RESTORATION OF PREHENSION AFTER SEVERE MUTILATIONS OF THE HAND

RAOUL TUBIANA, PARIS, FRANCE, H. GRAHAM STACK, LONDON, ENGLAND, and ROBERT W. HAKSTIAN, MONTREAL, CANADA

We intend to discuss the injuries of the hand that disrupt the motor and sensory elements necessary for prehension. Prehension is a complex mechanism, for which both movement and sensation are required if it is to be fully effective, though sensation can to some extent be replaced by vision. Discussing normal function, Napier (1956) stressed the importance of making a distinction between the "power grip" and the "precision grip," and emphasised that the type of prehension was determined more by the objective intended in grasping than by the actual form of the object grasped. Landsmeer (1962) described these functions rather more dynamically as "power grip" and "precision handling."

The whole pattern of precision gripping or handling is determined by the ability of the thumb to abduct and oppose. In the badly damaged hand an attempt should be made to reconstitute these different types of prehension, but it is often only possible to restore the basic grip necessary for pinch. This grip requires two opposing units, of which at least one must move and at least one should have sensibility.

Anatomically, two basic types of simple grip can be described: the digital pinch, between thumb and finger tips; and the palmar grasp, in which the fingers hold an object against the palm. For digital pinch, the minimum required is a thumb, or a reconstructed thumb of nearly normal length, and a finger to which it can oppose. For palmar grasp, the hand wraps round the object being held: for this action mobile joints are necessary. The principal hinge joint movement takes place normally at the metacarpo-phalangeal joints: these joints control the locking and unlocking of "grasp," since they close after the interphalangeal joints during flexion of the fingers, and open before the interphalangeal joints during extension. If this hinge function is faulty the proximal interphalangeal joints can substitute for it. The strength of grasp of the whole hand depends on the breadth of the palm and on the degree of preservation of the peripheral parts of the fingers. The thumb is not essential for this grip, but it considerably increases the strength of grip and improves control. It is because of its influence on the strength of grip and its ability to oppose that the thumb constitutes such an essential part of prehension.

Every effort should be made to re-establish both these anatomical types of prehension, making use of the parts that remain. The level and site of injury will influence the method of reconstruction employed.

Because of the importance of the thumb, we propose to consider the injuries under the following headings: 1) mutilations of the fingers, in which thumb function is spared; 2) mutilations of the thumb alone; and 3) mutilations of the thumb and fingers.

MUTILATIONS OF THE FINGERS

Loss of one, two, or even three fingers—This is usually compensated for by the remaining fingers. Reconstructive measures are indicated only when there are secondary problems caused by unsatisfactory position, angulation or inadequate skin cover.

Partial amputation of all four fingers—It is important to conserve as much length as possible by covering the exposed ends with local skin flaps from the neighbouring finger, or with distant

*From the Clinique Chirurgicale Orthopédique et Réparatrice de l'Hôpital Cochin, Paris
flaps from the chest or opposite arm. Here it is more a matter of making good the skin defects than of digital reconstruction: the indication for the latter seldom arises.

**FIG. 1**

![Figure 1](image1.png)

Phalangisation of the fifth metacarpal. Figure 1—Technique. Incision in dorsal skin, with angulations. Osteotomy of base of fifth metacarpal. Figure 2—Result. Figure 3—For social occasions, a flexible glove prosthesis made from polyvinylchloride masks the mutilations and permits grasp of small objects.

**Complete loss of all four fingers**—If thumb function is undisturbed, prehension is still possible in spite of the loss of all four fingers. The grasp can be improved by phalangisation of the
fifth metacarpal (Figs. 1 to 3). This procedure makes use of the normal mobility of about 30 degrees of the carpo-metacarpal joint of the little finger. The same joint in the ring finger allows about 15 degrees of movement, but the middle and index finger metacarpals are practically immobile.

The mobility of the fifth metacarpal is normally checked by the deep transverse ligaments of the palm, and by adjacent soft tissues. Phalangisation permits a greater range of movement of the fifth metacarpal, and resection of the fourth metacarpal increases it even more. It is not advisable to reduce the width of the palm by resection of the fourth metacarpal if the thumb is long enough to reach the head of the fifth metacarpal with ease. This type of phalangisation is most useful if the thumb is short or has lost some of its range of movement.

**Technique of phalangisation**—An incision is made over the palmar and dorsal surfaces of the fourth metacarpal. These incisions should be sinuous or angulated in order to prevent scar retraction. By careful dissection, the common digital artery and nerve of the fourth interspace are located, and the digital artery to the ring finger is tied off. The nerve is split proximally for some distance before the branch to the ring finger is divided. Prehension is facilitated by osteotomy of the fifth metacarpal and fixation of the distal part in slight abduction and flexion, provided that carpo-metacarpal joint mobility is not disturbed. Finally a skin graft is necessary to resurface the newly created cleft.

When not at work, the patient can wear a supple plastic prosthetic hand, which is pulled on like a glove, and which allows the hand to move.

**Loss of all fingers, involving the metacarpals**—In these cases an opposition post to face the intact thumb must be created (Fig. 4). If an area of skin with normal sensation can be preserved an attempt should be made to use this on the opposition post, with the aid of a surviving metacarpal element or with a bone graft.

A prosthetic post can take the place of a reconstructed one if skin with suitable sensibility is not available (Figs. 5 and 6).

Verdan (1964) reported a case in which he made a mobile ulnar digit by transplanting the phalanges of a normal thumb to oppose the thenar eminence, both elements then having normal sensibility.

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**MUTILATIONS OF THE THUMB**

There are many reconstructive procedures for the thumb. Some of these aim to rebuild the thumb—the osteoplastic procedures; others employ an adjacent or more distant finger—pollicisations. It is even possible to employ a toe: we have not had experience with this operation, but it has given good results as reported by Clarkson (1955) and discussed by Reid (1960). This cannot of course provide a digit with normal sensibility, but it is a method which provides a nail. The indications, however, appear to us very exceptional.

In the past few years there have been many improvements, both in osteoplastic reconstruction and in pollicisation.
OSTEOPLASTIC RECONSTRUCTION OF THE THUMB

Osteoplastic procedures reconstruct a thumb with the aid of a bone graft covered with a skin flap, raised either locally or at a distance.

Although the idea for this method was probably Nicoladoni's (1900), it is unlikely that he ever carried out the complete operation because his three patients all refused the bone graft necessary to support the skin flap stage. According to Carcassonne (1930) it was Noëske (1909) who completed the first reconstruction, using a thoracic tube and a tibial bone graft.

Osteoplasty constitutes one of the least destructive procedures in respect of the rest of the hand. It previously presented two serious disadvantages which often restricted its use by the patient: the frequency of resorption of the bone graft, and the occurrence of atrophic skin changes. These problems are due to defective vascular and nerve supply, and the absorption of the bone graft may be a disuse phenomenon consequent upon lack of sensation.

![Figure 5](image1.png)  ![Figure 6](image2.png)

Figure 5—Traumatic amputation of fingers and metacarpals with thumb intact. Figure 6—Prosthetic appliance fitted to provide a fixed post opposing the thumb. The distal part of the prosthesis bears an anti-slipping pulp substitute.

In order to avoid these complications, in the past, bone grafts were kept short and were covered when possible by local skin flaps which provided a certain degree of sensibility. These flaps can be raised from the base of the thumb and advanced distally, as in the Gillies and Millard (1957) "cocked hat" procedure, or they may be raised from the dorsum of the hand or index finger. They permit the reconstruction of a thumb of restricted length, with the limited sensibility of dorsal skin. A maximum increase of length of about one inch can be obtained by this method (Figs. 7 to 9).

A technique is now employed which gives a thumb with good sensibility, and with a minimum of atrophic change. The special feature of this method is the combination of a tubed pedicle flap with a sensory skin island transfer (Tubiana and Duparc 1960). The operation embodies the general technique of heterodigital neurovascular island transfer, as developed by Moberg (1955) and Littler (1960), but applies it further to a particular situation.

Technique—The osteoplastic reconstruction of a sensitive thumb by this method requires several operative stages.
Preparation of the tube flap—The thoracic area (infraclavicular in men and submammary in women) is the most favourable site for the tube, because the skin is thin and supple. If necessary the abdomen or the opposite limb can be used, but it is undesirable to apply a thick tube pedicle containing an excess of fat, because sliding of the skin over the bone will occur. If the tube does not have to be long it can be applied to the thenar eminence at once. Otherwise it is safer to do this at a later stage. It is important that the suture line at the base of the
Reconstruction of the thumb by a tubed flap equipped with a sensory zone. Figure 10—The tubed flap, previously inserted into the thenar region, has been opened on its palmar aspect for the insertion of the bone graft and the transfer of a heterodigital sensory island from the medial surface of the middle finger. This has been transferred through a subcutaneous tunnel to the thumb base; its neurovascular pedicle is shown in the palm supported by a haemostat. Figure 11—The reconstructed thumb has approximately the same size as a normal thumb. Figure 12—Radiograph showing the bone graft which is pegged into the first metacarpal in line with the long axis. The surface to be used in prehension is flat.
thumb should be made in a zig-zag fashion, rather than circular; this provides a wider vascular junction and prevents constriction by the scar. The longitudinal suture line of the tube is placed on the palmar aspect of the thumb.

Division of the tube—The tube is divided three weeks after its implantation in the thenar eminence. The sensory island transfer may be undertaken at this time because it provides an additional blood supply, and therefore increases the nutrition of the tube. Nevertheless we prefer to carry out this procedure at the third stage, at the same time as the bone graft. This avoids the possibility of damage to the fragile neurovascular pedicle when the bone graft is being inserted and also provides additional skin which is sometimes needed.

Insertion of bone graft and setting in the neurovascular skin island—The graft is taken from the iliac crest and is pegged securely into the medullary canal of the first metacarpal. Kirschner wires can be used if additional stability is desirable. The shape, inclination and length of the graft must be adjusted to each case. It is preferable that prehension should occur by pulp to pulp contact, rather than by terminal pinch. The bone should present a flat, fairly wide surface, and the end must not be pointed, nor curved towards the palm.

There are some variations of this technique. Several surgeons have endeavoured to take the skin and bone together, believing that such a method preserves the blood supply and prevents serious bone resorption. This was done with bone from the iliac crest by Broadbent and Woolf (1960), and with bone from the clavicle by McGregor and Simonetta (1964). These surgeons also added a skin island flap to augment sensibility. Our view is that it is important not to compromise proper shaping or solid fixation of the bone graft by leaving the overlying skin and soft tissues attached to the bone.

The sensory island to be transferred is raised on the medial or lateral surface of the distal two segments of the donor finger. The neurovascular bundle is carefully dissected proximally as far as the arcade in the palm. It is a wise precaution to expose the artery at the bifurcation at an early stage to ensure that there are no anatomical abnormalities. Liberation of the pedicle requires division between ligatures of the digital artery to the neighbouring finger, and careful proximal splitting of the common digital nerve.

The skin island itself is oval, with an average length of about four to five centimetres and a width of one centimetre. The donor site is selected so as to cause the least inconvenience to the patient. The ulnar sides of the palmar surface of the middle and ring fingers are donor areas that cause little interference with later hand function.

After release of the tourniquet, the sensory island and pedicle are transferred across the palm, either by an open incision or through a palmar tunnel, to the palmar surface of the reconstructed thumb. It is then set in place between the previously reopened wound edges of the tube in the best position for prehension. The additional skin of the pedicle (Fig. 10) permits easy closure of the tube around the bone graft.

Size of reconstructed thumb—The reconstructed thumb may be of normal length, but as it has no joint it is preferable to make it a little shorter than normal (Fig. 11). However, the state of mobility of the opposing fingers must be taken into account, and the thumb given sufficient length for satisfactory opposition.

Results.

Sensibility—The acuity of sensation approximates to normal, but at first it is interpreted as coming from the donor finger. Over a variable period of time a "double sensibility phenomenon" occurs. To the feeling interpreted as coming from the donor area, sensory perception in the reconstructed thumb is added. Although during objective neurological examination there may be errors of perception between the thumb and the donor finger, the patient rarely makes mistakes of perception in the course of normal use of the reconstructed thumb.
We have noted in some cases that from the beginning of the second month sensibility spreads gradually into the skin tube around the border of the transferred skin. This is protective sensibility and provides perception of pinprick and of heat and cold, although the intensity of feeling is less than normal.

In one case tenderness of the scar at the base of the sensory island interfered considerably with pinch. This patient had previously had tenderness at the tip of the thumb stump. It is considered unwise to proceed with island transfers in painful hands.

*Nutrition*—It seems clear that the nutrition of the reconstructed thumb is considerably improved by the heterodigital pedicle transfer. The procedure provides not only sensibility but also an important vascular supply. The rapid consolidation of the bone graft obtained in all our cases is evidence of this (Fig. 12).

**POLLICISATION**

The procedure of pollicisation, like osteplastic reconstruction, has been greatly improved by successive modifications. Although Guermonprez (1887) emphasised the importance of transferring a digit without damaging either tendons or nerves, there was considerable delay in applying these principles (Bunnell 1929; Murray 1946). Our technique has developed considerably over the years, particularly under the influence of Gosset (1949) and Littler (1953).

Any of the fingers can be transferred to replace the thumb, and the respective advantages of each will be discussed. The principles applicable to all pollicisations will be dealt with at the outset (Figs. 13 to 17).

1) The design of the incisions must be such that a satisfactory web between the new thumb and the next finger is obtained. Transfer of a finger as an "island" with the neurovascular pedicles intact, but without a skin pedicle, has simplified and improved skin resurfacing.

2) The finger to be pollicised must have a satisfactory circulation, sensation, length and mobility. Each of these points must be clarified.

*Vascular supply*—It is obviously preferable that the finger to be transferred has a normal vascular supply. None the less, we have succeeded (Merle d'Aubigné, Tubiana and Ramadier 1952) in pollicising an index finger that had one digital artery destroyed. Littler (1952) has referred to similar cases. The bulk of the venous return is by the small deep veins which travel with the arteries, but it is preferable to retain one or two dorsal veins, and this is only possible when the index is being pollicised.

*Sensibility*—The finger to be pollicised must have sensibility, but no tender areas. Tender neuroma should be dealt with beforehand, both in the finger being transferred and in the thumb remnant. The transferred finger is not interpreted as a thumb by the patient, but tends to retain its original identity. A certain difficulty in perception results, which requires reorientation by the patient, just as with sensory island transfers. According to Hilgenfeldt (1950), stereognostic perception is improved if the flexor pollicis longus is fixed to the flexor profundus of the transferred finger.

*Length*—The tip of a normal thumb reaches to just short of the proximal interphalangeal joint of the index finger. A reconstructed thumb should be as near to this length as possible, but it must not be any longer nor have any more phalanges than a normal thumb. The length of the unit to be transferred will depend upon whether it is intact or where it has been injured. The adjustment of length during reconstruction is made at the proximal end. If it is an intact finger the proximal phalanx will become the first metacarpal and this allows retention of the distal phalanx with the flexor profundus insertion and the nail, which improves the appearance and makes finger-nail pinch possible.

*Mobility*—The transferred finger must have mobile and stable joints. Good movement in the distal joints is all the more important if the first carpo-metacarpal joint has a limited range. It is well known that stability in a proximal joint is necessary for motion in a more distal
Pollicisation of the index finger. Figure 13—The incision. Anteriorly it runs across the base of the finger. The flap for the cleft is based anteriorly. A long V-shaped tongue of skin is preserved on the dorsum of the index finger. Figure 14—Note the careful preservation of the dorsal veins. Figure 15—Extensor tendons divided proximally as high as possible to provide extra tendon length, to replace both the long thumb extensors and the intrinsic thenar muscles. Figure 16—Division of the index metacarpal. Figure 17—Result.
joint, and for this reason the principal stabilising muscles must be carefully retained or reattached: abductor pollicis longus for the first carpo-metacarpal joint, and the aponeurotic insertion of the intrinsic muscles for the metacarlo-phalangeal joint.

3) The reconstructed thumb must be fixed in position after rotation through about 90 degrees, so that the pulp does not face anteriorly, but makes an angle of about 80 or 90 degrees with the palm. Bony fixation and control of rotation are assisted by the use of Kirschner wires.

4) It is essential to reconstitute the musculature of the thumb, not only the long muscles, but also the intrinsic muscles, which play such an important role in the stability and movement of the digit.

A different scheme for reactivation of the thumb may be required for each case. Extension, flexion, abduction, adduction and opposition of the reconstructed thumb must all be considered (Figs. 18 to 23).

Extension—It is inadequate simply to attach a thumb extensor to the finger extensor; an extension deficit will occur and persist. One must also supply motor power to the intrinsic muscle insertions of the transferred finger by attaching those thenar muscles that are present. For example, in an index pollicisation the adductor pollicis is attached to the first palmar interosseous, and abductor pollicis brevis to the first dorsal interosseous. If the thenar muscles have been destroyed, a thumb extensor or abductor pollicis longus can be employed; in the latter case the carpo-metacarpal joint must be stable.

Flexion—Flexion is provided by the long flexors tendons transferred with the finger. It is usually sufficient after pollicisation of the index, even when the proximal phalanx becomes the metacarpal and the finger is shortened. The muscles adjust and compensate for this shortening, and it is only rarely necessary to shorten the muscles at the musculo-tendinous junction.

Pollicisation of other fingers is more likely to be associated with a flexion deficit because of the crossing and angulation of the flexor tendons which occur. It is probably for this reason that Hilgenfeldt advised, in the case of middle finger transfer, division of the flexor profundus tendon and suture of the flexor pollicis longus tendon to the distal divided end.

Adduction—This is provided by the first palmar interosseous and the extrinsic tendons. Adduction must be counterbalanced by the abducting muscles. Otherwise, as one often sees, the pollicised digit will take up a permanently adducted position which is of little use.

Adduction and opposition—It is necessary to counteract the natural tendency to adduction. This may be difficult in those cases, seen relatively often, in which the lateral units of the thenar eminence have been destroyed. The long extensor of the finger can be employed as Harrison (1964) proposed, by dividing it proximally, rerouting the tendon and suturing it to the existing flexor pollicis longus muscle. Other tendon transfers are possible. We have transferred the abductor digitii minimi muscle, which has the advantage of providing a good thenar contour as well as motor power.

5) Finally, it is important that the use of a finger to replace the thumb should not create a significant deficit in the hand, nor seriously alter its architecture. Pollicisation does not by itself produce a disability because it puts to better use those elements of the hand that remain. However, if only a few fingers remain it is often better to construct a new thumb by an osteoplastic method rather than to decrease further the number of fingers by pollicisation.

Choice of finger for transfer—We prefer to use the index or a partly damaged finger. This choice requires some discussion.

If the index finger is used, the dorsal veins can be preserved, the flexor tendons and the neurovascular pedicles are shifted without the problem of angulation or crossing and the architecture of the hand is minimally upset by the displacement of this peripheral finger. The web is created with the help of a dorsal flap, but it is deeper than normal because the finger has been moved proximally, and the appearance therefore lacks some elegance.

The middle finger was preferred by Hilgenfeldt because it is larger, and less important than the index. However, the displacement of this central digit affects the strength and stability.
FIGS. 18 TO 23
A case of mutilation of both hands. Krukenberg operation was done on the left. Figure 18—Right hand. Traumatic amputation of the entire thumb, the distal and middle phalanges of the index and the distal phalanges of the ring and little fingers. Figure 19—Radiograph after pollicisation. Bony fixation is made more secure by using an intramedullary graft, and rotation is prevented by two parallel wires. Figure 20—Reconstruction of the muscles. The extensor communis of the index is transferred to the extensor pollicis brevis, and the extra length of tendon is then sutured to the first dorsal interosseous tendon. The extensor indicis proprius is sutured to the extensor pollicis longus. The first palmar interosseous tendon is attached to the adductor pollicis. (After Littler.) Figures 21 to 23—Results showing the mobility and the prehension of the pollicised finger. Note the cleft flap.
of the hand. Amputation through the metacarpal results in loss of the stabilising effect of the transverse metacarpal ligament. In resecting the third metacarpal head there is a risk of producing rotation and overriding of the adjacent fingers and an unattractive hand posture. Perhaps the index ray should be transferred to the third metacarpal when the middle finger is used in pollicisation.

The ring finger was recommended by Letac (1954) and is the present choice of Gosset (1964) because it is less important for hand function. Also, it is distant enough for satisfactory tension to be re-established in the flexors after transfer. The architecture of the hand is upset less by using the ring finger than by using the middle finger, because the mobile fifth carpo-metacarpal joint allows the little finger to approximate to the rest of the hand.

The little finger can be used but it is really too slender to make a good thumb. Also, contrary to general opinion, this finger is far from being unimportant. Its removal considerably reduces the stability of palmar grip.

In spite of the good results obtained by pollicisation now that the technique is well established, we hesitate to move an intact finger when another method of reconstruction is available. When possible, we use a finger that has been damaged. These shortened or slightly stiffened fingers that are of little value, especially when the thumb is absent, may gain considerably when transferred.

A thumb of adequate length is achieved if the metacarpal is preserved, and even though there may be cosmetic loss from lack of a nail, the functional value is great.

**INDICATIONS FOR OPERATION**

Each case of thumb restoration poses particular problems. Factors that must be considered are the level of amputation, the age of the patient, the mobility of those joints that will subsequently function in prehension, the condition of the remainder of the hand, and sex, occupation, mental and social status. The operative indications are governed also by the advantages and disadvantages of the different procedures at our disposal.

Pollicisation has the advantage of being accomplished in one stage. A mobile thumb with sensibility is provided. The disadvantage is that one of the remaining fingers is taken.

A tube flap with bone graft and sensory island allows one to retain all the fingers, but several operative stages are required, and a mobile joint is not provided.

Osteoplasty, using a local skin flap, provides an expedient solution, but can be performed only if the remaining bone stump is of sufficient length, and can be covered with locally available tissue.

In summary, we consider that the level of amputation remains the essential factor in choosing the reconstructive procedure (Fig. 24).

As a guide the following levels are considered.
When a sufficiently long fragment of proximal phalanx remains—It is unnecessary to use a major resurfacing procedure. It suffices simply to phalangise the first metacarpal, or if the neighbouring soft tissues are of good quality a short osteoplasty can be carried out, covered by a local skin flap.

When the amputation is at the level of the metacarpo-phalangeal joint—If the first carpo-metacarpal joint is mobile we employ a tube flap with a sensory pedicle. Pollicisation is indicated for occupations where precision is essential; for aesthetic reasons, especially in women: and for cases in which a partly damaged finger can be used.

When the amputation is at the level of the base of the first metacarpal—We can use either of the major procedures, but pollicisation is especially indicated when the carpo-metacarpal joint is stiff.

MUTILATIONS OF THE THUMB AND FINGERS

When the surgeon is faced with a mutilation of the thumb and the fingers that destroys the power of prehension it is important to determine at once the possibility of restoring a pinch from the tissue remaining. Several questions must be considered: 1) Are there mobile stumps remaining which are capable of separating and of coming together? 2) Are there elements already opposed to each other, or are they capable of opposition by reason of active rotation of the first metacarpal? 3) Is it possible to cover the surfaces necessary for prehension by skin of good quality, and is it possible to provide sensibility?

One must in these complex cases be judiciously and selectively conservative. The aim is not necessarily the same as in the care of the freshly injured hand: that is, to conserve all the remaining fragments. The object is now to improve the nutrition, the sensibility, the mobility, and the direction of the usable elements in order to restore a pinch grip.

The following procedures may be of value in improving the hand, apart from specific measures for reconstruction: 1) Correction of contracted scars, particularly in the webs; 2) Deepening of the clefts to increase the separation of the first metacarpal or to increase the play of the metacarpo-phalangeal joint; 3) Improvement of movement by capsulectomy of the first metacarpo-phalangeal joint or the first carpo-metacarpal joint, or by excision of the trapezium; 4) Covering the stumps when necessary by cutaneous flaps. The area of prehension should, when possible, be recovered with sensitive skin obtained locally by rotation or sliding, or by a "coiled hat" procedure or by taking an island flap from a distance on a neurovascular pedicle; 5) Correction of the direction of a bony element by rotation or angulation osteotomy or by lengthening if necessary: and 6) Occasionally it is necessary to activate or reinforce movements by means of tendon transplantations.

Specific reconstructive measures can be discussed under the following headings, divided according to the level of amputation: 1) Cases in which the phalanges are present; 2) Cases with mobile metacarpals, which can be utilised; 3) Amputations through the metacarpals or the carpus, preserving wrist movements; and 4) Disarticulation through the wrist.

When some phalangeal stumps remain—1) When the elements of the pinch are of equivalent length: it may be possible to create opposition between them by a more or less atypical transposition or pollicisation, if the state of the stump to be transferred permits. At least one palmar neurovascular pedicle must be intact. Simple rotation or angulation osteotomies of the metacarpals may also be possible.

2) When the opposable elements are of unequal length it depends whether the amputation is predominantly radial or ulnar, the former being more severe.

It is possible to lengthen the shorter segment. Sometimes the first metacarpal can be lengthened by using the metacarpal of an amputated index finger, which also permits the deepening of the cleft. Alternatively a bone graft may suffice. A mobile fifth metacarpal can also be lengthened with profit in certain cases, but no benefit will accrue from having a fixed metacarpal longer than its mobile opposable partner.

3) When only one finger or finger stump remains, the prognosis of the "digital hand"
(Pierre, Bureau, Perpere and Jouglard 1964) depends essentially on the presence of a mobile first metacarpal. If this does exist it should be lengthened. Sensation can be provided by using a sensitive flap raised on one of the neurovascular pedicles of the remaining finger. By this means it is possible with these two elements to restore a digital pinch, or even palmar grasp, if the finger retains sufficient mobility.

4) If the first metacarpal is destroyed, or has lost its mobility, one can only hope to restore a digital pinch against an opposition post constructed from a bone graft covered with a sensitive flap.

These operations for lengthening are only indicated if the nutrition of the skin is satisfactory and the sensibility can be preserved or replaced on the areas of prehension. If not, it is preferable to use a prosthetic post.

When all the fingers and the thumb are amputated, but mobile metacarpals remain—These metacarpal hands can be classified in three groups: simple distal hemi-amputation; ulnar distal hemi-amputation; and radial distal hemi-amputation (Clarkson and Pelly 1962).

Distal hemi-amputation—All the metacarpals remain, but the clefts are eliminated. Phalangisation of the mobile metacarpals, the first and the fifth, restores their independence, and creates new clefts.

Simple first metacarpal phalangisation, as carried out initially by Huguier (1873), is improved when the adductor can be preserved and its detached tendon reinserted into the shaft of the metacarpal (Wierzejewski 1919).

Usually a Z-plasty is performed to improve the cleft, and skin grafting may be necessary to cover the sides of a deepened cleft. In addition the phalangised fifth metacarpal requires an osteotomy, inclining it towards the first.

The mobility of the peripheral metacarpals can be increased, and the cleft deepened by resecting the intervening metacarpals, namely the second and fourth. The adductor of the thumb is preserved by keeping the third metacarpal.

The grip of this metacarpal hand can, as the figures show, be conveniently restored for holding objects of various sizes (Figs. 25 to 28). It is evident that this is only pinch and not grasp.

The presence of a third point of contact improves the precision of prehension. The mobile metacarpals can be lengthened if it is possible to cover the areas of prehension with sensitive skin. This lengthening can often be achieved by using the resected metacarpals.

Ulnar hemi-amputation—An ulnar element can be constructed with the aid of a bone graft, to oppose the first metacarpal. The latter can also be lengthened if necessary. The intermediate metacarpals are resected.

Radial hemi-amputation—The restricted movement of the fifth metacarpal can be usefully employed only if there is a persistent stump of the first metacarpal, capable of being lengthened. One can restore a gross pinch by resecting the intermediate metacarpals.

If the first metacarpal is useless it is probably better to use a total prosthesis or perform a Krukenberg operation.

Transmetacarpal and transcarpal amputations—If all mobilisation operations at the level of the metacarpals prove impracticable, use of the movements of the wrist can give good service. The flexion of the wrist forms a powerful natural hook.

The movements of flexion and extension of the wrist can also be used to establish sensitive prehension against a prosthesis.

Disarticulation through the carpo-metacarpal joint, particularly in children, can be used in the same way if active movements of the radiocarpal joint are present.

It is useful to fix the flexor and extensor tendons of the wrist distally at the level of the carpus (Swanson 1964).

Amputations at the wrist—Finally in cases of complete loss of the hand and of the wrist two possibilities are available for restoring prehension: prosthetic apparatus for disarticulation at the wrist, and the Krukenberg operation.
Of all the functional prostheses we prefer the type with a hook or a split hook, mounted on a rotation piece, and controlled by the opposite shoulder (Houssa and Maurer 1958).

The Krukenberg operation creates a pinch at forearm level by opposing the radius to the ulna. It offers the inestimable advantage of retaining sensibility for grasp and appears to be specially indicated in cases of bilateral mutilation or in blind patients.

The Krukenberg operation has given (R. T.) very satisfactory results as much from the point of view of strength as of sensibility for pinch. It is important to retain skin flaps with good sensation for the facing surfaces of the two components. When it is necessary to use skin grafts these must be placed on the non-pinch areas (Kallio 1948).

The muscles necessary to activate this pincer are the biceps, supinator and pronator teres, all of which are proximally located. The bulk of the long flexors and long extensors may be removed so that the pincer components can be made long enough, not too padded, and yet mobile and easy to cover with skin.
The interosseous membrane must be totally resected in such a way as to obtain the greatest spread between the two bones, that is about 8 to 9 centimetres. The median nerve is divided very high in order to avoid a painful neuroma.

The best length of the arms of the pincer seems to be about 12 to 15 centimetres, but in cases of necessity very short arms of about 7 to 8 centimetres are capable of rendering good service (Figs. 29 to 31).

Active rehabilitation is very important, and all rotatory and scissoring movements must be prevented. It is possible to mask the unattractive appearance of the forearm for social activities by providing the patient with a hand prosthesis, which can to some extent be activated by the pincer components.
RESTORATION OF PREHENSION AFTER SEVERE MUTILATIONS OF THE HAND

BILATERAL HAND MUTILATIONS

Bilateral mutilation is a major disaster. It would be an error to think that it is simply twice the disability of a unilateral case. Certainly the problems may be at first sight appear to be the same, but they are in fact more complex, more varied, and some are completely new (Tubiana and Elbaz 1965).

Every effort must be made to restore to the patient the independence that he has lost. This means the necessity of restoring a strong grasp that has some sensibility.

However good the result of a reconstruction in a unilateral case, the other hand is always better. In bilateral cases the patient is obliged to use the reconstructed hands to face the normal demands of daily life. This requires a detailed programme of reconstruction, avoiding as far as possible the simultaneous immobilisation of both limbs, and foreseeing the requirement for skin cover from a distance for the two hands.

It is important at all costs to preserve one limb long enough to reach the buttocks and the interscapular region; if possible one hand should have a strong pinch—a power grip—and one a fine pinch—a precision grip.

It is important during the arrangement of the programme to discuss carefully the possibilities of the use of mechanical appliances which, in spite of recent great developments in this field, still remain insensitive. But the use of prosthetic devices should not preclude attempts at surgical reconstruction, but should complete and improve on them.

The provision of apparatus must not interfere with the adaptation, aided by surgery, of the patient to his disability. This spontaneous adaptation is less important after traumatic amputations than in the cases of congenital deformity, but none the less can be considerable.

PROSTHETIC APPLIANCES FOR THE MUTILATED HAND

It is not possible here to consider fully the question of appliances for these hands, but it seems to us to be essential that all decisions regarding prosthetic appliances should be made by the surgeon in collaboration with the patient and the appliance maker.

We will not discuss prostheses for total loss of the hand, but we consider that partial prostheses can render great service to these cases of greatly mutilated hands, as much from a cosmetic as from a functional point of view.

Cosmetic prostheses in the form of supple gloves can be made of plastic material and imitate the normal hand. They can cover the hand entirely or leave the remaining fingers exposed. In the case of manual workers they are only for use after work, but their use is becoming more and more widespread. Nevertheless, many patients who desire them to begin with discard them later as they become more adapted to their disability.

Functional partial prostheses have a much more limited use. They will be rejected by most patients since surgery has more to offer by giving a mutilated hand a strong sensitive pinch.

They can take the form of a simple opposition post or plate. This will vary according to the remaining mobile element. Special designs are required for special jobs. They must be comfortable, simple and strong, and must not interfere with the movements of the wrist. Some of these partial prostheses can also be activated by controlled movements, preferably of the opposite shoulder.

CONCLUSION

The cooperation of the patient and the appreciation of his wishes are the determining factors in the choice of treatment, but we cannot over-emphasise the fact that any natural grip, if it is sensitive, will considerably assist the patient in his adaptation to his disability.

SUMMARY

1. Prehension is a complex mechanism for which both movement and sensation are required.
2. Two basic grips are considered: the digital pinch and palmar grasp, which are simpler
expressions of the precision grip and the power grip. For the digital pinch the minimum requirement is a thumb or a reconstructed thumb, and a finger to which it can oppose. For palmar grasp mobile fingers are necessary so that they can wrap round the object grasped.

3. The restoration of prehension is considered under the following headings: mutilation of the fingers; mutilation of the thumb; and mutilation of both together.

4. The various methods of reconstruction are described that are appropriate to each type of mutilation, so as to provide restoration of length, mobility and sensation.

5. The indications for the various main methods to compensate for loss of the thumb are discussed. These methods include pollicisation and osteoplastic repair with neurovascular island flap.

REFERENCES


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