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The Reconstruction of the Injured Foot with Microsurgical Technique

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— Abstract —

One hundred and thirty-seven patients had reconstructive surgery of injured feet with microsurgical technique in the Department of Orthopaedic Surgery at Yonsei University College of Medicine from 1983 to 1997.

The results were as follows:

1. There were 89 cases in men and 48 cases in women, who together had a mean age of 21.3 years.

2. The causes of injuries were 97 cases from traffic accidents, 15 cases from burns, 11 cases from machinery injury, 5 cases from infection, 2 cases from falling, 2 cases from glass injury, 2 cases from snake bite, 2 cases from explosive injury, and 1 case from ulceration.

3. There were 47 cases with inguinal flaps, 36 cases with scapular flaps, 36 cases with parascapular flaps, 7 cases with deltoid flaps, 4 cases with lateral thigh flaps, 3 cases with latissimus dorsi flaps, 2 cases with tensor fascia lata flaps, and 2 cases with dorsalis pedis flaps.

4. One hundred and twenty-seven (92.7%) cases were successful in reconstructive surgery with microsurgical technique.

5. Functionally, the thick skin flap or sensory flap has less ulceration and good protective sensation.

We considered that the function and cosmetic appearance were excellent after reconstructive surgery of the injured feet with microsurgical reconstructive technique and that the thick skin flap or sensory flap has less ulceration and good protective sensation.

Key Words : Reconstruction, Microsurgery, Feet

INTRODUCTION

The microsurgical reconstruction of the feet plays an important role in the extensive soft tissue and bone injuries caused by the increasing number of traffic accidents, mechanical injuries, and in the soft tissue contracture and limb salvage operation after tumor resection. Many types of microsurgical reconstructive procedures have been developed and reported for patients who have sustained extensive traumatic soft tissue injuries of the extremities. Krizek et

al.[14] achieved experimental free flap transfers and Harii and colleagues[11] introduced several important technical modifications, including primary closure of the donor site and extremely large flaps of virtually any shape. However, applications of the flap for the feet have been needed to provide protective sensibility for the proper function or weight bearing. Arterial and island flaps incorporating the dorsalis pedis artery were reported by McCraw and Furlow[16], and flap conversion to neurovascular free flaps was achieved by Daniel and Terzis[7]. In 1980, Franklin[9] clinically used and reported the deltoid sensory flap for the restoration of protective sensibility after soft tissue injury.

Our study includes 137 cases of patients who underwent microvascular surgery with many types of flaps from May 1983 to February 1997, with follow-up and evaluation of the results.

MATERIALS AND METHODS

1. Subjects and analysis of patients

From May 1983 to February 1997, 137 free-flap transplantations were performed on feet by the authors at Severance Hospital, Yonsei University, Seoul, Korea. Age at the time of operations ranged from 3 to 56 years and average age was 21.3 years. The period of follow-up was from 4 to 141 months and the average was 64.5 months. In age, the most common group was under 10 years and 69 cases (50.4%) belonged to the first decade, followed by the third decade with 20 cases (14.6%). Both males and females were common under 10 years (Table 1). In the causes of injuries, the most common was traffic accidents, including 97 cases (70.8%), followed by machinery injuries 11 cases (8.0%), burn (15 cases:10.9%), glass injury (2 cases:1.5%), snake bite (2 cases:1.5%), infection (5 cases:3.6%), falling injury (2 cases:1.5%), stab wound (1 case:0.7%), and ulceration (1 case:0.7%) (Table 2). In the site of injury, the most common site was the dorsum of the foot (59 cases:43.1%), followed by the ankle (35 cases:25.5%), plantar surface of heel (30 cases:21.9%), and the plantar surface of forefoot (13 cases:9.5%) (Table 3). The recipient sites were divided into five groups: Group 1 included 89 (65.0%) patients with the defects of the skin and soft tissue with exposure of the bone and tendon. Group 2 included 23 (16.8%) patients with soft tissue contracture around

Table 1. Age and Sex distribution (Total Number:137)

Age	Sex		Total	Percent(%)
	Male	Female		
0 - 10	39	30	69	50.4
11 - 20	11	8	19	13.9
21 - 30	17	3	20	14.6
31 - 40	12	3	15	10.9
41 - 50	6	1	7	5.1
51 - 60	4	3	7	5.1
Total	89	48	137	100.0

Table 2. Causes of injury

Cause	No.(%)
Traffic accident	97(70.8)
Burn	15(10.9)
Mechanical injury	11(8.0)
Infection	5(3.6)
Falling down	2(1.5)
Glass injury	2(1.5)
Snake bite	2(1.5)
Explosive injury	1(0.7)
Ulceration	1(0.7)
Total	137(100.0)

the joints. Group 3 included 17 (12.4%) patients with the unstable skin. Group 4 included 7 (5.1%) patients with defect of the bone with the osteomyelitis. Group 5 included 1 (0.7%) patients with an ulcerated area of the stump of below-knee amputation (Table 4).

The weight-bearing area of the foot among 137 patients totalled 43 cases (31.4%), compared with the non-weight bearing area of 94 cases (68.6%).

2. Donor sites of free flaps

The types of free flaps were as follows: 47 cases of groin flaps (34.3%), 36 cases of scapular flaps (26.3%), 36 cases of parascapular flaps (26.3%), 7 cases of deltoid flaps (5.1%), 4 cases of lateral thigh flaps (2.9%), 3 cases of latissimus dorsi flaps (2.2%), 2 cases of tensor fascia lata flaps (1.5%), and 2 cases of dorsalis pedis flaps (1.5%) (Table 5).

Table 3. Location of the Soft tissue lesion

Location	Number(%)
Dorsum of foot	59(43.1)
Plantar surface of heel	30(21.9)
Ankle	21(15.3)
Malleoli	14(10.2)
Plantar surface of forefoot	13(9.5)
Total	137(100.0)

Table 4. Condition of the Recipient site

Condition	No.(%)
Soft tissue defect with Bone & Soft tissue exposure	89(65.0)
Limitation of motion due to scar contracture	23(16.8)
Unstable skin	17(12.4)
Soft tissue defect with Bone exposure & Osteomyelitis	7(5.1)
Soft tissue defect due to ulceration	1(0.7)
Total	137(100.0)

3. Management of flaps

Before the operation, the size of the recipient site was measured and the angiography of the recipient site was carried out in all cases to confirm vascular variation.

After the flap had been isolated on its vessels and the recipient site had been prepared, we transected the artery first to allow additional venous drainage, and then transected the veins. The free flap was then placed into the recipient defect and oriented so that the flap vessels matched the recipient vessels. Then the arterial and venous anastomosis was performed. In the intraoperative field, the exposure time of vessels should be kept as short as possible and the

Table 5. Type of Operation on Foot

Type of Operation	No.(%)
Groin flap	47(34.3)
Scapular flap	36(26.3)
Parascapular flap	36(26.3)
Deltoid flap	7(5.1)
Lateral thigh flap	4(2.9)
Latissimus dorsi flap	3(2.2)
Tensor fascia lata flap	2(1.5)
Dorsalis pedis flap	2(1.5)
Total	137(100.0)

Table 6. Reconstruction area

Recipient area	No.(%)
Weight-bearing reconstructions	
Plantar	13(9.5)
Heel	30(21.9)
Non-weight bearing reconstructions	
Dorsum of foot	59(43.1)
Ankle	35(25.5)

flaps should be kept moist with intermittent saline irrigation. The postoperative foot should avoid the tensile position and compressive force. We elevated the recipient site to avoid swelling and hematoma. Room temperature should be above 22℃ and cigarettes, caffeine, and ice should be avoided to prevent vascular spasm.

RESULTS AND CASE REPORTS

Among 137 cases, 127 had successful results, making the overall success rate 92.7%, while the success rates of different kinds of flaps are as follows: 91.5% of groin flaps (43/47 cases), 91.7% of scapular flaps (33/36 cases), 85.7% of deltoid flaps (6/7 cases), 75% of lateral thigh flaps (3/4 cases), 50% of tensor fascia lata flaps (1/2 cases), and 100% of scapular flaps (36/36 cases) and dorsalis pedis flaps (2/2 cases) (Table 7).

Functionally, the thick flap on the foot had cosmetic complaints, especially from women and required larger shoes, while the thin flap or the flap without sensation showed results of frequent ulceration and delayed wound healing. The thick skin flap or sensory flap showed less ulceration and good protective sensation.

Table 7. Sucess rate

Type of Operation	Sucess rate(%)
Groin flap	43/47(91.5)
Scapular flap	33/36(91.7)
Parascapular flap	36/36(100.0)
Deltoid flap	6/7(85.7)
Lateral thigh flap	3/4(75.0)
Latissimus dorsi flap	3/3(100.0)
Tensor fascia lata flap	1/2(50.0)
Dorsalis pedis flap	2/2(100.0)
Total	127/137(92.7)

Case 1. A 4-year-old male sustained a crushing and degloving injury on the dorsum of foot and a loss of extensor hallucis longus tendon, left. The area was closed with a skin graft that became contracted and this led to an unstable skin and a flexion contracture of metatarsophalangeal joint of big toe (Fig. 1A, B). The loss of extensor hallucis longus tendon was replaced by the extensor digitorium longus tendon of second toe and reconstruction was instituted with a 11 × 6-cm scapular flap (Fig. 1C-E). One year after the procedure, the patient had gained the full range of motion of ankle and big toe and good coverage for the unstable dorsum of foot (Fig. 1F).

Case 2. A 29-year-old male sustained a crushing and degloving injury on the heel and posterior half of the sole, right. The area was closed with a skin graft that became contracted and painful and this led to an inability to bear weight (Fig. 2A). Reconstruction was instituted with a 9 × 13-cm free deltoid sensory flap (Fig. 2B-D). The posterior tibial artery was anastomosed to the posterior circumflex humeral artery end-to-side. Sensibility was acquired in the heel by anastomosing the sensory nerve of the flap to one of the sensory branches of the posterior tibial nerve. The donor site was closed primarily and healed with a linear scar (Fig. 2E, F). One year after the procedure, the patient continued to walk on the flap. He has good protective sensibility and the flap has adapted well to weight-bearing.

DISCUSSION

Currently, microsurgical reconstruction of the extremity plays an important role in the extensive soft tissue injuries caused by the

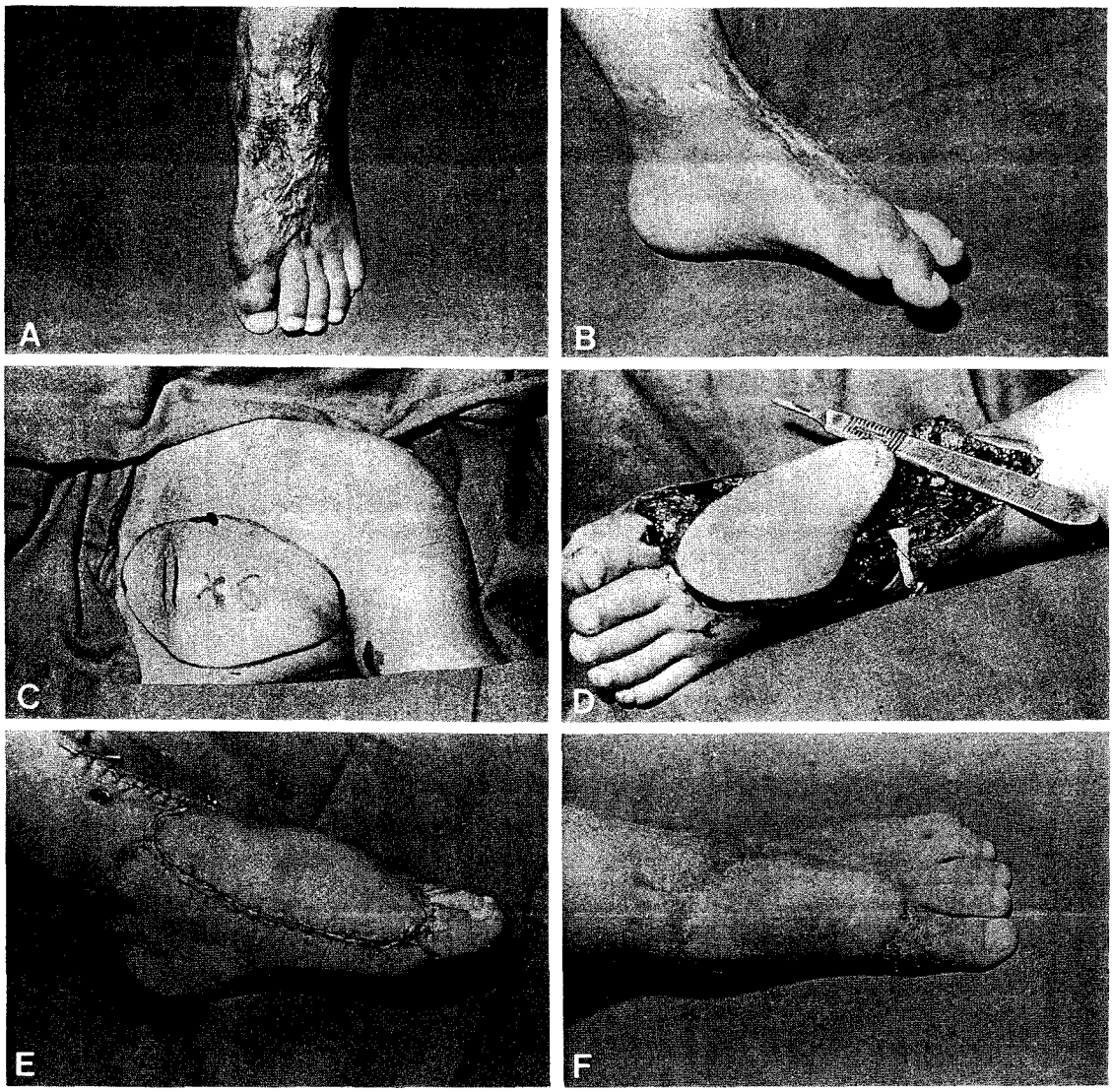


Fig. 1-A, B. Case 1. Preoperative finding of scar contracture and unstable skin on the dorsum of foot. **C.** Flap design on right scapular area. **D.** Anastomoses of circumflex scapular artery to anterior tibial artery. **E.** Postoperative recipient site. **F.** Good function after one year, postoperatively

increasing numbers of traffic accidents and mechanical injuries. Many types of microsurgical reconstructive procedure have been developed and reported for patients who have sustained extensive traumatic soft tissue injuries of the extremities. In 1906, Goyanes first performed a successful transplantation of the vessels, and then Jacobson and Suarez had successful experiments with microscopic vascular anastomosis of 1 mm diameter in 1960. McGregor and Jackson[17] performed a groin pedicle flap in extensive soft tissue injury in the upper extremities and Harii et al.[11] had a successful transplantation of free scalp flap in 1972. In 1973, Daniel and Taylor[5] first performed groin flap successfully, followed by O' Brien[19,20], Harii, Ohmori, Rigg[21], Baudet[3],

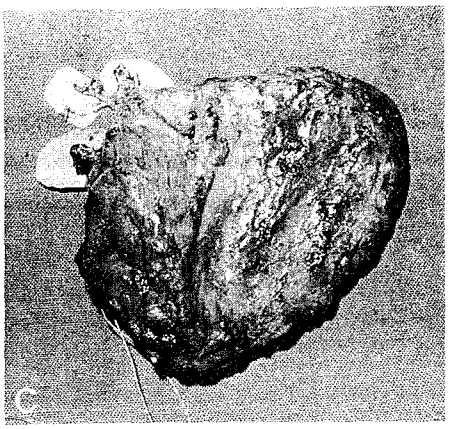
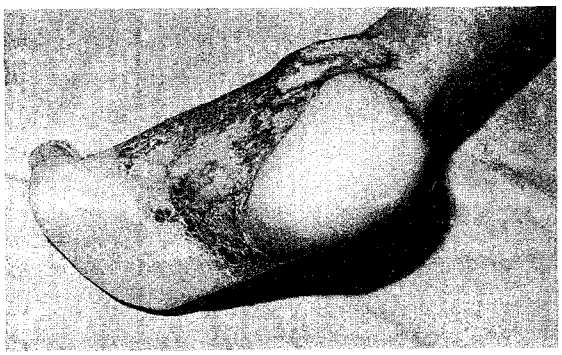


Fig. 2-A. Case 1. Preoperative finding of scar contracture and poor skin condition on right sole and heel. **B.** Flap design on left deltoid area. **C.** Elevation of inferior edge of deltoid muscle demonstrating neurovascular pedicle. **D.** Donor site scar.



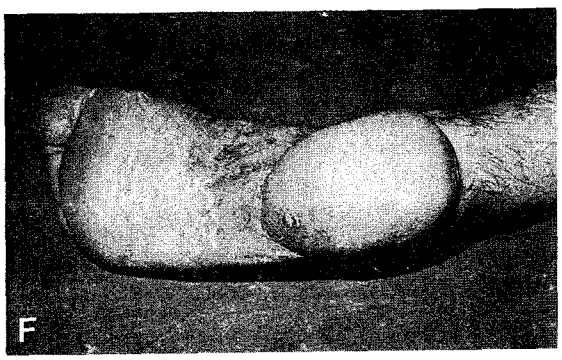


Fig. 2. continued. **E, F.** One year after procedurer.

Karkowski[13], and Serafin[22]. The microscopic free flap transplantation has some advantages and disadvantages. The advantages are one stage operation for the injured site, possible early range of motion exercise, the ability to get free-vascularized osteocutaneous flap, and possible primary closure of the donor site. The disadvantages are difficult, long operations, and partial or total necrosis of the flap due to circulatory dysfunction because of vascular compression or vascular spasms, intraoperatively or postoperatively.

Cutaneous flaps based on the circumflex scapular arterial system include the cutaneous scapular flap and the cutaneous parascapular flap. The scapular flap, described by dos Santos[8] and extensively reported by Gilbert et al. and by Urbaniak et al.[24], is considered a versatile cutaneous flap that can cover a defect measuring 10-by-16 cm. No functional morbidity of the donor site is appreciable. The skin is thin and hairless although the hilum may be fairly bulky. The pedicle is long and constant, with a length of 4 to 9 cm. The scapular flap can be elevated and dissected rather quickly and is suitable for small areas of skin loss. Its disadvantages include its lack of a cutaneous nerve as an innervated flap and the tendency for the donor site scar to spread, limiting its usefulness in women.

The iliofemoral (groin) pedicle flap, popularized by McGregor and Jackson, has been extensively applied to the repair and reconstruction surgery in the upper extremity. Since the report in 1973 by Daniel and Taylor describing its successful use as a free flap, many surgeons found it useful for coverage problems encountered in reconstruction of the trunk, head and neck, as well as in the upper and lower extremities. Although it has been used for the hand, it is particularly suited to coverage problems about the elbow. It has also been beneficial for coverage of the exposed tibia and for problems in the foot, especially over the heel. In some situations requiring a bone graft, the underlying iliac crest may be included with the groin flap, using either the superficial circumflex iliac artery or the deep circumflex iliac artery.

Building on the 1896 reports of Tansini, who used the latissimus dorsi muscle pedicle flap for breast reconstruction, and on the extensive use of the latissimus dorsi as a muscle pedicle flap for trunk, head and neck reconstruction. Baudet, Guimberteau and Nascimento, Harii et al., and Maxwell et al.[15] demonstrated the successful transfer of the latissimus dorsi muscle as a free flap. The myocutaneous free flap has been used extensively for soft-tissue coverage problems because of its large size, long and reliable pedicle of adequate vessel diameter.

Although the tensor fasciae lata flap may not adhere to a recipient site, it may be used for coverage of soft tissue defects in the upper or lower extremity, as a sensory innervated flap, as a functioning neuromuscular unit, and as an osseomusculocutaneous flap incorporating a portion of the bone of the iliac crist. Its function as an innervated flexor substitute is limited because of its limited excursion; however, it has potential as an extensor replacement. A 10-by -30 cm skin flap centered over the midaxis of the muscle may be harvested with the underlying muscle.

The advantages of the dorsalis pedis free-tissue transfer are that it has a large-caliber arterivenous pedicle, a long pedicle can be obtained, it can be innervated, it is a thin flap, bone may be included, the donor site

may be relatively inconspicuous after adequate healing, and in some patients a large (10-by-10 cm) flap may be obtained. The dorsalis pedis free flap is useful for coverage problems in the palm, the thumb web space, and the foot, especially in those areas requiring protective sensation. The disadvantages are difficult and tedious dissection, the possibility of a painful and gypertrophic donor site scar, and the frequently-restricted size (7- by-7 cm or smaller).

The deltoid flap is a fasciocutaneous neurosensory free flap that is elevated primarily from above the deltoid muscle. The advantages of the flap are that it is thin and pliable and that it may provide sensibility to the reconstructed areas. Despite the tediousness of dissection of the neurovascular pedicle from beneath the deltoid muscle, the basic elevation of the flap is quite simple. The healing of the donor site with a thick scar is a distinct disadvantage when considering this flap for some reconstructive procedures, but limitation of shoulder-joint motion has not remained. The flap has been most useful in reconstructing soft-tissue defects and in contouring about the foot and ankle.

Functionally, the thick skin flap or sensory flap has less ulceration and good protective sensation, compared with the thin skin flap or no sensory flap.

CONCLUSIONS

One hundred and thirty seven patients had reconstructive surgery of injured feet with microsurgical technique in the Department of Orthopaedic Surgery at Yonsei University College of Medicine from 1983 to 1997.

The results were as follows:

1. There were 89 cases in men and 48 cases in women who had a mean age of 21.3 years.

2. The causes of injuries were traffic accidents (97 cases:70.8%), followed by the machinery injuries (11 cases:8.0%), burn (15 cases:10.9%), glass injury (2 cases:1.5%), snake bite (2 cases:1.5%), infection (5 cases:3.6%), falling injury (2 casses:1.5%), stab wound (1 case:0.7%), and ulceration (1 case:0.7%) (Table 2).

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4. Among 137 cases, 127 (92.7%) cases were sucessful in reconstructive surgery with microsurgical technique.

5. Functionally, the thick-skin flap or sensory flap has less ulceration and good protective sensation.

We considered that the function and cosmetic appearance were excellent after reconstructive surgery of the injured feet with microsurgical reconstructive technique and that the thick-skin flap or sensory flap has less ulceration and good protective sensation.

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