Dorsal pentagonal island flap to reconstruct post-burn interdigital web

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ABSTRACT

INTRODUCTION This study reports the use of a dorsal pentagonal island flap for post-burn webbing contracture, in which the islanded flap is harvested from the burn scar tissue.

METHODS Fourteen dorsal pentagonal island flaps were harvested in seven patients with post-burn webbing. Each flap was selected by examining the scar tissue donor using a modified Vancouver scar scale. Modification from the basic design was made according to the density of the donor scar tissue and the metacarpophalangeal joint movement.

RESULTS All the flaps survived with normal abduction of the affected fingers. Modification of the flap design needed adjustment by assessing it through flexion and extension of the metacarpophalangeal joints. There was no incidence of web creep after two months to one year of follow-up.

CONCLUSION Dorsal pentagonal island flap shows promising results as an alternative for reconstructing post-burn webbing.

KEYWORDS

Burns – Cicatrix – Contracture – Hand – Syndactyly

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Introduction

Spanning the acute phase to the contracture sequelae, hand burn is a complicated injury to treat.¹ The resulting deformities could limit the hand functionality, which then determines the quality of life of burn survivors.² One of the most common deformities of the post-burn hand is interdigital webbing.³ The very versatile interdigital web spaces are crucial for the functionality of the hand.⁴

Many attempts to correct interdigital webbing in congenital syndactyly have been described,^{5–8} but there are few that focus on post-burn interdigital web reconstruction. In congenital syndactyly, the lack of skin can be easily overcome because of the high pliability of the skin and its connective tissue. On the other hand, the paucity of post-burn skin is complicated by the stiffness of the scars, which pose another challenge in reconstructing the post-burn interdigital web.^{3,4} Raw area to be grafted could increase the incidence of web creep more than in congenital syndactyly.⁹

The use of a dorsal pentagonal island flap was first described by Teoh and Lee in 2004 for the correction of congenital syndactyly.⁵ The dorsal pentagonal island flap is harvested based on the perforator originating from the dorsal metacarpal artery.^{10–12} The flap has been used in surgery for congenital syndactyly, but we accommodated the

flap for the correction of the post-burn interdigital web with some modifications to the flap design based on the pliability of the scar tissue and the related joint movement.

Methods

All cases were operated on by one senior hand surgeon between September 2016 and December 2017. The study fully implemented the principles outlined in the Declaration of Helsinki. Written consent was taken from all the subjects enrolled in this study. The selection of the dorsal pentagonal island flap was made by examining the donor site using modified Vancouver scar scale.¹³ The donor for dorsal pentagonal island flap could only be considered if the density of the scar was moderate or pliable.

Surgical approach

Surgical dissection was carried out with a tumescent technique to achieve clear surgical field. We used ‘one-per-mil’ tumescent solution, which was preferred over tourniquet as it could facilitate surgery lasting 6–14 hours without the need for a break every two hours had a tourniquet been applied.

In term of design, there are some anatomical landmarks to be addressed: the arch of the normal interdigital spaces,

Figure 1 The basic design of the dorsal pentagonal island flap. Three surgical landmarks in dorsal view: (i) the normal arch of the interdigital web spaces (yellow arrow); (ii) the mid-axis of each phalanx (green arrow); and (iii) the highest point on each knuckle when the metacarpophalangeal joint is flexed (blue arrow). In the palmar view, the zigzag incision was made in accordance with the zigzag incision of the dorsal side to be elevated as triangular flaps.

Figure 2 The distortion of the design based on the movement of the donor site at the metacarpophalangeal joints (case 3). The dorsal pentagonal island flap should follow the pliability of the donor site scar tissue while flexing (a and c) and extending the MCP joints (b and d). Sometimes the design had to be distorted in some way to accommodate the movement of the island flap (case 3).

the phalangeal mid-axis and the highest point of the knuckles (Fig 1). The pentagonal is designed between two metacarpal joint areas. The apex of the pentagonal is placed at the proximal from the metacarpal head level, while the laterolateral lines of the pentagonal do not necessarily reach the mid-axis of the phalanges. The base of the pentagonal is placed slightly over the interdigital web space. The zigzag incision is then made, starting from one of the bases of the pentagonal in the dorsal and volar planes of the syndactyly, as necessary.

Modifications were made to the original design as follows:

1. With regard to scar density, the scarred skin in the dorsal metacarpal had to be at least moderate or pliable according to modified VSS.¹³
2. In some cases, the design needed to be slightly shifted, which was guided by skin mobility when the metacarpophalangeal (MCP) joint was extending and flexing (Fig 2).
3. For multiple post-burn interdigital webbing which had moderate pliability score according to modified Vancouver scar scale, the flap would be made alternately with the rectangular or triangular advancement flap to avoid tension when closing the donor site primarily. On the other hand, multiple dorsal pentagonal flaps could be made that neighbored each other without tension in pliable scars (Fig 3).

Figure 3 Multiple pentagonal island flaps (case 1). According to the density to the donor scar tissue, the dorsal pentagonal islands could be made neighbouring to each other or alternately with rectangular advancement, as seen in Figure 2d.

Table 1 Characteristics of patients with post-burn interdigital webbing.

Case	Sex	Age (years)	Diagnosis	Web operated with dorsal pentagonal island flap	Island flaps (n)	Modified VSS score for the scar donor ¹³	Follow-up
1	M	24	Multiple webbing	2nd 3rd 4th	3	Density: pliable Density: pliable Density: pliable	1 year; the flap survived. Normal abduction was achieved. No scar hypertrophy but slight hypopigmentation was noted.
2	F	3	Multiple webbing with volar contracture of the fingers	2nd 3rd	2	No scar was found on the dorsal metacarpal skin No scar was found on the dorsal metacarpal skin	9 weeks; the flap survived and normal abduction was achieved. Hypertrophic scar was noted.
3	M	24	Multiple webbing with volar contracture of the fingers	2nd 4th	2	Density: pliable Density: moderate	10 weeks; the flap survived with normal abduction. No hypertrophy nor hypopigmentation.
4	F	23	Webbing	2nd	1	Density: moderate	8 weeks; the flap survived, with residual webbing and hypopigmentation. At 6 months after revision, no hypertrophic scar; normal abduction was achieved.
5	M	11	Webbing and contracture of the fingers; with peripheral ulnar paralysis	4th	1	Density: moderate	5 months; the flap survived; no hypertrophic scar. Finger abduction function could not be assessed due to peripheral ulnar paralysis.
6	M	3	Multiple webbing with volar contracture of the finger	3rd 4th	2	Density: moderate Density: moderate	5 months; the flap survived with normal abduction; no hypertrophic scar.
7	F	23	Multiple webbing	2nd 3rd 4th	3	Density: moderate Density: moderate Density: moderate	8 weeks; the flap survived with normal abduction; no hypertrophic scar.

F, female; M, male; VSS, Vancouver scar scale.

The fingers are separated after the pentagonal flap incision, from distal to proximal of both dorsal and volar sides through the zigzag incision. The pentagonal flap is then dissected and raised.

The dissection is deepened until all the scar tissue is released and the islanded flap can be moved to the designated position. Dissection should be cautious to ensure no undermining in the island flap to preserve perforator vessel, although it was not necessary to visualise or even skeletonise the perforator. The zigzag design should be dissected carefully and should be mirrored on the dorsal and volar sides while conserving the neurovascular bundle along the affected finger. Haemostasis is achieved using bipolar electrocautery.

A key suture is made at the mid-point of the pentagonal base after advancing the flap to the volar of the hand. Then the triangular flaps resulted from the zig-zag design, are sutured on the respected sides. Suturing is performed using 5-0 and 6-0 Polyglactin 910 in children to avoid the necessity of removal, while 4-0 and 5-0 polypropylene are used for adults.

Postoperative treatment

Immediately after surgery, the wound is covered with light dressing for seven days and petroleum jelly applied thereafter. The sutures are removed 10–14 days after surgery. Starting from the second week, soft splinting is applied at night for six months to prevent web creeping.

Results

Fourteen dorsal pentagonal island flaps were successfully harvested from seven cases (Table 1). With the aid of one-per-mil tumescent technique without tourniquet,¹⁵ all surgeries were conducted with a minimum to bloodless surgical field; thus, it was easy to dissect the tissue while avoiding any important structure.

Case histories

Case #1

A 24-year-old man who suffered a burn injury on the left hand 16 years prior to surgery had second, third, and fourth interdigital webbing and syndactylised fingers.

The scarred donor was pliable. A dorsal pentagonal island flap was designed for all the post-burn interdigital web contracture in the fingers (Fig 3). The dorsal pentagonal island flap was successfully advanced and each of the donor sites could be closed primarily without tension. Intraoperatively, the scar thickness was found to be moderate (3–5 mm). Congestion was found 24 hours after the surgery but subsided immediately without intervention. The suture was removed 10 days after the surgery. At one-year follow-up, the hand had returned to its previous abduction angle with no incidence of web creep. The scar appeared to be normotrophic and only slight hypopigmentation was noted.

Case #5

A 24-year-old man presented with severe contracture on his left hand 11 months after burn injury. The scar in his hand dorsum was categorised as moderate density. Interdigital web contracture was found between the second, third, and fourth fingers, with the addition of volar contracture of the second, third, fourth and fifth fingers.

The dorsal pentagonal island flap was harvested to reconstruct the second and fourth interdigital webs, while rectangular advancement flaps were used for the third web. Although the donor site for the third web reconstruction was sufficiently pliable to be designed as dorsal pentagonal island flap, rectangular advancement was chosen to prevent tension when the neighbouring donor sites for the second and fourth web dorsal pentagonal island flaps were closed primarily (Fig 2d). Interestingly, the design of the fourth web also had to be modified, as the flap needed

adjustment to reach the targeted volar site. It was obvious that the design moved radially when the MCP joints were extended, although it was correctly sited during flexion of the MCP joints. The design of the base of the pentagonal was therefore distorted laterally to accommodate correct movement (Fig 2a–d). On follow-up at 10 weeks, the webs were in good contour, accompanied with normal abduction. Although the fingers looked swollen by the pressure bandage to hold the soft pads for the webs, patient did not find that oedema prevented exercise (Fig 4a).

Figure 6 The nourishing vessel for dorsal pentagonal island flap showing the perforator artery (arrow). The wider areas where the dorsal pentagonal island flap can be observed (lower left); enlarged image of dorsal metacarpal perforator artery, along the yellow line (lower right).

Case #4
A 23-year-old woman suffered burn injury to the left hand 25 months before visiting the clinic. Interdigital webbing on the second finger was accompanied by first, third and fourth interdigital commissural contracture. The modified Vancouver scar scale for density of the donor site was pliable. The second interdigital webbing was overcome with a dorsal pentagonal islanded flap, while the first, third and fourth interdigital web commissural contracture was released with multiple Z-plasties. The islanded flap was successfully advanced to cover the web and the donor site was also successfully closed with minimal tension. Figure 5 shows the flap being transferred forward. There was no need for a skin graft as the defect could be closed seamlessly. At the eight-week-follow up, the flap had survived. The scar was observed to have residual webbing and was hypopigmented. Subsequently, minor secondary revision with Z-plasties was performed. The outcome was good at six months follow-up (Fig 4b and 4c).

Discussion

The histology of scar tissue and its vascular network has been described in various studies.^{15–18} Page *et al* observed that a mature scar of previous deep dermal burn had fewer blood vessels, smaller vessel diameter and less branching than in the normal subpapillary dermal plexus, based on histological study.¹⁵ This finding was the same in deep dermal burns that heal spontaneously or grafted. In 1991, Ehrlich *et al* employed laser Doppler flow monitor to measure the blood flow changes in healed burn scars.¹⁷

Figure 7 Representation of aesthetic outcomes. (a) The donor scar in case 4 did not look appealing because of the surrounding burn scar tissue. (b) The scar in case 2 stood out among the surrounding normal skin.

The study also found that blood flow in the burn scar was significantly decreased. Further evaluation also found that in normotrophic healed burn scar had 55–88% of the blood flow reading in normal skin. One study by Filippova *et al* suggested that the vessels in the burn scar tissue were compressed by the overabundance of collagen formation resulting in the reduced blood circulation.¹⁸ These findings lead to a paradigm that burn scar tissue has poor vascular network. Because of this reasoning, burn scar tissue has never been considered as a potential island flap donor because of the higher risk of flap loss due to vascular disturbance.

Contrary to this paradigm, the dorsal pentagonal island flap is not a random island flap that depends on the subdermal plexus. The flap is rather dependent on the perforator from the dorsal metacarpal artery. The perforator arises from the dorsal metacarpal arteries from the dorsal carpal arch, which lies deep to the extensor tendons at the level of the distal row of carpal bones. This perforator is approximately 1 cm proximal to the metacarpal heads and supplies the dorsal skin at the level of the neck of the second, third and fourth metacarpals (Fig 6).¹¹ The artery gives off its direct cutaneous branch and supplies the area between the two adjacent metacarpals skin until the proximal interphalangeal joint.¹²

Another aspect to consider in selecting dorsal pentagonal island flap over the rectangular advancement flap is the range of flap transfer. When using scar tissue as flap, the elasticity of the tissue is highly altered compare to normal tissue. Thus, by releasing the flap as islanded flap, the range of advancement could be greatly enhanced.

Examination of the donor scar to understand the probable condition beneath the scar is very important. The Vancouver scar scale is an effective method for evaluating scar condition, especially in the evaluation of the outcome of therapy.¹⁹ In the preoperative situation the density of the scar, which is assessed according to pliability in the Vancouver scar scale,¹⁵ is deemed to be sufficient to measure the potential of the scar to be the flap donor area. The more pliable the scar tissue the higher its potential to restore all interdigital web components: the interdigital fossa's depth, form, groove and the slant up to the metacarpal head level.³ In higher than moderate density, the scar tissue is too thick; even if it could be advanced to the recipient site, the interdigital web would be too thick and would limit finger movement, especially abduction. Therefore, the assessment using Vancouver scar scale is fundamental in surgical decision making.

Moderate pliability of the scar tissue was found in case 3. The fourth interdigital web contracture was yielding but it did not form a solid mass. In fact, the resistance was sufficiently hard that the donor scar tissue moved radially when the MCP joint was extended. The design then had to be adjusted accordingly to the direction of the recipient site.

In some multiple interdigital web cases, the pentagonal island flap should be used alternately with the rectangular advancement flap to avoid tension in the donor site, as

seen in case 3. The modification could be considered when the scar is moderate in pliability. However, the dorsal pentagonal island flap could be successfully placed adjacent to each other without tension of the donor site when the donor scar is pliable (case 1). Through this modification, it is advantageous to reconstruct multiple interdigital web contracture in one-stage surgery.

Although in reconstructive surgery the aesthetic aspect comes second in priority, one of the advantages of using the dorsal pentagonal island flap on scar tissue is that the resulting secondary scar on the donor site could easily mask the previous burn scar; thus, it would be less noticeable. For example, in case 4, hypopigmentation and slight hypertrophic of the wound scar was noted at eight-week follow-up, but it did not look prominent because of the surrounding scar tissue (Fig 7a). On the other hand, in case 2, where there was no scar tissue on the dorsal side of the hand, the hypertrophic scar stood out at the nine-week follow-up, resulting in less patient satisfaction (Fig 7b). Nevertheless, in all cases, the normal range of motion was achieved and there was no incidence of web creeping found.

Conclusion

The dorsal pentagonal island flap over scar tissue used as the donor could be promising technique and a reliable alternative in reconstructing the interdigital web for post-burn severe webbing. Modification from the basic design should be made accordingly based on the examination of the donor scar tissue using the density variable and the MCP joint movement prior to the surgery.

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