THE CLINICAL APPLICATION OF THE PROPELLER FLAP BASED ON THE DORSAL PERFORATOR OF PROPER DIGITAL ARTERY

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ABSTRACT

Objective*: To investigate the clinical effect of repairing the finger defects by applying the digital proper artery dorsal branch propeller flap.*

Methods: *From January, 2017 to January, 2019. 15fingers in 13cases with soft tissue defect were treated. Using the digital proper artery dorsal branch propeller flap was transferred to cover the defect.*

Results: *14fingers of the flaps successfully survived. Tension blisters of the flap and partial necrosis occurred in 1 case, and healed after dressing change. Donor sites healed without any complication. All cases were followed-up by 6-12 months, and the average time was 8months. The appearance and quality of the flaps were good. Two-point discrimination was7 to 11 mm on the flap. The range of motion of the metaearpophalangeal joints and interphalangeal joints was normal. According to the Upper Extremity Functional Evaluation Tentative Criteria set up by Hand Surgery Branch of Chinese Medical Association, 14 fingers were excellent, 2 fingers were good, and 1 finger was fair.*

Conclusion: *This procedure spares the proper digital artery and nerve, is a good method in repairing soft tissue defect of thumb tips due to its ease of operation, achievement of good blood circulation and good recovery of appearance and sensation after the surgery.*

Keywords: *Propeller flap, perforator flap, finger defect, surgical flap, digital artery.*

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Introduction

Cases of soft tissue defect of the distal segment of the finger are common in clinical practice, which are often accompanied by the exposure of bone and tendon, and entail higher repair requirements. Therefore, it has been a hot spot in clinical research to explore a flap with less damage in donor area and maximum appearance and functional recovery. Digital artery flap, proximal finger flap, abdominal pedicle flap and other traditional flaps have been the first choice for repair in some historical stages, but they were gradually relegated to the second choice because of their obvious deficiencies.

With the in-depth study of anatomy and the development of perforator flap, digital artery perforator flap has gradually become the first choice for repair because it does not sacrifice the main artery. In particular, the digital artery perforator propeller flap, which appeared in 2014, has been clinically recognized for its advantages of not only considering donor site, but also can ensuring that the pedicle is not bloated. Propeller flap was first proposed by Hyakusoku et al., the advisory group of the first session Tokyo meeting on perforator flap and propeller flap offinally reached a consensus that the propeller flap was defined as: the propeller flap is an island flap that covers the wound surface in the affected area by shifting with the perforator pedicle as the rotating axis, including two parts located on both sides of the perforator (two blades of the propeller, or two parts of the head or tail of the flap), and each island flap can be changed into a propeller flap[1, 2]. Under the advocate of professor Xu Yongqing, the 12th Chi-

nese medical association conference on microsurgery was held in 2018 of Kunming, on which the editorial department of Chinese Journal of Microsurgery organized relevant experts to draft "expert consensus on perforating propeller flap", and discussed and reached consensus on the concept, name, surgical method, perioperative treatment and complications of propeller flap. Propeller flap pedicled with perforating branches of large vessels in limbs and trunk has been widely used, and the application of perforating propeller flap to repair finger tip defect was reported for the first time in 2014[3].

Zhang Jianchao et al., applied the finger side perforator propeller flap to repair the finger tip defect in 11 cases and 13 fingers, but only 2 cases had partial skin flap necrosis after surgery, and the rest of the flaps were healed at stage I, and the affected finger sensory function recovered well after surgery[4]. With the development of flap surgery in recent years, the application of perforating propeller flap to repair finger tip defect has been increasing. Zhou ke et al., used the dorsal perforator propeller flap of digital artery to repair the soft tissue defect of finger tip in 16 cases[5], and all survived except one case of partial necrosis after surgery, the wound healed at stage I with soft texture and satisfactory appearance, and the follow-up time was 6-12 months, with an average of 10 months.

Sun yi et al., used the dorsal perforator propeller flap at the end of the middle node artery to repair the skin defect of the finger tip in 21 cases, and all the 21 cases survived with good wound healing. The postoperative follow-up time was 3-18 months, the affected finger was in good shape, not bloated, with good color and texture of the flap and normal joint activity of the affected finger[6]. Under the premise of not sacrificing the main artery, the perforator propeller flap is supplied by the dorsal branch of the digital artery, which has the advantages of constant blood vessel, shallow surface, high survival rate and strong anti-infection.

Since the dorsal branches of the finger nerve can be anastomosed during the operation, postoperative flap sensory recovery is good, the skin flap texture and color are similar to the skin of the affected area, and the appearance of the repaired finger is beautiful, so such method can be widely applied in clinical practice. Through extensive and in-depth application, we found that this flap still has deficiencies, mainly because when the finger is completely located on the side of the finger, in the case of separating the flap, too much exposure and separation of vascular and nerve bundles increase the collateral damage of vascular and nerve bundles, resulting in long-term numbness in the surgical area and making it difficult to improve the adverse complications.

Therefore, from January 2017 to January 2019, 13 cases of 15 fingers with defect of middle and distal segment of fingers were repaired with pedicle propeller flap of digital artery perforator, and the flap design was further optimized. We designed the flap to be inclined to the proximal end of the flap to the dorsal side of the finger by 30°, and the large part of the flap was inclined to the dorsal side of the finger, in order to maximally conceals the donor area and makes it more convenient to close the donor area directly, minimizes the separation and exposure of the vascular and nerve, and reduces the collateral damage to the vascular and nerve bundles. The results showed that this improvement could significantly improve the occurrence of numbness and strangeness in the operative area.

Materials and methods

General data

There were 13 cases including totally 15 injured fingers in this group, including 6 males and 7 females, with age range from 19-58, averaging at 35 years old. There were 7 cases of stamping injury, 5 cases of electric saw injury and 1 case of electric gouging injury. Of all injured fingers, there were 7 indicating fingers, 5 middle fingers, 2 ring fingers, 1 little finger. Injury site: distal segment defect with phalanx bone defect in 9 fingers, middle distal segment injury with exposed tendon in 5 fingers, wound size 1.5cm×1.0cm~3.5cm×1.5cm. According to the condition of wound contamination, there are 13 fingers under moderate pollution and 2 fingers under severe pollution, all of which are repaired in the first stage after debridement.

Surgical method

Design of the flap:

take the proximal interphalangeal joint or middle phalangeal bone and the distal interphalangeal joint as the puncture fulcrum of the digital artery as the rotation point, and give priority to the puncture fulcrum adjacent to the wound; The medial point on the side of the wound was inclined to the radial dorsal or ulnar dorsal side of the proximal node of the finger at 30°, which was set as the longitudinal axis, and the rotation point was located on the axis of

the flap. Large flap paddle: according to the wound surface and rotation direction, the dorsal flap of the proximal segment was designed as the large paddle.

Small flap paddle:

Gradually shrink along the longitudinal axis and extend to the wound surface after the point of rotation of perforator, and the adjacent wound surface can be appropriately relaxed to adapt to the wider area when the large paddle passes to the pedicle. The width of the small paddel should be about 1/3 of the width of the large paddle.

Flap incision:

The flap was cut at the dorsal side of the flap design line and separated from the superficial aponeurosis of the extensor tendon to the palmar side. Pay attention to the specific position of perforating pedicle, if necessary, it is recommended to wear magnifying glasses to observe, and properly adjust the flap proximal cutting edge position after determining the specific position of perforating pedicle, that is, adjusting the flap design twice, marking the specific position of perforating pedicle with methylene blue, so as to prevent the flap bleeding and unclear perforating position.

The flap was dissociated along the design line, and the dorsal nerve of the finger was labeled and separated to the pedicle. Magnifying glasses can be worn on the head to preserve the fascia tissue about 0.4 cm around the pedicle of the perforator. The flap can be rotated 180 degrees to cover the wound with the big paddle, and the small paddle can partially or completely supply the flap area. The dorsal digital nerve and the contralateral digital nerve were sutured to provide the flap area. The residual wound surface can be covered with free skin graft or with digital artery perforator pedicle flap.

Results and dicussion

All the flaps survived the operation, and 1 case had blisters and scabs at the distal end of the flap, which healed after dressing change. Flap cutting area: small paddle: 0.5cm×0.3cm~1.5cm×0.4cm, large paddle: 3.0cm×1.2cm~5.0cm× 1.8cm (the length of the large paddle includes the distance from pedicle island to perforation). In total, 7 donor areas were closed directly, 6 flap areas were repaired, 2 skin grafts were repaired, and donor areas were healed well. The 14 fingers were followed up after the operation for 6 to 12 months, with an average of 8 months. The flap was in good shape and texture, and the 2-point recognition was 7-11mm. According to the trial standard of the function evaluation of upper limb of the Chinese society of hand surgery: 10 fingers with excellent performance, 3 with good performance and 1 with acceptable performance[7] (Typical cases seen in Figures 1-2).

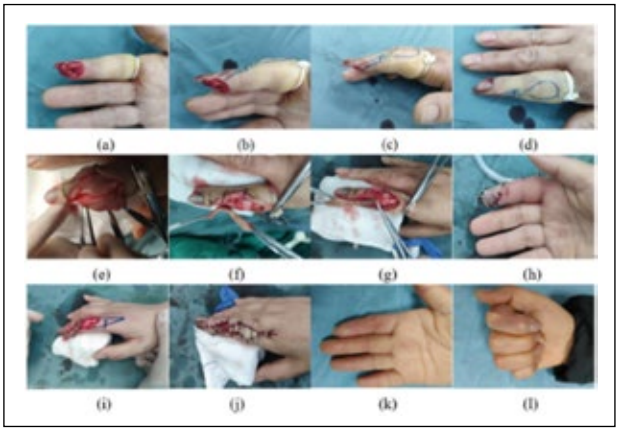

Figure 1: Defect of distal segment of right hand; (a-c) show the defect and the flap design distortion; (e) intraoperative exploration of local part of perforation; (f) flap resection; (g) flap free rotation (h) immediate shape of finger abdomen repair; (i) the small paddle covering part of the donor area, and the perforating thrust flap designed at the proximal end to cover the residual donor area; (j) immediate postoperative dorsal morphology; (k) and (l) show functional recovery after 6-month postoperative follow-up.

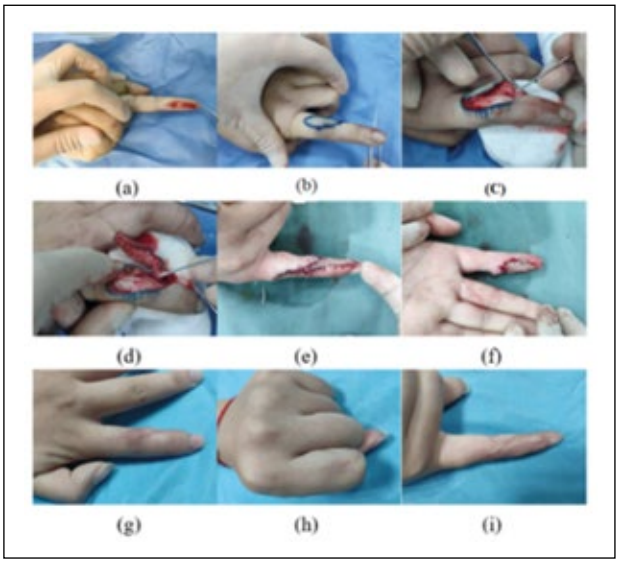

Figure 2: Defect of distal midabdominal segment in left index finger: (a) & (b) show defects and flap design; (c) specific position of perforation during intraoperative exploration; (d) flap cutting and reperforation; (e) the flap is rotated to cover the donor area immediately after direct suture; (f) immediate postoperative repair of finger abdomen; (g-i) show functional recovery after 7 months of postoperative follow-up.

Flap dissection

Some researches found that the digital artery was in the middle and distal 1/3 of the proximal phalanx respectively, and there were four relatively thick dorsal cutaneous branches in the middle and distal interphalanx joints, which are now called perforating branches[8, 9].

During the dorsal branch of the digital artery running from both sides of the finger to the dorsal side of the finger, it sends out multiple secondary branches, among which the ascending branch and the descending branch anastomose to form the dorsal branch of the finger, which is the anatomical basis of the propeller flap of digital artery perforator[10-12].

The choice of finger defect repair methods

There are many methods to repair finger soft tissue defect, such as pedicle flap, digital artery island flap, digital dorsal fascia pedicle flap, venous flap and free flap, etc., all of which have their own advantages and disadvantages[13, 14]. Among these methods, the fascia flap is widely used in clinic practice because of its simple operation and the similarity in skin texture with recipient area.

However, the fascial pedicled flap may involve necrosis due to insufficient arterial blood supply and poor venous return[15-16]. According to the anatomy of Ding Zihai et al., the transplantation effect of fascial flap mainly depends on whether there is reliable perforation of digital artery at the rotation point of pedicle[17]. In the traditional dorsal digital fascia flap, there is no clear site for perforation during the operation, and the pedicle carries too much tissue.

After the swollen pedicle is rotated, the appearance will be affected, and blood circulation will be obstructed due to vascular compression. Therefore, the key to the survival of the flap is to determine the position of the perforating branch and to deal with the pedicle properly.

Characteristics and precautions of propeller flap and flap in this group

The application of propeller flap was first reported in 1991 when the flap rotation was only 90°. In recent years, the propeller flap has been combined with the perforator flap to form the perforator propeller flap, which is only pedicled by the perforator vessel and can be freely rotated to 180°.

The propeller flap can also be designed to be multi-foliated, and the propeller flap is widely used[18]. The obvious advantage of double-bladed propeller flap is that the big paddle can repair the recipient site and the small paddle can cover the whole or part of the donor area. The digital artery perforator propeller flap was reported in 2014 and then gradually reported sporadically[4, 19-21].

The flap is mainly located on the side of the finger and is characterized by more concealment of the operative area, but it is obviously insufficient due to a large amount of exposure and damage of vascular and nerve bundles during operation. To this end, we designed the flap to be inclined to the proximal end of the flap to the dorsal side of the finger by 30°, and the large part of the flap was inclined to the dorsal side of the finger, in order to maximally conceals the donor area and makes it more convenient to close the donor area directly, minimizes the separation and exposure of the vascular and nerve, and reduces the collateral damage to the vascular and nerve bundles. The results showed that this improvement could significantly improve the occurrence of numbness and strangeness in the operative area.

At the same time, this group of flaps also has the following characteristics:

• The flap is easy to cut. After probing and perforating, the fascial flap can be cut to the pedicle.

• It overcomes the bloated appearance of fascial flap pedicle that needs to carry more wide fascial tissue, and it does not need to lift part of the epidermis to the wound surface to accommodate more fascial tissue in the pedicle. Meanwhile, it avoids the obstacle of flap reflux and necrosis of distal flap caused by twist and compression of the pedicle.

• Adjusting the flap twice according to the position of perforator increases the flexibility and reliability of the flap coverage and improves the appearance of the flap repair.

• The small propeller paddle can cover part or all of the wound in the donor area to reduce the skin grafting area and reduce the complications caused by postoperative scar hyperplasia.

• The dorsal digital nerve is sutured to improve the sensation of the flap, which is in line with the principle of repairing the palmar digital flap[22-25].

Conclusions

The Surgical precautions can classified as:

• The position of exploration and perforation is the key point. Please do not expel blood before operation, stop bleeding carefully during operation, and keep the perforation vessels filling, so as to facilitate intraoperative exploration of perforation;

• During the operation, for the purpose of probing the perforating branch, the head can be assisted by magnifying glasses to improve the resolution, and the tourniquet can be loosened if necessary. After the perforating branch is congested, it will be easier to observe and avoid damage to the perforating branch.

• Pedicle treatment is another key point for the survival of the flap, which can be dissociated to the pedicle of the flap to retain about 0.4 cm of fascial tissue around the perforator. The extra fascia tissue can be removed with the assistance of the head-mounted magnifying glasses to avoid the twist or compression of perforating branches and veins during the rotation of the flap.

• The separation level of the flap should be consistent. The flap should be separated along the superficial surface of the extensor tendon without damaging the hypodermic chain vessels to ensure reliable blood supply of the flap.

• The backflow of the flap is perforated with the accompanying vein, which is relatively small. The flap should not be sutured too closely at the distal end, and the occurrence of venous crisis should be prevented by using the edge ooze blood of flap[26-37].

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