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Repair and sensory reconstruction of the children's finger pulp defects with perforator pedicled propeller flap in proper digital artery

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Abstract. – OBJECTIVE: This study was designed to investigate the clinical effects of adopting perforator pedicled propeller flap in the proper digital artery for treatment and sensory reconstruction of finger pulp defects in children.

PATIENTS AND METHODS: Perforator pedicled propeller flap of proper digital arteries in thirty-one fingers from twenty-three children patients were selected for repairing the pulp defects on the 2nd to the 5th fingers. All cases were treated from September 2012 to December 2013. To properly reconstruct the pulps' feeling we needed the dorsal branch of the proper digital nerve in the flap to be consistent with the broken end of proper digital nerve in pulps' wound. A free skin graft was carried out with full-thickness skin taken from the medial thigh for flap donor area. We scheduled two post-operation return visits, one in six months and the second visit in twelve months following the operation. Parents' satisfaction with the postoperative appearance of their children's fingers was assessed based on Michigan Hand Outcome Questionnaire.

RESULTS: All operations were performed successfully and all wounds healed in the first period and all flaps survived. During the final follow-up, the shape recovery of flaps and their donor areas were examined and satisfactory results were obtained. All pulps were full and round without any obvious pigmentation or scar contracture. The sensory recovery of pulps was achieved S3+, and the two-point discrimination was 4.5 to 6.0 mm (with 5.1 mm being the average value). Parents' satisfaction with the postoperative results was very promising with twenty-one cases of very satisfied and two cases of satisfied parents.

CONCLUSIONS: The operation method used in this study demonstrated to be a safe and reliable procedure producing a very good flap blood supply as well as excellent sensory recovery and satisfactory postoperative appearance.

Key Words

Finger, Soft-tissue defect, surgical flaps, Dorsal branch of the proper digital nerve.

Introduction

The modern lifestyle of children is full of different types of entertainment and activities. This has resulted in higher numbers of cases involving the children with hand injuries in recent years[1]. Pulp which is often called "eyes" of the fingers, plays an extremely important role in the functionality of the hand and pulp defects are usually very difficult to treat. The principle of children's pulp defect repair is to complete the soft tissue coverage and reconstruct pulp sense with minimal degree of damage. At the end, the shapes of the repaired pulps must be restored properly[2].

Patients and Methods

Clinical Data

Inclusion criteria: (1) All cases had defects on 2nd to 5th fingers' pulps; (2) They did not suffer any damages to the surface of the wounded fingers' proximal ends; (3) In all cases the wounds had exposed nerves or/and tendons or/and sclerotins; (4) Every single parent was required to preserve the fingers' lengths and conduct aesthetic recovery.

Exclusion criteria: (1) Cases with thumb pulp defects were excluded; (2) Parents reluctant to either preserve fingers' length or conduct fingers' aesthetic recovery were excluded; (3) Cases with damaged flap donor site were excluded; (4) Cases with no major tissue exposure on pulp defect wounds were excluded; (5) Cases with no intention to accept flap treatment were also excluded.

General information: From September 2012 to December 2013, twenty-three cases (with 31 damaged fingers), all children with the 2nd to 5th pulp defects, were chosen for this study. The Ethics Committee of Xuzhou Central Hospital approved this study. We had sixteen male and seven female

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cases aging from 3 to 12 years with the average age being 5.3 years.

Nature of injuries: Nine cases suffered from crush injuries, five cases with gouging injuries, four suffered from twist injury and finally four cases with burns or scalds.

Injured fingers: We had twelve cases of index fingers injuries, nine middle fingers, seven ring fingers and three litter fingers injuries.

Pulp defect areas were ranging from 1.2 cm×1.0 cm to 2.0 cm×1.5 cm and flap cut areas were 1.3 cm×1.2 cm to 2.2 cm×1.6 cm. Duration from injury to operation for emergency cases were 1.5 to 6.0 hours with an average of 3.6h. For 4 cases with burns or scalds, wounds were disposed at the second phase after opening for dressing change in the first phase. The courses of disease were 1 to 2 weeks with an average of 1.2 weeks.

Operation Method

For all cases, total intravenous anesthesia was employed. To stop bleeding, we used inflated and compressed tourniquet on the patients' upper arms. To start, hand injuries debridement was performed followed by trimming the wound edges. Wounds were then rinsed using hydrogen peroxide saline and the broken ends on both sides of proper digital arteries (proximal to the wound) were separated and ligatured. The wounds were soaked in diluted iodine for about 10 min and aseptic towels replacement was coupled with changing aseptic gloves.

Flap Design

For index and middle fingers pulp defects, flap vascular pedicles were designed at ulnar side. For ring and little fingers pulp defects, flap vascular pedicles were designed at radial side. The patterns were cut according to the shape and size of the pulp defects. The rotation points of flaps were the junctions between the horizontal and lateral central lines of pedicle distal interphalangeal joints. The axis line of flap design was the line connecting the vascular pedicle point to the lateral border of horizontal line of proximal interphalangeal joint (Figure 1a). Based on the pattern, the corresponding flap was designed with its axis line used as the central line and the pattern was pasted on both sides at the back size of the wounded finger's middle part. The width of the cut flap did not exceed the dorsal stripes of interphalangeal joint, and the length did not exceed the central side line contralateral of the finger. At the proximal end of the flap, projection line was outlined according to the shape of dorsal branch of proper digital nerve. The design of flap was 1 to 2 mm larger than the practical wound surface so the flap cut could cover the wound surface smoothly.

Flap Cut

Initially, the extensor tendon was cut on the flop in the shallow layer in accordance with the design line, which was near the end of distal interphalangeal joint and at the end of vascular pedicle's opposite side. Subsequently, the corresponding nerve length was separated, in accordance with the design line of dorsal branch of the proper digital nerve, then cut and marked. The continuity between dorsal branch of proper digital nerve and flap was protected well, and the whole flap out of the vascular pedicle was separated. In vascular pedicle flap side, the flap was separated near the periosteum. The dorsal perforator vessel

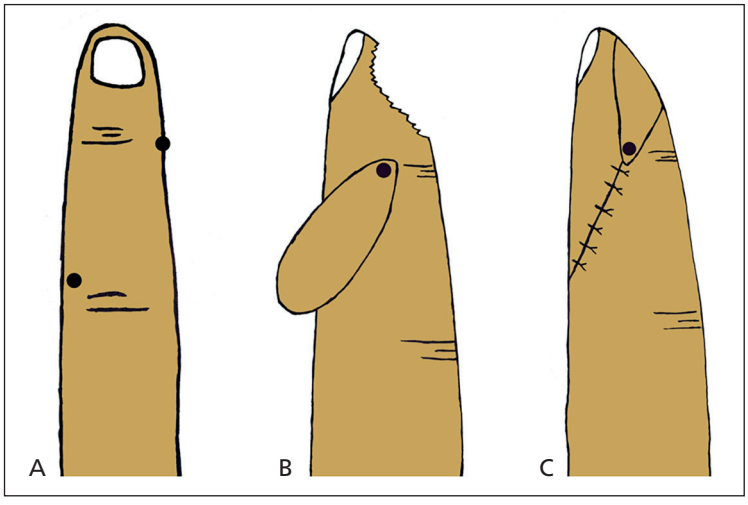

Figure 1. Schematic diagram of perforator pedicled propeller flap in proper digital artery. **A**, schematic diagram of flap rotation point and its axis line (the line connecting two black points); **B**, schematic diagram of flap cut; **C**, schematic diagram of the covered wound surface after flap transfer.

of distal interphalangeal joint in digital proper artery was identified carefully under the microscope and the whole flap was cut (Figure 1b). Once the flap was cut successfully, it was flipped further in order to cover the wounded surface (Figure 1c). After a good adjustment of the flap, it was fixed by a few simple stitches. Under the microscope, end to end anastomosis was completed between the broken end of proper digital nerve and the dorsal branch carried by it. Subsequently, the wound was closed and rubber drainage strip was placed and the flap donor site was then covered by full-thickness skin taken from the medial thigh, and wrapped up with package and pressure.

Postoperative Management

Regular treatments for detumescence were carried out and affected limb was lifted following the operation.

The skin-grafting compression package was dismantled after 5 days and the suture was removed after 10 days.

The functional exercise of pulp touch sensation began 15 days later.

Results

All operations were performed successfully with all wounds healed in the first period with all flaps and skin graft survived efficiently. Post-operation follow-ups were scheduled for 6 to 20 months (with an average of 13.8 months) post-operation. During the final follow-up, the flap and their donor sites were all very healthy, and the pulps were appeared to be round and in full shape. The flaps were elastic and had soft texture, without any obvious pigmentation or scar contracture. The sensory recovery of pulps was achieved S_3^+; the two-points discrimination were 4.5 to 6.0 mm with an average of 5.1 mm.

The parents' satisfaction rate on postoperative outcomes was highly promising with twenty-one cases being very satisfied and two cases satisfied.

In one case we had a male (6 years and two months old) with a crush injury on his ring finger (on the right hand) resulted from a serious cut with an ironware in playground. The patient was suffering from pain and bleeding. An initial examination, revealed his ring finger to be pulp defected, phalanx was exposed and the defect area of soft tissue was about 1.7 cm×1.3 cm. After 3.5h from the incident causing the injury, ring finger debridement was performed under general anesthesia and the wounded surface was repaired with perforator propeller flap of proper digital artery (size: 1.8 cm×1.5 cm). Epineurial end-to-end anastomosis, between dorsal band of proper digital nerve, was carried out in the flap and the broken end of the proper digital nerve (near the proximal end of the wound) was operated with 9-0 nerve anastomosis thread under the microscope. Full-thickness skin from medial thigh was cut to cover the flap donor site and the site was wrapped up with package and compression. Treatments of detumescence, inflammation resistance, and lift the affected limb were carried out after operation. Wounds were all properly healed in the first phase after the operation and the postoperative follow-ups were set for 18 months after operation. The recovery of the finger shape was satisfactory and the two-point discrimination of pulps was 5.0 mm. The satisfaction degree amongst patients' parents, on postoperative appearance of the repaired fingers, was very encouraging (Figure 2).

Discussion

Children's Pulp Defect Repair

Children by nature are more vulnerable to unfortunate accidents and more frequently suffer from hand injuries. One category of these injuries is pulp defect which is a frequently-occurring problem in children. Microsurgical repairs are proven to be challenging and cumbersome. For cases with pulp defects, we had several treatment options. These treatments are divided into the following categories: i) V-Y advancement flap, ii) thenar flap, iii) cross-finger flap, iv) reversed digital artery island flap, and v) free toe mini-flap. In the V-Y advancement flap, we are dealing with a limited repair area because it can only be applied to defect length of wounded surface within 7 mm[4]. In the thenar flap and cross-finger flap, we have a few advantages such as simple operation procedure and high survival rate. Nevertheless, there are a few downsides associated with this method as well. Children patients are required to maintain passive position fixation for 2 to 3 weeks, which is very difficult for a kid to achieve. Besides that, surgical pedicle division is necessary for the second phase, which usually increases the level of the pain and discomfort. There are more negative factors associated with this method: the pulp sense recovery is often poor and the economical burden can be hard to support for some parents[5,6]. Reversed digital artery island flap has the advantages of a reliable blood supply, high survival rate, and easy operation procedure. On the downside, there is a risk of damage to a major artery in the course of the operation and the cicatrix is large and the pulp sense recovery is poor[7].

Figure 2. Repair of the ring finger pulp defect on patient's right hand with perforator pedicled propeller flap of proper digital artery. **A**, Wounded surface condition of ring finger pulp defect in right hand before the operation; **B**, Pulp covered by the flap; **C**, Compression bandage situation after the application of full-thickness skin for flap donor site; **D-E**, Ring finger in right hand with good flap survival and satisfying appearance. Full pulp and donor site 18 months after the operation.

The best treatment is to repair the pulp defects using toe pulp free grafting. This method can achieve the recovery effect of building up the body part with similar body. However, in children, we are dealing with small blood vessels, high risk of microsurgical vascular anastomosis and difficult nursing care. For children patients, crying and screaming make them prone to vascular crisis which may result in flap necrosis[9]. Dorsal perforator vessels are from the proper digital artery at finger distal interphalangeal joint. Perforator pedicled propeller flap of proper digital artery is designed to repair children's pulp defects and reconstruct pulp sensory function. This offers a complete tissue coverage and sensory function with small flap cut cicatrix and satisfactory postoperative appearance.

Anatomical Basis of Perforator Propeller Flap in Proper Digital Artery

Proper digital artery gives out several perforator vessels from both sides of fingers to dorsal fingers, forming vessel chains with dorsal artery network at fingers' dorsal part so as to supply dorsal finger skin[10]. Dorsal perforator vessels of proper digital artery are distributed in distal interphalangeal joint[11], therefore, the design of supplying blood for vascular pedicle flap with dorsal perforator vessel of proper digital artery in distal interphalangeal joint is reliable. This can provide anatomical basis for the successful implementation of this operation method.

Advantages of this Operation Method

Application of perforator propeller flap in proper digital artery to repair children's pulp defects and re-

construct fingertip sensory function has several advantages such as: i) The operation does not damage any major arteries in fingers, ii) This method is low risk and produces small surgical trauma, without any major cicatrix on wounded fingers after operation; iii) The anatomical position of dorsal perforator vessels in distal interphalangeal joint of proper digital artery is constant. There is no obligation to isolate vascular pedicle and it is readily possible to separate the flap according to design line. The operation is simple and blood supplement is reliable and the survival rate is high; iv) Once the application of full-thickness skin flap graft is completed, the appearance recovery of flap donor sites is satisfactory without visible depressions or cicatrix formation; v) Based on the principle of proximity in microsurgical tissue repair, the texture of flap repair after operation is similar to pulp tissue, which gives a proper aesthetic appearance; vi) Microscopic nerve anastomosis can be carried out in the flap, so the adequate blood supply of the flap can accelerate the healing of nerves and improves the recovery effect of sensory function after the flap operation; vii) The appearance of wounded fingers is usually satisfactory after operation, pulp sensory function recovery is decent. Keep in mind that the operation requires microscopic nerve anastomosis, which involves a high level of the operator's proficiency.

Operation Attentions

In order to ensure a satisfactory result in children's pulp defects treatment, the following aspects should be considered carefully: i) Cases inclusion and exclusion criteria should be designed properly in order to ensure a smooth implementation of the surgery; ii) The design of flap should be 1 to 2 mm larger than the periphery of the wounded surface in order to prevent postoperative pulp contracture usually caused by tension suture after flap flip; iii) In the process of flap cut, a great deal of diligence must be considered to keep peri-tendon tissues of extensor tendon properly with the purpose of keeping the skin in flap donor sites smooth after the recovery of full-thickness skin graft coverage; iv) The continuity between dorsal branches in proper digital nerve and the flaps must be kept during the operation and the integrity of dorsal branches in proper digital nerve must be protected.; v) In order to protect the perforator vessels in the flap from any kind of damage, the vascular pedicle of the flap must be kept as close as possible to the periosteum; vi) The width of vascular pedicle is suggested to be about 5 mm in order to avoid the aesthetic appearance differences of vascular pedicle after flap transposition; vii) Epineurial end-to-end neurorrhaphy without tension is the significant assurance for flap sensory function recovery after operation; viii) Full-thickness skin is applied to cover the flap donor sites, which can avoid the depression of flap donor sites and scar contracture, so that the appearance in flap donor sites would be satisfactory.

Conclusions

Perforator propeller flap in proper digital artery is the ideal method to treat children's pulp defects and reconstruct senses. This method offers a reliable blood supply of the flap, satisfactory aesthetic appearance of wounded fingers and sensory function recovery. All this can be accomplished with very few complications.

Conflict of Interests

The Authors declare that they have no conflict of interests.

References

1) Ramirez EG, Hoyt KS. Assessment of acute hand injuries: part I. Adv Emerg Nurs J 2014; 36: 9-21.
2) Cui JJ, Peng B, Lin W. Effects of combining CBCT technology with visual root canal recurrence in treatment of elderly patients with dental pulp disease. Eur Rev Med Pharmacol Sci 2017; 21: 903-907.
3) Chung KC, Pillsbury MS, Walters MR, Hayward RA. Reliability and validity testing of the Michigan Hand Outcomes Questionnaire. J Hand Surg Am 1998; 23: 575-587.
4) Kinoshita Y, Kojima T, Matsuura S, Hayashi H, Miyawaki T. Extending the use of the palmar advancement flap with V-Y closure. J Hand Surg Br 1997; 22: 212-218.
5) Spokevicius S, Gupta A. The modified cross finger flap for finger pulp and nail bed reconstruction. J Hand Surg Br 1997; 22: 745-749.
6) Fitoussi F, Ghorbani A, Jehanno P, Frajman JM, Pennecot GF. Thenar flap for severe finger tip injuries in children. J Hand Surg Br 2004; 29: 108-112.
7) Karacalar A, Sen C, Ozcan M. A modified reversed digital island flap incorporating the proper digital nerve. Ann Plast Surg 2000; 45: 67-70.
8) Zheng H, Liu J, Dai X, Machens HG, Schilling AF. Free lateral great toe flap for the reconstruction of finger pulp defects. J Reconstr Microsurg 2015; 31: 277-282.
9) Sohn WI, Jung SN, Kim SW, Kwon H, Im KS. Reconstruction of fingertip defects with great toe pulp grafts. Ann Plast Surg 2012; 68: 579-582.
10) Beldame J, Havet E, Auquit-Auckbur I, Lefebvre B, Mure JP, Duparc F. Arterial anatomical basis of the dorsal digito-metacarpal flap for long fingers. Surg Radiol Anat 2008; 30: 429-435.
11) Braga-Silva J, Kuyven CR, Fallopa F, Albertoni W. An anatomical study of the dorsal cutaneous branches of the digital arteries. J Hand Surg Br 2002; 27: 577-579.