FLEXOR TENDON REPAIR IN THE HAND

AN ANALYSIS OF THE MANAGEMENT AND RESULTS IN 41 CASES: WITH SPECIAL REFERENCE TO POLLICIS REPAIR AND THE ACCESSORY SHEATH *

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Industrialization has caused a great increase in the number of injured hands, and has also changed the nature of the injuries. It therefore became important that tendon surgery should develop as a field of its own, and that the principles should be established for the sound reconstruction of so highly specialized and important a functional unit as the hand.

This field of surgery was pioneered by Nicoladoni in 1882, when he reported the first tendon-transplant. It was, however, not until Bunnell's work (1918), that this important aspect of surgical practice was placed on a sound foundation. Many other workers have contributed to our understanding of the anatomy, physiology, pathology, operative treatment and after-care of severed tendons but, despite the progress, the final word has not been said on the subject, and tendon repair is still difficult and unsatisfactory in many cases.

The restoration of function to damaged finger-tendons is one of the most difficult of surgical problems. It is not difficult to appose the ends of divided tendon so that they unite, but it is technically difficult to achieve union without adhesions to surrounding structures—and in a finger, if a tendon does not glide fully within its sheath, function is not regained. It is therefore no wonder that in this field the results of the beginner show a marked discrepancy with that of the experienced surgeon. Unfortunately we never see the results of general surgeons who get the occasional cut tendon and apply the fundamental principles of repair but lack the practical experience or finesse necessary to produce good results. Any surgeon doing a large series of cases over a period of years must develop a specific technique, operative procedure, and follow-up; and where many surgeons operate, with varied experience, and some procedures show consistently good results and others continually bad results, it follows that the method is at fault and not the dexterity of the operator or his technique. In the literature the abundance of new methods and modified techniques is impressive, but assessment of results are less common; and careful follow-ups of the work of individual operators, or of a number of individuals, are relatively rare.

MATERIAL

An analysis is made of 41 flexor-tendon repairs performed by the surgeons and registrars of the Birmingham Accident Hospital from June 1951 to June 1954. Because simple injuries raise sufficient problems for the surgeon, no cases are included in this series that are complicated by extensive loss of skin, multiple involvement of digits, fractures, or extensive destruction of soft tissue. Only those cases that attended a personal follow-up are included. Nevertheless, cases done before or since the 1951-54 period, those that did not attend for assessment, and those in which tendon injuries were complicated by soft-tissue destruction or fractures, were invaluable in confirming the conclusions drawn from the analysed series. The series is small, but Table I gives an indication of the amount of tendon surgery done at the hospital during one year.

TABLE I. TENDON SURGERY OF THE HAND AT THE BIRMINGHAM ACCIDENT HOSPITAL DURING 1 YEAR (JUNE 1953—JUNE 1954)

(excluding hand injuries with extensive loss of skin, multiple involvement of digits, fractures, or extensive destruction of soft tissue)

Method of Repair	*No. of Cases*
Main Theatre	
Flexor-tendon grafts to fingers	12
Flexor-tendon grafts to thumb	6
Secondary suture of flexor tendons to fingers	18
Secondary suture of flexor pollicis longus	4
Extensor-tendon repair to fingers	14
Repair, suture or transplant of extensor pollicis longus	11
Trigger finger	8
Exploration of tendon sheath	3
Tendon repairs—notes not traced	5
Casualty Theatre	
Primary suture of profundus tendon in hand	1
Total	82
Total flexor tendons repaired during 1 year	40

Extensor tendons done in Casualty not included (several hundreds per year).

In this analysis I found it extremely difficult to obtain all the required data, because so often details were omitted from the operation notes. None of my own cases are included in the series

AGE, SEX, OCCUPATION

Table II classifies the cases by age, sex and occupation. Of the 41 cases, 70% were in adults (over 15 years old)

TABLE II. AGE, OCCUPATION, AND SEX

	No. of Cases
Age in years	
1–5	5
5–15	7
15–40	23
40–60	6
Occupation	
Machine workers	15
Glass workers	2
Farmers	2
Plumbers	2
Fireman	1
Painter	1
Engineer	1
Laboratory Assistant	1
Sex	
Males	34
Females	7

* From a paper read at the Birmingham Accident Hospital on 21 February 1955.

and as many as 30% in children under 15. 83% were males, the proportion of males to females being 5:1. Although only 2 of the 41 patients were glass workers, in 14 cases the tendons were cut by glass. O'Shea (1939) found that in 53% of his 870 cases the tendons were severed by broken glass. The 15 machine workers all sustained their injuries at work. Siler (1950*a*) reported that in a series of 84 flexor-tendon injuries at Cincinnatti General Hospital 52% were caused by knife cuts; males also predominating in this series (73%).

PRIMARY TREATMENT

For the indications of primary and delayed suture or grafting, other works should be consulted. There is hardly a paper that does not stress the importance of primary attention by an experienced surgeon. This is ideal but, alas, not always possible. The great majority

TABLE III. EXAMINATION AND PRIMARY TREATMENT IN CASUALTY

	No. of Cases
Attended to by Surgeon	4
Attended to by Registrar	4
Attended to by Casualty Surgeon	33
Time interval between Injury and Primary Treatment	
1–6 hours	6
6–12 hours	26
12–24 hours	0
2 days	2
3 days	1
Longer than 3 days	6
Cause of Injury	
Cut by glass	14
Sharp object or blade	15
Crush injury	8
Site of Injury	
Wound over proximal phalanx of thumb	10
Wound over middle phalanx of fingers	5
Wound between distal palmar crease and proximal interphalangeal crease	15
Wound proximal to distal palmar crease	10
Nature of Wound	
Clean	26
Dirty	4
Lacerated	7
Primary Skin Suture	
In Casualty Theatre	26
In Main Theatre	2
Primary Nerve Suture	3
Multiple Injuries	
Skin loss	1
Fracture of phalanx	1
Nerve injury	5
More than one digit involved	7
Antibiotics	
Penicillin	19
Sulphonamides	1

of the tendon injuries in this series were handled primarily by house surgeons, although in many more than indicated the surgeons were consulted (Table III). In the absence of experienced opinion, the medical attendant should do the minimum, mostly a careful toilet of the wound and skin suture. In this series 28 cases were given a primary wound-toilet and skin-closure; but 7 cases were only seen in casualty on or after the 3rd day of injury and in these the wounds were dressed, but not closed (Table III). Drains should never be used. O'Shea (1939) found that 40% of 53 cases that were drained became infected.

It cannot be stressed sufficiently that the primary treatment is as important as the delayed repair or the subsequent rehabilitation, if not more so. In each case, when first seen the following points should be carefully considered:

1. *Is primary tendon suture indicated?* Consider the age and occupation, the nature of the injury and state of the wound, and theatre facilities and available surgeon. If these requirements cannot be fulfilled, consider

2. *primary wound-toilet and skin-closure with subsequent (delayed) repair* (Fig. 1). Consider the age, work, mental make-up, associated injuries, and operative facilities. If the chances are that tendon repair would not yield satisfactory results, rather perform a

3. *primary amputation* and get the patient back to work in 3 or 4 weeks. A neat amputation is not such a cosmetic drawback and functionally it may be infinitely more desirable than a poor tendon-repair (Fig. 2). The operation for restoring tendon function entails meticulous attention to detail and considerable technical skill; the assessment of damage and management of injury demand great judgment and personal insight. In Fig. 3 the patient still has 5 fingers but the hand is relatively useless. When amputation was suggested to him at the follow-up, he felt that the finger was only in his way, but that he could not leave his work at this stage to have it amputated.

The *time interval* generally regarded as safe for primary tendon-suture is 6 hours. With modern aseptic surgery and antibiotics, in the clean case it can probably be done much later than this (Mason 1954). Koch and Mason (1933) produced an excellent result after primary suture of the flexor profundus over the distal interphalangeal joint 24 hours after injury. Tendon division over the distal half of the middle phalanx should almost always be sutured as a primary procedure, especially when more than one finger is involved. At this site there will be no interference with the sublimis action. If left, the retracted profundus may adhere to sublimis and limit the movement of all finger joints. An immediate suture may not result in full movement of the terminal phalanx, but full movement at the terminal finger joint is not as important to a working man as control of this joint. Even if adhesions do form after primary suture at this level, the finger tip will be strong, stable and under control.

The sublimis when intact should never be sacrificed for profundus action, especially in a labourer. In one of my patients a deep cut extended over the distal finger-crease of the middle and ring fingers of the right hand, penetrating the joints. The joint capsules were closed by small sutures before suturing the profundus tendons, although the wounds were badly lacerated. The patient had only 50% of movement afterwards in the terminal interphalangeal joints, but full stability, which to him meant a 'normal hand'. He was back to work in 5 weeks.

It has been shown that *antibiotics* prophylactically do not materially change the incidence of infection. It might be wise, however, to put all these cases on penicillin in high doses for a few days (Tables III and IV).

Skin sutures should not be removed too early. Some

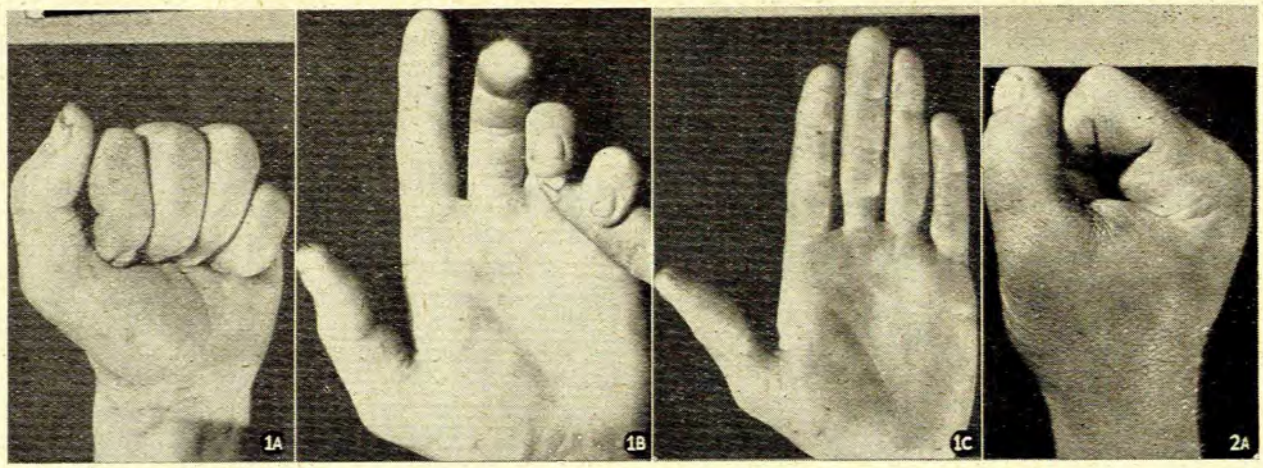

Fig. 1A, 1B and 1C. Both ring-finger tendons damaged in the theca. Primary wound-closure and delayed palmaris-graft. At the time of operation a good paratenon was noted; length was adequate, fixation secure both ends, and the tension just right. Perfect result.

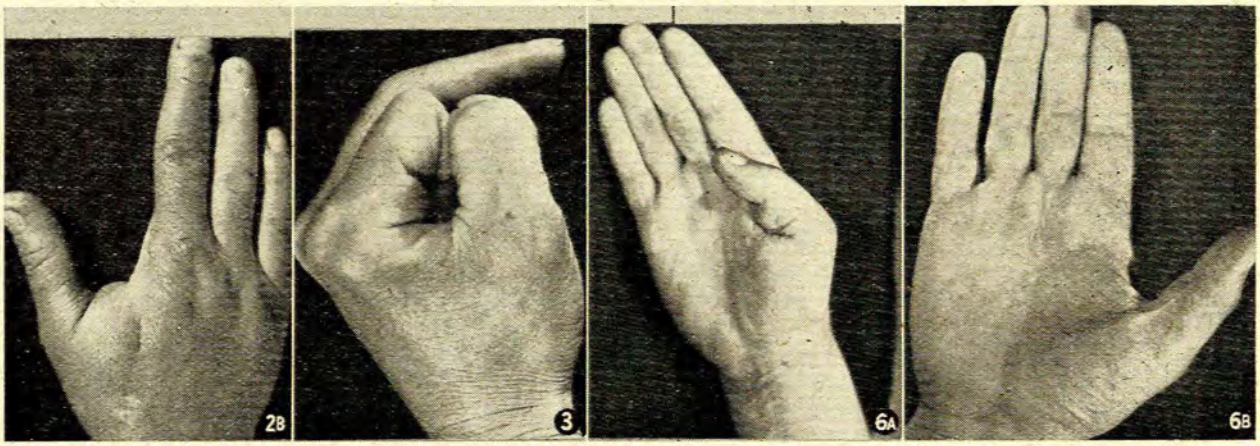

Fig. 2A and 2B. Crush injury to proximal phalanx of index finger. Primary amputation. Back to light work in 3 weeks. Patient very satisfied—does not 'know' there is a finger missing.

Fig. 3. Lacerated wound with skin loss and division of tendon over the middle phalanx. Successful primary pectoral flap. Delayed sublimis graft. A plumber, discharged from hospital 11½ months after injury, with a sensitive stiff finger. Primary amputation was indicated.

Fig. 6A and 6B. A fair result after delayed suture of the flexor pollicis longus. Although there is some contracture and marked limitation of flexion, the patient carried on with his work and was satisfied. Our only 'failure' after pollicis repair.

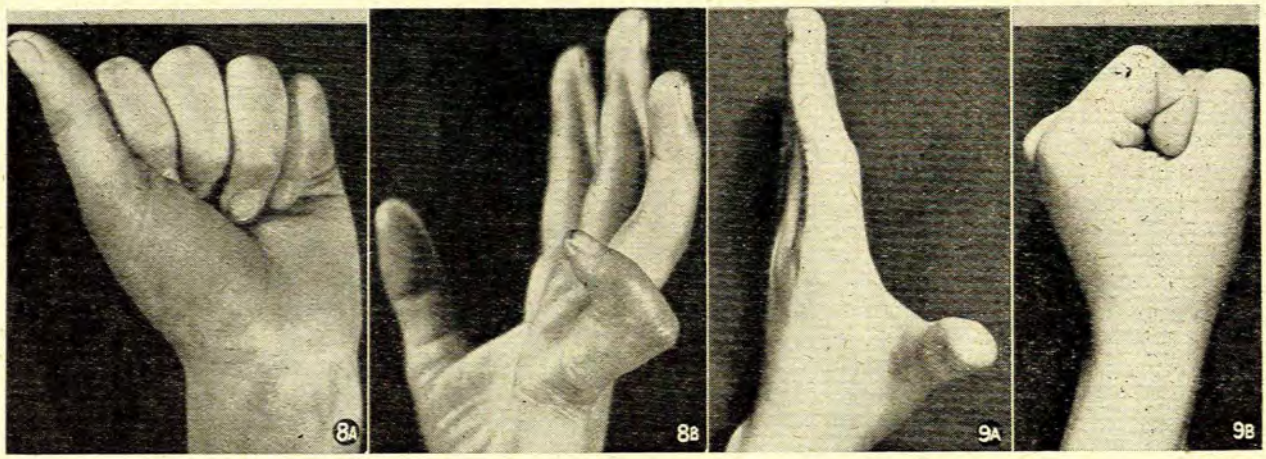

Fig. 8A and 8B. Both tendons cut over web of little finger in an 8-year-old girl. Delayed profundus-suture without sublimis excision. Later followed by sublimis graft from ring finger. Full flexion, but shortening, contracture, and gross limitation of extension. Fair result.

Fig. 9A and 9B. Palmaris-longus graft in a 6-year-old boy. Excellent result.

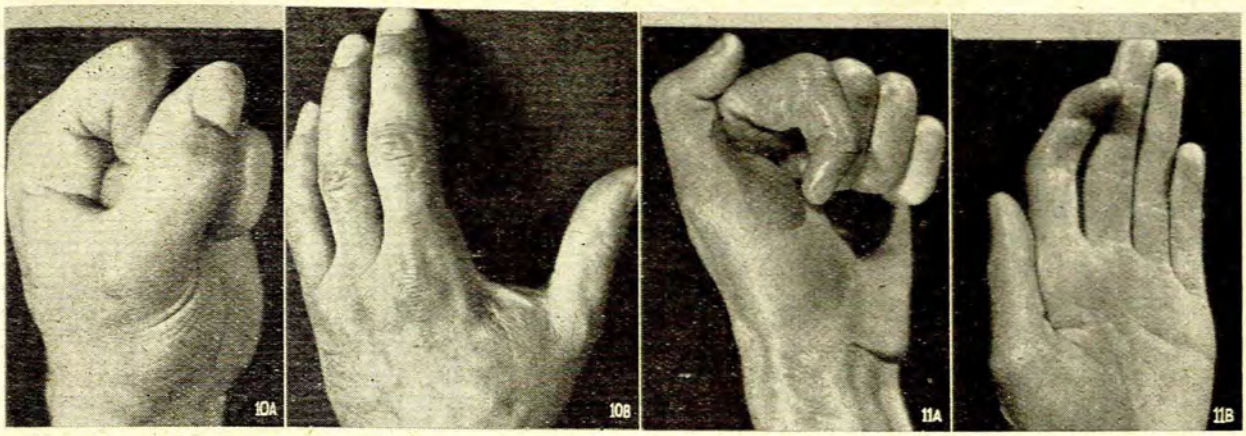

Fig. 10A and 10B. A tendon injury over the proximal phalanx was treated by primary wound-toilet and skin-closure and delayed sublimis-graft. Amputation, after tenolysis failed to improve a fair result. The patient is very satisfied and described his hand as 'perfect'.

Fig. 11A and 11B. This patient was discharged from hospital after two failed palmaris-grafts, with a sensitive stiff finger which forced him to a change of work. Surgeons are often reluctant to amputate useless fingers after repeated endeavours to repair a tendon. Compare Fig. 10A and 10B.

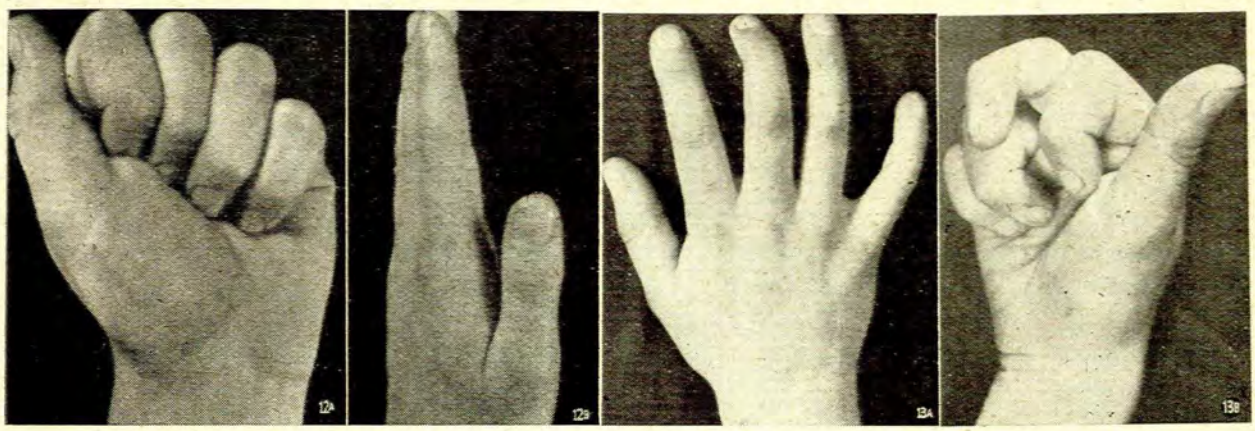

Fig. 12A and 12B. This 6-year-old boy was treated by primary wound-closure, after both tendons were cut to the middle finger. Distal sublimis excised and proximal sublimis sutured to profundus. Excellent result.

Fig. 13A and 13B. Primary closure of wound over the distal palmar crease in a 5-year-old boy. Delayed profundus-suture, sublimis not excised. Tenolysis did not improve this fair result.

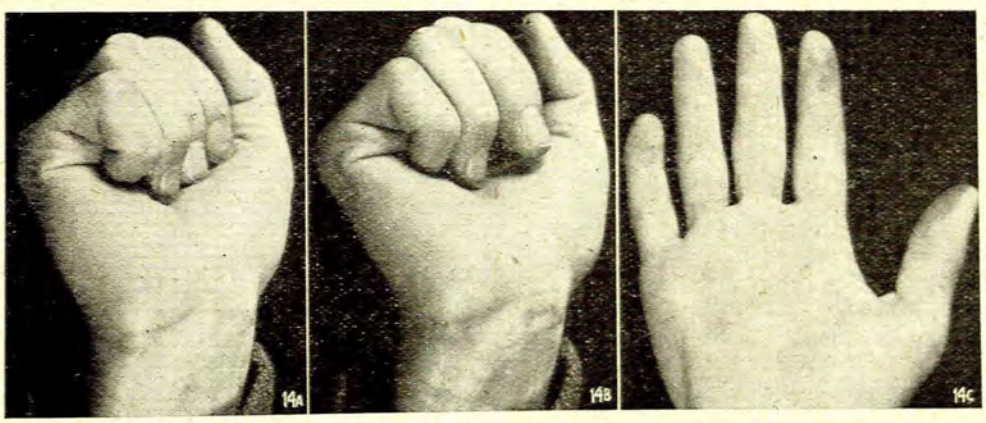

Fig. 14A, 14B and 14C. Wound over proximal phalanx. Both tendons severed. Primary skin-closure and delayed palmaris-graft. A trick movement may convert this good result to an excellent one.

wounds open after premature suture removal, especially in wounds over the creases. This is even more likely to happen when immediate active movements are encouraged. As with any tissue, rest is beneficial after injury. Early movement 'to prevent the joints from getting stiff', is unscientific and promotes excessive scar-tissue, which itself causes loss of movement. Unless there is serious joint-damage, adequate finger exercises and assisted *physiotherapy* will provide full passive movements, even after 2 or 3 weeks' complete rest to achieve sound healing. If the finger is immobilized for the first 10-14 days and movements then encouraged, the optimal condition will be reached 4-6 weeks after injury, when tendon repair can be performed. Physiotherapy seldom makes stiff fingers work, but it prevents mobile joints getting stiff. Some cases develop a certain amount of stiffness if postponed too long. Good results, however, have been observed 9 months or longer after injury.

TABLE IV. FOLLOW-UP AFTER PRIMARY TREATMENT

Average time for re-attendance	6– 8 days
Removal of sutures	6–14 days
Average	9 days
	No. of Cases
Encouraged to start active movements within	
1st week	11
2nd week	15
3rd week	2
Healing of Skin Wound	
Within 2 weeks	25
Longer than 2 weeks	6
Referred to Surgeon's Clinic	
2 weeks	23
1 month	8
2 months	1
Referred to Rehabilitation Unit	
After 2 weeks	8
After 4 weeks	5
Infection	3

A full passive range of movement is essential before any form of tendon repair is embarked upon. Post-operative active movement can only be as good as passive movement was before the operation.

SECONDARY REPAIR

Nowhere should traumatic surgery be more 'atraumatic'. Special fine skin-hooks, fine forceps, and light instruments are essential. A lead hand is sometimes of more value than an assistant. A good anaesthetist is almost as important as a good surgeon—for the procedure may be a long one. Needless to say, a brush-over with mercurochrome or iodine before operation is quite inadequate—the patient's hand should be surgically as sterile as that of the surgeon before he dons his gloves. A bloodless field under a pneumatic cuff-tourniquet is quite essential—at least during the dissection stage. Careful surgeons like to release the tourniquet after every hour.

The Exposure

A postero-lateral incision as advocated by Rank *et al.* (1951) was used in the majority of cases in this series. The skin flap is thin where raised and, dissected free in front of the nerve, gradually increases in thickness towards the base. This gives an excellent exposure in the finger. I personally prefer a postero-lateral incision from the tip to the base, cutting boldly down on the theca. The skin, subcutaneous fat and neuro-vascular bundle are lifted forwards in one block. It has the following advantages:

1. No incision lines crossing the tendon.
2. No danger to the neurovascular bundle, which lies far forward (Fig. 4).
3. Timid and exploratory cutting, 'trying to save the nerve', is avoided, thus limiting scar tissue and fibrosis —the arch-enemies of good function.
4. Preservation of the *accessory sheath*, as I would like to call it. In a number of cadaver, post-morten and operative dissections, I have seen a smooth, shiny, almost synovial-like layer of areolar tissue between the theca proper and the overlying subcutaneous tissue (Fig. 5). This, I believe, is most important in contributing to the formation of a soft, unscarred gliding mechanism after tendon repair.
5. Exposure is as good as with any other procedure and is less time-consuming. No adverse effects have been seen after cutting of the dorsal branch of the digital nerve, and haemorrhage is not troublesome.

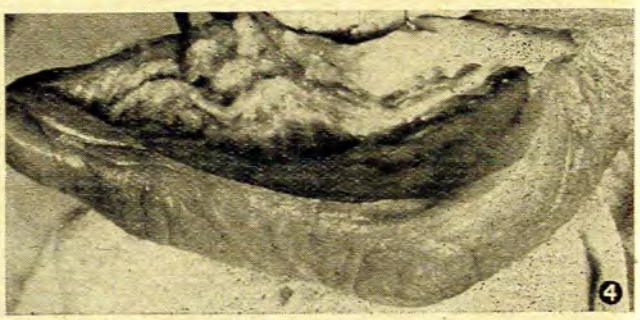

Fig. 4. The neurovascular bundle dissected out to illustrate its anterior relationship in the postero-lateral incision.

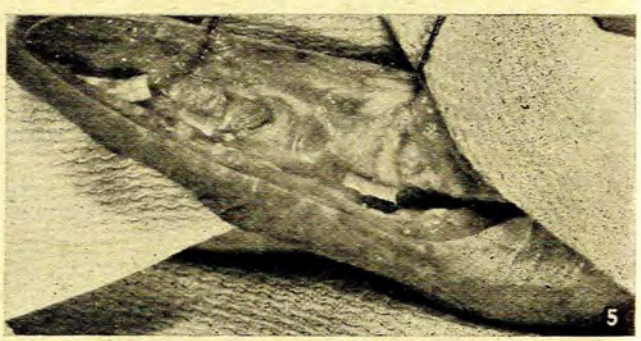

Fig. 5. The postero-lateral incision. The skin, neurovascular bundle and subcutaneous fat reflected, exposing the 'accessory sheath'. Perfect exposure with minimal trauma; the two phalangeal pulleys and distal end of profundus clearly visible.

Bruner (1951) stresses the importance of correctly placed incisions in reconstructive surgery of the hand.

Even the most expert suturing of a tendon leaves some irregularity at the suture line, from where 'un-

satisfied' fibres reach out to the surrounding structures, which firmly immobilize the tendon (Bunnell 1944). From an experimental study Skoog *et al.* (1954) hold the opposite view, viz that the attachment is mainly due to ingrowths from adjacent paratenon to the injured part of the tendon. Either way, however, the end result is a frozen finger. To overcome adhesions in the rigid thecal cylinder is the greatest problem in restorative surgery. Countless ways of suturing, replacing or isolating the tendon have been tried. The secret, no doubt, does not lie in more complicated manoeuvres, but in the careful application of basic principles; and a faultless technique acquired over many years.

There are two practical ways out of this dilemma:

1. *Thecal resection, partial or complete.* Local excision of the theca over the excursion of the suture line prevents the tendon from sticking to the theca. Adhesions to subcutaneous fat, which have more give, are not so serious. In children especially the result is very satisfactory.

2. *Replacement of the injury site by a smooth healthy tendon graft.* Here no adhesions should form in the thecal tunnel.

Direct Suture

This may be done primarily, or as a delayed procedure. When both tendons are cut, the distal sublimis must be excised. Tables VIII and IX bear out the truth of this statement. With retraction and shortening of the proximal profundus, the sublimis acts very well when sutured to the distal profundus. Otherwise it may either be tucked away or cut short. Pulleys over the suture-line excursion are bound to cause trouble and should be excised with the theca—new ones can easily be formed.

TABLE V. SECONDARY REPAIR

	No. of Cases
Time Interval from Injury to Secondary Procedure	
1 month	4
1½ months	8
2 months	8
3 months	9
4-8 months	7
9 months	1
Joint Function before Operation	
Passive range:	
Full or almost full	17
More than half	18
Less than half	1
Sensation	
Full	22
Loss	1
Partial	5
Trophic changes	0
Scarring Found at Operation	
Severe	14
Slight	14
Secondary Nerve Suture	
Sutured	1
Neurolysis	1
Attempted but failed	1
Procedure of Tendon Suturing of Grafting	
Direct Suture:	
Profundus to Profundus	10
Profundus to Sublimis	4
Flexor Pollicis Longus	3
Sublimis transplant	1
Tendon Graft:	
Palmaris Longus to thumb	6
Palmaris Longus to fingers	14
Sublimis to fingers	3
Toe Extensors	4
Profundus of finger	1
Nature of Paratenon	
Good	3
Bad	1
Suture Material	
Silk	5
Stainless steel	9
Mersilene	3
Braided nylon	1
Tension of Graft	
Positive	9
Equal	3
Negative	0

Entire removal of all scar tissue is advisable. Tendon strippers (Bunnell 1918) are still used, but the use of these instruments cannot be advocated. In no case in this series has the pull-out suture of Bunnell been used. An end-to-end figure-of-eight suture, or a modification of this, was usually employed, the knots being tied on the outside of the tendon or between the stumps (Table V). The choice depends on the individual surgeon and provided the work is well done, the one is about as good as the other.

Tendon Grafting

Grafts are divided into those gliding in a synovial sheath and those containing an areolar paratenon. If grafts of the first variety are used (sublimis or profundus), as much as possible of the sheath should be left. This provides a future synovial covering; and experimental work has shown that such grafts develop an excellent gliding mechanism. Therefore, to use a sublimis graft with the theca removed is to rob the tendon of one of its major adjuncts to a good result. Kyle and Eyre-Brook (1954) claim a 75% success with sublimis graft and an intact theca.

The second type of graft—palmaris and the toe extensors are those most commonly used—does not develop a synovial sheath; the loose, elastic, areolar paratenon forms the gliding mechanism. Thus, as much as possible of the fibrous theca should be excised; it serves no purpose and may only lead to scar formation and restricted movement. From these remarks it is obvious that the type of graft should be selected at the time of operation. If the finger is 'one block of fibrous tissue', complete excision and a paratenon-covered graft is the answer. If the synovial sheath is in good condition a sublimis graft may be used without excising the sheath. To confuse these important mechanisms is often to be frustrated by 'inexplicable disappointments'.

The absence or limitation of terminal phalangeal movement has been conspicuous. However carefully the profundus stump is sutured, scarring and adhesions form over the volar aspect of the joint and middle phalanx. Only technical perfectionists can always be sure that the suture line is distal to the joint (Fig. 5). This complication can be avoided by complete excision of the profundus and fixation of the tendon, covered by paratenon, to the terminal phalanx. A pull-out suture placed far forwards prevents nail-bed complications. In one of these cases a toe extensor was split and sutured around the terminal phalanx; no adhesions and almost 100% function resulted.

Repair of flexor pollicis longus

Functionally, the thumb forms the opposing half of the hand. It acts as a separate functional unit, where stability and control are much more important than mobility. While a stiff interphalangeal joint of a finger may hamper movements of the hand, a stiff interphalangeal joint of the thumb may hardly be noticed. Conservative surgery is here the key word.

The flexor pollicis longus is usually damaged over the proximal phlanx, where it may be sutured primarily or repaired later by direct suture, graft or transplant.

Because of contracture (Fig. 6) that sometimes develops after a long incision to expose the retracted proximal

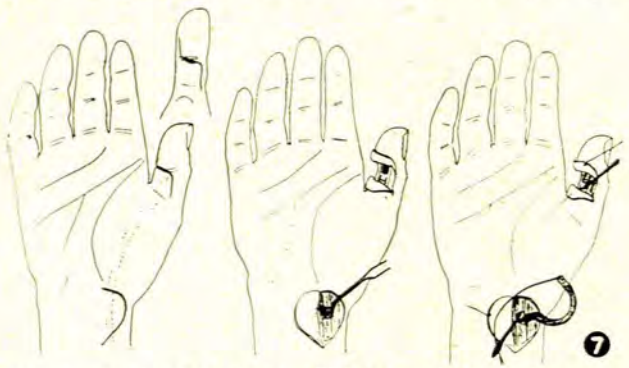

Fig. 7. Repair of the flexor pollicis longus in the early clean case by primary suture and later by direct suture or grafting. This method prevents contracture, avoids digital nerve damage, provides the most adequate synovial covering, and produces the least trauma.

tendon-end, we expose the distal stump by small extensions of the wound. The long flexor is exposed above the wrist by a small curved incision and an opening made in the synovial sheath. After delivery of the tendon, a soft probe is passed inside the synovial sheath distally, taking the threaded tendon end along. The thin sheath is excised over the suture line excursion. This has been done in the early clean case as a primary procedure, and also in the delayed suture or graft (Fig. 7). The advantages are obvious.

The ring-finger sublimis is most useful and satisfactory as a transplant, but the extensor carpi radialis has been used by some people (Luckey *et al.*, 1947).

After-care

The most satisfactory dressing was found to be one layer of gelonet and a few thin layers of wet cotton-wool. Soaking-wet 1-inch gauze loosely applied keeps this in position. The dressing is completed by dry cotton-wool, crepe bandage and a dorsal plaster-slab, with the fingers in a position of function and slight flexion at the wrist. The tourniquet is undone, watching the return of circulation. If colour changes do not correspond to that of the other fingers, it is far safer to re-dress the wound. No difference has been noticed between those cases where the tourniquet was removed during operation and haemostasis secured, and those where it was removed after the final dressing was applied. A roller bandage elevates the hand, prevents post-operative oedema, and reduces the risk of haemorrhage.

In an excellent experimental study of the tensile strength of tendons, Mason and Allen (1941) found that early active use and mobilization gave rise to bulbous thickening at the sutured ends and dense peritendinous adhesions, which defeated the whole purpose of early movement. Tendons that were completely immobilized developed first-class sliding mechanisms. All the cases in this series (Table VI) have been immobilized for at least 2 weeks. Pulvertaft (1948) commences movement straightaway and claims superior results. Immediate, active, unguarded movement after 3 weeks of immobili-

TABLE VI. FOLLOW-UP AFTER THE SECONDARY PROCEDURE

	No. of Cases		No. of Cases
Immobilization		*Repeat Operations*	
Immediate active movement	0	Re-exploration	3
Movements after two weeks	14	Tenolysis	8
Movements after three weeks	19	Re-suturing	1
Movement after five weeks	3	Re-grafting	2
Referred to Rehabilitation Unit		Digital amputation	
Immediately	0	Partial	1
2 weeks	2	Total	2
3 weeks	18	Bow Stringing	6
5 weeks	5	Scarring	6
7 weeks	2	Contracture	4
Infection	1	*Back to Previous Work from Time of Injury*	
Various Sensory Changes	8	3 months	2
		4 months	6
		5 months	4
		6 months or longer	11

zation may be associated with stretching of the suture line, and always leads to increased reaction. One often finds that all splints are completely discarded after 3 weeks. In one of my cases a perfect primary direct suture was carried out over the proximal phalanx of the index

TABLE VII. OVER-ALL RESULTS

Results	*No. of patients*
Success	
Excellent	7
Good	15
Total	22
Failure	
Fair	8
Poor	11
Total	19

% success 56
Patients satisfied with end-result—29.
Patients dissatisfied with end-result—12.

finger. While demonstrating in follow-up at 5 weeks that his finger tip could almost touch the palm the patient used too much force. The result was a complete dehiscence of the tendon; and he had to undergo a second operation. Supervised physiotherapy is the surgeon's responsibility, the importance of which cannot be over-stressed. To refer patients at this important stage to people unfamiliar with tendon injuries is asking for disaster.

Tenolysis

Tendon repair should be such that tenolysis is seldom a necessity. There is no time like the first time. Primary repair, when indicated, is very satisfactory; but a delayed repair on a failed case is not only much more difficult but more liable to failure. Immediate active and passive movements after tenolysis are essential. In this series, 8 cases were subjected to this operation (Table VI). Most were disappointing. Pulvertaft mentions 20 cases, of which the majority show recovery to a high degree. Graham (1947) reports that operative

tenolysis with the use of tendon strippers has given satisfactory results.

Tendon Repair in Children

The principles underlying the repair of severed tendons in a child are exactly the same as those for an adult. The child has youth on his side; the remarkable powers of reconstitution of damaged tissues and adaptation of function ensures a superior result to the equivalent in an adult. Nature, however, cannot rectify a

TABLE VIII. THE RESULTS OF SECONDARY REPAIR IN CHILDREN UNDER 10 YEARS

Age in years	*Method*	*Digit involved*	*Result*
6	Palmaris graft	Index	Excellent
7	Palmaris graft	Ring	Good
2	Palmaris graft	Index	Good
6	Sublimis to Profundus—distal Sublimis excised	Middle	Excellent
5	Proximal Sublimis sutured to Profundus—distal Sublimis not excised	Middle	Fair
8	Profundus sutured to Profundus. *Later Operation:* Sublimis graft to ring finger	Little	Fair
6	Profundus to Profundus—Sublimis excised	Middle	Fair
3	Profundus to Profundus—Sublimis not excised	Little	Fair
3	Profundus to Profundus—Sublimis not excised	Little	Bad

Total 9
Success 4
Failure 5

wrong surgical procedure (Table VIII, Fig. 8). Postponing operation for any length of time is unnecessary; it only deprives the child of a better chance to regain normal function and activity. Immobilization after repair is as essential as for the adult—even more so, because the child cannot understand the significance of the injury and fails to cooperate. Physiotherapy afterwards is not necessary. The correct repair in a child should yield satisfactory results (Fig. 9).

RESULTS

The results of tendon repair has until very recently been painfully disappointing. A reviewer in the *Lancet* (1941) said, 'If the sheath is involved the prognosis is hopeless'. Jones (1944) thought it worth while reporting a 'successful suture of finger flexor tendon'. Fortunately the picture is no longer so gloomy, as the results will indicate.

Blum (1942) found it so difficult to appraise the results of tendon surgery in a statistical fashion that he chose a clinical exposition to present the procedure of myotomy as an auxiliary to tendon repair. Controllable and uncontrollable factors makes comparison of one's own end-results, as well as those of others, almost impossible. A relatively clean wound, early operated on with the most perfect atraumatic technique and a good functional result, may be useless to the first violinist. Similarly, a badly crushed finger in a manual worker, with subsequent infection and ultimate amputation, may result in a thankful patient with a useful hand.

Various criteria for classifying results have been used. Individual differences, even on the same classification, are frequent, and photographs are notoriously deceptive. Despite all these difficulties however, surgery of the hand demands a common platform for discussion and comparison.

In classifying results, the cosmetic appearance is important; but the emphasis should always be placed on function. Consider the function of thumb and

TABLE IX. THE RESULTS OF DIRECT SUTURE

	Result	*Previous Operation*	*Subsequent Operation*
Profundus to Profundus			
With excision of Sublimis ..	Success 2	0	0
	Failure 1	0	1
Without excision of Sublimis ..	Success 0	0	0
	Failure 7	0	3
Profundus Sutured to Proximal Sublimis			
With excision of distal Sublimis ..	Success 2	0	0
	Failure 0	0	0
Without excision of distal Sublimis	Success 0	0	0
	Failure 2	0	1
Flexor Pollicis Longus			
	Success 2	0	0
	Failure 1	0	0
Transplant			
Flexor Sublimis of ring finger to thumb	Success 1	0	0

Total Success of Direct Suture 6
Total Failure of Direct Suture 11

fingers as separate units, but also as individual digits. Fingers may act singly or in combination as *pincers, antennae, hooks, a press, or a vice.* The patient's age and occupation also influence the final assessment. Together with the above considerations, we have used the following practical scheme: *An excellent result:* Where the finger tip reaches to within $\frac{1}{2}$ inch of the distal palmar crease; there is full extension and no sensory disturbance. *A good result:* Where the finger tip reaches to within $1\frac{1}{4}$–$1\frac{1}{2}$ inches of the distal crease; there is almost full extension and no sensory loss. *Fair or bad results:* Those with less flexion than above, limitation of extension, ankylosis, contracture, or sensory changes. In the present analysis the first two are classed as successes, the last two as failures.

TABLE X. THE RESULTS OF TENDON GRAFTING

Donor Graft	*Result*	*Previous Operation*	*Subsequent Operation*
Palmaris Longus			
To fingers	Success 7	0	0
	Failure 3	0	3
To thumb	Success 6	0	1
	Failure 0	0	0
Toe Extensors	Success 2	0	0
	Failure 2	0	0
Sublimis	Success 0	0	0
	Failure 2	1	1
Profundus	Success 0	0	0
	Failure 1	0	1

Total Success of Grafting 15
Total Failure of Grafting 8

The patient's own ideas about the injury and subsequent surgical intervention are sometimes illuminating (Table

VII). Amputation seems to be a shameful admission of failure; yet in the case illustrated by Fig. 10 the patient had an almost normal functioning hand. He volunteered that there was nothing he could not do with this hand, yet it was classed as a failure (compare Fig. 10 with Fig. 11).

On the above basis Table VII shows an over-all success rate of 56%. The series has really been over-critically assessed. Many of these 'failures' will probably be regarded elsewhere as successes. Tables VIII, IX and X indicate results with various methods of repair. In 5 cases of delayed primary suture with excision of sublimis, 4 were successful (Fig. 12). In 9 cases the sublimis was not excised, and every one ended in failure (Fig. 13). The palmaris was the most commonly used graft; it proved successful in 10 out of 13 cases (Fig. 14), In the thumb 8 of the 9 repairs were successful (Fig. 6).

COMPARISON WITH THE RESULTS OF OTHER WORKERS

Garlock (1956) divided his tendon injuries into 5 groups:

1. Immediate primary tenorrhaphy: 16 cases repaired in the palm with 9 good results, 3 fair and 4 poor.
2. Early secondary tenorrhaphy within 6 weeks: 6 good, results 2 fair and 1 poor.
3. Late secondary tenorrhaphy after 6 weeks: 3 good results, 1 fair and 2 poor.
4. Late secondary repair with soft-tissue reconstruction: 2 good results, 3 fair and 2 poor.
5. Tendon grafting: 1 good result, 2 fair and 1 bad.

O'Shea (1939) reported on a large series of 870 severed tendons; 15·1% of the operations became infected (this was in the pre-antibiotic era). In his series of followed-up cases, 9 flexors of the fingers were excellent, 20 good and 16 unsatisfactory.

Miller (1942) gave a statistical analysis of 300 cases of severed tendons operated on by a fixed house-staff at the Detroit Receiving Hospital. Of 58 flexor tendons followed-up, 72·4% gave good results. His lowest percentage success of 64 was over the proximal phalanx (this corresponds with our experience). The flexor pollicis was repaired in 9 cases with 8 successes.

In a series of 21 cases, all but one operated on by himself, Kinmonth (1947) had only 4 failures. Pulvertaft (1948) in 20 injuries of tendons in the theca, claimed 75% success in 13 cases and 50% or less in 4 cases (3 too early to assess). In 9 cases with flexor pollicis injury, he did one primary and one delayed suture, both with 75% recovery. Elongation and suture yielded 2 full recoveries and 2 with 50% recovery. A graft was used in 3 cases, with 50-70% recovery.

An interesting analysis of the results of primary tendon-suture at the Cincinnatti General Hospital has been reported by Siler (1950*a*). A total of 35 surgeons in the Graduate School of Surgery performed the operations. 65 cases attended follow-up. Pollicis-longus suture gave 3 excellent results, 5 good and 1 fair. In the fingers, 32 repairs gave 3 excellent, results, 17 good, 9 fair and 3 poor. Out of 24 injuries in the palm, 9 results were excellent, 11 good, 1 fair and 3 bad. They classified as follows: Excellent—80% function with no nerve lesion; good—50% function and no nerve lesion; fair and bad, those with less function, ankylosis or nerve lesion.

Jennings *et al.* (1952) reported on the results obtained in 21 unselected severed tendons with the use of a new type of suture. Of these cases 11 were in the palm or fingers, in which 4 results were good, 4 fair and 3 poor. A good result was one where the finger tip could be approximated to 1 inch from the distal crease and a fair, between 1 and 2 inches. Siler (1950*b*) showed an over-all success of 74%. In a consecutive series of 57 cases, operated on by Eyre-Brook and analysed by Kyle (1954), the results of a single surgeon over a 6-year period are given. Their results are very similar to ours, except that the sublimis was their most effective graft in 20 cases, with 75% success. Palmaris yielded 50% success. Cases of direct suture of the profundus were satisfactory in 6 out of 9 cases.

In a recent paper by Bogdanov (1955), the results of a number of Russian surgeons are given in flexor and extensor tendon repairs. We were impressed by their uniform good results. They claimed 100% satisfactory results in extensor injuries in two series. The best flexor-tendon series claims 83% good results. Bogdanov bases his paper on a personal series of 375 cases; of these 123 were industrial injuries, of which only 28 had simple isolated tendon-injuries and the remaining 95 had accompanying extensive skin-defects, fractures or nerve-lesions. Despite these handicaps he shows 75% good results in flexor tendons and 89% in extensor. Unfortunately, the exact criteria for good and bad results were not given. We have not yet achieved this degree of success.

Watson (1955) published his results in 51 cases as follows: in the palm—4 were normal, 1 very good and 3 improved; direct suture of the flexor pollicis longus—5 very good and 2 improved, and 3 very good after a free graft; simple attachment of the profundus—normal in 5, improved in 5, and 1 case had a stiff but stable joint; division of both tendons and replacement by a free graft—8 very good, 7 improved, 2 poor and 2 failed, and 3 improved but too early for final assessment. The terms used in assessment may be difficult to evaluate.

THE IMPORTANCE OF HAND SURGERY

Many writers have stressed the importance of hand surgery. There are still, however, big hospitals even in industrial areas where 'hand surgeons' and hand clinics do not exist. Table XI is submitted as a plea for the establishment of a hand clinic in every centre where hand injuries are dealt with. Our duty as surgeons is not only to restore movements to a damaged finger, but to assist in getting the patient back to work as soon as possible. The majority of these patients are not able to resume their old job for many months after the injury (Table VI). Dr. Allen Kanavel has righty remarked that the hand of the working man is his most valuable asset. Without it, life becomes a burden.

TABLE XI. FREQUENCY OF HAND OPERATIONS IN TRAUMATIC SURGERY DURING 1 YEAR (JUNE 1953—JUNE 1954) AT THE BIRMINGHAM ACCIDENT HOSPITAL

Main Theatre	
Total number of operations	2,180
Hand operations	275
Percentage hand surgery	12·5%
Casualty Theatre	
Total number of operations	15,439
Hand operations:	
Local Analgesia	5,359
General Anaesthesia or Brachial Plexus Block	1,346
Percentage hand surgery	43·5%
Total percentage hand operations in Hospital during 1 year	39%

CONCLUSION AND SUMMARY

That tendon surgery has progressed by leaps and bounds is without question; but there still remains a great leeway to make up. The excellent experimental and clinical work of people like Mayer, Koch, Allen, Mason, Bunnell and Biezalski, to name but a few, made one hesitant to publish this small contribution. However, careful follow-ups are relatively uncommon in the literature; because of this, a large number of tendon injuries were studied, 41 cases were analysed, and suggestions are put forward to improve the outcome in tendon surgery.

Emphasis is placed on adequate assessment when first seen, with primary amputation where indicated.