Indications and Limits of Digital Replantation

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Abstract: Replantation should be the prime indications for treatment of amputated fingers, due to functional and aesthetic advantages. Among all cases of finger amputations, the thumb and children’s fingers are the most appropriate indications for replantation, since fingers are replanted with more necessity even when conditions are not favorable in these cases. With respect to the levels at which fingers were amputated, indications have been conventionally limited to the proximal level. However, indications have been expanded to include even the level at the nails, and when there is a request from the patient, replantation is attempted even for a single finger amputation, regardless of the amputated level. Replantation was attempted for 107 digits in 85 cases during the past 10 years, and 100% replant survival was achieved. When amputation has occurred at the proximal level of the finger, functional recovery of the PIP and DIP joints are not very favorable. However, the closer the amputated level is to the tip of the finger, the less functional impairment there is in the replanted finger. When multiple fingers have been amputated, the replanted finger has generally been used as the “useful finger.” Amputation of 3 or more fingers would be the best indication, in which case all fingers should be replanted. With respect to the type of injury, sharp amputation is a good indication, while blunt amputations are less likely to be regarded as indications for replantation. If amputated fingers are chilled, replantation can be attempted even after 24 hours have passed.

Key words: Digital replantation; Microsurgery; Hand surgery; Digital amputation

Introduction

Finger loss can be a significant impairment functionally as well as aesthetically. Hence, replantation should be the prime indications for treatment of amputated fingers. However,
not all amputated fingers are the indication of replantation, since indications are determined by many factors, such as patients’ request, type of finger, level of amputation, condition of injury, treatment period, and functional prognosis. Indications may also vary, depending on the skills of surgeons and hospital facilities.

**Indications and Limits of Digital Replantation**

Digital replantation has been conventionally indicated for fingers that have been amputated at levels proximal to the midsection of the middle phalanx, based on the notion that functional impairment of the finger will not be severe so long as the finger is preserved up to the midsection of the middle phalanx. However, indications have been expanded, and replantation is attempted regardless of the amputated level when there is a request from the patient.

1. **Indication based on the type of finger**
   The best indication of replantation is first of all, the amputated thumb, among all fingers, since the thumb is functionally the most important digit and good use of the replanted thumb is being made regardless of the range of mobility and recovery of sensation. In order to have a more functionable thumb, a length as close to normal is equally as necessary as sensation and mobility. Therefore, replantation of the thumb should be attempted even under unfavorable conditions (Table 1).1-3) In children, replantation is indicated for all fingers because they have a unique capacity for regeneration, the function of the replanted finger recovers well, continued growth of the finger can be expected, and also because it is aesthetically important.4) When multiple fingers, including the thumb, have been amputated, the thumb is replanted first, followed by the opposing finger, so that to pinch and grip functions can be regained. In addition, amputation of a single finger is also an indication if the patient has a career in which hands are seen by people all the time or if the patient is a young woman.

2. **Indications based on amputated site**
   While replantation has conventionally been indicated for amputation at the proximal portion of the finger, recovery of the functions has not been very favorable. On the other hand, the closer the amputated level is to the tip of the finger, the less functional impairment there is in the replanted finger. Therefore, replantation of the distal portion has recently become more popular.5,6) As techniques of angiostomy have improved, some medical institutions have started to achieve high success rates even for replantation at areas distal to the DIP (distal interphalangeal) joints.

3. **Indications based on the number of fingers**
   Based on the number of digits amputated, multiple amputations of 3 or more digits would be the best indication. When 3 or more digits have been amputated, the greatest of efforts should be devoted towards reattachment of all digits because each individual replanted digit may have some impairment of function and it would therefore make a large difference to have even one extra finger.2) On the other hand, however, when return to work, usage, and long duration of treatment are taken into consideration, amputation of a single finger in

<table>
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<th>Table 1</th>
<th>Indications of Digital Replantation</th>
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<td>1. Most favorable indications</td>
<td>Amputation of the thumb at a location proximal to the IP joint</td>
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<td></td>
<td>Amputation of 3 or more fingers</td>
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<td>Children</td>
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<td>2. Relatively favorable indications</td>
<td>Amputation of the thumb at a location distal to the IP joint</td>
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<td>Amputation of 2 fingers</td>
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<td>Women</td>
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<td>3. No indications</td>
<td>Fingers that would become significantly shortened</td>
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the case of a laborer is rarely regarded to be an indication of replantation. Since nerve repair is also essential for recovery of sensation, it is also unlikely that replantation would be indicated for treatment of a single finger amputated at the base and without any chances of nerve repair.

4. Indications based on the degree of injury

With respect to the type of injury, clean cut amputation is a good indication, while blunt amputations are less likely to be regarded as indications for replantation. Although favorable recovery of the functions of a replanted finger is hard to expect to start with, severe shortening or repair by tissue transplantation becomes necessary and the survival rate drops with crush or blunt amputations. As there is at present a limitation in the extent of functional recovery, it is necessary to make a definite decision as to whether emphasis is to be placed on function or cosmetic appearance. If the request for the procedure is strong, the author generally attempts replantation even when tissue damage seems to be severe and replantation appears difficult. Ring injuries can also have severe tissue damage, which may require tissue repair by transplantation and thus make replantation difficult. Although functional recovery is not favorable even when replant survives, there are usually strong requests for replantation because this is a common injury among women.

5. Preservation of amputated fingers and temporal limits

Muscular tissue begins to degenerate approximately 5 hours from the time blood supply has been cut off, and if major amputations are replanted past this point, replantation toxemia may occur. However, degeneration caused by loss of blood supply progresses relatively slowly in fingers that do not include any muscular tissue, making it possible for the finger to survive even when replanted many hours after the injury. The author had experienced about 10 cases of amputated fingers that had been without blood supply for 15 hours or longer, and fingers in all of these cases had survived successfully. After that, the author has seen the cases of finger amputations for these ten years. Hence, it seems reasonable to attempt replantation even after 24 hours has passed since injury as long as the fingers were chilled.

6. Indications viewed from the perspective of functional prognosis

Although it would naturally be ideal if injured fingers could be repaired so that they can be used for daily activity, in reality, this is rather difficult. As mentioned earlier, the best indications of replantation based on the functional recovery of the replanted finger, as well as usage, would be amputation at levels proximal to the IP (interphalangeal) joint of the thumb, amputation of 3 or more fingers at levels proximal to the midsection of the middle phalanx, and amputation in children in whom continued growth of the finger can be expected. Since nerve repair is also essential for recovery of sensation, it is also unlikely that replantation would be indicated for treatment of a single finger amputated at the base and without any chances of nerve repair.

Preservation of Amputated Fingers and Procedure of the Stump

Preserving the amputated finger to keep it from degeneration is important if replantation is to be successful. First, the amputated portion should be wrapped in a sheet of gauze, and placed in a plastic bag. The bag should be sealed tightly so that water cannot enter, and chilled in ice water that is approximately 4°C. Dry ice can cause the amputated finger to freeze, and even normal ice can cause it to be chilled below 0°C if the ice is contacting the finger.

The stump of a forearm or a finger should be covered with gauze. It is easy to stop hemorrhage by simply using compression bandage
and raising the patient’s arm. Vessels should not be ligated or grabbed with Kocher’s forceps or the like, as they can cause problems for subsequent angiostomy. The use of tourniquet should also be avoided as much as possible to prevent pain and degeneration caused by loss of blood supply.

**Surgery**

1. Treatment of the amputated finger

The site of injury should be disinfected and scrubbed with a brush during the golden hour, the period up to 5 hours since the time of injury, so infection can be prevented. Then, débride-ment and identification of tissue should be conducted under a microscope, and vessels and nerves can be occasionally marked with nylon suture. In many instances, additional skin incisions are made in the midlateral on both sides of the amputated finger to further identify each tissue. These incisions should be as short as possible and no more than 1 cm so that veins will not be injured. To what extent to shorten the bones will be determined based on the degrees to which vessels, nerves, tendons, and skin are injured. The amputated finger is then wrapped back into gauze soaked in physiological saline solution, and chilled in a container with ice water until replantation.

2. Anesthesia

The author uses brachial plexus block and axillary nerve block for replantation, and general anesthesia for children (Table 2). Surgery is also very possible when anesthesia of a single nerve is conducted at the extremity. For example, median nerve block at the wrist can be selected for amputation of the tip of the index finger or the middle finger, and ulnar nerve block can be used for the little finger. Anesthesia can last for a long surgery lasting at least 4 hours if 5 cc of bupivacain is used with 15 cc of lidocaine.

3. Perfusion in the amputated finger

Perfusion is not performed for amputated fingers, since it can cause injuries to the vascular stump or vascular endothelium and since there is no risk of replantation toxemia.

**Techniques of Replantation**

The author makes it a rule to repair all repairable tissues during the first surgery.9–11)

1. Osteosynthesis

While bones may be shortened depending on how much other soft tissues are damaged or lost, when bone shortening greater than 1 cm is required, the finger should be repaired by transplanting other tissues.

2. Tendon suture

Tendon sutures are performed in the order of extensor tendon and flexor tendon.

3. Nerve suture

Nerve suture is conducted in a bloodless area before angiostomy. Since secondary repair of nerves is difficult due to scar, nerves should be repaired primarily. Nerve transplantation is primarily conducted in a similar manner when there is a defect in the nerve. Although some have reported that recovery of sensation can be achieved without nerve suture for replantation at the tip of the finger, the author considers that nerves should be sutured to the extent that it is possible to do so, so that recovery of sensation

| Table 2 Anesthesia in Digital Replantation (since the opening of the clinic in October 1990) |
|-----------------------------------------------|-----------------|
| Brachial plexus block                        | 64 cases 86 fingers |
| Ulnar nerve block                            | 7 cases 7 fingers |
| Low median nerve block                       | 6 cases 6 fingers |
| High median nerve block                      | 3 cases 3 fingers |
| Ulnar nerve +                                | 1 case 1 finger  |
| Low median nerve block                       | 4 cases 4 fingers |
| General anesthesia (all children)            | 4 cases 4 fingers |
| **Total**                                    | **85 cases 107 fingers** |
will be even more favorable.

4. Vascular anastomoses
The stump of the vessel will need to be resected under a microscope until normal vascular endothelium can be found. Arteries are anastomosed before veins so that blood supply to the amputated finger is performed earlier, and also so that it makes it easier to spot veins with good blood perfusion returning from the distal part. While it has conventionally been said that one artery and two veins should be anastomosed, it would be better if as many vessels as possible are anastomosed. If end-to-end anastomosis of an artery cannot be performed even when the bone has been shortened, vessels can be transplanted or transferred from other fingers. The crucial point for angiostomy is to make sure to anastomose one vessel precisely rather than to attempt to anastomose multiple vessels imprecisely, and to anastomose a thin vessel precisely rather than to attempt to anastomose a large vessel imprecisely. For this purpose, it is essential to improve one’s surgical techniques. Surgeons should practice angiostomy with at least 100 vessels in animals before applying the technique to humans. Another important point is to frequently monitor the replanted fingers following surgery, and to perform another surgery as soon as possible should there be any circulation problems, such as those manifested as even a slight change of color. Survival rate may be higher in private clinics like ours in such cases, since surgeries can be performed immediately.

Indications and Limitations Based on the Amputation Site

Indications and limitations based on the amputation level of the amputated finger are explained below with reference to Tamai’s classification (Fig. 1).8)

1. Amputation at zone V
Suture can be pretty difficult when amputation has occurred at a level proximal to the base of proximal phalanx in the case of a thumb or at a level proximal to the MP (metacarpophalangeal) joint in the case of other fingers, since vessel and nerve stumps exist in deeper areas, causing the visual field to be limited. There are cases when it is easier to perform osteosynthesis after suturing vessels and nerves. Amputation at this level is commonly seen in cases of multiple amputations, for which re plantation is indicated.

2. Amputation at zone IV
This is the area, so-called “no man’s land.” Amputation most commonly occurs at this level. Since the recovery of motion at the DIP and PIP joints distal to the replantation site is poor, arthrodesis should be avoided to preserve as much mobility of the PIP joint as possible.

3. Amputation at zone III
Since this amputation occurs between the base of proximal phalanx and the IP joint of a thumb or between the midsection of middle phalanx and the DIP joint of other fingers, and the function of the MP and PIP joints are preserved, functional prognosis is favorable, and patient satisfaction is also generally high.
4. Amputation at zone II
Replantation at this level, between the DIP joint and the nail matrix, is very possible even though the vessels are small. Since the function of the PIP and MP joints is intact, and there would be hardly any impairment of the function, replantation at this level is being reassessed.

5. Amputation at zone I
It is functionally and aesthetically important to the finger that nails are preserved. Amputation at the nail is, therefore, also an indication of replantation.\textsuperscript{5,6} If replantation succeeds, there will be several benefits: aesthetic excellence, preservation of the length of finger and the nail, and no need for more than one surgery. However, in some cases when replantation cannot be performed or replantation is unsuccessful, reconstruction using various types of flaps or toes may be required.\textsuperscript{10}

Although procedures of arterial anastomosis may seem intimidating because the branch of the digital artery needs to be anastomosed at the distal where the outer diameter is no more than 0.5 mm, it is not difficult once surgical techniques are mastered. However one must be creative in performing these procedures, since the conventional vascular clip used to hold vessels are generally difficult to use in this case. An alternative to the vascular clip would be to use a single micro clip only on one side. For suture, 11-0 or 12-0 nylon suture should be used. At least one artery and one vein should be anastomosed. When veins cannot be anastomosed at all, the replant will nevertheless survive with or without the use of a clinically used leech or by continuous exsanguination through puncture. Also, even when veins to anastomose cannot be found on the day of surgery, they can often be found more easily the day after surgery, making it possible to anastomose veins.

Results and Discussion
While the survival rate for replanted digits has improved in microsurgical techniques, the survival rate varies largely from 60% to 94%, depending on the medical institution. Also, since whether or not an institution or surgeons will attempt replantation when the finger has been amputated anywhere distal to the DIP joint varies from one institution to another, such information would be essential along with the survival rate at each institution when referring a patient. In our clinic, replantation procedures have been carried out on 85 cases involving 107 digits. Classification by digit showed that thumb was involved in instances; index finger; middle finger; ring finger; and little finger (Fig. 2).

Favorable recovery of function is difficult to achieve in digital replantation, since all tissues are repaired at the same level. The present problem the surgeon faces is how good functional restoration can be achieved. There is still some limit even though functional recovery can be expected to some degree through secondary surgeries such as tenolysis. However, the Japanese tend to place as much as importance on the appearance of the hand as they do to its function and this feeling applies equally to both sexes.

Review of the state of use would be that the thumb was being used in all cases, and activity in 90% of the replanted thumb, showing how they can be useful enough even if recovery of mobility functions is poor, as long as there is enough length left in the thumb, and sensibility has recovered to a certain degree. Since growth of replanted fingers occur in children, and functions and senses improve, the author uses this procedure frequently.\textsuperscript{4}

With respect to fingers other than the thumb, there are differences in state of use between amputation of a single finger and that of multiple fingers. When multiple fingers have been amputated, the replanted finger is used as the “useful finger” since there are no other fingers to replace it even if it is somewhat short and has a poorly recovered function. On the other hand, when only one finger has been ampu-
tated, the replanted finger is not used regularly unless both the sensory and motor functions are fairly favorable. Review by site of amputation showed that fingers in which replantation had been made at the distal portion were being more actively used than those reattached at the proximal portion. The finger can therefore be in the way in carrying out activities of daily living, which brings up the topic of whether or not replantation should be performed in these cases. Patient satisfaction is also high with an 85% rate of return to work. 2)

**Conclusion**

Indications of replantation of amputated fingers are changing constantly. Although the functional prognosis of replantation is not very favorable at this point, our objective should be to repair the finger so that it can at least be used for daily activities. Indications of replantation may be further expanded if we endeavor to improve surgical techniques so that we will be able to meet the multifarious needs of each patient, and thereby achieve favorable recovery of functions.

**REFERENCES**

5) Yamano, K.: Treatment and indications of


