

Alternative techniques for restoration of bony segments in digital replantation

Alexandros S Touliatos, Panayotis N Soucacos, Alexandros E Beris, Aristidis B Zoubos, Theodosios H Koukoubis and Haris Makris

We present our experience from 108 partially or totally amputated digits in 87 patients which were replanted or revascularized successfully by the Orthopaedic Microsurgical Team at the University of Ioannina Medical School in Greece, during the period from 1978 to 1994. The majority of the patients were men involved in occupational accidents. Bone shortening always preceded the osteosynthesis and the vessel anastomosis, and most of the available methods for osteosynthesis were used, including small plates, single lag screws, crossed Kirschner wires, a combination of intraosseous cerclage wires and Kirschner wires, and intramedullary Kirschner

wires. Our findings suggest that the most appropriate method for bone fixation in digital replantation is the insertion of one intramedullary Kirschner wire, supplemented by another wire which is inserted at the end of the procedure. This technique was found superior for the following reasons: 1) its simplicity and the speed of the technique reduced the ischemic time; (2) less bone exposure was required; (3) less skeletal mass was needed for fixation; and (4) prior to the insertion of the second Kirschner wire, rotation of the replanted part was possible if it was necessary to re-align the vessels or to correct any rotational deformity.

Department of Orthopaedic Surgery, University of Ioannina, School of Medicine, Ioannina, Greece.
Correspondence: Alexandros S. Touliatos, M.D.
Tel +30-651-45 731. Fax +30-651-46 222

The viability of replanted digits and hands depends on successful vessel anastomoses. The anastomoses should be done on normal intima of both the proximal and distal vessel segments and must not be performed with undue tension. In traumatic amputations, a degree of soft tissue damage always coexists necessitating debridement, by which a soft tissue gap, including vessels, is inevitably created. In these cases, the alternatives for the suturing of the vessels without undue tension include the use of interpositional grafts and bone shortening. It should be noted that the use of interpositional vessel grafts doubles the number of anastomoses for each vessel. Thus, the 3 anastomoses (one artery and two veins which have been found necessary for successful replantation) will become 6 by the use of interpositional graft. The increased number of anastomoses also increases the probability of failure, as well as considerably prolonging the operation time. Consequently the severed nerves and other soft tissues tend to be sutured under tension which increases the possibility of poor functional results.

In this regard, bone shortening appears to be the best alternative to solve the problem. The bone ends can be carefully resected to insure ease of approximation of the vessels and nerves. The amount of bone

removed varies with the type of injury and the level of the amputation. In an avulsion or crush injury, a greater amount of bone must be removed until normal intimal coaptation is possible without tension.

Patients and methods

Bone shortening and method of bone fixation

Bone resection was performed in all our cases of digital replantation in order to minimize tension for later vessel, nerve, tendon, and skin reconstruction. Between 0.5 and 1.0 cm of bone was usually removed in digit replantations and 2 to 3 cm in amputations at the level of the proximal hand and wrist. Bone removal was done from the distal and/or proximal ends depending on the level of amputation.

In thumb amputations, the major portion of bone shortening was done on the severed or partially severed distal part. In this manner, the maximum amount of bone was left on the proximal stump to insure good bone stock in case the replantation failed (Figure 1A). In an attempt to obtain a resection arthroplasty, we preferred the resection of the metacarpal head and leaving the base of the proximal phalanx with the cartilage intact in amputations through

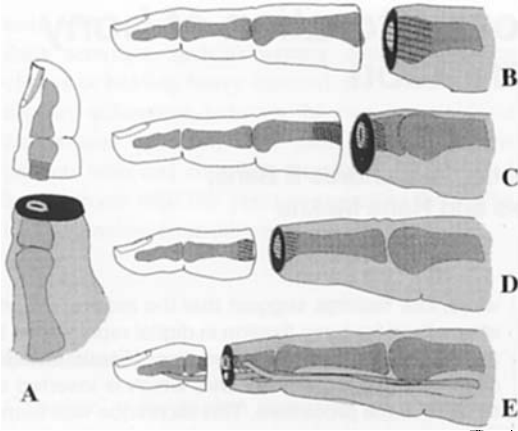


Figure 1. Bone shortening is a critical step in any replantation procedure. The amount of bone removal (the parallel lines) depends upon the level of the amputation, as delineated in the methods.

the metacarpophalangeal joint (Figure 1B).

In amputations through the shaft of the phalanges, we usually removed bone from both ends (Figure 1C), while in amputations through the interphalangeal joints, bone was also removed from both ends and the joints were arthrodesed (Figure 1D). In cases of amputations distal to the proximal interphalangeal joint with the insertion of the superficialis flexor tendon intact, the preservation of the proximal interphalangeal joint led to a "sublimis finger" with satisfactory functional results (Figure 1E).

Bone resection was followed by osteosynthesis. The healing of microvascular anastomoses and nerve

sutures, as well as repaired tendons in replantation surgery is made possible when the bones have been stabilized. Of the various methods for bone fixation which have been described, the fixation devices used in the present study included small plates (straight or condylar), single screws using of the lag screw principle, tension band wiring with or without the use of Kirschner wires, crossed Kirschner wires and the intramedullary Kirschner wires.

In the beginning we aimed towards a sound osteosynthesis, according the definition for stability in bone surgery devised by Swiss Association for Study of Internal Fixation (ASIF) (Heim and Pfeiffer 1982). As experience was gained, the techniques requiring extensive tissue dissection, bone exposure and valuable time were abandoned and simple and rapid methods of bone fixation were preferred in order to decrease the ischemic time and damage of soft tissues.

Results

After appropriate bone shortening and preparation of the bony ends to resemble a transverse fracture, the small plates (small straight or T- and L-condylar plates, with 2.7 mm screws) were used as a tension band in 18 fingers amputated at the shaft or the metaphyses of the proximal phalanx (Barton 1979 and 1989, Büchler and Fischer 1987) (Figure 2A, B). In 11 fingers bony union was achieved uneventfully, while in 4 fingers union of the bones failed, resulting in aseptic pseudarthrosis. In 3 fingers skin healing was delayed and septic pseudarthrosis developed.

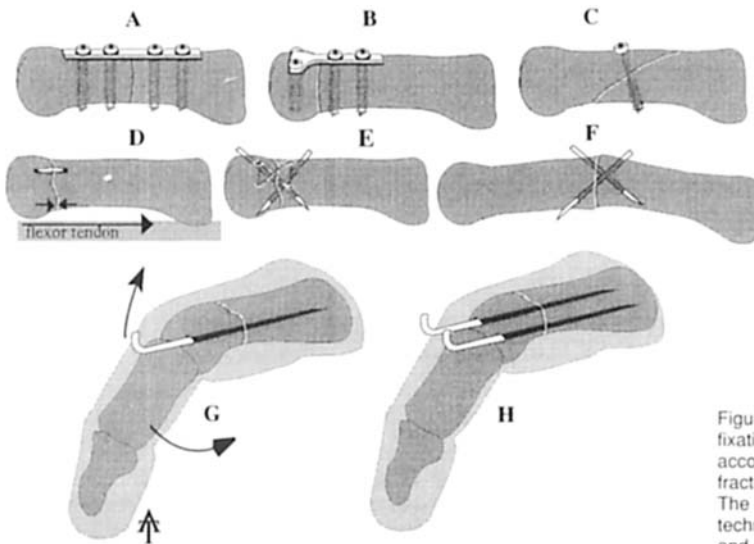


Figure 2. The various methods of bone fixation used for the replantation of digits according to the level of amputation and fracture type, as described in the results. The two intramedullary Kirschner wire technique (H) appears to be the simplest and safest method in digital replantation.

Single compression screws were utilized in 7 phalangeal level replantations with a long spiral fracture. The decision was made to use single screws, since after shortening the bone over 0.5 cm, there was still an obliquity of the fracture (Figure 2C). In 2 fingers aseptic pseudarthrosis developed. After 0.5 cm of bone removal which was done only at the proximal end, tension band wiring was used in 8 fingers with amputations at the level of the neck of the head of the first phalanx.

In 6 cases in which a single wiring was applied without any other supplement (Figure 2D), an angulation of the fracture developed postoperatively and in 2 cases, the fracture pseudarthrosed. In 2 cases with figure-eight wiring combined with 2 crossed Kirschner wires (Figure 2E) sound bony union was established. Two crossed Kirschner wires were applied in 16 cases with an amputation through the interphalangeal joint. In these cases, an arthrodesis which was soundly fused was performed after bone removal from both ends (Figure 2F).

In 18 cases fixation was done with a single intramedullary Kirschner wire (Figure 2G). Of these, the fracture was united with rotational deformity in 7 patients and a pseudarthrosis developed in 4 patients.

In 36 cases a single intramedullary Kirschner wire was used which was supplemented at the end of the procedure of the replantation with a second intramedullary Kirschner wire, which was applied parallel to the first. (Figure 2H). No deformity was observed in any of these cases postoperatively, but in 4 cases the fracture did not unite.

In multiple digit amputations bony segments from a nonreplantable digit can be used to bridge a bony defect in a replantable digit. This was done in a shotgun injury where the proximal phalanx of a nonreplantable index finger was used to bridge the metacarpal defect of the middle finger with satisfactory result.

Discussion

Restoration of the bone segments in digital replantation is ideally achieved with bone shortening and a simple, fast and safe osteosynthesis with the least damage of soft tissue. Although compression plate fixation results in excellent mechanical stabilization, the volume of the device is relatively large. Its application must be preceded by preparation of a vast area of bone which may produce extensive damage to soft tissues and biological weakening of the fractured area (Stern et al. 1987). Moreover, the whole procedure is time-consuming increasing considerably the

ischemic time.

Screw fixation using the lag screw principle can only be applied to oblique surfaces (Hastings 1987). The bone shortening necessary for replantation usually results in a transverse fracture for which interfragmental screws are not indicated.

The single intraosseous cerclage wire which is applied on the dorsum of the phalanx as a tension band, can be used even on very small surfaces. However, normal function of the flexor tendons is required for it to be mechanically adequate, otherwise the fracture results in angulation (Fyfe and Mason 1979).

The combination of a figure-eight intraosseous cerclage wire and crossed Kirschner wires provides a rigid fixation with excellent bone apposition allowing for early motion (Brown and Wood 1990). However, we agree with Urbaniak that the insertion of the Kirschner wires is associated with the risk of damaging a neurovascular bundle either directly or indirectly by causing mechanical obstruction by tethering a vessel or its supporting ligaments (Urbaniak et al. 1978). The same applies to the use of crossed Kirschner wires for interphalangeal fusion.

Bone fixation with a single intramedullary Kirschner wire was found to be both a simple and fast technique, requiring minimal bone exposure and providing the possibility of realigning the vessels when needed. The inherent instability of the method in rotational deformities can be prevented by adding a second intramedullary Kirschner wire parallel to the first one.

In conclusion the ideal method of osteosynthesis which is the initial step in digital replantation should balance the goal of stable fixation with that of surgical efficiency, simplicity and speed. Although the ideal technique varies with the level of the amputation, intramedullary fixation using two parallel Kirschner wires appears to provide considerable advantages.

References

- Barton N J. Fractures of the shafts of the phalanges of the hand. *Hand* 1979; 11: 119-133.
- Barton N J. Internal fixation of hand fractures. *J Hand Surg* 1989; 14B: 139.
- Brown M L, Wood M B. Techniques of bone fixation in replantation surgery. *Microsurgery* 1990; 11: 256-260
- Büchler U, Fischer T. Use of a minicondylar plate for metacarpal and phalangeal periarticular injuries. *Clin Orthop* 1987; 214: 53.
- Fyfe I S, Mason S. The mechanical stability of internal fixation of fractured phalanges. *Hand* 1979; 11: 50-54.

- Hastings H II. Unstable metacarpal and phalangeal fracture treatment with screws and plates 1987; 214: 37.
- Heim U, Pfeiffer K M. Small Fragment Set Manual. Springel-Verlag, New York 1982.
- Ikuta Y. Method of bone fixation in reattachment of amputations in the upper extremities. Clin Orthop 1978; 169-178.
- Massengill J B, Alexander H, Parson J R. Mechanical analysis of Kirschner wire fixation in a phalangeal model. J Hand Surg 1979; 4: 351-356.
- Meuli H C, Meyer V, Segmüller G. Stabilization of bone in replantation surgery of the upper limb. Clin Orthop 1978; 133: 179-183.
- Stern P J, Wieser M J, and Reilly D G. Complications of plate fixation in the hand skeleton. Clin Orthop 1987; 214: 59.
- Tupper J W. Techniques of bone fixation and clinical experience in replanted extremities. Clin Orthop 1978; 133: 165-168.
- Urbaniak J R, Hayes G H, Bright D S. Management of bone fixation in digital replantation: Free vascularized and composite bone grafts. Clin Orthop 1978; 133: 184-192.