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Reconstruction of fingertip defects with digital artery perforator flap

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Objective: The aim of this study was to present our findings for the use of the digital artery perforator (DAP) flap in the covering of digital pulp defects.

Methods: The study included 15 patients who underwent reconstruction of the fingertip using a DAP flap between July 2007 and February 2012. The blood supply of the perforator island flap was based on the distal and either radial or ulnar sides of the digit. Donor sites were closed using skin grafting in all cases. Static two-point discrimination (s2PD) and Semmes-Weinstein monofilament (SWM) testing was performed at the final follow-up to determine extension loss and sensorial improvement.

Results: Mean follow-up was 22 (range: 7 to 62) months. Flaps size was between 2x1 cm and 2.5x1.5 cm. Temporary venous congestion was observed in 12 of the 15 patients and was without complication. All patients returned to their normal daily activities and work within an average of 39 (range: 30 to 45) days. Mean two-point discrimination was 5.3 mm and SWM test results were between 3.61 and 4.56 at the final follow-up.

Conclusion: The DAP flap appears to be a reliable procedure with several advantages as a single-stage operating procedure, easy to harvest, good sensory recovery and preservation of digital arteries.

Key words: Digital artery perforator flap; fingertip; pulp reconstruction.

The fingertips are highly specialized parts of the hand that perform pinching and grasping functions, allow certain sensation and are important aesthetic features. Because of these considerations, reconstruction of defects, which constitutes one of the most common traumatic injuries in the reconstructive field, must be performed with care and the most appropriate technique chosen for each patient.[1-6]

The digital artery perforator (DAP) flap was described by Koshima et al.[7] as a perforator based flap. It is a vascular island flap elevated on the distal and either the radial or ulnar sides of the digit for the reconstruction of fingertip defects. The flap is based on the small perforators coming out of the digital artery at the level of the distal interphalangeal joints (DIPJ) or near the DIPJ. Modifications of the DAP flap were also reported by Mitsunaga et al.[8]

The aim of this study was to present the results of the use of the DAP flap for coverage of fingertip defects caused by traumatic amputations.

Patients and methods

The study included 15 patients (13 males, 2 females; mean age: 33 years, range: 19 to 56 years) who were

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Table 1. Clinical data of the patients.

Age	Gender	Side	Defect type	Flap size	SWM vs SWM control	s2PD vs s2PD control	Follow-up (months)
30	Male	Right 5th digit	Transverse	2x1 cm	4.17/3.22	5 mm/2 mm	11
34	Male	Left 3rd digit	Transverse	2x1 cm	4.08/3.22	4 mm/2 mm	9
40	Female	Left 3rd digit	Transverse	2x1 cm	4.08/2.83	4 mm/2 mm	10
25	Male	Left 4th digit	Lateral oblique	2x1 cm	3.61/3.22	4 mm/3 mm	8
36	Male	Left 4th digit	Transverse	2x1 cm	4.17/3.22	5 mm/3 mm	7
20	Male	Left 3rd digit	Dorsal oblique	2x1 cm	3.61/3.22	4 mm/3 mm	7
34	Male	Right 1st digit	Transverse	2x1 5 cm	3.61/3.22	5 mm/3 mm	8
31	Male	Right 5th digit	Transverse	2x1 cm	4.31/3.22	7 mm/3 mm	13
19	Male	Left 2nd digit	Transverse	2x1cm	4.56/3.61	6 mm/2 mm	48
22	Female	Left 2nd digit	Dorsal oblique	2x1 cm	4.17/3.22	5 mm/3 mm	36
56	Male	Right 3rd digit	Volar oblique	2x1 cm	4.08/3.61	7 mm/4 mm	27
37	Male	Right 4th digit	Transverse	2x1 cm	4.31/3.61	8 mm/4 mm	18
28	Male	Right 2nd digit	Transverse	2x1 cm	4.56/3.22	6 mm/3 mm	29
35	Male	Right 3rd digit	Volar oblique	2x1 5 cm	4.56/3.84	6 mm/4 mm	34
52	Male	Left 4th digit	Volar oblique	2x1 cm	4.17/2.83	4 mm/2 mm	62

s2PD: Static two-point discrimination; SWM: Semmes-Weinstein monofilament test.

operated on using the DAP flap between July 2007 and February 2012. In all cases, defects were caused by traumatic fingertip amputation. Distribution of the defects sites were; five middle fingers, four ring fingers, three index fingers, two small fingers and one thumb. All operations were carried out under digital block anesthesia and required a loupe magnification for the flap dissection. All defects were distal to the lunula in the injured fingers. No preoperative investigation was used to locate the perforators. The planning and harvesting of the DAP flap was undertaken as described by Koshima et al.[7] The flap was located in the lateral or medial aspect of the finger close to the defect with a long axis parallel to the finger (Fig. 1a). As these areas are rich in perforators, the most distal ones were preserved to enable flap transposition to the defect. Before the incision, a tourniquet was placed at the base of the finger. During dissection, the digital neurovascular bundle was protected; so the flap was raised solely on the perforator (Figs. 1b to d).

Patients were encouraged to undertake active range of motion (ROM) exercises after 72 hours postoperatively. Stitches were taken out at the 10th to 14th postoperative day. In the follow-up period, cyanosis, necrosis, donor site and early wound complications were monitored. Subjective outcome evaluation was measured six months postoperatively at the final follow-up. Extension loss and sensorial improvement of the repaired fingertips were evaluated using static two-point discrimination (s2PD) and Semmes-Weinstein monofilament (SWM) testing.

Results

Clinical data of the patients is summarized in Table 1. Nine patients had transverse defect, three patients volar oblique defects, two patients dorsal oblique defects and one patient lateral oblique defect (Fig. 2). All flaps were safely harvested with a single perforator. Flap sizes were between 2x1 cm and 2x1.5 cm. The donor site was closed using a full-thickness skin graft from the ulnar

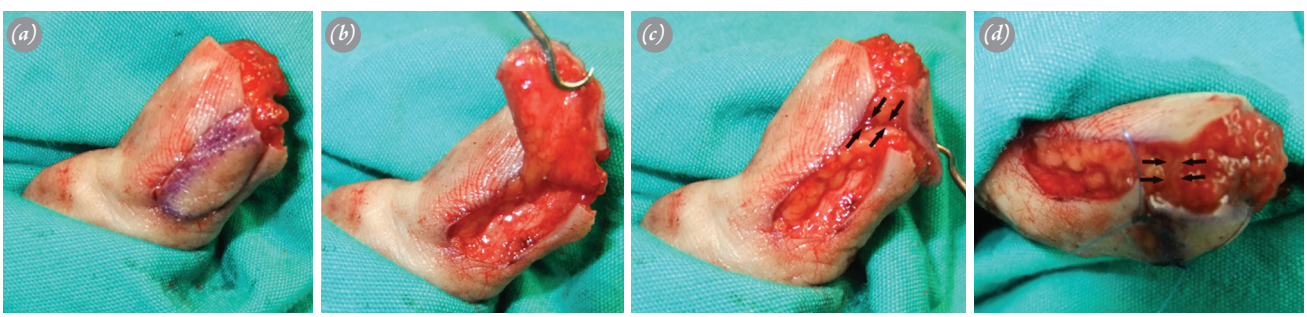

Fig. 1. **(a)** Design of the flap. **(b)** Flap elevated from the donor area. **(c, d)** Perforator of the flap (black arrows). [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

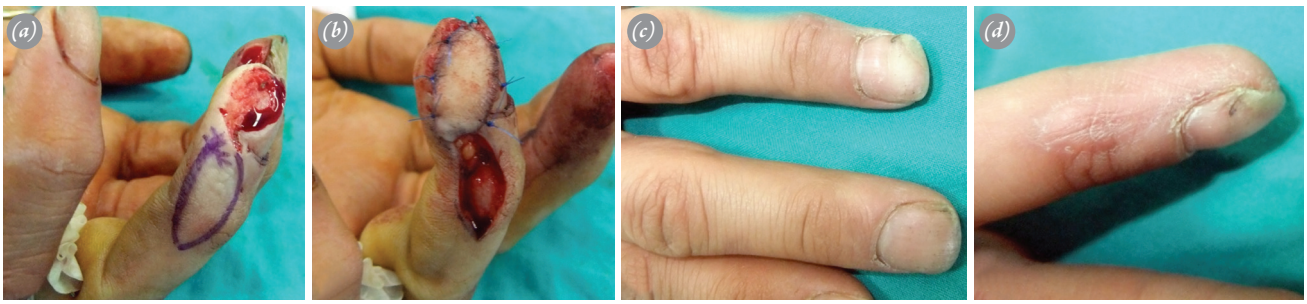

Fig. 2. **(a)** Design of the flap before transfer. **(b)** Flap is easily transposed to the defect. **(c, d)** Final result. [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

site of the wrist crease or split-thickness skin graft from the hypothenar region in all patients. A branch of the digital nerve was also included in five flaps. Venous congestion was observed in 12 patients and all venous congestions were resolved within one week after the operation without any further secondary intervention. Skin grafts healed uneventfully in all patients (Fig. 3).

Mean follow-up period was 22 (range: 7 to 62) months. All patients returned to normal daily activities and work after an average of 39 (range: 30 to 45) days. Extension loss, hypersensivity and donor site scar contractures were not observed in any patient, except in one who displayed cold intolerance. The average s2PD test was 5.3 (range: 4 to 8) mm and the contralateral fingers' average s2PD was 2.86 (range: 2 to 4) mm. SWM test results for the injured finger ranged between 3.61 and 4.56 and between 2.83 and 3.84 for the contralateral finger. There were no differences in the s2PD and SWM tests between the flaps of those who had a branch of the digital nerve and those who did not. The sensorial recoveries in both groups were satisfactory.

Discussion

The main principles of fingertip reconstruction involve providing durable coverage for adequate cushioning surface, preserving sensation and length, minimizing discomfort, and prompting a timely return to work and leisure.[5,6] Local flap methods are well described and include homodigital or heterodigital flaps.

The volar V-Y advancement flaps work well for the covering of fingertip defects.[3,6] However, these flaps have limited size, deliver restricted mobility and are impossible to use for volar oblique defects or relatively distal transverse injuries of the fingertip without bone shortening. Lemmon et al. described bilateral V-Y advancement flaps as having certain limitations in cases with such indications.[5] Regional flaps, such as a cross finger or thenar flaps, require two-stage operations.[1,5,6] The reconstructed finger must be flexed with a prolonged immobilization, which causes joint stiffness. This makes such flaps uncomfortable for the patients. In cases where the amputated part was not available for replantation, composite grafts deliver a high success rate and good results in treating fingertip amputations in children.[9] Although lower success rates have been reported, in recent studies, successful functional and aesthetic outcomes have also been reported in adults.[5,10]

Venkataswami and Subramanian[11] described the oblique triangular flap in 1980, Evans and Martin[12] developed the step-advancement flap based on neurovascular bundle in 1988 and Lanzetta et al.[13] described the versatile homodigital triangular neurovascular island flap in pulp reconstructions in 1995. The advantages of these flaps are that they are single-stage procedures that produce a sensate flap and can be performed without sacrificing the digital artery.[5,11-14] The limitations of these flaps include the difficulty in advancing more than 2 cm and risk of proximal interphalangeal (PIP) joint

Fig. 3. **(a)** Volar oblique defect in the right middle finger. Planning of the DAP flap on the ulnar side. **(b)** View of the flap after the operation. **(c)** Final result of the flap in volar and lateral views. [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

flexion contracture. Ozaksar et al. reported very good results in covering large pulp defects with the homodigital dorsal middle phalangeal neurovascular advancement flap.[15] Disadvantages of this flap are extensile incision and donor site graft requirement.[5,16-18]

Retrograde flow flaps are versatile flaps which may be performed homodigitally or heterodigitally.[5,16-18] Advantages include the fact that it is a one-stage procedure resulting in a reliable vascular pedicle and extensive arc of rotation. Its disadvantages include increases in cold intolerance by 41.6%, sacrifice of a digital artery, long operating procedure, venous congestion, PIP joint contracture and higher incidence of total or partial loss.[5,18]

Free flaps are also available for fingertip coverage such as the medial plantar artery and its perforator flaps, the medialis pedis flaps and arterialized venous flaps.[19-22] These techniques require a steep learning curve and strong microsurgical skills for the surgeon and a long operating time and period of recovery before to return to work.

The DAP flap was first described by Koshima et al. as a perforator based flap.[7] Mitsunaga et al. developed DAP flaps in 2010 and reported their experiences and modifications with successful results in a limited numbers of patients.[8]

In a previous study, we reported the innervated digital artery flap as a new technique providing a sensate reconstruction for pulp defects with successful results and low complication rates.[23]

Classically, the fashion of defects such as transverse, volar or dorsal oblique with/without exposed bone is critical in choosing the most appropriate treatment method. However, it is not necessary to analyze the geometry of defects when using the DAP flap, as it is rotated around the perforators in a propeller-like fashion and can be easily applied and rotated to all types of fingertip defects. This allows surgeons to insert the flap to the defect area in a tension-free manner. Although we have reconstructed all types of pulp defect with the DAP flap, coverage of the dorsal oblique defects were easier.

The time period needed for recovery and return to work is relatively short when compared to the other methods mentioned above. This factor is crucial in patients with a number of occupations, such as manual laborers or musicians.

The dissection and harvesting of the DAP flap is neither difficult nor laborious. Koshima et al. reported that rich perforating arterioles and venules exist between the perforators of the digital artery within the subcutaneous tissue in the distal phalanx, and that these perforators permit the harvesting of the flap based on adipose tissue, which generally has superficial arterioles, in case of absence of the dominant perforator at the flap base.[7] In contrast to previous reports on DAP flaps, we encountered a high rate of venous congestion (12 in 15 patients) which improved spontaneously approximately seven days after surgery (between 6 and 12 days).[7,8] The exact reason for the venous congestions is unclear, but it may be due to insufficient venous plexus compared to the arterial supply within the pedicle in the fingertip region. Completely elevating and skeletonizing the pedicle may contribute to the congestion, and is thus accepted as a second cause of venous failure. Temporary cyanosis has not been previously reported in any article. We did not observe this complication in the three patients with thick subcutaneous soft tissue around the pedicle when harvesting the flaps.

The color and tissue characteristics of the flap are excellent. DAP flaps allow reconstruction of pulp defects without sacrificing the digital artery. Nevertheless, the main drawback of the DAP flap is that surgeons cannot be sure whether the flaps will involve the perforator or not until the flap is completely elevated and the risk of damaging the perforator in situations that require further dissections is high.[24] However, according to our experience and the original report by Koshima et al.,[7] further dissection of the perforator to visually confirm entrance in the flap is not necessary. The two main disadvantages were observed with the reconstruction of the fingertip defects with DAP flaps; donor site grafting and temporary venous congestion was necessary in the majority of the patients.

In conclusion, the use of the DAP flap for fingertip reconstruction appears to result in excellent functional and aesthetic outcomes without sacrificing the digital artery. Therefore, we suggest that the DAP flap may be a useful technique in all types of fingertip pulp defects.

Conflicts of Interest: No conflicts declared.

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