Original Article

Replantation of ring avulsion amputations

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ABSTRACT

Replantation of ring avulsion injuries is a challenge because of the long segment damage to the vessels and intrinsic damage caused to soft tissues at the proximal edge of the amputation. Eight patients with total ring avulsion amputations underwent microsurgical replantation in the period 1994 to 2002. Arterial repair was done by direct vessel suture in three patients, interposition vein grafts in two and cross anastomosis of the digital arteries in three patients. Venous anastomosis was carried out by mobilization and direct suture in seven patients and vessel transfer from the adjacent finger in one patient. Seven of the eight replantations were successful, while one patient had a partial failure. At a minimum follow-up of one year, these patients showed good functional and cosmetic recovery. All successful patients were happy with the outcome and none have requested for amputation, even those whose results were not functionally adequate. However, in addition to technical factors, it is important to evaluate the patient's motivation to undergo not only the long surgery, but also multiple secondary procedures and regular supervised physiotherapy. We also describe a simple method which prevents the soft tissues inside the degloved digit from becoming wrapped around the K wire during bony fixation, thus making one step of this technically challenging procedure a little easier.

KEY WORDS

Ring avulsion amputation, Replantation, K-wire insertion.

INTRODUCTION

Injuries caused to the finger by avulsion of the soft tissues when the ring is pulled forcefully can cause a wide range of damage. It could extend from a circumferential soft tissue injury, which needs only appropriate wound care to total amputation of the finger. In between there is a spectrum, where the part is not amputated, but requires arterial repair or venous augmentation or both for survival. Urbaniak et al,[1] classified these injuries into three types based on the circulatory status (Table 1). Nissenbaum[2] added an additional subclass, IIA, denoting circulatory insufficiency caused by arterial injury only (Table 2), while Kay et al,[3] proposed an alternative classification

Table 1: Urbaniak classification of ring avulsion injuries[1]

Class I	Circulation adequate. Standard bone and soft tissue treatment is sufficient
Class II	Circulation inadequate. Vessel repair preserves viability permitting immediate or delayed repair of other tissues
Class III	Complete degloving or complete amputation. Judgment is essential because, although a complete amputation can be revascularised and viability restored, the potential for function is limited. In degloving injuries, the potential for useful function exists, but revascularisation is not easy or may not be possible

that took into account the presence of skeletal injury, which they found had a bearing on functional outcome (Table 3). In all classifications, total amputation has been maintained as the last and separate group. Many authors have maintained that a degloved finger, with the exception of the thumb, should be a candidate for amputation in the interest of total hand function.[4,5] With the development of microsurgery, the choices have become more complicated and alternatives include replantation, local flap, pedicle flap, graft coverage and free tissue transfers.[3] In most series, the patients whose fingers were salvaged by replantation had satisfactory outcomes with nearly complete cosmetic and functional restoration and none have subsequently requested for amputation.[1-4] However in spite of the advances in microsurgery, achieving satisfactory results in Class III ring avulsion amputations is difficult due to the extensive surgery and rehabilitation involved.[3] In this retrospective study, we are discussing our experience of reconstructing Urbaniak Class III total avulsion amputations.

Table 2: Nissenbaum classification of ring avulsion injuries[2]

Class I	Circulation adequate
Class II	Circulation inadequate
Class IIA	Circulation inadequate (only arteries injured)
Class III	Complete degloving or complete amputation

Table 3: Kay's classification of ring avulsion injuries[3]

Class I	Circulation adequate, with or without skeletal injury
Class II	Circulation inadequate (arterial and venous), no skeletal injury
a	Arterial circulation inadequate only
b	Venous circulation inadequate only
Class III	Circulation inadequate (arterial and venous), fracture or joint injury present
Class IV	Complete Amputation

Class III digital ring avulsion amputation often occurs through the level of the distal interphalangeal joint, so that the distal phalanx is present in the avulsed, amputated part. This makes bony fixation technically difficult, as access to the bone through the sleeve of the degloved finger soft tissue envelope is limited. It is easy to unintentionally wrap the soft tissues (including important neurovascular structures) around the Kirschner (K) wire as it is inserted, which may compromise subsequent revascularisation. We present a simple method to surmount this problem.

MATERIAL AND METHODS

Five male and three female patients, ranging in age from 18 years to 74 years (average, 31.5 years), underwent microsurgical replantation of total ring avulsion amputations during the period 1994 - 2002. All the patients were right handed and the left ring finger was amputated in five of the eight patients. Five of the amputations were through the distal interphalangeal joint, one was through the proximal phalanx and two were total degloving wounds without any bony injuries. The details regarding the age, sex, level of injury, no. of vessels repaired, complications, secondary procedures and follow up period are given in Table 4.

The amputated part is first examined under the microscope. A single longitudinal incision is made on the volar side for isolation of the arteries. Two incisions, which are usually used for vessel isolation in regular

Table 4: Patient data

Case No.	*Sex*	*Age*	*Finger*	*Bony level of amputation*	*Arteries repaired*	*Veins repaired*	*Complications*	*Secondary procedures*	*Follow-up period (yrs.)*
1.	F	25	Rt. Ring	DIP Jt.*	1 vein graft	2	• Marginal skin necrosis	• Split skin graft • DIP Arthrodesis	6
2.	F	19	Lt. Ring	DIP Jt.	1 cross over	2adj. finger	• Marginal skin necrosis	• Split skin graft • DIP Arthrodesis	5
3.	F	27	Lt. Ring	DIP Jt.	1 cross over	3	• Marginal skin necrosis	• Split skin graft • DIP Arthrodesis	5
4.	M	26	Lt. Ring	Total Degloving	1	2	• Nail bed necrosis • Marginal skin necrosis • PIP Jt.‡. Contracture	• Reverse dermis flap • Split skin graft • PIP Arthrodesis	3
5.	M	33	Lt. Little	DIP Jt	1 cross over	2	• Marginal skin necrosis	• Split skin graft • DIP Arthrodesis	2
6.	M	23	Rt. Ring	DIP Jt.	1 vein graft	3	• Partial Failure	• Cross finger flap	1
7.	M	25	Lt. Ring	Total Degloving	1	3	–	–	2
8.	M	74	Lt. Ring	PPx†	1	3	• Marginal skin necrosis	Split skin graft	1

DIP Jt*: Distal interphalangeal joint/ PPx†: Proximal phalanx/ PIP Jt‡: Proximal interphalangeal joint

digital replantation, are avoided. When multiple incisions are used, the skin between the incisions may undergo necrosis. The available arteries are isolated and marked. The veins are also marked. The quality of the vessels is assessed under the microscope and the edges are trimmed till the point where the ends are normal.

The patient is then administered a brachial block for the examination of the proximal part. The vessels are isolated and marked. In all patients, we were able to identify suitable vessels. The digital nerves were found avulsed and the edges could not be approximated for primary repair in any of the cases, except one. All would have needed nerve grafts and nerve grafting was deferred in the acute situation. Most cases had long length of digital nerves in the proximal part and it was just left in situ and the distal part was draped over them.

Skeletal fixation is technically demanding, since the distal phalanx is deep inside and there is risk of the soft tissues getting entangled during the process of introduction of the K-wire. A long sleeve is required to protect the tissues. We found a simple solution for the problem by using the plastic protective guard of a long hypodermic needle. The closed end is cut off and this results in a slim tube open at both ends to be used as a sleeve for the introduction of the K-wire (Figure 1a). The K-wire is passed through the plastic sleeve (Figure 1b) and then the protected wire is inserted into the soft tissue envelope of the amputated part in a retrograde fashion (Figure 1c). The sleeve must be retained inside the amputated finger as the K-wire is withdrawn from the outside of the finger until it reaches the proximal end of the distal phalanx. The sleeve is then removed from the amputated part, which is then placed over the proximal skeleton, and the K-wire is driven proximally into the middle phalanx. Using sleeves to protect important structures during wire insertion is a common orthopaedic practice. When custom made sleeves are not available, the plastic protective guard of the long hypodermic needle, which we have described, is very useful.

The vessels are then anastomosed. All had one arterial reconstruction. Two patients required vein grafts, which were harvested from the volar aspect of the wrist. Three had cross anastomosis of the artery i.e. the radial side digital vessel anastomosed to ulnar side digital vessel and vice versa. During an avulsion injury, the vessels on each side may suffer damage to differing extents and this is a useful technique to get vessels of good quality for anastomosis. In five patients, two veins were repaired, while in three patients, three veins were repaired. Vein grafts were not used for veins.By dissecting proximally and diverting veins from adjacent finger we were able to manage without vein grafts.In the five patients with amputation through the DIP joint, the FDS insertion was intact in the proximal segment, while the FDP was avulsed from its insertion. To provide stability, the DIP joint needs to be arthrodesed and hence no attempt was made to do any tendon repair.

Post-operatively all patients received continuous intravenous infusion of Dextran - 40 (mw : 40,000)@ 15 –20 micro drops per minute with 5000 units of heparin added to every 500 ml, everyday for five days, followed by Tablet Aspirin 150 mg, once daily for 3

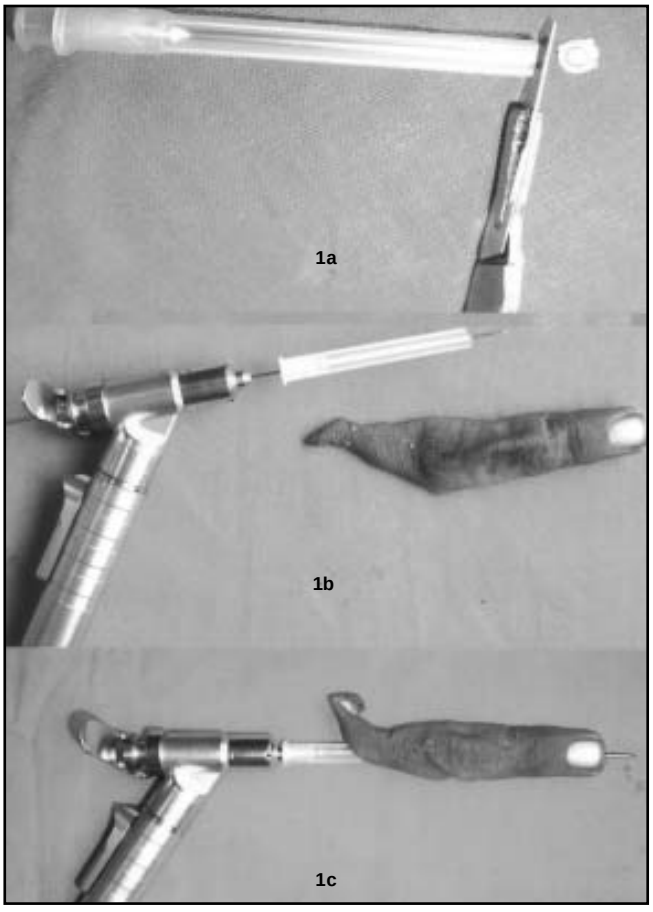

Figure 1: Use of the protective guard of a hypodermic needle as a sleeve during K wire fixation

weeks.

CASE REPORTS

1. Case No. 3: A 27-year-old lady veterinary surgeon sustained an amputation of the left ring finger when it accidentally got caught in an iron gate. The patient presented to us three hours after the accident with an avulsion amputation of the left ring finger through the distal interphalangeal joint (Figures 2a & 2b). The FDS insertion was preserved and there was avulsion of the FDP tendon. On examination of the amputated part (Figures 3a & 3b) under the microscope, there was ecchymosis of the volar skin overlying the middle phalanx (Figure 3a). A longitudinal incision was made along the ulnar aspect. Only the radial digital artery could be identified and tagged. Three veins were identified and tagged on the dorsum. Both digital nerves could not be traced. On examination of the proximal part, both arteries, full length of both digital nerves (explaining absence in the amputated part) and three veins were identified and tagged.

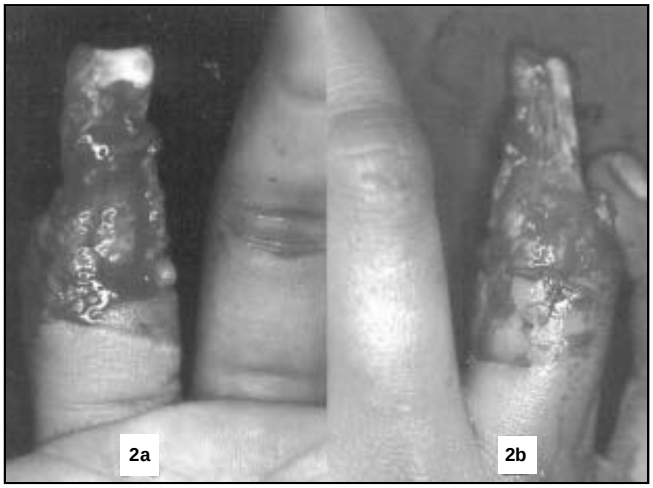

Figure 2: (Case No. 3) Ring avulsion injury with skeletal disruption through the distal interphalangeal joint

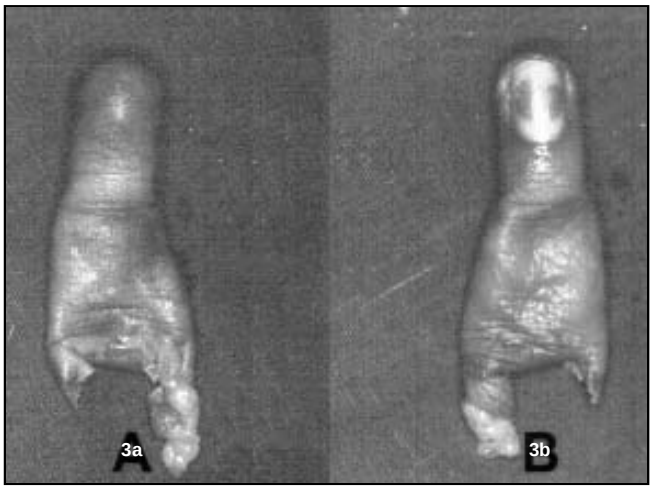

Figure 3: (Case No. 3) The avulsed parts

A longitudinal K-wire was driven in a retrograde manner and then driven proximally to fix both interphalangeal joints. Three dorsal veins and the ulnar side proximal digital artery was crossed over and anastomosed to the radial side distal digital artery with 10.0 Ethilon sutures. On release of clamps, the finger pinked up. Dorsal skin was sutured loosely, while the volar raw area was covered with a split skin graft. The total ischaemia time was 8 hours. The post operative period was uneventful. At three weeks a 2x1 cm raw area was seen over the volar aspect of the suture line for which split skin grafting was done. She underwent arthrodesis of the distal interphalangeal joint six months later.

At her final follow up five years after injury, she had an active range of motion of 100^0 at MCP joint & 90^0 at PIP joint (Figures 4a & 4b), excellent return of protective

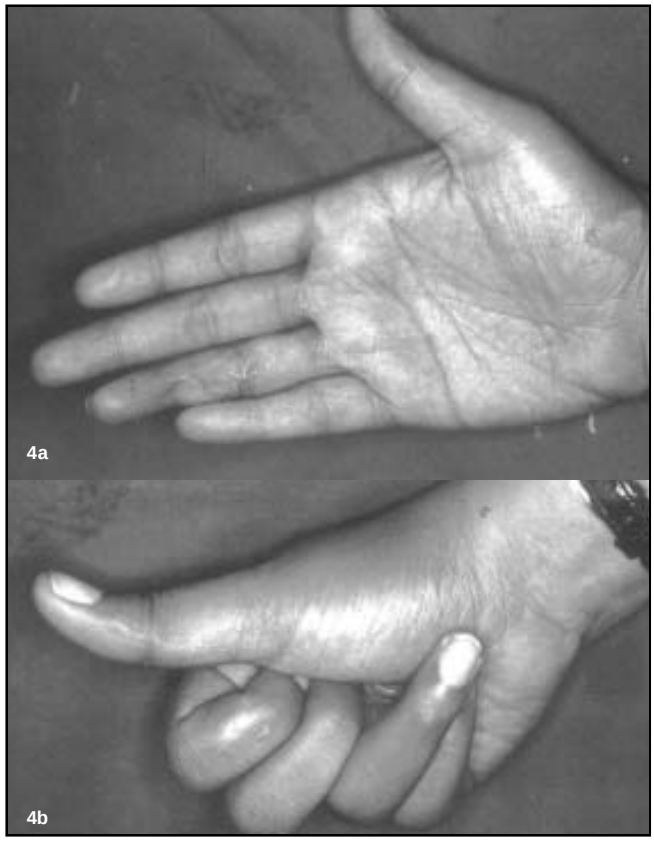

Figure 4: (Case No. 3) Post operative result at five years. The patient had arthrodesis of the distal interphalangeal joint

sensation and had returned to her previous job.

2. Case No. 7: A 31 year old business man sustained an amputation of the left ring finger when his finger got caught in the door, while he was getting out of a car. He came to the hospital within an hour of sustaining the injury and was found to have a total avulsion amputation of the ring finger at the base of the finger. The distal 2/3rd of the proximal phalanx, the middle phalanx and the distal phalanx were exposed (Figures 5a & 5b). The digital arteries were seen in the stump at the level of the head of the middle phalanx. The insertions of the FDP and FDS were preserved. The distal amputated part consisted only of a skin sleeve with a nail bed and a loosely overhanging nail and was split along the ulnar border (Figures 6a & 6b).

On examining the amputated part under the microscope, the radial digital artery was identified at the level of the terminal phalanx. Three dorsal veins were also identified and tagged. The stump was then examined and both digital arteries were identified at the distal phalangeal level. Three dorsal veins were also identified and tagged.The amputated part was stabilized by a single axial K-wire passed through the distal phalanx into the middle phalanx. Three dorsal veins and the radial digital artery were anastomosed using 10.0 ethilon. On release of clamps the finger pinked up and there was bleeding from the nail bed. The skin was loosely sutured and an above elbow slab was given. The total warm ischaemia time was six hours. The patient did not need any secondary procedures and on follow up two years later, he had an active range of motion of 100^0 at MCP joint & 60^0 at PIP joint, good protective sensation and had resumed his original job three months after injury (Figures 7a & 7b).

3. Case No. 8: A 74 year old gentleman sustained an amputation of his left ring finger when it accidentally got caught in the door handle. He came to the hospital within two hours of sustaining the injury and was found to have an avulsion amputation through the neck of the proximal phalanx (Figures 8a & 8b). The proximal part of the proximal phalanx was exposed and the FDS tendon was protruding through the stump. We were reluctant to offer replantation in view of his age, but he was extremely persistent and hence an attempt was

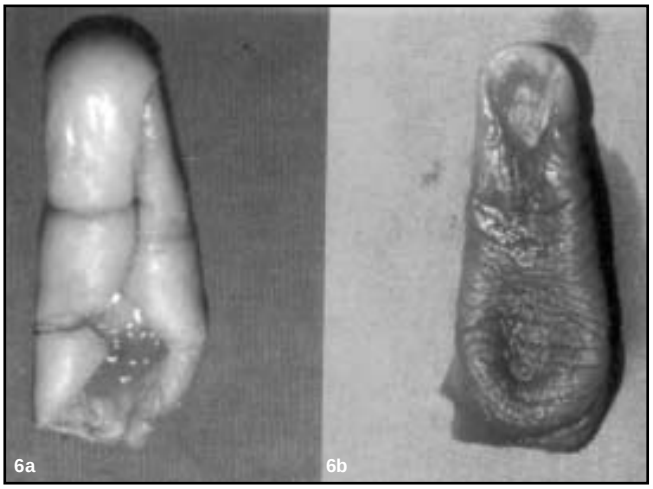

Figure 6: (Case No. 7) The degloved finger

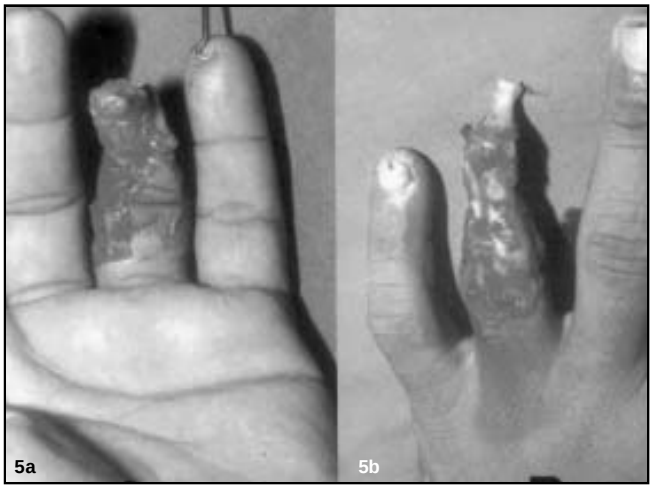

Figure 5: (Case No. 7) Total degloving of the finger including the nail bed component

Figure 7: (Case No. 7) Post–operative result

Figure 8: (Case No. 8) Ring avulsion amputation with fracture through proximal phalanx

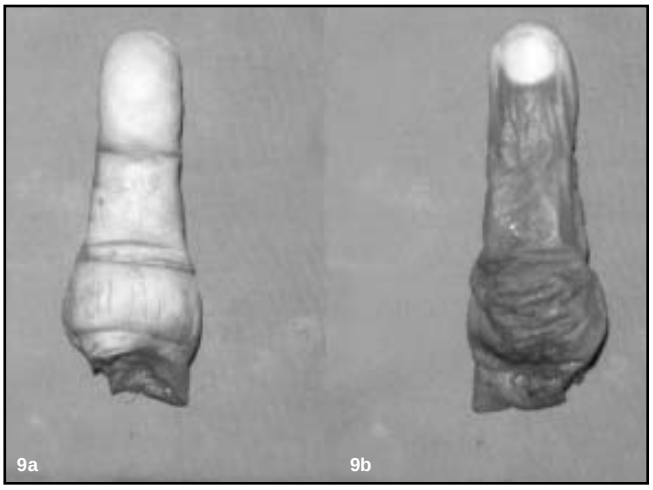

Figure 9: (Case No. 8) The avulsed finger. Note the impression of the tight ring at the base

made. On examination of the amputated finger (Figures 9a & 9b) under the microscope, the radial digital artery and two dorsal veins were identified and tagged. Two dorsal veins and both digital arteries were identified and tagged in the stump.

The proximal phalanx was shortened and fixed with a single axial K-wire. The volar plate, FDS and extensor tendon were repaired. The radial digital artery and two dorsal veins were anastomosed with 10.0 ethilon. On release of clamps the finger pinked up. The skin edges were approximated with a few tagging sutures and an above elbow cast given. The total ischaemia time was 8 hours. The post operative period was uneventful. Three weeks later he underwent split skin grafting for marginal raw areas on the volar aspect of the suture line.

On follow up one year later, patient was extremely satisfied with the reconstruction (Figures 10a & 10b). He had an active range of motion of 90^0 at MCP joint & 55^0 at PIP joint) and good return of protective sensation.

Figure 10: (Case No. 8) Result of the successful replantation at one year

RESULTS

All eight fingers survived, although one patient had a partial failure. This patient had severe intrinsic damage and vein graft reconstruction. He had necrosis of the volar skin and was managed by a cross finger flap.Seven patients (including the partial failure) needed secondary surgeries. Six of them had raw areas at the wound margin on the volar side, which was managed by split skin grafting at three weeks post replantation. Four patients underwent formal arthrodesis of the distal inter phalangeal joint and one patient underwent arthrodesis of the proximal inter phalangeal joint. Necrosis of the nail bed occurred in one of the patients with complete avulsion of the soft tissues only. We covered the exposed terminal phalanx with a reverse dermis cross finger flap and he did well.

All patients have a minimum follow up of at least one year and on review, all of them were glad that they had the procedure.Total active range of movement at the MCP and IP joints put together averaged 140^0. Protective sensation was present in all of them. No sensory recovery occurred to measure 2 PD in any of them. None of them had any episodes of ulceration.

All of them have resumed their original job and the average time taken to go back to work is about three months. All the patients were satisfied with the outcome and none would prefer amputation to the result they got.

DISCUSSION

All patients who sustain ring avulsion amputation request replantation. With microsurgery, satisfactory outcome is possible. Though technically demanding, this has become the recommended procedure in skilled microsurgical centres. High rates of survival are possible, since skill levels and adequate infrastructure are available in many centres.[6] Presently microsurgeons have the responsibility to justify the indication by producing function in an acceptable period of time. Replantation of a single distal phalanx would not impair the hand function even if the DIP joint was arthrodesed, as the nearly normal active proximal interphalangeal and metacarpophalangeal joint motion still enables patients to use these digits successfully.[7] Most total ring avulsion amputations would fall into this category.

We have successfully established circulation in all eight patients. Using the plastic protective guard of a long hypodermic needle as a sleeve is very useful. It successfully prevents the wrapping of the soft tissues as the K-wire is introduced, which may spell disaster to the replantation effort. This technique may also be used for safe K-wire insertion in other situations where soft tissue entrapment is a possibility. Even if the amputated part has no bone, the avulsed part is fixed with a thin K-wire to prevent shearing of the part with risk to the vessel anastomosis.

Vein grafts are recommended if the vessel ends are damaged and have been used frequently in many published series.[6,8,9] In our series, we have used vein grafts only in two cases, for arterial reconstruction. We are not reluctant to use vein grafts and probably our technique of cross anastomosis of the digital arteries accounts for this less number. Similarly for veins we can compensate to some extent by dissecting the vessels or by delivering the veins from the adjacent finger. Simultaneous need for vein graft and skin cover can be achieved by a reverse dermis cross finger flap.[10] We did not have occasion to use this step. Though nerve repair was not done, protective sensation was present in all fingers. This is probably because the digital nerves in most instances were lying beneath the skin of the replanted finger. Sensory recovery was not good enough to distinguish two points, but was adequate to prevent trophic ulcers. There was no problem of neuroma in any of the patients.

Complete avulsion without any bony segment in the amputated part is very rare. We had two such patients in this series. In one patient, the nail bed was retained on the proximal side. Though the nail bed appears viable at the time of injury, with time it necroses. This has been the experience of many who have tried to make a hole in the pedicle flap used to cover such amputations and bring the nail bed to the surface. Ten days after successful replantation, we found that the nail bed had become dark. Since there was no infection we waited for three weeks and used a reverse dermis cross finger flap to cover the area. The finger had no nail growth, but the flap with the graft gives satisfactory cosmesis.

Injuries with less intrinsic damage had good function but they too needed at least one secondary procedure with an average of 1.5 secondary procedures per patient. If secondary procedures are needed, it is better to do them early. This enables earlier therapy, prevents stiffness and earlier return of function. Secondary procedures were commonly needed for marginal raw areas and for unstable interphalangeal joints. Marginal raw areas were mostly on the volar side at the wound margin. In one case, a cross finger flap was used, while in others skin grafting sufficed. All the patients were satisfied with the outcome and none would prefer amputation to the result they got.

When compared with other digital replantations, we find that ring avulsion replants need more intensive physiotherapy. In a routine digital replant, the soft tissue interface where healing takes place is relatively small and limited to the skin suture line. However in ring avulsion replants, it extends all along the finger. Probably this gives more area for fibrosis. In most Class III ring avulsion amputations, the insertion of FDS is

preserved on the proximal side. Though we expect good proximal interphalangeal joint flexion, it is not easily achieved unless a good post operative physiotherapy regimen is followed. In addition the possibility of stiffness in adjacent uninjured fingers is a real risk with any digital replant. Every patient who desires to have the replant must be made to understand that they have to be compliant with the demands of a regular supervised therapy programme for a period of at least 6 months.

At present, definite contra-indications for replantation of ring avulsion amputations would be amputations, which have destroyed the PIP joint or where both the flexor tendons have been avulsed from the musculo tendinous junction. Generally it is considered that nerve avulsion is one of the factors that restrict indications for replantation of a long finger.[11] This is because of the usual poor sensory recovery. This and the likely functional outcome must be discussed with the patient and a decision made. With microsurgery and adequate supervised physiotherapy, it is possible to obtain satisfactory outcomes in total ring avulsion amputations.

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