first dorsal interosseous muscle.[16-18] The artery runs above the first dorsal interosseous muscle fascia in 57% of cases, while taking a subfascial course in the rest. After it trifurcates the ulnar branch supplies the index finger while the other two travel to the first web space and thumb.[16] The ulnar branch runs between the shaft of the second metacarpal and the ulnar head of the first dorsal interosseous muscle until it reaches the metacarpophalangeal (MCP) joint, where it anastomoses with the branches of the second dorsal and palmer metacarpal arteries. Thereafter, it ramifies into a leash of small blood vessels that feed the subdermal plexus on the dorsal aspect of index proximal phalanx. The artery is accompanied by two venae comitantes that connect with large superficial veins in the first intermetacarpal space.[17]

This study was designed to evaluate the effectiveness of this flap with a reasonably well defined and predictable anatomy in reconstruction of thumb and first web space defects resulting from low voltage electric burn injuries in a tertiary care hospital setting in Eastern India.

METHODS

This prospective study was performed between March 2014 and February 2017. Patients presenting to the Department of Plastic Surgery at the Medical College and Hospital, Kolkata, India with complex soft tissue defects of the thumb and first web space resulting from low voltage electric burn injuries were included in the study. Exclusion criteria involved children <6 years of age (for difficulty in assessing and interpreting outcomes in this age group) and patients lost to follow up before 6 months.[19] Approval was obtained from the Institutional Ethics Committee for Human Research and written informed consent was procured from all patients.

Patients were operated under either general or regional anaesthesia. The adequacy of the first dorsal metacarpal artery was assessed pre-operatively using an 8 MHz hand-held doppler probe. The flap paddle was planned in reverse with the help of a defect template. The skin island of the flap was kept within the confines of the two mid-axial lines over the dorsum of the index finger proximal phalanx.

The proximal and distal flap paddle limits were maintained to the MCP and proximal inter-phalangeal (PIP) joint creases respectively (except in one patient with large pulp defect where we utilised an extended flap design incorporating skin from the middle phalanx as well).A line was drawn from the proximo-radial corner of the flap paddle just radial to the second metacarpal in a lazy-S fashion up to the apex of the first web space, which represents the pivot point. The dissection was performed under pneumatic tourniquet control set at 200-250 mmHg pressure. The skin flaps were elevated in the subdermal plane preserving the large subcutaneous veins. The flap was elevated distal to proximal and from ulnar to radial side preserving the paratenon to ensure free gliding of the extensor tendon and skin graft take. The pedicle was then dissected towards the pivot point incorporating the extensor hood at the radial aspect of the MCP joint, the periosteum of the radial shaft of the second metacarpal and the first dorsal interosseous muscle fascia to avoid any inadvertent injury. The dorsal sensory branch from the radial nerve was included in the flap, having been identified while entering the flap paddle radial to the MCP joint and superficial to the extensor apparatus. Following completion of flap elevation, the tourniquet was released, the flap vascularity assessed and

hemostasis ensured. The flap was then passed through a tension- free subcutaneous tunnel, either open or closed, to the defect and sutured with insetting stitches. The index finger donor site defect was covered with a full-thickness skin graft obtained from the groin. The skin graft was covered with a non-adherent dressing and overlying bolster; a bulky dressing was then applied to the entire hand along with a volar splint in neutral position. A window over the distal tip of the flap was kept open to allow flap monitoring.

All flaps were monitored for early complications of hematoma, partial/complete necrosis, wound infection or dehiscence. The full thickness skin graft at the donor site was checked following removal of the bolster dressing after 7 days. Guarded supervised passive and active mobilisation was permitted from the seventh post-operative day under care of our dedicated physiotherapy team and continued for six months. The patients were followed up in the outpatient department monthly for the first three months and three monthly thereafter.

At the clinic follow-up appointments the sensation was examined by static 2 point discrimination test (s2-PD). Cortical reorientation was assessed by asking whether the patient was able to trace pin-prick sensation back to thumb or index finger (C= complete, I= incomplete). The mobility of the reconstructed thumb (opposition) was assessed by the Kapandji score (Table 1).[20] Subjective Satisfaction Score was assessed by using a visual analogue scale (1-10: 1 being extremely dissatisfied to 10 being extremely satisfied).

Table 1: Kapandji score.

Kapandji score	Level of thumb opposition	Number of patients
1	Radial side of the proximal phalanx of index finger	0
2	Radial side of the middle phalanx of index finger	0
3	Tip of index finger	0
4	Tip of middle finger	0
5	Tip of ring finger	0
6	Tip of little finger	3
7	Dip joint crease of little finger	5
8	Pip joint crease of little finger	6
9	MCP joint crease of little finger	2
10	Distal palmer crease	0

The data were tabulated and interpreted using standard statistical tests and a value of $p<0.05$ was considered statistically significant.

RESULTS

From March 2014 to February 2017, 16 patients between the age of 6 and 46 years (mean 23.75 years) were operated on, of whom 11 were male (Figure 1). 10 patients were operated on within the first 6 weeks of sustaining the injury (after initial debridement of eschar); the rest had delayed presentation after having developed contracture of the interphalangeal (IP)/MCP joints or the first web space and required simultaneous contracture release and resurfacing. All patients had defects over their dominant hand (right in 13 and left in 3).

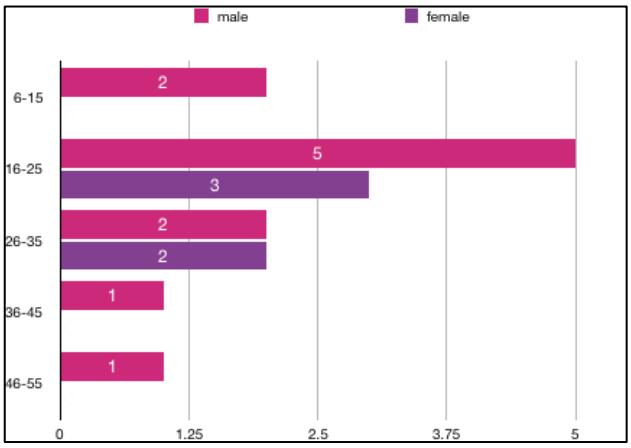

Figure 1: Patient demographics.
Y-axis denoting the age ranges in years, X-axis denoting the number of patients (male/female).

Figures 2-5 depict clinical photographs of 5 patients from our series. Most of the patients had the site of defect at the thumb IP joint (43.75%) which was significantly higher than the rest (Figure 6). Overall, 12 patients had defects over the thumb (including IP joint, MCP joint and, pulp) and 4 had it over the first web space.13 patients had exposure of the underlying bones, joints or tendons. The defect size ranged from 22×16 mm to 42×20 mm. The donor defect was resurfaced with full thickness skin graft in all cases. The mean duration of surgery was 82.75 minutes (range 70-100 minutes). The mean duration of follow-up was 11.5 months (range 6-15 months). Only 1 patient had marginal flap necrosis which was not significant statistically ($p>0.05$) and was managed conservatively. The outcomes have been charted in Figure 7. As per Kapandji score (Table 1) most of the patients had thumb opposition up to the PIP joint crease of the little finger (37.5%) followed by distal interphalangeal (DIP) joint crease of the same (31.25%). The mean (mean±SD) Kapandji score was 7.33 over10 (7.33±0.90). 13 out of 16 patients achieved painless opposition up to a minimum of the DIP joint of little finger (Kapandji Score 7 or more), which was statistically significant. The mean (mean±SD) s2-PD was 8.33 (8.33±2.06) mm (range 6 - 12 mm). In 3 patients (18.75%) cortical reorientation was complete, whereas in the rest it was incompletely achieved. The mean (mean±SD) overall Subjective Satisfaction Score was

7.67 (7.67±0.72) with a range from 6 to 9. Most of the patients (87.5%) had subjective satisfaction score between 7 and 8 which was significantly higher ($p<0.05$).

Figure 2: 32 year female with post electric burn defect over left thumb dorsum: top left- pre-operative; top right- flap planning and Doppler assessment; bottom left- flap elevation; bottom right- flap inset and donor site grafting.

Figure 3: 6 year boy with post-electric burn adduction contracture right hand first web space with ulcer: top left- pre-operative with flap planning; top right- flap elevated; bottom left- flap inset and donor site grafting; bottom right- flap inset volar view with web span demonstration following contracture release.

Figure 4: a) 21 year female with post electric burn severe flexion contracture right thumb IPJ along with flexion contracture index PIPJ: top left- pre-operative; top middle- contractures released with elevation of FDMA flap and cross-finger flap from long finger middle phalanx; top right- both flaps inset and donor areas skin grafted. b) 16 year male with post electric burn flexion contracture left thumb IPJ: top left- pre-operative; top middle and right- 3 month follow up showing good opposition and thumb function.

Figure 5: 28 year male with post electric burn defect over right (dominant) thumb MPJ: top left- pre-operative; top right and bottom left - flap elevation and tunnelling; bottom right- flap inset.

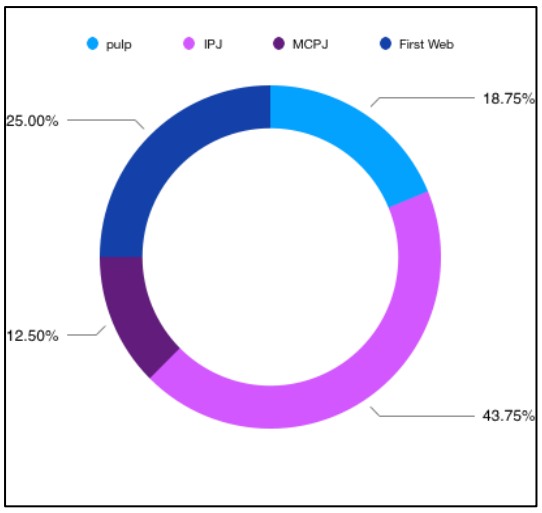

Figure 6: The relative proportion for the site of the defect.

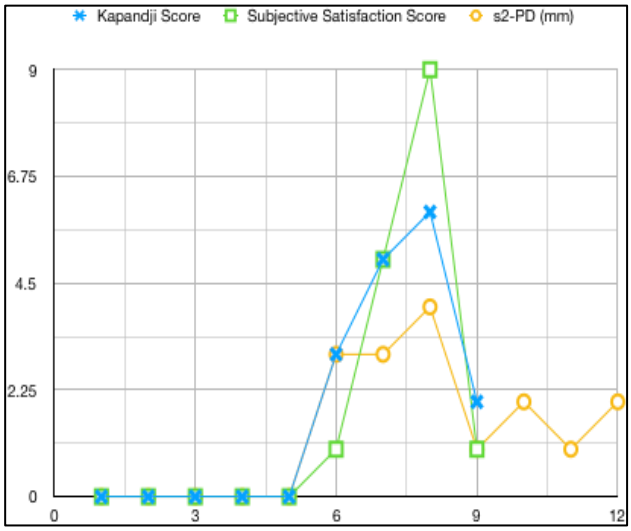

Figure 7: Outcome measures.

X-axis denoting the scores/measures as outlined in the legend; Y-axis denoting the number of patients.

DISCUSSION

Electrical burn injury is a significant cause of morbidity in the developing parts of the world.[21] Low voltage electrical burn of the hand is commonly seen in children under 5 years of age.[22] However, in our patient population, such trauma to the dominant hand in older children and young adults sustained from handling household or workplace wirings with faulty insulation is encountered with reasonable frequency. Extensive defects of the thumb and first web space with the exposure of tendon, bone or joint are challenging reconstructive problems because of the paucity of locally or regionally available appropriate soft tissue. The main goals of thumb reconstruction are the preservation of length and sensation while maintaining mobility and stable skin cover. Surgical treatment options of complex defects include local, regional and free flaps, as discussed earlier.

The low voltage electrical burns of hand, as seen in our patient group, are usually localised deep wounds involving the thumb and first web space that either leads to exposure of deeper structures or severe joint and web contracture. However, the dorsum of the index finger is usually spared making this site a viable flap donor option with similarly textured regional tissue from the hand.

The FDMA flap has a wide arc of rotation around its pivot point and easily reaches the volar and dorsal aspects of thumb, thumb pulp and first web space. The venous drainage via the concomitant veins is very reliable provided the superficial veins are included in the pedicle. The potential flap paddle is quite sizeable and the donor site morbidity is low. Being a single stage procedure it allows for early hand mobilisation and hence, results in less stiffness.

Following the initial description by Foucher and Braun, the use of the FDMA flap to cover extensive pulp defects in the normal-length thumb was first described by Ratcliffe et al.[15,23] In a study of 23 patients, Sherif reported the use of FDMA flaps to resurface defects of the first web space, thumb palmar and dorsal aspects as well as the dorsal surface of the hand.[24] Eski et al subsequently described its use in treating 14 post-burn thumb contracture.[25] Although the first dorsal metacarpal artery supplies only the skin cover over the proximal phalanx of index finger, the dorsal skin over the middle phalanx can potentially be incorporated in the flap design as a random pattern extension based on the rich dermal–subdermal plexus. Based on this principle, El-Khatib reported his clinical experience with the extended first dorsal metacarpal artery island flap providing coverage of total palmar or dorsal defects of a normal length thumb.[26] This study reported promising results, albeit involving only 5 patients. Important concerns about neurovascular island flaps include the problems of cortical reorientation and the dual-location phenomenon. This refers to the condition when the brain recognises a sensory stimulus from the flap area as one originating from the recipient and not from the donor digit. This adaptation takes some time, but is usually complete after a couple of years. If, however, the patient wishes, this can be corrected surgically with a technique (débranchement–rébranchement) described by Foucher, which involves anastomosing the transected nerve of the transposed island flap to the native digital nerve of the thumb. Shun-Cheng et al followed up eight patients with extensive pulp defects of the thumb over a period of 3 years after reconstruction with FDMA flap.[28] Skin defects in all these patients were associated with bone, joint, or tendon exposure. All flaps survived completely.[27] The s2-PD of the flaps ranged from 6 to 14 mm, and the patients needed 4-8 months to reorient the flap to the new site. Ege et al in their article found that the average subjective satisfaction score was 8.37/10 with all their patients using the reconstructed thumb in daily activities, except for one with a low IQ.[29`]

In our series 16 patients with soft tissue defects over the palmar and dorsal aspects of the normal length thumb, including the thumb pulp, as well as the first web space were successfully resurfaced with the FDMA flap. All of our patients were children or young adults who sustained accidental low voltage electric burns to the dominant thumb or first web space. All of these patients had complex or very deep injuries necessitating flap cover. In all these cases the dorsum of the index proximal phalanx was completely unaffected by the injury. The FDMA flap was thus considered an ideal reconstructive option. Flap survival in all but 1 case was excellent. Our only patient with marginal (tip) necrosis had a large pulp defect where we used the extended flap design as advocated by El-Khatib.[26]

However, this complication did not warrant any operative intervention and eventually healed with conservative wound care with acceptable cosmetic and functional outcome. In all the cases the donor site skin graft healed uneventfully. Our mean duration of follow up was 11.5 months, during which time the cortical reorientation was complete in 3 out of the 16 patients. The higher number of incomplete cortical reorientation may be attributed to a lack of long-term follow up. However, none of these 13 patients experienced any substantial hindrance to activities of daily living that could have warranted considering any further surgical correction of this condition. The mobility of the first ray, evaluated with the Kapandji score, showed good opposition of the reconstructed thumb. The grip strength was adequate in all patients. The return of protective sensation was also good in our study group and comparable to other series. All our patients were satisfied with the final functional and aesthetic results.

Our study concludes that the FDMA flap is a versatile option to cover soft tissue defects of the dorsal and volar aspects of the thumb, including the pulp and first web space. Especially in cases of low voltage electric burn injuries this is a very attractive regional flap option. In these injuries, it can resurface the complex defects with vascularised tissue and address potential joint or first web space contracture. It has the advantages of having a constant anatomy and ease of dissection. But our experience with the extended flap design has not been too encouraging. However, this being limited to just one case, cannot lead to a definite conclusion and warrants further studies. Being a single staged procedure, the flap has encouraged good patient compliance with follow up and physiotherapy, resulting in less hand stiffness. The donor site morbidity was low and overall functional and aesthetic results were satisfactory.

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