Eur J Plast Surg (1997) 20:181–185

European Journal of Plastic Surgery

The flow-through free flap in replantation surgery: a new concept

H. Costa[1], **C. Cunha**[1], **A. Conde**[1], **A. Barsdley**[2], **D.A. McGrouther**[2]

[1] Department of Plastic Surgery, S. João Hospital, Oporto, Portugal
[2] Department of Plastic Surgery Canniebum Hospital, Glasgow, UK

Abstract. The concept of flow-through circulation in free flaps was previously described as a one-staged technique for cover and revascularisation of ischaemic traumatized extremities. This paper describes the practical use of the concept in replantation surgery. Two clinical cases of hand replants are presented in which an uninterrupted flow was established through the selected free flap.

Key words: Replantation – Flow-through free flap

Höpfner [15] and Lapchinski [17], using techniques of vascular surgery, successful replanted canine extremities. With the advent of the clinical microscope and microsurgical instrumentation, Buncke et al. reported their experimental work in the rhesus monkey with one successful digit replantation out of 10 cases [7, 8]. The improvement in microsurgical instrumentation allowed a more predictable outcome in small vessel anastomosis and Buncke and Schulz were able to replant ears in the rabbit [9].

Komatsu and Tamai reported the first successful clinical replantation of a totally amputated thumb by microvascular anastomosis, although they had already performed the case in 1965 [16]. Biemer et al. presented the, until then, largest series in Europe of 184 replantations in 132 cases [3]. During the years 1985, 1986 and 1987, a total number of 6236 replantations, including macro and micro-replantations were performed in several national replantation centers through Europe [6].

Costa et al. [12] described the concept of one-stage coverage and revascularization of traumatized limbs by a flow-through radial mid-forearm free flap. An uninterrupted arterial and venous flow was established through the flap, allowing revascularisation of the ischaemic extremities. We report the use of the flow-through free flap concept in two hand replants (Fig. 1).

Correspondence to: H. Costa, Consultant Plastic Surgeon, Rua do Corvo, 323 – Praia da Granja, P-4405 Arcozelo VNG, Portugal

Case reports

Case 1

A 27-year-old man sustained a transmetacarpal amputation of his right hand in a road traffic accident on the 7th May 1987 in Glasgow. The amputated part included all the 4 fingers, metacarpal joints and different parts of the metacarpal bones with a crush-degloving component of the dorsum (Fig. 2a, b). After bone fixation, arterial flow was reestablished through a basilic vein graft, harvested from the right forearm and end to side anastomosed to the radial and metacarpal arteries (Fig. 2c). As there was skin loss of the dorsum, no dorsal veins were present for venous drainage; so, a free dermal flow-through venous flap was harvested from the contralateral forearm and proximal and distal end to end venous anastomoses were performed between dorsal and cephalic veins (Fig. 2d). A split-skin graft was applied over the venous flap (Fig. 2e). The post-operative course was uneventful. After a rehabilitation progam, a good range of motion was achieved with a useful grasp (Fig. 2f, g, h).

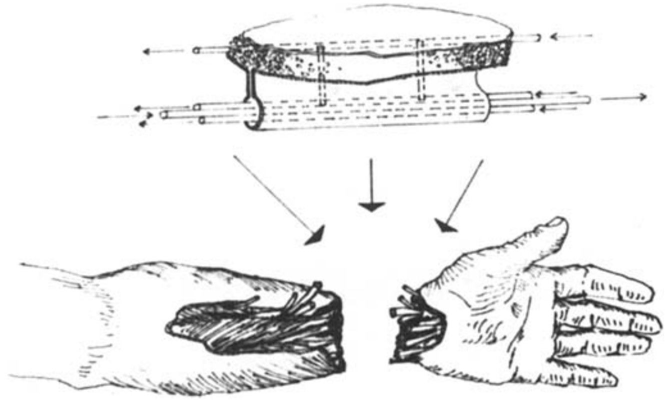

Fig. 1. Diagram showing the anatomical and dynamic concept of a flow-through fasciocutaneous free flap in replantation

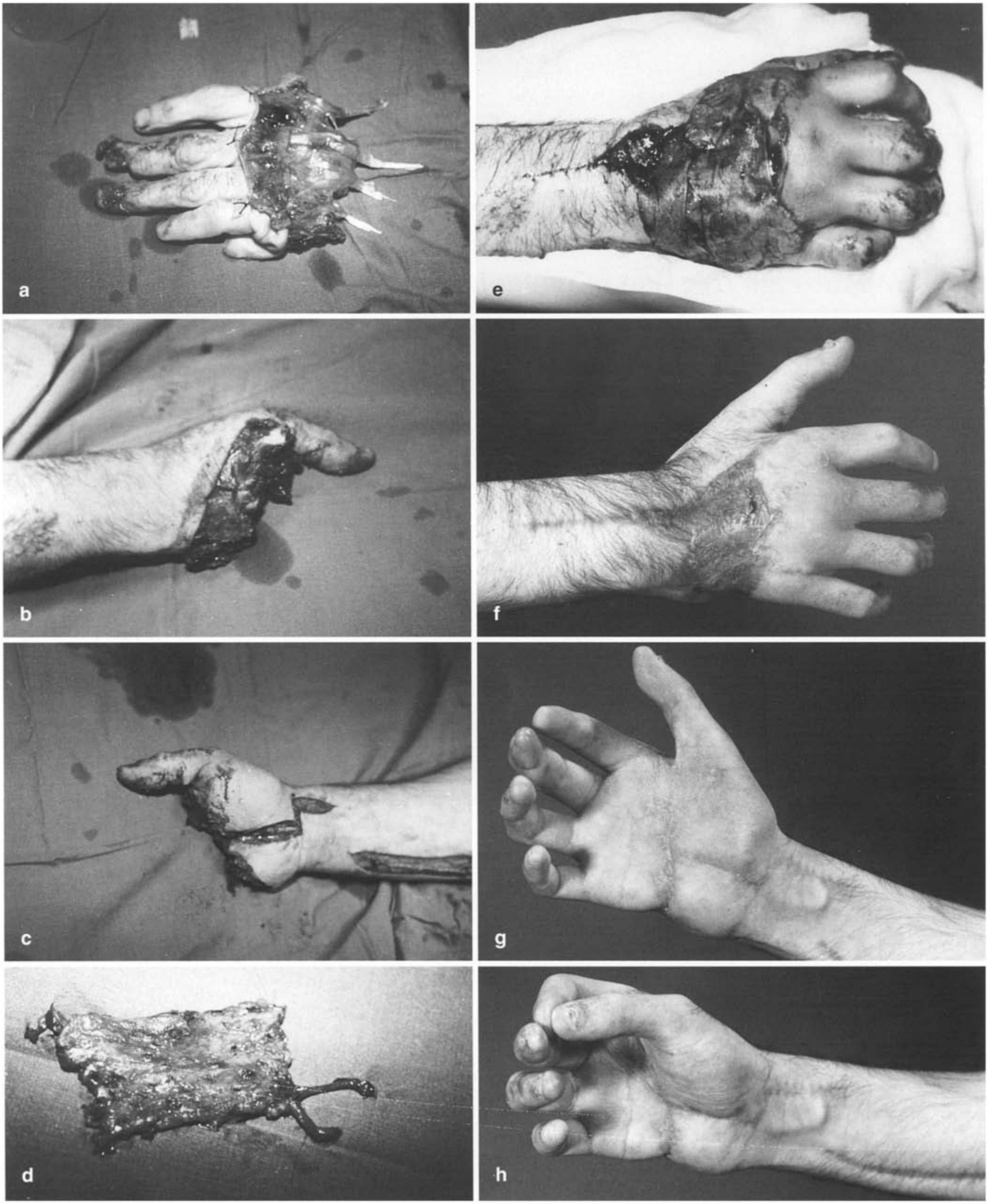

Fig. 2. a Transmetacarpal amputation of right hand. **b** Dorsal aspect of the amputated sumpt with skin loss and absence of dorsal veins. **c** Palmar aspect of the amputated stump with skin incisions for dissection of the radial artery and harvesting of the basilic vein graft. **d** The free dermal flow-through venous flap. **e** Immediate P.O. result with split skin grafts applied over the flap. **f, g, h** Appearance at 5 months after surgery. A good range of motion was achieved with an useful grasp

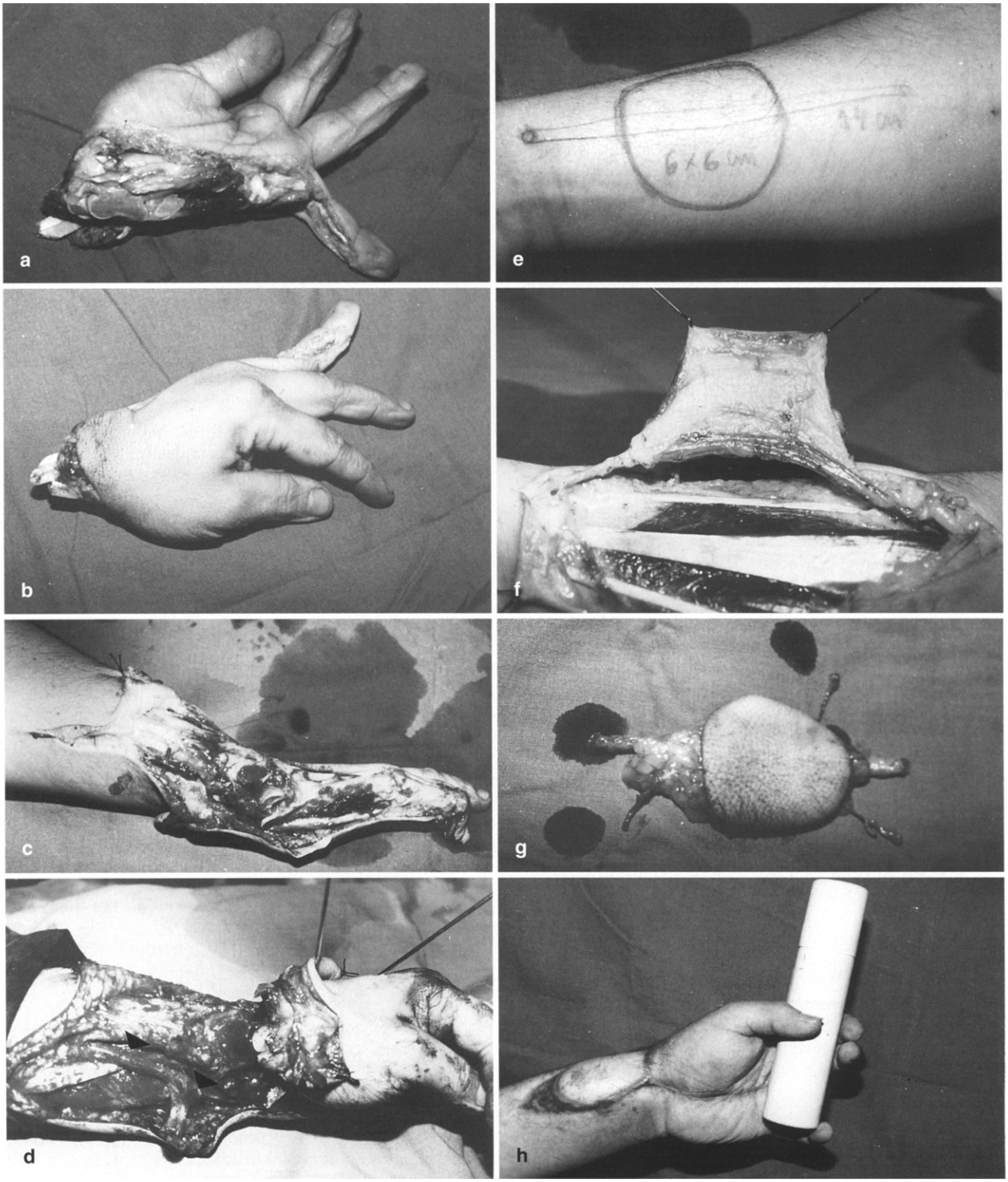

Fig. 3a, b. Oblique transcarpometacarpal amputation of left hand (palmar and dorsal aspects). **c** The crush-degloving injury of the amputated stump. **d** Bone fixation of the amputated part without bone shortening. The segmental injury of the radial vessels is shown between *arrows*. **e** Marking of the flow-through fasciocutaneous radial flap. **f, g** Harvesting of the free flap. **h** Appearance at 4 months after surgery. The patient already has an useful grip capacity

Case 2

A 30-year-old man sustained an oblique transcarpometacarpal amputation of his left hand in a pressure-cutting machine on the 28th December 1993 in Oporto. The amputated part included the thumb, index and middle fingers, the radial aspect of the ring finger, metacarpal joints and bones, thenar eminence and the radial two-thirds of the wrist (Fig. 3a, b). The amputated stump was heavily crushed and under the microscope an exploration of the radial artery was performed which revealed multilevel lesions of the vessel in the distal 10 cm (Fig. 3c, d).

A decision to use a flow-through type of flap was made and the selection was the radial mid-forearm flap (Fig. 3, e, f, g). The flap was transposed and the two ends of the radial artery, the venae comitantes and the cephalic vein of the contralateral forearm flap were anastomosed end-to-end to the proximal and distal ends of the sectioned vessels of the injured forearm and hand.

After flow-through was established, the hand became well perfused. Most of the defect was covered and healing was uneventful. After a rehabilitation program of 4 months, the patient had some grip strength and a range of excursion which allowed him to grasp small and large objects (Fig. 3h).

Discussion

Reimplantation and revascularisation of extremities continue to be a demanding task for the plastic and reconstructive surgeon. Their needs increase in proximal, total or subtotal amputations because of length losses. If we are dealing with avulsion type injuries, the major pitfall is the assessment of the extent of vessel damage, both in the proximal amputated stump and in the distal amputated part. Consequently, vascular anastomosis must be performed as far proximally and distally, requiring greater bone shortening or longer interposition vein grafts.

Total amputation requires that the damaged part is completely severed and separate from the body. Subtotal amputation is considered when the damaged part is still attached by a bridge of skin, subcutaneous or some other structure, without any sign of blood circulation, accompanied by blood vessel destruction. Amputation is further divided into major (proximal at the wrist or ankle joints) and minor (at or distal to the referred joints) and consequently we can speak about macro and microreplantations. Amputations are also classified according to the nature of injury as cutting, crush, degloving, avulsion or combined.

Biemer defined replantation as the operative reconstruction of the amputation injuries, including the reconnection of the various structures, including the blood vessels which will guarantee the viability of the amputated part [6].

Since the introduction of the vein grafts by Biemer, replantation and revascularization became possible, in avulsion and heavy combined crushing injuries allowing re-anastomosis through a bridge over and out of the zone of trauma [4]. Nowadays, they play a major role in replantation surgery; but this useful technique doesn't have soft tissue coverage capacity which sometimes is paramount in certain types of replants.

Considering the main vascular pedicles, we have to deal with two kinds of situations; 1- the absence of major longitudinal losses of the vessel ends, allowing end to end anastomosis with some bone shortening and 2- the presence of major longitudinal losses of the vessel ends making techniques for their reconstruction the key point for restablishement of the blood flow.

Bone shortening is limited, particularly in the lower limb to a maximum of 5–6 cm and can be performed either proximally in the amputated stump or distally in the amputated part. Interpositional vein grafts are the method of choice to bridge the vascular gaps and are usually harvested from the great and small saphenous, cephalic and basilic veins or their tributaries, depending on the length of the vascular defect and the diameter of the vessels. Biemer and Duspiva put as indications for them [5].

- Vessel defects (arterial and venous)
- Difficult anastomoses with short vessel stumps
- To by-pass bifurcations and tributaries
- Tension at the site of anastomosis
- Differing vessel caliber.

In major trauma of the extremities, including total and subtotal amputations, flap cover is desirable when exposure of deep structures, like tendons, nerve and/or bone, is present [24]. In these clinical situations the flow-through free flap concept is the method of choice [12]. There are two types of free flaps which allow the clinical application of this concept in replantation surgery:

- The flow-through free fasciocutaneous flap for arterial supply and venous drainage of the replant
- The flow-through free venous flap for venous drainage of the replant.

The flow-through free fasciocutaneous flap achieves a one-staged technique of soft tissue cover and distal revascularisation. This technique has other important advantages, not previously discussed:

- Reconstruction of the arterial defect by another artery
- Reconstruction of the superficial and deep venous systems by the superficial and deep veins of the flap
- Anatomical link between superficial and deep venous systems through the flap
- Maintenance of the collateral vessels in the traumatic defect by the flap tissue
- No major discrepancies in the microvascular anastomosis.

The flow-through venous flap is also an interesting and evolutionary concept. Baek et al. [2] and Amarante et al. [1] presented experimental work in the dog, testifying the viability of the flow-through venous saphenous flap [1, 2]. Also, successful clinical cases have been reported [1, 10, 13, 22] and Honda et al. have used skin and subcutaneous tissue as free venous carriers for digital replants, including dorsal skin losses, with success in two out of five cases [14].

A recent aspect must be brought into discussion about the survival of these flow-through venous flaps. The experimental work of Noreldin et al. has confirmed the importance of the perivenous areolar tissue in perfusion of the skin island in the rat inferior epigastric venous flap [19]. Shalaby and Saad presented histological studies of the pedicles of long and short saphenous and cephalic venous flaps in fresh human cadavers and in two clinical cases, showing that one or two arterioles and multiple capillaries were present in the perivenous areolar tissue [21].

Lenoble et al. [18] showed experimental incapacity for a vein to nourish a flap, in the epigastric and thoraco-abdominal flow-through venous flaps of the rat, if the vein was meticulously clean of the perivenous areolar tissue. These authors concluded that the survival observed in clinical reports could be explained by the conjunction of arterial micro circulation preservation in the perivenous fat, augmentation of blood flow and pressure and by exchanges with the recipient bed. This challenges the concept that these flaps are purely venous. These explanations seem to be supported by Chow et al. [11].

Sequentially linked free flaps are a very interesting and useful concept. The complex three-dimensional nature of composite head and neck defects after tumor extirpation may challenge the ability of any single osteocutaneous flap to adequately reconstruct all aspects of the resultant defect. Sequentially linked free flap reconstructions, consisting of one free flap linked to the second, have become a preferred method of reconstruction for complex composite head and neck defects when there is limited recipient site vascularity [20, 23].

As a conclusion, the flow-through flap concept is one of considerable use in the clinical field of major trauma of the extremities, including replantations.

Acknowledgements. The authors would like to thank Ms Margaret Murray from the Department of Medical Illustration at Canniesburn Hospital and Mr. Albert Alfaia from the Anatomy Department of Oporto University for providing the medical illustrations. Our sincere thanks go to Ms. Fernanda Zenha, the author's wife, in the preparation and typing of this manuscript.

References

1. Amarante J, Costa H, Reis J, Soares R (1988) Venous skin flaps: an experimental study and report of two clinical distal island flaps. Br J Plast Surg 41:132–137
2. Baek SM, Weinberg H, Song Y, Park CG, Biller HF (1985) Experimental study of the survival of venous island flaps without arterial inflow. Plast Reconstr Surg 75:88–95
3. Biemer E (1977) II – Zehentransplantation. Vortrag Third Congress of European Section of the International Confederation for Plastic and Reconstructive Surgery, The Hague May 1977, pp 22–27
4. Biemer E (1977) Vein grafts in microvascular surgery. Br J Plast Surg 30:197–201
5. Biemer E, Duspiva W (1982) Reconstructive microvascular surgery. Springer, Berlin Heidelberg New York
6. Biemer E (1993) Current status of replantation surgery. In: Soutar DS (ed) Microvascular surgery and free tissue transfer. London Melbourne Auckland, pp 43–53
7. Buncke HJ, Buncke CM, Schulz WB (1965) Experimental digital amputation and reimplantation. Plast Reconstr Surg 36:62
8. Buncke HJ, Buncke CM, Schulz WB (1966) Immediate Nicoladoni procedure in the rhesus monkey, or hallux-to-hand transplantation, utilizing microminiature vascular anastomoes. Br J Plast Surg 19:332
9. Buncke HJ, Schulz WB (1966) Total ear reimplantation in the rabbit utilizing micro-miniature vascular anastomoses. Br J Plast Surg 10:15
10. Chavoin JP, Rouge D, Vachand M, Boccalon H, Costagliopa M (1987) Island flaps with an exclusively venous pedicle. A report of eleven cases and a preliminary haemodynamic study. Br J Plast Surg 40:149–154
11. Chow SP, Chen DZ, Gu YD (1992) A comparison of arterial and venuos flaps. J Hand Surg 17B:359–364
12. Costa H, Guimarães I, Cardoso A, Malta A, Amarante J, Guimarães F (1991) One-staged coverage and revascularisation of traumatised limbs by a flow-through radial mid-forearm free flap. Br J Plast Surg 44:533–537
13. Foucher G, Norris RW (1988) The venous dorsal digital island flap or the neutal flap. Br J Plast Surg 41:337–343
14. Honda T, Nomura S, Yamanchi S, Shimamura K, Yoshimura M (1984) The possible applications of a composite skin and subcutaneous vein graft in the replantation of amputated digits. Br J Plast Surg 37:607–612
15. Höpfner E (1903) Über Gefäßnaht, Gefäßtransplantation and Reimplantation von amputierten Extremitäten. Arch Klin Chir 70:417
16. Komatsu S, Taimai S (1968) Successful replantation of a completely cut-off thumb. Plast Reconstr Surg 42:374
17. Lapchinsky AG (1960) Recent results of experimental transplantation of preserved limbs and kidneys and possible use of this technique in clinical practice. Ann NY Acad Sci 64:539
18. Lenoble E, Foucher G, Voisin MC, Maurel A, Gontallier D (1993) Observations on experimental flow-through venous flaps. Br J Plast Surg 46:378–383
19. Noreldin AA, Fukuta K, Jackson IT (1992) Role of perivenous areolar tissue in the viability of venous flaps: an experimental study on the inferior epigastric venous flap of the rat. Br J Plast Surg 45:18–22
20. Sanger JR, Matloub HS, Yousif NJ (1990) Sequential connection flaps: a logical approach to customized mandibular reconstruction. Ann J Surg 160:402–404
21. Shalaby HA, Saad MA (1993) The venous island flap: is it purely venous? Br J Plast Surg 46:285–287
22. Thatte RL, Thatte MR (1992) Cephalic venous flap. Plast Surg 45:18–22
23. Wells MD, Luce EA, Edwards AL, Vasconez HC, Sadove RC, Bouzaglou S (1994) Sequentially linked free flaps in head and neck reconstruction. Clin Plast Surg 21:59–67
24. Zhong-Jia Y (1987) Microsurgical composite free tissue transfer for extremity trauma. Plast Reconstr Surg 79:222–233

H. Costa