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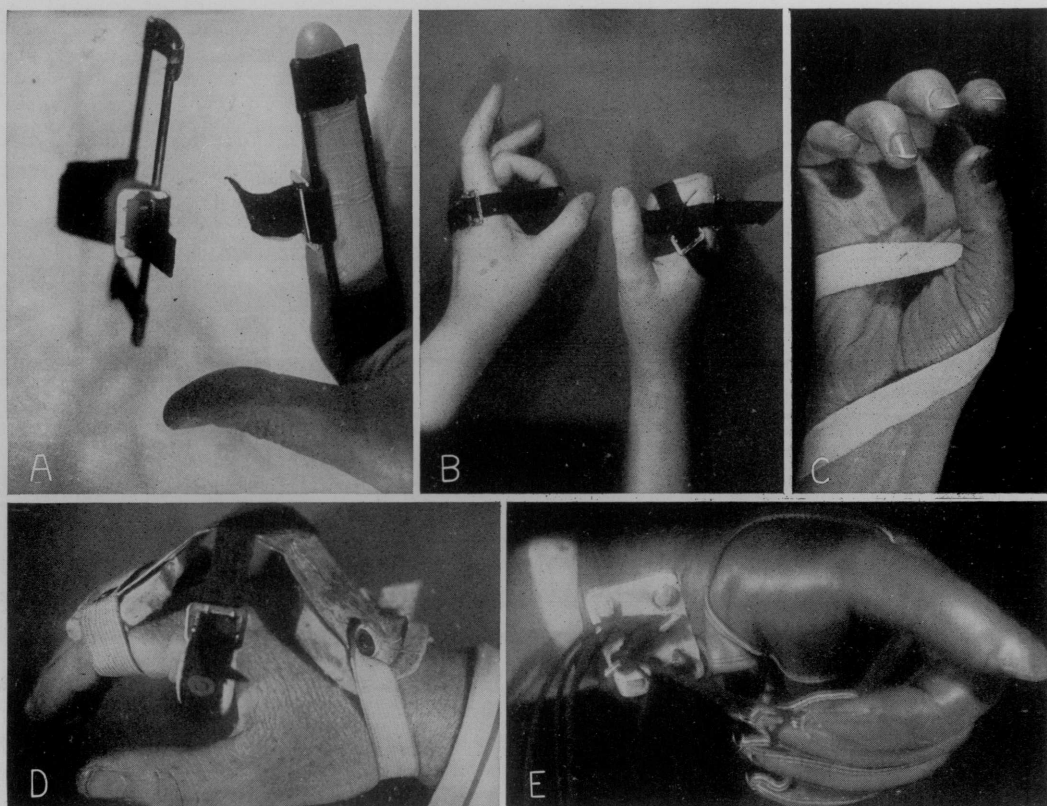


FIG. 17. TYPES OF SPLINTS USED BY AUTHOR.

A, "Safety pin" splints used to extend a finger or thumb, or to straighten a fractured phalanx. The strap draws the finger forward between the two rods.

B. Web belts and buckles used to draw the finger joints into flexion by slow, mild, continuous traction. Various other ways of applying the straps can be used.

C. Method of maintaining opposition of thumb to fingers in median palsy. The thumb is drawn toward the pisiform bone by two arms of a strip of adhesive that grip around the hand and forearm. The thumb is pulled along the line of the resultant of these two forces.

D. Splint used to flex the proximal finger joints. A metal bar crosses under the heads of the metacarpals and by tightening the belt and buckle which are attached to the bar the desired strain is put upon the finger joints.

E. Method used to flex further the proximal finger joints after using splint shown in D, and of flexing the middle finger joints. The cords pulling from the finger ends are made fast to a line-cleat riveted to the glove at the wrist. The cleat will open to allow removal of the glove.

## RECONSTRUCTIVE SURGERY OF THE HAND

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**I**NJURIES from manual labor are usually of the hand, and so it is that hand injuries constitute by far the largest part of industrial accident cases. As a number of these result in permanent disabilities there are in every large city thousands of crippled hands in need of repair. If a worker be entirely dependent on manual labor for his livelihood, his earning power is seriously impaired when his most valued member is crippled.

When we consider what a wonderfully perfected piece of mechanism the hand is, it is not surprising that successful reconstruction of it by surgery is unusual. Much, however, can be done if one will give the time, care and patience. The usual surgical procedure is too rough, so it is necessary in this work to use as nearly as possible an atraumatic technique.<sup>1</sup>

In hand reconstruction certain main principles must be kept in mind. The rest depends on a host of tiny but important details.

### MAIN PRINCIPLES

The wrist and fingers must first be put into functionating positions. That is, the wrist should be cocked up in extension and the fingers should be partially flexed and especially in their proximal joints. The thumb should oppose the fingers. A hand with a straight wrist, with extended proximal finger joints, and with the thumb at the side of the hand, is practically useless. While the case entrusted to

our care is undergoing healing from infection or injury, we will be negligent if we do not maintain these functionating positions.

Joints must be mobilized before tendons are repaired or no motion will result. We cannot expect a newly repaired tendon to move a stiff joint; nor should we repair a bone, and at the same time a tendon or joint. The former demands postoperative immobilization, and the latter mobilization.

In all dissections of the hand it is essential, in order to protect anatomical structures, especially nerves, to dissect with accuracy and to avoid the trauma of sponging, to operate under the ischæmia of a tourniquet, such as a blood-pressure band. Too long an ischæmia will provoke a generalized tissue reaction, which results in a degree of firm induration of the parts—an hour is safe; 2 hours gives some reaction. The pneumatic blood-pressure band will not cause paralysis. After the arm has been held vertically long enough for the veins to collapse, the band should be pumped up very rapidly until over the systolic pressure so that the veins will not have time to refill. For this speed a bicycle pump excels a bulb. Local anæsthesia, and especially with adrenalin, is best avoided as it lowers the resistance of the tissues. The tissues must have maximum vitality for healing.

After trauma, infection, or operation the tissues are usually densely indurated. A second operation on such tissues will result in the summation of scar tissue and so had best be

<sup>1</sup>An essential in reconstructive surgery—"atraumatic" technique, California St. J. Med., 1921, May.

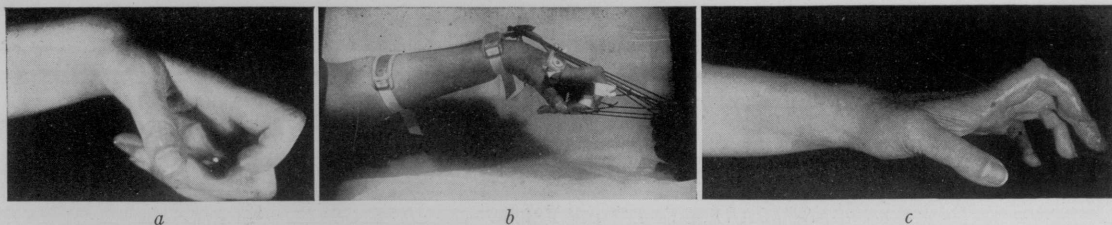


Fig. 1. Mrs. J. D., age 48. Following a severe encephalitis, the hand was drawn by the unequal pull of the muscles into the extreme contracture of wrist and fingers shown in *a*, which had existed 3 years.

*Treatment.* By the principle of slow, mild, steady traction the joints were gradually straightened and the flexor muscles stretched. In *b* is shown the commencement of treat-

ment, using an inverted cock-up splint, with metal extension distally, for traction cords. Various other splints were used and finally the joints were mobilized under anaesthesia. In *c* is shown the extension obtained in 10 months. Strength returned in the extensor muscles which had been overstretched and excellent function of the hand and wrist was obtained.

delayed a few months. The final result is not obtained until after the softening up process has taken place. This often takes a year.

I have been disappointed with the results of physiotherapy as usually practiced, and have far more faith in certain exercises, the actual use of the member, and last, but not least, the time factor.

For most reconstruction, special splints must be used. These the surgeon, himself, should make to fit the case. They are usually made of metal. They should be boiled up for application at the end of the operation.

It is most important for later reference to make a complete record of a case before the repair is attempted. This should consist of photographs showing limits of motion, measurements of joint motion, condition of the bones, joints and tendons, amount of loss of

nerve function, both motor and sensory, presence of contractures, degree of induration of tissues, and finally the strength and practical function of the hand. By establishing a record of the exact condition before repair, the degree of improvement in the final result can be ascertained.

#### MOBILIZING JOINTS

In examining a hand if we request the patient to flex his fingers fully and to maintain the flexion and then we find that we can passively flex the fingers still further without encountering resistance, we know that in his case the tendons are more to blame for his lack of power of flexion than are the joints. If, however, we cannot passively flex the fingers further than he can do so actively, we know that in this case the joints are more at fault than are the tendons. If we can bring the joints into

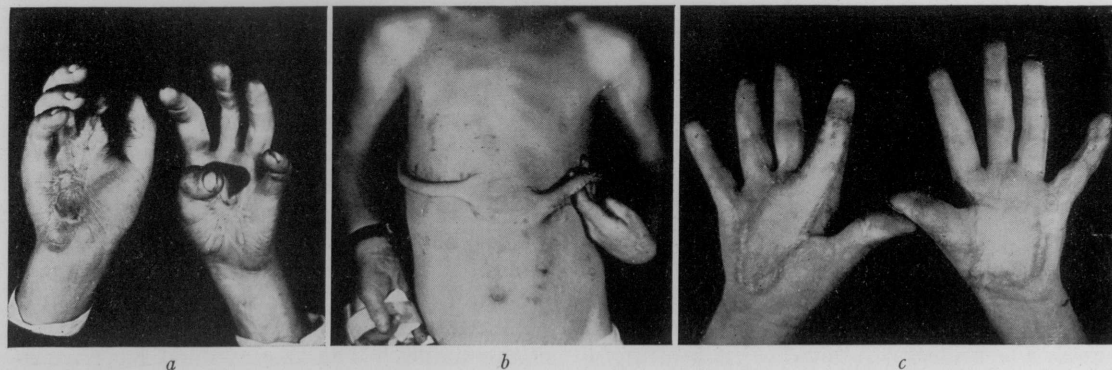


Fig. 2. E. M., age 7. At the age of 14 months his chair fell forward and both hands rested on a hot stove, resulting in the deformity seen in *a*. The digits are at their limit of extension.

*Operation.* Two tubular pedicles were prepared as in *b*. The scars on the moderately contracted fingers were re-

lieved of their tension by cutting a series of V's along them and suturing them in Y's. The large keloid scars were excised and the areas covered with good skin from the pedicles. The hands were held in extension by metal splints. The result immediately after the completion of the operations is shown in *c*.



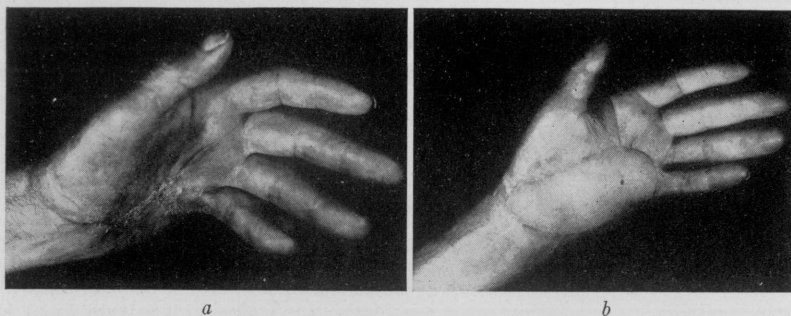


Fig. 3. P. S. Seven months previously his hand was caught and held by a hot metal roller, resulting in a deep contracting palmar scar adherent to the tendons and preventing extension of the fingers as shown in *a*.

*Operation.* The scar tissue was excised and the denuded area so left was covered with skin from a tubular pedicle from the chest, as shown in *b*.

functionating positions, so that the hand can be used, much will have been accomplished, as the mere use of the hand, together with the time factor, will greatly increase the range of motion.

When a hand has suffered a severe traumatism or an infection, and especially if splinted during the recovery, the tissues about the finger joints, as well as all of the tissues of the hand, have become thickened and less flexible and we find much loss of ability to flex the fingers. It is frequently found after palmar infection that the metacarpophalangeal joints have become permanently stiffened in the extended position and that the two distal joints of the fingers have become flexed. This is the position assumed, because the same mechan-

ics take place as in paralysis of the ulnar nerve. The small hand muscles normally flex the proximal joints and extend the distal two joints, and when bathed in palmar infection they temporarily cease functioning and the fingers assume the opposite position, just as they do in ulnar paralysis.

Stiffened finger joints may be mobilized by using the principle of slow, steady, mild traction; much as the dentist draws into line mal-placed teeth. If the traction is too severe the tissue strain thus produced will cause arthritis and pain. The restraining tissues must not be merely stretched, as this only further stiffens the joints by provoking tissue reaction. The tissues must be held on a mild stretch steadily for weeks until they grow longer. The pump

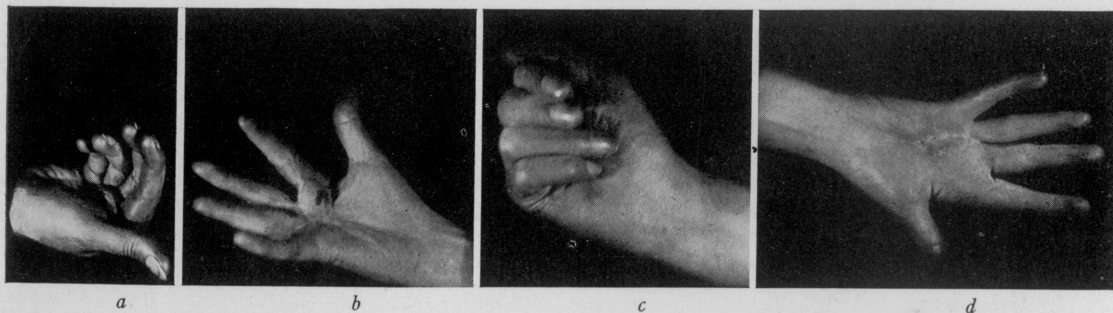


Fig. 4. L. M. Ten months previously the hand was burned by being caught in a mangle. The distal part of the palm, including the palmar fascia, sloughed, and the area had been later covered by a poor pedicle skin graft. The hand as seen in *a* and *b*, shows flexion and extension much limited. There is a stellate contracting keloid in the palm drawing together the thumb and fingers. The grafted skin is dome-like and does not stand work. The flexor tendons are held by adhesions in the palm and fingers.

*Operation.* All of the scar tissue was dissected out of the palm, including that which matted together the deeper structures. The tendons were stripped well into the fingers and mobilized. A tubular pedicle which had been prepared and taken from the abdomen was used to furnish good skin for the palm. A splint held the fingers in extension. The result obtained in flexion and extension of the fingers and in new skin in the palm is shown in *c* and *d* taken 6 months later.

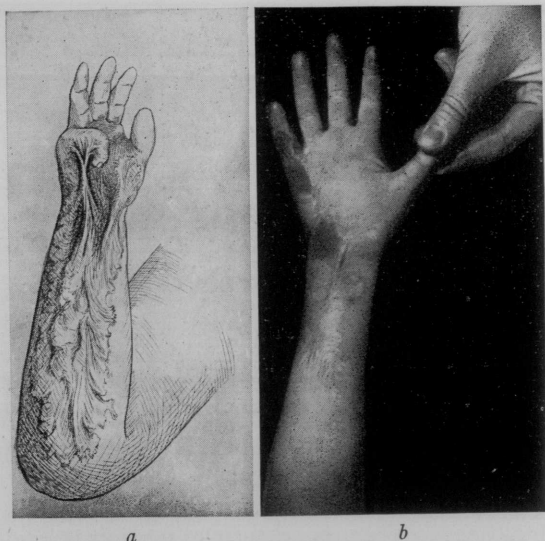


Fig. 5. P. W. Age 21 months. Three months previously the hand and forearm were burned by hot coals, resulting in keloid formation and contracture, as shown in *a*.

**Operation.** The scar tissue was excised and the hand was placed in a previously made metal splint, which held the thumb, little finger, and wrist in extension. The skin of the upper half of the forearm was extensively undermined and the edges were drawn together leaving a linear scar on the dorsum not shown in *b*. A whole thickness free graft of skin from abdomen was used to cover in the little finger and part of wrist. This later became pigmented. The thenar eminence was closed by sliding flaps and the lower half of the forearm successfully by a Thiersch graft from the mother's leg. Except for the pigmentation of the Wolfe grafts, which does not occur in pedicle grafts, a good result was obtained, as shown in *b*.

handle method traumatizes microscopically and results in increased scar contraction of the restraining joint capsules. Elastic traction by its vibratory fluctuation traumatizes. Steady, firm traction is preferable. It is well to remove the traction for short intervals several times a day, to exercise the joints and bathe the hand in hot water.

If adhesions prove too unyielding for the slow traction method, the joints may be flexed under anæsthesia and held so until the traumatic reaction is over.

The wrist joint, which tends to be straight, can be drawn into the extended position by the Jones cock-up splint. This is the position in which a wrist is most useful, and in which we generally use it.

The metacarpophalangeal joints can be flexed in two stages. The first is by a padded metal splint on the back of the hand bent at

the knuckles (Fig. 17, *D*). It presses the fingers and wrist palmarward, while a palmar cross-bar under the heads of the metacarpals draws these joints backward. As an encircling web belt and buckle are tightened the joints are made to flex. After about a week, when partial flexion has been obtained, the joints are bent still further by means of a kid glove (Fig. 17, *E*). The finger joints are drawn into flexion by strings from each finger tip, which are made fast to a line cleat that has been riveted to the wrist of the glove. To flex the finger tips still further a flattened bracelet about the hand will hold the strings into the palm. Individual fingers may similarly be flexed by fastening the string to them with adhesive and anchoring it to a web belt about the wrist by means of a safety pin used as a line cleat.

To flex the distal finger joints, a narrow web belt may be made to encircle the proximal and distal finger segments (Fig. 17, *B*). A nail can be passed under the belt to keep it from slipping off the finger. This belt may include all of the fingers, and another belt may encircle the middle segments and the dorsum of the hand for flexion of the proximal joints also.

If the finger joints have ankylosed too firmly they will not yield to mild force. Greater force will result in evulsing two discs of cartilage from the proximal joint surface.

If the extension of the fingers is desired and the flexion is extreme the finger tips can first be drawn out by tape loops on traction cords from a distal metal extension of a Jones cock-up splint (Fig. 1, *b*). If flexion is not so extreme they can be still further extended by drawing the fingers into small curved metal gutter splints on their volar surfaces by belts encircling at their middle joints. Another way is to draw the fingers into extension by tape loops from a splint belted along the dorsum of the hand and forearm.

The final straightening of the fingers can be done by what I call the safety pin splint (Fig. 17, *A*). It consists of two rods and two ribbon cross pieces of sheet metal soldered to them and is placed on the volar surface of the finger. A web belt over the dorsum of the finger is looped about each rod and draws the finger forward between the two rods until it is straight.

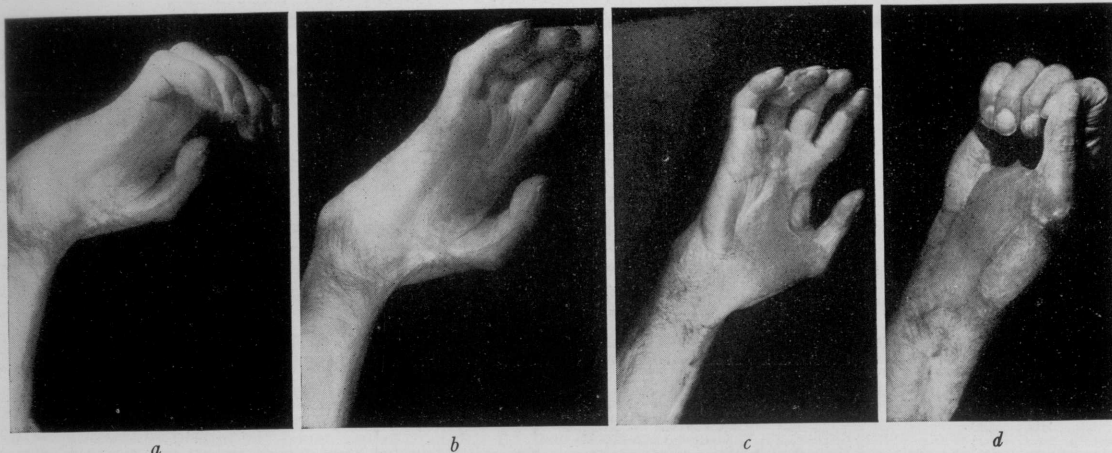


Fig. 6. R. L. A year previously the hand was caught up to the wrist between two steel rollers, causing multiple fractures, exposing the flexor tendons and tearing away the thenar muscles. The wound healed in 6 months and physiotherapy was used for 5 months. The hand was completely disabled. He could not grasp an object; his only way of holding one was by pressing it between his hand and something else. The wrist was flexed out of use and the proximal finger joints were extended out of use. A broad keloid extended from the distal end of the palm up the forearm for 6 inches, holding the wrist in flexion and the thumb in adduction. The finger joints were quite stiff. The thumb lacked an inch of touching any finger. In *a* and *b* is shown the extent of flexion and extension.

*Operation.* After bringing the proximal finger joints into flexion by the slow traction method (Fig. 17, *D* and *E*), the scar tissue was dissected from the palm and forearm, and from between the tendons, nerves, and blood vessels, which were matted solidly together. A gap of  $1\frac{1}{4}$  inches which was found between the ends of the nerve to the third cleft was bridged by a free graft from the sural nerve. The flexor tendons freed from scar were made to pull the fingers into flexion. The wrist was put into extension and the thumb in abduction. The large skin defect was covered by a tubular pedicle from the chest. *c* and *d*, taken 4 months later show fairly good extension and flexion of the hand. The thumb touched every finger. Sensation returned in the third cleft. He returned to his work.

This splint is also useful in straightening fractured phalanges.

In some cases the joints are limited in their movements by adherent tendons, or scar con-

tractures, and it will be necessary to liberate or excise these before the joints can be mobilized. The distal end of a flexor sublimis tendon, severed at the base of a finger, will

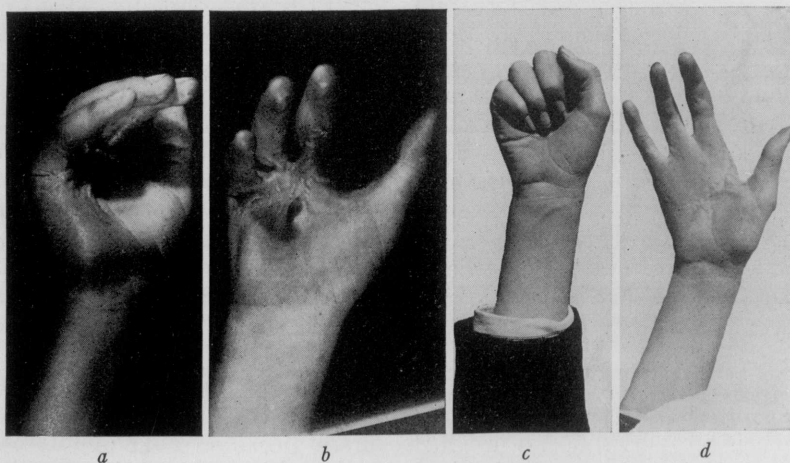


Fig. 7. G. T., age 8. Scar contracture due to burn from stove at age of 2. *a* and *b* show limit of extension of the thumb and fingers.

*Operation.* The scar tissue was excised; the hand was placed in extension on a splint and a skin graft from a tubular pedicle on the chest was used to cover the denuded area. *c* and *d* show result.



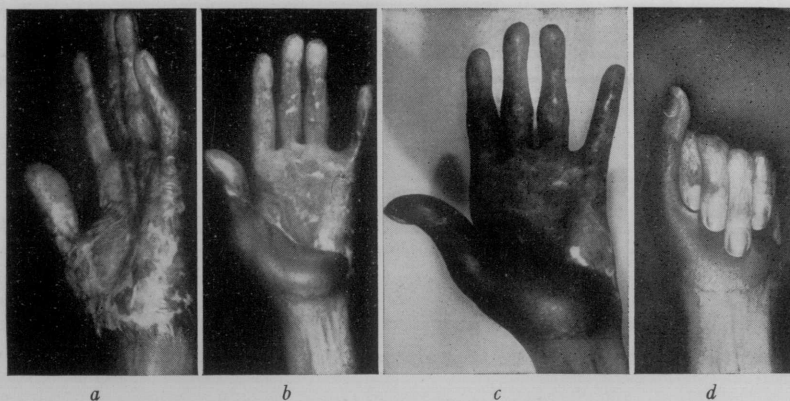


Fig. 8. R. W. (colored). Fourteen months previously the hand was badly burned in a gasoline explosion, taking 4 months to heal. A stiff hard keloid covers the base of the thumb and palm, drawing the thumb in adduction, preventing flexion of the wrist and causing pain, as shown in *a*. The little finger had a slight contracture by a band running in the wrist. The finger joints were stiffened so that the fingers lacked an inch of touching the palm.

**Operation.** A zigzag plastic relieved the flexion band of the little finger. The keloid over the thumb and base of the palm was excised and in its place was sutured skin from the side of the chest from a previously prepared tubular pedicle. The finger joints were mobilized by the slow traction method. In *b* is seen the skin graft in place, but the linear scar running to the thumb being under some tension is forming a keloid and adducting the thumb. This was excised and the tension was relieved by a zigzag plastic which allowed the thumb to abduct, as shown in *c*. Little finger is straight. In *d*, taken 7 months after operation, is seen degree of flexion and absence of keloid.

become adherent from lack of movement and thus hold the middle joint in flexion. Following tenosynovitis a finger may be held resis-

tantly in flexion by the adherent flexor tendons acting as a bow cord. Adherent extensor tendons will prevent flexion. If superficial skin on the dorsum of the hand or finger is preventing flexion, the skin can be cut in several places transversely. On fastening the fingers in flexion these incisions will gap and the defects can be covered by Thiersch grafts. If the cicatrices are greater pedicle grafts must be used.

A hand that can be but partially flexed may, when used, cause pain whenever the limit of flexion is reached and so prevent the person from working. If such joints be drawn into full flexion and held there until by growth there is no more tension the condition will be relieved.

A flat hand is sometimes seen due to flat splinting. Here the curves of the transverse carpal and metacarpal arches have been straightened; this tilts the angles of the axes of the proximal finger joints and the carpo-metacarpal joint of the thumb, so that the normal convergence of the finger tips in flexion will be lost and the thumb will no longer oppose the fingers. The tendons will then be

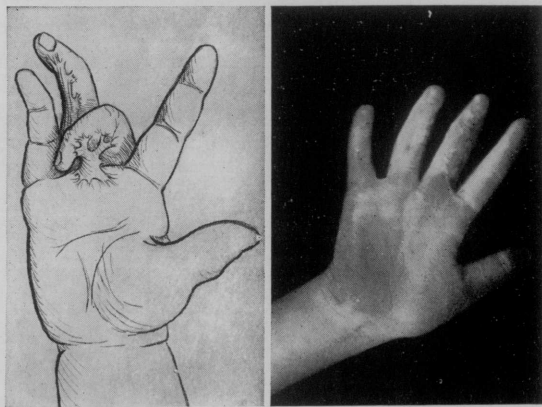


Fig. 9. B. S., age 3. The deformity shown in *a* resulted from two previous operations for webbed fingers.

**Operation.** The contracting scars were excised and the fingers were overextended and placed on a splint. The large denuded areas so left were closed by a plastic on the ring finger and by whole thickness free grafts of skin from the abdomen on the long finger. The result is shown in *b*, taken 4 years later. The hand could be completely flexed, all skin is soft, but as usual there is slight pigmentation in Wolfe grafts.

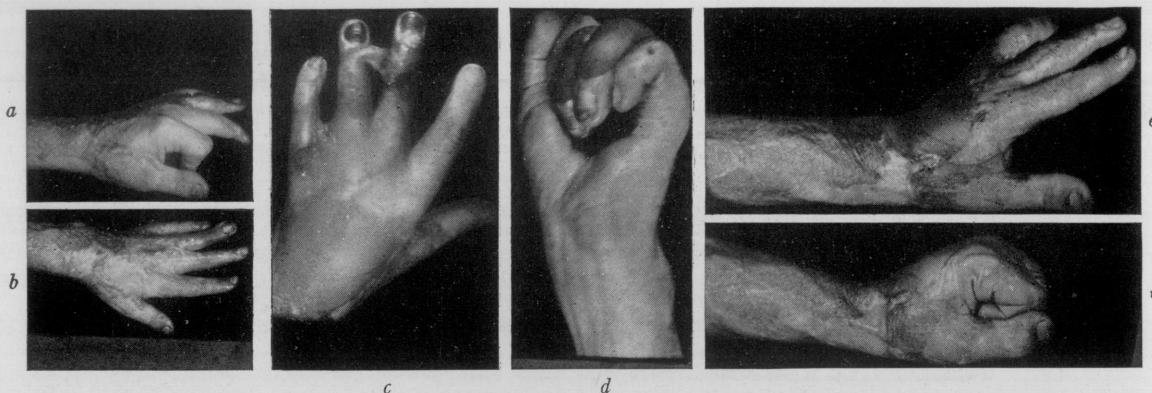


Fig. 10. C. P. Seven months previously hot lead ran over the left hand and forearm, resulting in a tough thick keloid over the dorsum of fingers, hand, and forearm, and in webbing of the fingers for one and one-quarter inches beyond the knuckles. The movements of the wrist are much limited, the thumb is held in adduction and extension, and the fingers are drawn into extension. The last three fingers are covered with thin red scar adherent to bone and tendon and preventing motion of the joints. The nourishment of the hand is poor because of the ischæmic effect of the contracting scar. *a* shows the inability

to close the hand and *b* the condition of the hand before operation.

*Operation.* The scar tissue was excised and by a series of tubular pedicle skin grafts from the chest was replaced by good skin. *c* shows the method of "waltzing" a pedicle, originally from the chest, from the ring to the long finger, resulting in the flexible skin and joints shown in *d*. *e* and *f* show the degree of function gained. All joints now have good range of motion. The hand and forearm are covered with flexible skin throughout and good nutrition has returned.

pulling at a mechanical disadvantage and pain and weakness will result. A corrective strapping for this condition is the one described above to produce opposition of the thumb (Fig. 17, C).

#### FLEXION CONTRACTURES

Burns, infections, or extensive injuries often leave contracting keloid scars, which draw joints into extreme positions and limit their motion. For these radium and X-ray, in my experience, have proved unsatisfactory, but good results are obtained by complete excision of all the scar tissue, both deep and superficial, followed by tubular pedicle skin-grafting. A tubular pedicle is previously prepared. This is usually on the side of the chest and care is used to make the direction exactly in line with the wrinkles of the skin. This leaves a less conspicuous scar. Sometimes the pedicle is made in the pectoral or deltoid region or on the hand itself, as the patient can then be less tied up than when the chest is used. After making two parallel skin incisions a ribbon of skin is lifted up and sutured into a tube with the epidermis outside (Fig. 2, *b* and Fig. 11, *a*). The surrounding skin is then widely undermined and the incision is closed without ten-

sion under the pedicle. There will then be no raw area, so the work can all be aseptic. After wearing this "shawl strap" 2 weeks or more the scar tissue is removed from the hand, the joints are fully bent in the opposite direction, cutting the capsules if necessary and the hand is held in this position by a splint of metal with web belts and buckles that has been made for the case and sterilized by boiling. The pedicle is severed from one end and enough of it is opened out to cover the denuded area. The core of the pedicle and its longitudinal scar are removed and the skin flap is sutured in place on the hand under normal skin tension. The hand and arm are held in place by adhesive plaster and guy ropes, so placed that all possible pull on the pedicle is avoided. The pedicle should be made long enough to give freedom of motion and to allow the patient to be ambulatory. After 2 weeks the hand is freed by severing the pedicle and the ends of the pedicle are trimmed off and the skin is sutured into place. Slight infection and separation is often encountered at the angles of the pedicle. This can be avoided by so cutting the pedicle that a triangular flap of skin forms the angle itself and by daily applying to the suture line a 2 per cent ammoniate of mercury ointment.

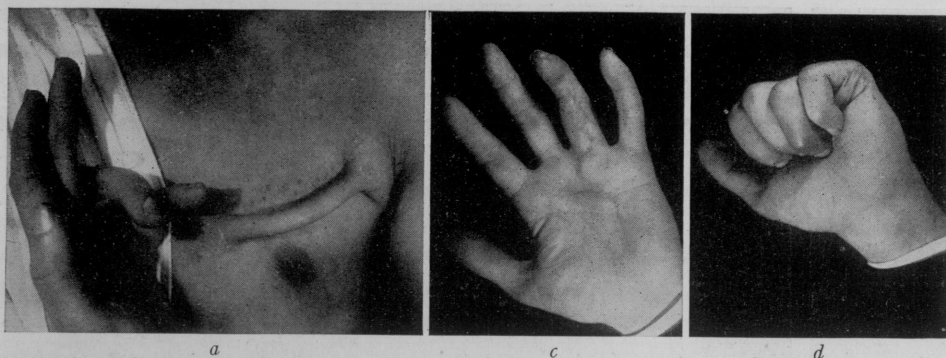


Fig. 11. C. J. J. An infection 5 months previously in the sheath of the flexor tendons of the ring finger which was drained through a median longitudinal incision in the base of the finger resulted in loss of the flexor tendons and in the scar contracture of the finger which limits the extension, as shown in *a*.

*Operation.* The scar was removed from the volar surface of the finger together with the remains of the flexor tendons, the finger was straightened on a splint and the denuded area was covered by a skin graft from the tubular pedicle in the pectoral region shown in *a*. Four months after good skin was supplied, a new flexor tendon was transplanted into the finger from the flexor sublimus of the same digit, which was removed from the forearm. In the palm it was sutured to the tendon of the flexor profundus, and distally it was fastened through a drillhole in the distal phalanx to the insertion of the extensor tendon, as shown in *b*. *c* and *d* taken three months later show the result. Soon practically normal function will be obtained.

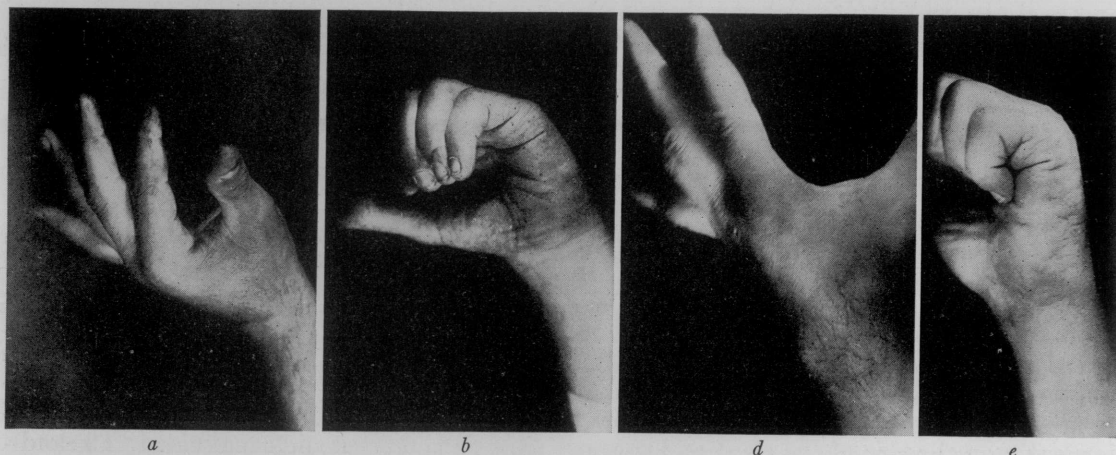
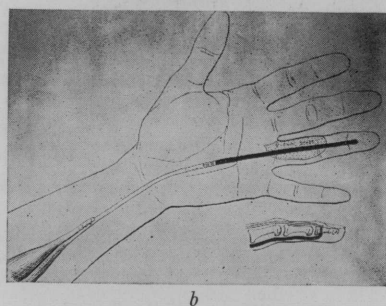
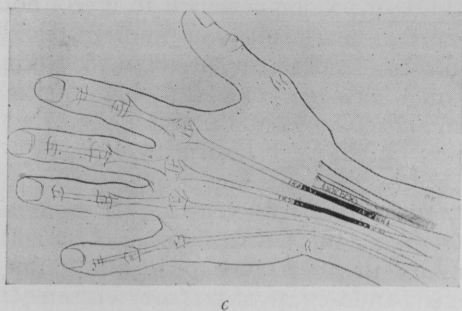


Fig. 12. E. L. E. Two months previously an axe flew off its handle and severed the extensor tendons of the index and long fingers and the extensor carpi radialis brevis. Infection followed leaving the rest of the dorsal tendons bound in scar tissue. Extension of the fingers was much limited as shown in *a*, and flexion was prevented by the attachment of the extensor tendons in the scar, as shown in *b*.

*Operation.* The scar was excised and all of the extensor tendons of the wrist and fingers were dissected from the dense scar tissue. The severed extensor carpi radialis brevis was sutured together. Between the severed ends of the extensor tendon to the index and long fingers was a gap of  $1\frac{1}{2}$  inches due to sloughing of the tendon ends. These two gaps were bridged with free tendon grafts from the palmaris longus, with its paratenon fat about it, as in *c*. The function 4 months later is shown in *d* and *e*.





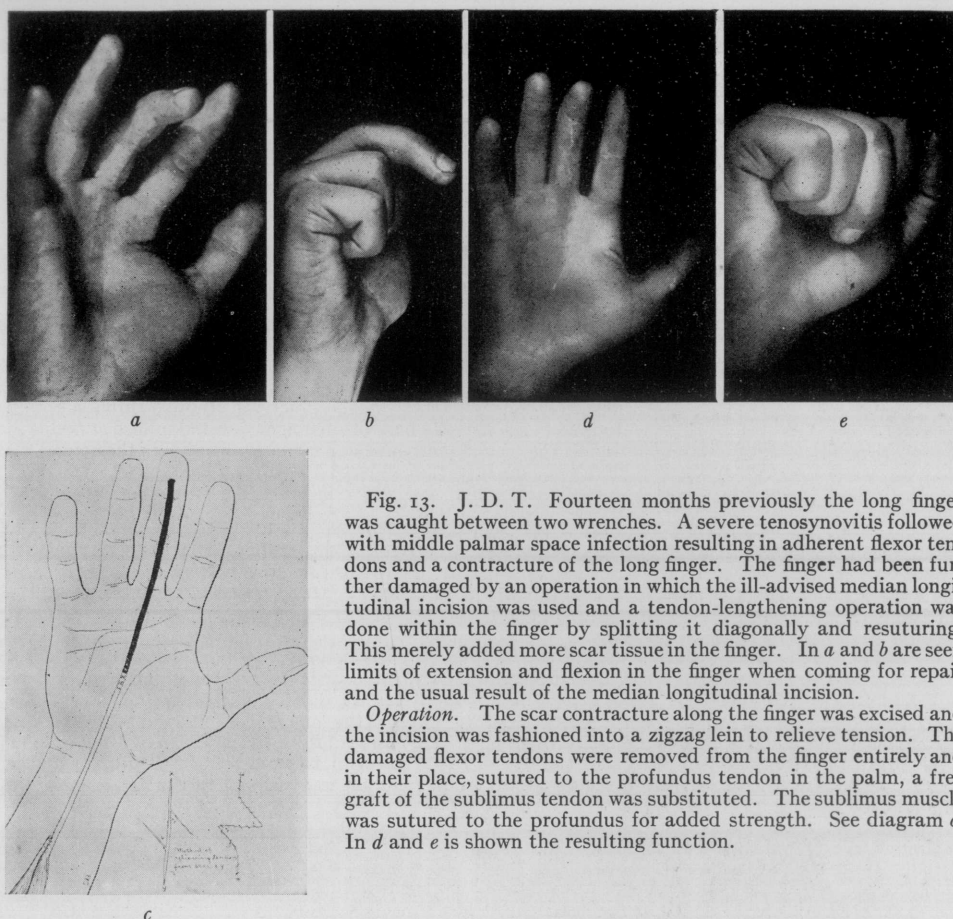


Fig. 13. J. D. T. Fourteen months previously the long finger was caught between two wrenches. A severe tenosynovitis followed with middle palmar space infection resulting in adherent flexor tendons and a contracture of the long finger. The finger had been further damaged by an operation in which the ill-advised median longitudinal incision was used and a tendon-lengthening operation was done within the finger by splitting it diagonally and resuturing. This merely added more scar tissue in the finger. In *a* and *b* are seen limits of extension and flexion in the finger when coming for repair and the usual result of the median longitudinal incision.

*Operation.* The scar contracture along the finger was excised and the incision was fashioned into a zigzag line to relieve tension. The damaged flexor tendons were removed from the finger entirely and in their place, sutured to the profundus tendon in the palm, a free graft of the sublimus tendon was substituted. The sublimus muscle was sutured to the profundus for added strength. See diagram *c*. In *d* and *e* is shown the resulting function.

Good tactile sense is acquired in the graft in several months.

If the contracting scar is very superficial and there are soft tissues underlying, a Thiersch graft may be used instead of a pedicled one. If the contracting scar is very narrow, it may be excised and by making parallel oblique cuts an inch or so apart alternately into each opposite skin edge, undermining well and transposing the pointed skin flaps, the resulting incision can be converted into a zigzag line, which will, when it later contracts, merely pull straighter and not cause contracture (Fig. 13, *c* and Fig. 8, *c*). This is the best method of removing a short web between fingers, but in this case the plastic is done in three dimensions.

In all contractures in the palm it is best to remove the palmar fascia. Dupuytren's con-

tracture can readily be corrected by the above method and here the two lateral bands of contracting tissue must also be excised from the fingers distally to beyond their middle joints. Foci of infection should also be removed in this case, because of their rôle in the etiology.

Keloid formation is racial, but is also due largely to tension and usually when a keloid is excised and all tension is removed, it will not reform. It is surprising how a wide keloid scar will often soften up if a soft pedicle skin graft is made in it or across the line of tension. Scars should, wherever possible, be placed crosswise to the lines of tension.

#### INCISIONS

The median longitudinal incision is the one to be most avoided whether in the wrist, palm, or fingers, as it leads to flexion contracture. It

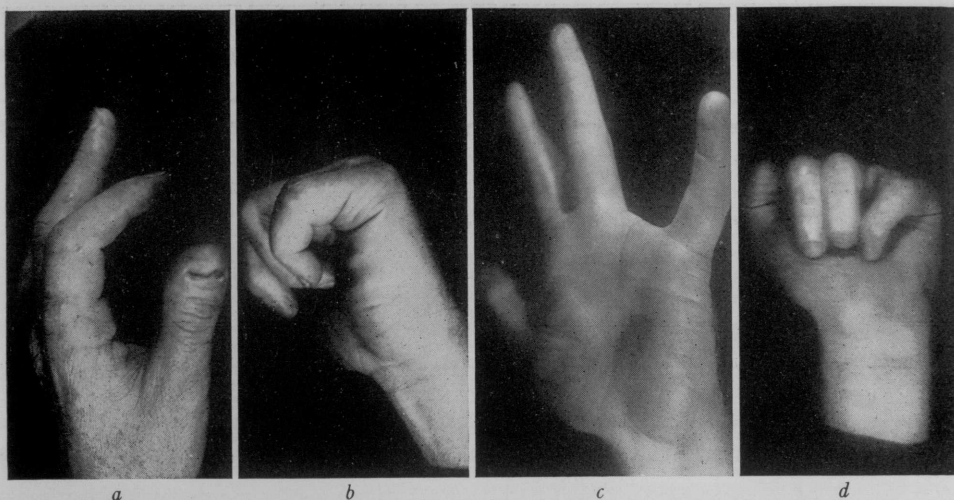


Fig. 14. C. B. A buzzsaw amputated the ring finger and severed the extensor tendons of the three remaining fingers in their proximal segments. In *a* is seen the resulting limitation of power of extension. The difference in the positions of the index and long fingers is due to the severance in the long finger of only the central portion of the tendon allowing lateral portions to pull around the middle joint and extend the distal joint. In *b* is shown the lack of flexion as checked by the extensor tendons which are adherent in the scars.

*Operation.* The scars across the backs of the fingers were excised and the severed ends of the extensor tendons were freed of scar tissue and sutured together. The extensor tendon of the index finger was so adherent that a free graft was made sheath-like about it for its full length in the finger from the specialized paratenon fat from over the triceps tendon. Later as the fingers still could not be flexed completely the flexor tendons of the amputated ring finger were removed from the palm. They had become adherent to the stump and so prevented the rest of the flexor tendons from being pulled upon by the flexor muscle as in the case shown in Figure 21. Normal function was restored to the hand, as shown in *c* and *d*.

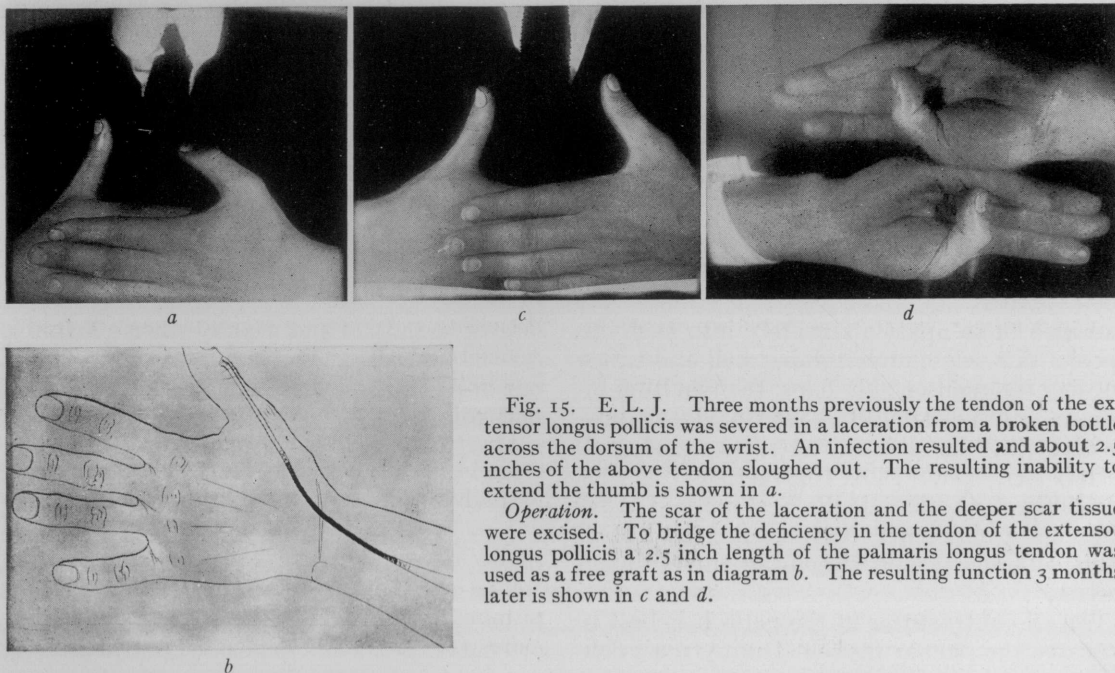


Fig. 15. E. L. J. Three months previously the tendon of the extensor longus pollicis was severed in a laceration from a broken bottle across the dorsum of the wrist. An infection resulted and about 2.5 inches of the above tendon sloughed out. The resulting inability to extend the thumb is shown in *a*.

*Operation.* The scar of the laceration and the deeper scar tissue were excised. To bridge the deficiency in the tendon of the extensor longus pollicis a 2.5 inch length of the palmaris longus tendon was used as a free graft as in diagram *b*. The resulting function 3 months later is shown in *c* and *d*.

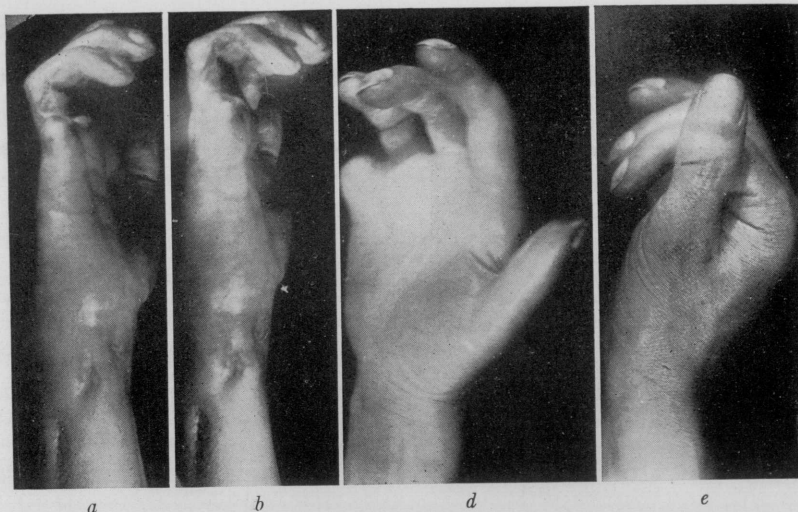
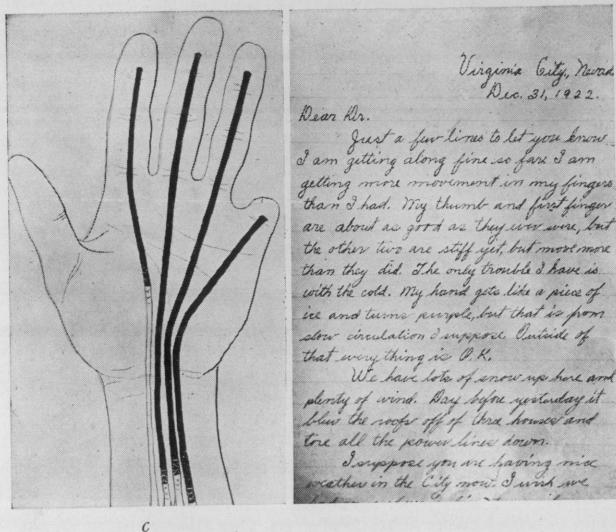


Fig. 16. W. J., age 29. Nine months previously he touched with his little finger a high powered wire and was rendered unconscious. Great necrosis and infection followed in the hand and forearm; pus was discharged for 8 months. All of the flexor tendons in the hand sloughed out with the exception of the flexor pollicis longus and this became densely adherent. So much ankylosis resulted that the wrist could not be extended, the proximal finger joints were fixed in the overextended position and the distal finger joints had practically no motion. As the limit of extension is shown in *a* and of flexion in *b*, it is seen that the hand was useless.

**Treatment.** The joints were first slowly drawn by mild and continuous traction into functioning positions, the wrist into extension by a cock-up splint and the proximal finger joints into flexion by the means shown in Figure 17, *D* and later in Figure 17, *E*.

**Operation.** The scar tissue was excised from within the palm and forearm; remnants of the flexor tendons were removed; that of the thumb was freed from adhesions. Four free tendon grafts from the long extensor tendons of the toes were used to act as flexor profundus tendons for each finger, as shown in diagram *c*. A very useful degree of function returned, as shown in *d* and *e*, 7 months later. He



stated that he uses a pick and shovel, digs post holes, and works as fast as the other men. A sample of his writing with this hand is shown in *f*, 4 months after operation.

makes a longer line for the formation of adhesions to the tendons and in the finger cuts the pulleys and makes adhesions and roughness in just the line where the flexor tendon should glide most smoothly.

In the finger, lateral or cross incisions do less harm and in the palm L-shaped ones are preferable; incisions following the lines of the palm are the least deforming. Transverse incisions in the wrist and forearm and on the dorsal surface leave less disfiguring scars, as they fit into the natural lines of the wrinkles

of the skin. Where an incision is apt to result in a contracture, as in crossing a flexion crease, it is well to zigzag it, so its later shrinkage will be spent in merely widening out the angles.

The greatest care should be observed to avoid injuring nerves, as much of the function of the hand depends on the trophic condition and on the sense of touch. The volar nerves in the fingers should be carefully spared. In the palm the nerves lie just beneath the palmar fascia. It is most important to spare the median motor branches to the



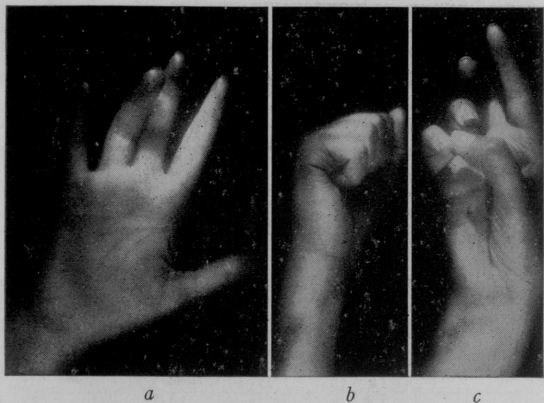


Fig. 18. H. L. A girl of 14 years thrust her right hand through a window severing just above the wrist both the ulnar and median nerves, the tendons of the flexor ulnaris and palmaris longus; also all of the flexor tendons, sublimus and profundus, of all fingers.

*Operation.* Twenty-four hours later the wound surface was excised and a primary repair was done on all of the severed tendons and nerves. *a* and *b* taken a year later show the power of flexion and extension obtained. Each finger can be flexed independently. Sensation commenced to return in the hand in 2 months and at the end of a year complete sensation returned including stereognosis. She could spread the fingers except at the third cleft, as shown in *a*. The action of the thenar muscles returned well, restoring opposition to the thumb, as shown in *c*.

thenar muscles, as they run transversely across the inner part of the thenar eminence; if cut, opposition of the thumb is lost. This often happens when incising for drainage in infection.

#### INJURIES TO NERVES

The nerves in the palm and the volar nerves of the fingers are as important as any other structure of the hand. Unless this is realized these tiny structures are often severed in incisions for drainage, or in dissections of the hand, resulting in loss of sensation and in trophic changes, which affect not only the skin but also the joints and all the deeper structures. One of the principal functions of the hand is that of sensation. If the nerves of a finger have been severed surgical repair of the tendon should be delayed until regeneration of the nerves has been accomplished after nerve suture. If this is not done the tissues will not heal well and if a tendon graft be put in, it will not only become adherent but it will degenerate, so that later it may break. It is perfectly possible to suture a nerve in the palm or finger. I have done it 54 times and in each in-

stance with gratifying success. In one instance all of the eight nerves at the bases of the fingers were sutured and every one regenerated. Often the fingers must be slightly flexed to allow the nerve ends to be approximated, but they can be allowed to gradually straighten out after a month. Sensation to cotton and pin prick returns throughout the fingers in 5 months on the average. It may start to return in a month and extends in this short time the length of a finger segment. After a year even stereognosis may be present. This satisfactory regeneration is due to the fact that the nerves in the hand are not mixed ones and so sensory axones are not lost in growing down motor pathways and vice versa. Also, the more peripheral an injury is in the nervous system, the better is the repair. In those cases in which the nerve to the thenar muscles was sutured good function returned to these muscles and opposition of the thumb was restored. In some cases a free nerve graft from the sural nerve in the leg was used to bridge a gap in a nerve. In these cases a fair degree of sensation returned. No harm resulted from the loss of the sural nerve. In one case a 6 inch graft in the ulnar nerve restored sensation to the fingers (Fig. 20, *c*). In another case a similar graft in the median restored sensation to the fingers, which commenced to return in 2 months. Several other shorter grafts in the hand were also successful.

Nerve sutures above the wrist, though successful, are not always as completely so because here the ulnar and median nerves are mixed ones and some of the fibers may grow down the wrong channels. Thus, in median nerve sutures sometimes opposition of the thumb does not return if the one tiny motor bundle of nerve is not matched exactly opposite its distal continuation. In some of my cases it has, however, returned completely after suturing the main trunk of nerve (Fig. 18).

Severing the median nerve practically wrecks the hand, as objects can no more be felt by the special tactile surfaces of the thumb and first two and a half fingers, and because the thumb assumes a position at the side of the hand and can no longer oppose the fingers.

While a nerve is regenerating it is necessary to hold the muscles supplied by it in a state of

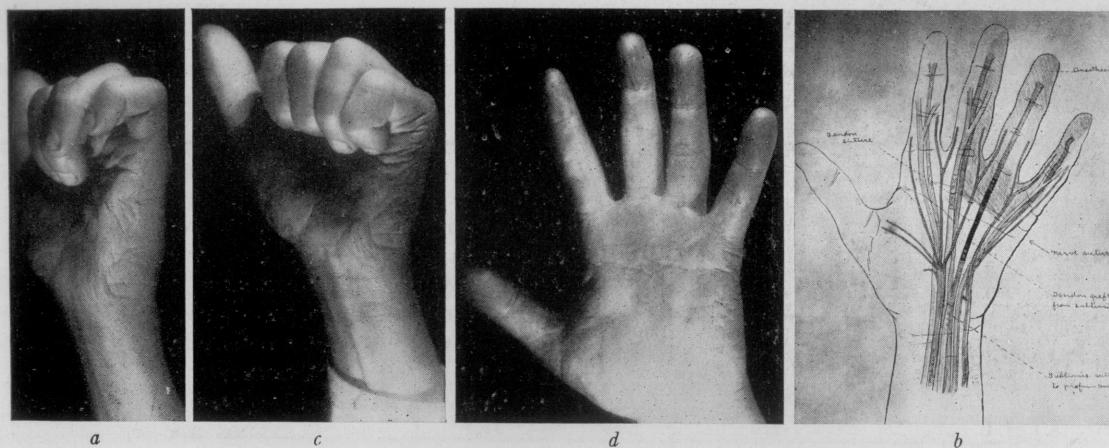


Fig. 19. H. R. Four months previously he fell, lacerating his palm with a broken bottle, severing the flexor sublimus of the long finger, both flexors of the ring finger, and the nerves to the third and fourth clefts. Infection followed with sloughing of some of the tendons of the ring finger. The tendon of the little finger became bound in scar tissue. The degree of flexion possible when coming for repair is shown in *a*. The hand is anæsthetic distal to the palmar scar and including the radial half of the little finger, all of the volar surface of the ring finger and the ulnar half of the long finger.

*Operation.* The structures of the palm were dissected free from scar tissue. The severed branches of the median and ulnar nerves were found to have a separation of one-half inch between their ends. The ends were trimmed off

to good nerve fibers and by flexing the fingers were brought together and sutured with fine blood vessel silk perineurally. The ends of the sublimus tendon of the long finger which were separated an inch were sutured. There was a gap between the ends of the profundus tendon of the ring finger and its sublimus tendon had withdrawn up the forearm. One and a half inches of the sublimus tendon was used as a free graft to bridge the gap in the profundus tendon. See diagram *b*. In 3 months sensation returned to as far as the middle creases of the fingers and in 5 months over the complete area. At the sixth month there was some paræsthesia which was almost gone at the eighth month, at which time stereognostic sense commenced to return. Perfect function of the tendons returned as shown in *c* and *d*.

relaxation, otherwise their function will not return. To do this for the thenar muscles in cases of median palsy has been a problem. It can readily be done, however, if a strip of one-half inch adhesive plaster be looped about the outer side of the metacarpophalangeal joint of the thumb and made to draw the thumb into opposition (Fig. 17, *C*). The two ends of the adhesive are then brought around the ulnar side of the palm and wrist and applied to the back of the wrist and forearm for anchorage.

#### OPPOSITION OF THE THUMB

If opposition of the thumb cannot be obtained by nerve suture, or if the thenar muscles have been destroyed, function can be regained by a tendon transference operation. At first I tried using the sublimus tendon of the ring finger, bringing it through the palm to a new insertion on the outer side of the thumb. This resulted in merely adducting the thumb across, but did not make the thumb stand out forward from the palm for grasp. Next, I

used the palmaris longus, with its prolongation of palmar fascia, and ran it subcutaneously to insert on the outer side of the distal end of the metacarpal of the thumb. This, combined with the former operation, gave a fairly good result. In later cases better results were obtained by leading either the tendon of the flexor sublimus of the ring finger, the flexor ulnaris, with a free graft extension, or the palmaris longus with its prolongation of palmar fascia, through a pulley in the vicinity of the pisiform bone and then subcutaneously directly to the distal end of the first metacarpal. The pulley was made by using a free tendon graft from an extensor tendon of a toe as a loop through the origin of the flexor minimi digiti. The pull on the thumb was then mechanically in the correct direction and the results were excellent (Fig. 22, *d* and *e*). In cases where the thumb has assumed a flexed position when opposed to the fingers from lack of power of extension, as in some cases of poliomyelitis, the tendon, which is to give op-

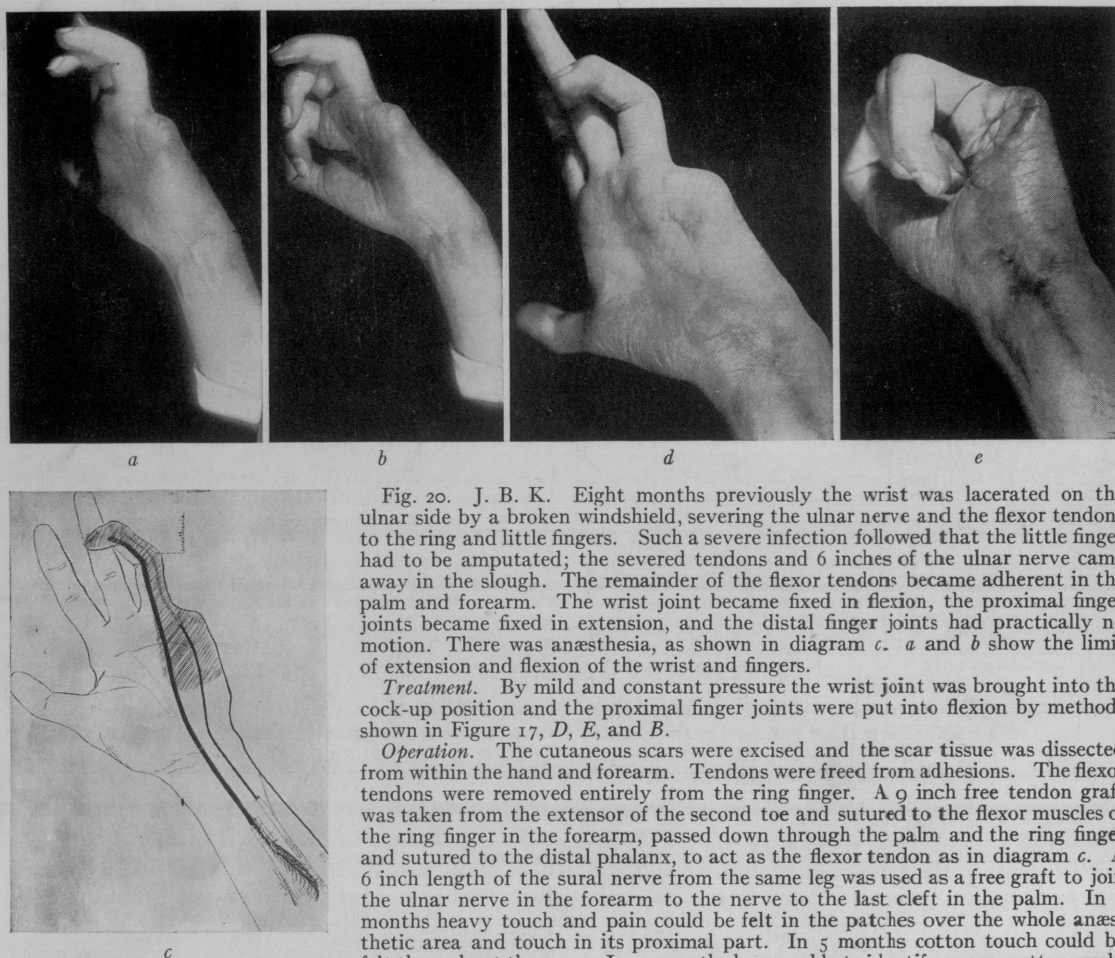


Fig. 20. J. B. K. Eight months previously the wrist was lacerated on the ulnar side by a broken windshield, severing the ulnar nerve and the flexor tendons to the ring and little fingers. Such a severe infection followed that the little finger had to be amputated; the severed tendons and 6 inches of the ulnar nerve came away in the slough. The remainder of the flexor tendons became adherent in the palm and forearm. The wrist joint became fixed in flexion, the proximal finger joints became fixed in extension, and the distal finger joints had practically no motion. There was anaesthesia, as shown in diagram *c*. *a* and *b* show the limit of extension and flexion of the wrist and fingers.

*Treatment.* By mild and constant pressure the wrist joint was brought into the cock-up position and the proximal finger joints were put into flexion by methods shown in Figure 17, *D*, *E*, and *B*.

*Operation.* The cutaneous scars were excised and the scar tissue was dissected from within the hand and forearm. Tendons were freed from adhesions. The flexor tendons were removed entirely from the ring finger. A 9 inch free tendon graft was taken from the extensor of the second toe and sutured to the flexor muscles of the ring finger in the forearm, passed down through the palm and the ring finger and sutured to the distal phalanx, to act as the flexor tendon as in diagram *c*. A 6 inch length of the sural nerve from the same leg was used as a free graft to join the ulnar nerve in the forearm to the nerve to the last cleft in the palm. In 3 months heavy touch and pain could be felt in the patches over the whole anaesthetic area and touch in its proximal part. In 5 months cotton touch could be felt throughout the area. In 10 months he was able to identify gauze, cotton swab, and the metal of a key or coin, when touched to the ulnar side of the ring finger. Paræsthesia had disappeared. The degree of motion gained in 10 months is shown in *d* and *e*.

and the metal of a key or coin, when touched to the ulnar side of the ring finger. Paræsthesia had disappeared. The degree of motion gained in 10 months is shown in *d* and *e*.

position to the thumb, can be attached to the tendon of the extensor longus pollicis at the metacarpophalangeal joint. The thumb will then properly oppose the fingers.

If no tendons are available the thumb can be placed in the position of opposition and held there by an ankylosis between the carpus and the metacarpus. This is but a last resort, however, as motion is restricted and there is danger of fracture if the hand is caught between two objects.

A better method where no tendons are available is to make a permanent check-rein by a free graft of fascia from the distal end of the first metacarpal to the pisiform bone. This will hold the thumb in opposition.

#### OTHER CONDITIONS

Cases of finger, thumb, and wrist-drop from musculospiral palsy may readily be corrected by bringing some of the flexor tendons around the forearm and attaching them to the extensor tendons. For this purpose the flexor ulnaris can be used to extend the fingers, the pronator teres to extend the wrist, the flexor carpi radialis to extend the wrist or thumb and the flexor sublimus of the ring finger to extend the thumb.

If the distal radio-ulnar joint is injured, so that supination is prevented, a small segment can be removed from the lower end of the ulna and thus make possible a complete degree of supination.