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PROSPECTIVE EVALUATION OF THE INNERVATED FIRST DORSAL METACARPAL ARTERY ISLAND FLAP FOR RECONSTRUCTION OF DEFECTS OF THE THUMB AND FIRST WEB SPACE

Plastic Surgery

Dr. M. Lopamudra* Assistant Professor, Department of Plastic Surgery, SCB Medical College, Cuttack, Odisha *Corresponding Author

Dr. Manabhanjan Jena Associate Professor, Department of Cardiology, IMS & SUM Hospital, Bhubaneswar, Odisha

ABSTRACT

BACKGROUND- Traumatic thumb injury results in a much more significant impact on daily activities than do injuries to the other digits. Daily tasks involving pinch, grip, grasp and precision handling are more easily accomplished with an opposable thumb. Restoration of sensibility after traumatic loss of the palmar and dorsal aspects of the thumb is of utmost importance for the usefulness of the hand. The First Dorsal Metacarpal Artery (FDMA) flap is an island pedicled flap proximally based on the first dorsal metacarpal artery and veins. A branch of radial sensory nerve is incorporated in the flap to make it sensate. In this study we have evaluated the effectiveness of FDMA flap in reconstruction of various defects of the thumb and first web space.

METHODS- This is a prospective study including 20 patients presenting with defects on the dorsal and volar aspects of thumb and first web space in a tertiary care hospital in eastern India. All defects were reconstructed with a sensate FDMA flap in a single stage over a period of 2 years.

RESULTS-The FDMA flap provided a thin, pliable and stable coverage of all the soft tissue defects around the thumb and first web space. No case of complete flap failure was noted. The sensory function was evaluated with static two point discrimination (mean value 12.77 mm). The mobility of the first ray was evaluated with Kapandji score which was found to be 7.95 over 10, reflecting a good opposition of the reconstructed thumb. The grip strength was also adequate in all patients. The subjective satisfaction score was 7.25 over 10.

CONCLUSION- The FDMA flap is a reliable heterodigital neurovascular island pedicled flap for reconstruction of soft tissue defects around the thumb and first web space, offering acceptable functional and aesthetic outcomes with minimal donor site morbidity. It provides pliable, durable and sensate coverage in a single stage procedure.

KEYWORDS

thumb, first web, neurovascular island flap

INTRODUCTION

Traumatic thumb injury results in a much more significant impact on daily activities than do injuries to the other digits. The thumb provides approximately 40% of the hand function. By far the most common cause necessitating thumb reconstruction is trauma (sharp cut, avulsion or crush). Other insults resulting in thumb tissue loss requiring reconstruction include burn (thermal, electric or chemical), infection and neoplasm. The thumb is used in virtually all activities that involve the arm and hand (Smutz et al.[1])Daily tasks involving pinch, grip, grasp and precision handling are more conveniently accomplished with an opposable thumb. Coverage of soft tissue defects on the digitspose difficulty due to the paucity of locally available flap options. Moreover, exposure of the deeper structures such as joint, bones or tendons requires a reliable technique for prompt, stable coverage. Restoration of sensibility after traumatic loss of the palmar aspect of the thumb is of utmost importance for the usefulness of the hand (Trankle et al.[2])

Innovations in skin flap design have led to a gradual evolution in the use of flaps in hand surgery. The development of the heterodigital island flap by Littler (Littler[3]) in 1956 was an important step forward in that surgeons could now transfer a skin island based on a specific neurovascular pedicle. Many island flaps were subsequently developed, including the FDMA flap (also known as kite flap), described by Foucher and Braun[4] in 1979.Flaps could now be transposed, rotated, or advanced into a defect based on a predictable blood supply. Refinements in island flap design wasalso brought about by a better appreciation of the vascular communications between the volar and dorsal vascular networks of the hand and digits. Key advantages of these flaps include single stage reconstruction, straightforward elevation and low donor site morbidity (Karacalar[5]).

The FDMA Flap is an island pedicled flap proximally based on the first dorsal metacarpal artery and veins. A branch of radial sensory nerve is incorporated in the flap to make it sensate (Pederson[7]).

Our study was designed to evaluate the effectiveness of FDMA flap in reconstruction of various defects of the thumb and first web space in a tertiary care hospital setting in Eastern India. Moreover, this study was aimed at evaluation of the donor site morbidity of the index finger, comparing the function of the reconstructed hand with its counterpart and assessing the sensation, mobility as well as aesthetics of the affected thumb and first web space.

METHODS

A prospective study was designed with subjects aged between 1 and 65 years of both the genders. Appropriate approval was obtained from the Institutional Ethics Committee for Human Research. The study period was from January 2015- December 2016. The study population included all patients admitted in the afore-mentioned period with defects on the dorsal and volar aspects of thumb and the first web space using the convenience sampling method.

Patients with trauma, burn or irradiation around the anatomical snuff box and index finger of the affected hand or those without any detectable good quality doppler signal by 8MHz hand-held probe at the apex of first web space were excluded from the study.

Pre-operative evaluation-All patients were provided with detailed information sheet regarding the proposed procedure and a written informed consent was obtained. Relevant history and clinical examination findings, including the site, size and complexity of the defect, pre-operative mobility and sensation of the hand and the donor index finger were noted. Pre-operative photographs were recorded for comparison following reconstruction and rehabilitation. A predetermined proforma was decided on to tabulate the various data collected for analysis.

Surgical technique -All the patients were operated on by a single senior plastic surgeon under brachial plexus block. Thorough debridement was done and exact dimensions of the defect noted. The adequacy of the first dorsal metacarpal artery was assessed pre-operatively using an 8 MHz hand-held doppler probe. The flap paddle location was determined by planning in reverse with the help of a defect template. The skin island of the flap was designed over the dorsum of the index finger proximal phalanx.The metacarpo-phalangeal (MCP) and proximal inter-phalangeal (PIP) joints represented the proximal and distal limits of the skin island respectively. The flap territory extended between the radial and ulnar mid-lateral lines on either side of the proximal phalanx of the index finger. After the outlines of the skin island were marked, a line was drawn along the radial border of the second metacarpal in a zig-zag or lazy-S fashion, beginning from the proximal-radial edge of the base of the skin island and extending proximally up to the apex of the first web space, which represents the most proximal point of the pedicle dissection. This point represents the pivot point of the flap. In order to

predict the flap reach, the maximum rotation arc of the flap design was estimated by measuring the distance of the index PIP joint from this pivot point. The dissectionwas performedunder tourniquet ischemia. Because it is recommended to include a large subcutaneous vein in the subcutaneous pedicle, the skin flap elevation was continued along the radial aspect of the second metacarpal. The vascularity of the flap was maintained by incorporating the fascia overlying the musculo-osseous groove in the pedicle. Because the ulnar branch of the FDMA usually sticks to this fascia, this method avoids the need for meticulous tedious dissection of the artery. The dorsal cutaneous branch from the radial nerve was included in the flap for obtaining sensory restoration. The nerve can easily be identified while it enters the flap lateral to the MCP joint and superficial to the extensor apparatus. Great care was taken not to violate the paratenon over the extensor hood to secure the take of the skin graft for reconstruction of the donor site. Another modification in our flap elevation technique involved inclusion of a small strip of the extensor hood on the radial aspect of the index MCP joint to protect the delicate vascular leash reaching the skin island from the pedicle. Following completion of flap elevation, the tourniquet was released and the flap vascularity assessed. As an island sensory flap, the FDMA flap has a pedicle length up to 7 cm, allowing a wide arc of rotation, and has proved to be very useful in resurfacing pulp defects of the thumb. The flap was then passed through a subcutaneous tunnel (open or closed) to the defect and sutured with insetting stitches. The index finger dorsal donor site defect was covered with a full-thickness skin graft obtained from the ipsilateral medial arm. The skin graft was covered with a non-adherent dressing and overlying bolster; a bulky dressing was then applied to the entire hand. A window over the distal tip of the flap was kept open to allow flap monitoring.

Post-operative care and rehabilitation- the flap was regularly monitored using the usual clinical parameters in vogue including colour, temperature, turgor and capillary refill time. The full thickness skin graft at the donor site was evaluated following removal of the bolster dressing after 7 days. Guarded supervised passive and active mobilization was permitted from the seventh post-operative day. The patients were discharged and followed up in the outpatient department weekly in the first month, fortnightly in the second month and monthly thereafter. They received regular input from the hand therapists in the following 6 months in order to restore maximal functionality and minimize pain and stiffness.

Follow up-At the clinic follow-up appointments the sensory restoration over the reconstructed site was primarily examined by static two-point discrimination(mm).Patient satisfaction with the reconstruction was assessed by using Subjective Satisfaction Scores(calculated in a Visual analogue Scale with following score interpretation: 8-10=extremely satisfied, 5-7= satisfied, 3-5 = satisfied to some extent, 1-3= dissatisfied). The other specific parameters recorded include flap/donor site complications,flap and donor site paresthesia (scale 0-4; 0 = no paresthesia, 4 = severe paresthesia), cortical reorientation(C= complete, I= incomplete), pain in flap and donor site (scale 0-10; 0 = no pain, 10 = maximal imaginable pain), flap and donor site aesthesis (scale 0-10; 0= worst result, 10= best result).The mobility of the reconstructed thumb (opposition) was assessed by the Kapandji score as shown in Table**.**

The data collected was analysedwith the help of Epi Info (TM) 3.5.3 software. Descriptive statistical analysis was performed to calculate the means with corresponding standard deviations (S.D).Test of proportion was used to find the Standard Normal Deviate (Z) and chi-square (x^2) test was performed to find the associations. Corrected chi-square (x^2)test was used where any one of the cell frequencies was less than zero. The t-test was used to compare the means; a value of $p<0.05$ was taken to be statistically significant.

RESULTS

From January 2015 to December 2016, a total of 20 patients with soft tissue defects over the thumb and first web space underwent reconstruction using the FDMA flap. Table 1 depicts the patient demographics and pre-operative clinical parameters. The mean(mean±S.D.) age of the patients was 28 (28.00±11.96) years ;of whom 70% were males and 30% females.In 15 out of 20 patients the defect was over the dominant hand (right in 14 and left in 1).Most of the patients had the site of defect at the thumb IP joint (40%) which was significantly higher than the rest($Z=3.08$;$p=0.0021$).Overall, 16 patients had defect over the thumb (including IP joint, MCP joint, thumb tip, pulp and dorsum) and 4 had it over the first web space.13patients had exposure of the underlying bones, joints or tendons. In most of the cases the deformity was caused by electric burn (45%), with thermal burn (35%) being a close second($Z=4.49$; $p<0.0001$). In 1 of the cases the etiology was tumor excision and 3 followed infection. The defect size ranged from 30x14 mm to 45x31 mm. Elective surgery was done in all cases at a mean interval of 4 days from the time of presentation. The donor defect was resurfaced with full thickness skin graft in all cases. The mean duration of surgery (mean ± s.d.) was 42.5 (42.50±7.16) minutes. The mean duration of follow-up was 11.35 (11.35±4.86) months.Only 2 patients had flap tip necrosis which was not significant statistically ($Z=1.45$; $p=0.14$). 55% of the patients had paresthesia at the flap site. The mean paresthesia score at the flap site was 0.65 over 4. 90% of the patients had no paresthesia at the donor site. Only 10% had mild paresthesia. The mean paresthesia score of the donor site was 0.1 over 4. As per VAS the mean pain score at the site of the flap (mean ± s.d.) was 2.75 (2.75±1.71)and the same at the donor site was 2.25±1.3. The mean score of cosmetic satisfaction forboth the flap and the donor area was 7.20. As perKapandji score most of the patients had thumb oppositionupto the PIP joint crease of the little finger (35%) and MCP joint crease of the little finger (35%) followed by distal interphalangeal(DIP) joint crease of the same (20.0%) ($Z=2.37$).Only 2(10%) of the patients had thumb opposition to the tip of the little finger. The mean Kapandji score was 7.95 over 10 . The mean static 2 PD (mean ± s.d.) was 12.77±3.88 mm. In 3 patients(15%) cortical reorientation was complete, whereas in the rest it was incompletely achieved.The mean overall subjective satisfaction score (mean ± s.d.) was 7.25±0.96.

DISCUSSION

The FDMA flap is harvested from the dorsal aspect of the index finger including the first dorsal metacarpal artery with its concomitant veins and a branch of the superficial radial nerve as an neurovascular island pedicled flap. It was first described by Hilgenfeldt ,refined by Holevich[10] and modified as a pure island flap by Foucher and Braun[4]. It has a wide arc of rotation 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, the potential flap paddle is quite sizeable and the donor site morbidity is low.

Extensive defects of the thumb with the exposure of tendon, bone or joint are challenging reconstructive problems because of the paucity of locally available soft tissue. The main goals of thumb reconstruction are the preservation of length and sensibility while maintaining mobility. Surgical treatment includes the use of local, regional and free flaps. In 1953 Littler[3] described a neurovascular island flap, harvested from the ulnar aspect of the ring or middle finger. Various microsurgical free flaps from the first and second toe and web space of the foot were described as alternative solutions in 1978 and 1979. Defects of the proximal phalanx and the first web space can also be reconstructed with the posterior interosseous artery flap and the radial forearm flap, depending on the size of the defect.

Ratcliffe et al.[14] first described the use of the FDMA flap to cover extensive pulp defects in the normal-length thumb. Sherif[15] reported a study of 23 patients with FDMA flaps to resurface defects of the first web space, thumb palmar and dorsal surfaces and the dorsal surface of the hand. Eski et al.[16] described the use of this flap in treating 14 post-burn thumb contractures. Although the first dorsal metacarpal artery supplies only the proximal portion of the index finger, harvesting the dorsal skin over the middle phalanx as a random extension is possible because of the existence of the rich dermal–subdermal plexus supplying the dorsal skin of both segments. Based on this principle, El-Khatib[17] reported his clinical experience with the extended first dorsal metacarpal artery island flap for thumb reconstruction. This surgical procedure was created to provide composite resurfacing of total palmar or dorsal defects of a normal length thumb. In this study five cases were reported. Flap survival was excellent, and grafting at the donor site was successful in all. Important concerns about pedicled neurovascular island flaps include the dual-location phenomenon and the problems of cortical reorientation. Cortical reorientation is the fact that the brain recognizes a stimulus from the flap area as one originating from the recipient and not from the donor digit. This process takes some time, but is usually complete after 2 years. If, however, the patient wishes, this can be corrected surgically with a technique (débranchement–rébranchement) described by Foucher[18] which involves joining the divided nerve of the transferred island flap to the original nerve of the thumb. Shun-Cheng et al. [21] followed eight patients with extensive pulp defects of the thumb over a period of 3 years after reconstruction with FDMA flap. Skin defects in all these patients

were combined with bone, joint, or tendon exposure. All flaps survived completely. The eventual static 2-point discrimination of the flap ranged from 6 to 14 mm, and the patients needed 4–8 months to reorient the flap in the new location. Satish and Nema[19] studied 9 cases of thumb pulp defects over a period of 2 years. One peculiar problem encountered by them was the feeling of sensation of the flap coming from the dorsum of the index finger, which the patients learnt to adjust to over time (dual sensibility phenomenon).This cortical disorientation, however, did not persist and faded with time. Ege A et al [20] in their article found that the average subjective satisfaction score was 8.37/10 (range 4± 10). Twelve patients (60%) experienced cold intolerance, and 7 patients (33%) dysesthesia. All patients used their reconstructed thumb in daily activities, except for one who had a low IQ. Prabhu et al[21] studied 8 cases ,in 7 of whom the flap survived completely. The one with distal flap necrosis healed without any surgical intervention. Only one patient had an unstable scar at the donor site which required excision, grafting and pressure garment application. All patients returned back to normal activities within 6 weeks with no significant impairment of hand function.

In our series 20 patients with soft tissue defects over the palmar and dorsal aspects of the normal length thumb, including the thumb pulp and tip, as well as the first web space were successfully resurfaced with the FDMA flap. The defects followed a variety of etiological factors including burns (electrical and thermal), trauma , infection and tumor excision . We did not use the extended donor territory in any of our cases. The dubious viability of the distal part of the extended flap as well as the associated possibility of donor digit PIP joint stiffness resulting from scar contracture urged us to avoid this flap design modification. Flap survival in all but 2 cases was excellent. The 2 patients who had flap tip necrosis were both long-term smokers. This complication did not warrant any operative intervention and eventually healed conservatively with acceptable cosmetic and functional outcome. In all the cases the donor site skin graft healed uneventfully without any significant hypertrophic scarring. Our mean duration of follow up was 12 months during which the sensory and motor function restoration was evaluated. Donor (index) finger stiffness and hypertrophic scarring was noted in 6 patients which subsided with regular physiotherapy, scar massage and pressure garment use. The Pain and paresthesia over the flap and donor site were minimal which decreased with time. The sensory function was specifically evaluated with static two point discrimination, the mean value for which was 12.77 mm. The cortical reorientation was complete in 3 out of the 20 patients. However, in other cases ,partial cortical disorientation was not found to be disturbing and did not interfere with the daily activities.

The mobility of the first ray ,evaluated with the Kapandji score, showed good opposition of the reconstructed thumb. The grip strength was also adequate in all patients.The subjective satisfaction score was 7.25 over 10 which was fairly acceptable.

However, our study was limited by the fact that the duration of follow-up was not substantially long. Moreover, two of the patients were lost to follow up at around 6 months after the surgery.

It can be concluded from our study that the FDMA flap is a versatile means to cover the defects of the dorsal and volar aspects of the thumb and first web space. The flap is sensate, durable and can be extended to include the skin from the dorsum of the index finger middle phalanx if extensive defects need coverage.

It has the added advantage of a constant anatomy ,easy dissection and being a single-staged procedure. It has a low donor site morbidity and shows good functional and aesthetic results.

The main goal of the plastic surgeon facing a complex soft-tissue defect is to replace “like with like” tissue with minimal donor site morbidity .The FDMA flap, which allows the surgeon to accomplish this goal better, should serve as a valuable option for sensory resurfacing of the thumb.

Our good results further reinforce the value of this flap in achieving sensate reconstruction of thumb pulp defects. Other than that, it can also reconstruct virtually any other soft tissue defects of the thumb and the first web space maintaining an adequate web span and thumb abduction.

Fig.1- 29 year old male with post-infection defect over left (non- dominant) thumb (vide case no. 5 in table 1): top left- pre-operative; top right- flap elevated & tunnelled; middle left- flap inset & full thickness skin graft over donor site; middle right- 1 week post-operative; bottom left & right- 6 months post-operative

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