

Review Article

THE TREATMENT OF INJURIES TO THE FLEXOR TENDONS IN THE DIGITAL THECA

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Injuries to the flexor tendons within the digital theca have always constituted a challenge to the surgeon. The results vary from excellent to poor, from optimism on the one hand to pessimism on the other. Those surgeons of the latter school believe that these injuries are often best treated by amputation, in this way saving the patient both money and time. Though in certain instances this may be true, the attitude as a generalization is to be condemned, for even a less than optimum result from flexor-tendon grafting often results in an overall improvement in the function of the hand. It is hardly justifiable to expect excellent results from flexor-tendon grafting, e.g. if less than optimum conditions exist before the flexor-tendon grafting procedure.

In keeping with modern trends in hand surgery, much attention has been directed toward improving the results in treating these injuries, for many are aware of the shortcomings in this field of endeavour. This paper sets out to outline the modern treatment and thoughts relating to these injuries in the hope that this will lead to improved results.

SURGICAL ANATOMY

The surgical area under discussion extends from the metacarpo-phalangeal joint region to the base of the distal phalanx of the fingers. In this region an unyielding fibro-osseous tunnel exists, formed by the metacarpo-phalangeal joint, proximal, middle and base of distal phalanx posteriorly, and by fibrous bands extending in an arch attached to the margins of the bones and to the palmar ligaments over the interphalangeal joints anteriorly. This fibrous band, the digital theca, shows areas of greater and lesser thickening along its course. The thickened areas are located over the phalanges, are transverse, and constitute the pulley system. Over the joints the theca is thinner, annular and cruciate. The significance of this arrangement lies in the fact that the thinner cruciate fibres allow for joint mobility, while the thicker areas over the phalanges are preserved in flexor-tendon grafting in order to prevent anterior prolapse of the graft.

As the flexor tendons enter the theca they lie in 2 layers; the superficial, the flexor digitorum sublimus and the deep, the flexor digitorum profundus. Soon after entering the tunnel the sublimus tendon splits into 2 elements which embrace the profundus tendon, the 2 diverging elements re-uniting behind the profundus tendon in the region of the proximal interphalangeal joint. The reunited tendon then diverges again into 2 elements to gain attachment along the lateral aspects of the middle phalanx for some considerable distance along the middle phalanx. The profundus tendon is therefore completely encircled by the sublimus tendon and the tunnel thus formed has a diameter which will allow a normal profundus tendon to glide through. It is obvious, therefore, that any repair of the profundus tendon at or just distal to the sublimus tunnel will result in the tendon jamming in the tunnel and becoming adherent at this point. Moreover any injury at this level results in the sublimus tunnel closing down within 3 weeks of the time of injury, so that if it is necessary to replace a divided profundus in the presence of an intact sublimus by means of a flexor-tendon graft, this should be done within 3 weeks of the injury.

The flexor digitorum profundus continues to gain attachment to the base of the distal phalanx of the finger just distal to the volar plate.

Surgically therefore, the digital theca may be divided into 2 zones:

Zone A. Extends from the metacarpo-phalangeal joint level to the point of insertion of the sublimus tendon in the middle phalanx. In this zone the theca is actually occupied by 3 tendons, the flexor digitorum profundus and 2 elements of flexor digitorum sublimus.

Zone B. The distal zone which extends to the base of the distal phalanx in which the digital theca is occupied by the flexor digitorum profundus only.

This division is of surgical importance. In zone A both flexor digitorum sublimus and flexor digitorum profundus are usually divided and in zone B the profundus only, leaving an intact functioning sublimus. The flexor digitorum sublimus is the prime flexor of the proximal interphalangeal joint with an insignificant subsidiary action on the metacarpo-phalangeal joint. The flexor digitorum profundus is the prime flexor of the distal interphalangeal joint with a subsidiary action on the proximal interphalangeal joint. Both the flexor digitorum sublimus and flexor digitorum profundus, however, have an interrelationship in producing a synchronous movement of the fingers. It is important to realize that the finger musculature exists in a state of balance which White¹ has aptly named the 'tripod of digital balance'. The tripod of balance is made up of the dual flexors, the long extensors and the intrinsics. The excursions of these tendons indicate that the flexors have a greater excursion power than the extensor-intrinsic complex combined. In normal finger movement flexion occurs at all joints simultaneously. With deletion of the flexor digitorum sublimus as occurs in flexor-tendon grafting the muscular tripod is upset; now the extensor-intrinsic has a greater excursion power than the flexors and normal flexion synchronism is upset. As a result, too, secondary deformities may occur.

The importance of the synovial sheath system lies in the fact that the mesentery of the tendon invaginates the synovial sheath, and it is through this mesentery that the tendon derives its meagre blood supply. In the finger the mesotendon is represented by vinculae, the vinculae brevi (2 in each finger) lying in the angles between the tendons and the bone at their insertion. The vinculae longae form an attachment between the posterior surface of the tendon and the posterior wall of the tendon sheath which at this point is synovial-lined phalangeal periosteum. It is the integrity or otherwise of the vinculae which determines what happens to the proximal divided portion of the tendon. If the tendon is divided distal to the vinculae the proximal end retraction is limited and the tendon is found close to the site of severance. If the division is near the base of the finger proximal to the vinculae, retraction occurs deeply into the palm where it is limited by the lumbrical attachment. The vinculae also constitute a definite point of adherence in flexor-tendon grafting, since their necessary resection creates haematoma formation.

TREATMENT

The treatment will depend on:

- (a) The nature of the injury,
- (b) The lapse of time since injury,
- (c) The ability of the surgeon, and
- (d) The operative facilities available.

It can be said without hesitation that *any surgeon not familiar with tendon surgery should deal with these injuries by wound toilet and closure of the skin only.*

Zone A

The typical injury in this zone involves both tendons and volar digital nerves. The inelastic fibro-osseous tunnel with the crowded tendons leads to difficulty in primary repair, for however meticulous the repair, no method can prevent adhesions between the tendon at the point of suture and the surrounding tissues. It was because of uniform failure of primary repair of tendons in this region that Bunnell² more than 50 years ago called this 'no-man's land' and laid down the principles of primary treatment by wound toilet, accurate skin closure, primary healing, and as a secondary procedure—when healing was complete, all reaction had subsided, and joints were fully mobile—performing flexor-tendon grafting. By means of flexor-tendon grafting the proximal suture is placed in the palm at the lumbrical level and the distal suture at the base of the distal phalanx, obviating any suture line within the digital theca. Moreover by exercising the fibrous flexor sheath leaving only the pulleys, adherence of the graft can be prevented and anterior prolapse of the graft obviated.

By paying meticulous attention to surgical detail excellent results have been reported by Littler,³ Boyes,⁴ Pulvertaft,⁵ and White,⁶ ranging from 70% to 80%, in which the tip of the finger can be approximated to within 1½ inches of the distal palmar crease. On the other hand depressingly poor results are known to occur commonly and it becomes necessary to analyse the reason for this.

Paul Brand⁷ has pointed out that a tendon graft as opposed to a tendon transfer derives its blood supply from surrounding tissues. As such, no matter how meticulous the surgery, the graft is converted into scar. The ability of the tendon to glide will be determined by the ability of the patient to pull the tendon through scar. The amount of scar present will in turn be determined by that produced by the initial injury and that subsequently produced by surgery. At any point in the surgical procedure, if the filmy covering overlying rigid structures be damaged, this will constitute a point of rigid adhesion, and however willing and able the patient is, he cannot produce any gliding. The importance of the surgical technique is obvious and accounts for the excellent results obtained by Littler, Boyes, Pulvertaft and White.

However, if the initial injury has been one which has involved the tendon bed or there have been associated injuries to bone joints, etc., no matter how skilled or meticulous the repair, only a less than optimum result can be obtained, since less than optimum conditions existed before surgery. The surgeon has to be content with an inferior result in these cases, but even this inferior result will often result in a vast overall improvement in the function of the hand. Naturally if the surgeon is going to be as highly selective as to perform flexor-tendon grafting in only optimum pre-operative conditions, his results will be in the region of 80% success. Those cases not suitable for him can then be delegated to arthrodeses or amputation and his statistics will remain unimpaired. It is in many ways a better surgical achievement to obtain a less striking result in the so-called 'poor risk' case than an excellent result in an ideal case.

Complications of Flexor-Tendon Grafting

1. *Adherence of the graft.* This is often the result of injury to the tendon bed. There is no, or limited, excursion.

2. *Tendon graft too short.* The finger is held in flexion with loss of extension so that even though the fingertip can approximate to within 1½ inches of the distal palmar crease, extension is lost. It is necessary therefore in evaluating results to measure not only the flexion range but also the range of extension. The exact amount of tension necessary will vary with each individual case and improvement with this comes only with experience.

3. *Tendon graft too long.* The fingertip cannot approximate to palm.

4. *Flexion deformity at distal interphalangeal joint* will occur if the profundus stump is left too long and the distal suture overlies the distal interphalangeal joint with adherence at this point.

5. *Flexion deformity at proximal interphalangeal joint.* If the sublimus ends are left too long, the dissatisfied fibres grow out and attach themselves to the proximal phalanx.

6. *Hyperextension deformity at proximal interphalangeal joint* will occur if:

(a) The sublimus ends are cut off too short,

(b) There has been injury to the volar plate, and if

(c) Deletion of the flexor digitorum sublimus causes imbalance so that the joint is pulled into recurvatum by the unopposed action of the extensor-intrinsic complex.

7. *Intrinsic plus deformity.* Flexion at metacarpo-phalangeal joint and extension at the interphalangeal joints may occur from the lumbrical action on the proximal suture line, and for this reason many people do not wrap the lumbrical around the suture line but resect the lumbrical muscle.

8. *Severance of the volar digital nerves.* The neurovascular bundles must always be visualized at all times during the procedure.

9. *Necrosis of skin flaps.* The skin flap must be raised carefully, carrying with it subcutaneous tissue and fat.

10. *Dehiscence of suture lines.* This may occur either distally or proximally. Though the average period of immobilization is 25 days this should be varied, especially if the graft has been done on a muscular patient.

11. *Contracture and shortening of the graft* will occur if the period of immobilization is too long.

12. *Infection.* Any degree of infection will mitigate against a good result.

13. *Asynchronous finger flexion.* In normal finger flexion all joints move at the same time. With a profundus graft the action is one of initiation of flexion at the distal interphalangeal joint, since no sublimus action is present. The proximal interphalangeal joint is held in extension by the extensor-intrinsic complex and remains so until flexion occurs at the metacarpo-phalangeal joint level. When this occurs some of the intrinsic action is expended and the proximal interphalangeal joint then breaks over into flexion. It is because of this that when mobilization of the finger is commenced, it is often wise to immobilize the distal interphalangeal joint to prevent this complication.

14. *Anterior prolapse of tendon graft* will occur if no pulleys are left. Pulley reconstruction, though widely described, is often not successful and probably the easiest method of dealing with this problem is to provide the patient with a ring for the finger.

15. *Skin flexion contracture* will occur if the incision on the side of the finger is placed too far volar-wards lying within the limits of the joint axis.

The complications are therefore many and frustrating but can be obviated to the point that *the only reason for failure should be the fact that less than optimum conditions exist before surgery.*

Improved Methods of Treatment

Recently, with growing specialization in the field of hand surgery, it is becoming apparent that primary tendon

repair in this zone can give results comparable to, or even better than, the orthodox method of treatment, where certain criteria of injury are present and where the surgeon is familiar with tendon surgery. Two methods are available:

1. *Primary profundus graft.* In highly selected cases in which the injury has been a clean incised wound, in which there has been no associated injury, and in which minimal time has elapsed since the injury, the procedure of primary tendon grafting has found favour. In this procedure the sublimus tendon is resected, the redundant portions of the sheath being resected, leaving the pulleys, and the flexor-tendon graft is done in exactly the same way as the secondary procedure. The advantages of this procedure are:

- The exact length of the tendon graft can be obtained.
- The gliding mechanism is intact. In the secondary procedure the divided tendon ends often become adherent to the tendon bed.
- Reduced time off work.

Harrison⁸ reported 16 such grafts in 14 patients, his results being comparable to those of his control series in which elective tendon grafting was done. Assessment of Flynn's highly selected 11 primary flexor-tendon grafts⁹ indicates that 3 out of 11 failed to flex within 1½ inches of the distal palmar crease. His results did not compare with 104 unselected cases done as secondary procedures by Boyes. However, *there is no reason why primary profundus tendon grafting should not become routine practice in the trained hand surgeon's repertoire.* This should indicate quite clearly that the primary treatment of these injuries should be done by surgeons familiar with tendon surgery.

2. *Primary profundus-tendon repair.* Primary repair of the profundus tendon with resection of the sublimus has been strongly advocated by Verdan.¹⁰ Verdan feels that in a clean fresh wound specialists capable of performing tendon grafts correctly are qualified to perform primary tendon repair. Verdan felt that the rigid principles laid down by Bunnell did not pertain in all cases and the method of suture as advocated by Bunnell should be modified. He resected the sublimus and 1 inch of the overlying fibrous sheath at the site of tendon suture, sutured the tendon with 6/0 epitendinous sutures as is done for nerve repair, and immobilized the suture line with 2 stainless steel pins passed through the tendon sheath and tendon distal and proximal to the line of juncture. Verdan and McCash¹¹ feel that in their hands their results were superior to results obtained with delayed procedures, though Van't Hoff,¹² reviewing his own and other series, indicated that the results of primary suture were inferior to the delayed procedure.

The controversy which exists is not easily resolved and further proof is necessary that both primary profundus-tendon grafting and primary profundus-tendon suture in zone A will yield as good results as the delayed procedure advocated by Bunnell.

Once again there is no reason why primary profundus-tendon suture should not be done and as Wakefield¹³ has pointed out, this is the procedure of choice in children under the age of 5 years, where the results are excellent.

In summary it can be said that for surgeons dealing with these injuries *only occasionally, the treatment should still be careful wound-toilet closure in order to produce optimum conditions for secondary tendon grafting.* For those surgeons

familiar with the problems of tendon surgery and fortunate enough to be able to treat these clean fresh wounds, primary repair either by flexor-tendon grafting or primary repair offers scope for both individual and collective experience to evaluate the exact status of these controversial techniques.

Zone B

In this zone the sheath is occupied by the profundus tendon only, and severance here will result in inability to flex the terminal phalanx, but a normally functioning sublimus tendon flexes the proximal interphalangeal joint.

The results of treatment here are encouraging:

1. If the point of severance is far distal enough not to encroach when repaired on the intact sublimus insertion, primary repair of the tendon with resection of the overlying sheath is indicated and gives good results. This opportunity is often missed since a misconception exists that all flexor-tendon injuries in the fingers should be left for secondary grafting. If primary repair is not carried out at this stage, the tendon subsequently retracts, the sublimus tunnel closes down and direct tendon repair as a secondary procedure becomes impossible.

2. If the point of severance is close to the intact sublimus tendon, the intact sublimus tendon must never be jeopardized. In this situation, in the acute injury, the following procedures are available:

- The profundus tendon can be withdrawn through a palmar incision and a thin palmaris or plantaris-tendon graft threaded through the sublimus tunnel.
- The distal interphalangeal joint can be stabilized either by tenodesis, using the profundus stump, or by arthrodesis.

If conditions are not favourable for surgery the skin is closed and secondary procedures can be carried out under more optimum conditions. The above procedures are also applicable to early secondary repair, i.e. within 2-3 weeks following injury.

Late Secondary Repair in Zone B

In these cases tendon retraction, fibrous obliteration of the sublimus tunnel, will preclude direct repair at any level if exploration is delayed beyond 3 weeks.

Three courses are open to the surgeon:

- If there is a good range of proximal interphalangeal joint movement and the patient is not greatly concerned with inability to flex the terminal joint, nothing need be done.
- If there is a range of 90 degrees or better in the proximal interphalangeal joint and the patient requires stability of the distal interphalangeal joint, this can be done by tenodesis utilizing the profundus stump, if this is long enough, or by arthrodesis.
- If the range of motion at the proximal interphalangeal-joint level is less than 90 degrees and a sufficient lapse of time has occurred to make further improvement unlikely, it will usually be best to sacrifice this ineffectual movement, provided the finger and the passive range are otherwise satisfactory, and to carry out a flexor-tendon graft.

Treatment of Failed Tendon Repair

Finally, the treatment of failed tendon repair can be considered. These are difficult problems since the scarring and joint fixation preclude attempts at restoring function. Four alternative methods exist:

1. *Tenolysis.* This may be useful, especially after flexor-tendon grafting, and is best done about 3 months after grafting if there has been no improvement and the passive range of motion is greater than the active range. The best results are obtained where the adhesions are thin and limited in extent, but will not be found to be of value where extensive or rigid adhesions exist.

2. *Further tendon grafting.* If tenolysis proves to be impracticable the only chance of restoring function is by preliminary excision of the adherent tendons and later tendon grafting.

This is best limited to children and young patients where the prospects of improving the passive range are good.

3. *Retention of stiff fingers.* If unsuitable for either tendon grafting or tenolysis, a stiff finger may perform an important function in the hand, especially if several fingers are injured. With an intact intrinsic flexing the metacarpo-phalangeal joint, interphalangeal joints arthrodesed in a functional position, the tip of the finger can be approximated to the palm, and a useful function can be obtained.

4. *Amputation.* In a single-finger injury, where there has been a failed tendon repair and the stiff finger embarrasses function, amputation is indicated. The amputation must be done at the most functional level.

SUMMARY

The results of treatment of injuries to the flexor tendons within the digital theca will depend on the following factors:

1. The nature of the injury.
2. The initial treatment.
3. The healing following primary treatment.
4. The surgical technique.
5. The postoperative care, both immobilization and mobilization.
6. The patient's ability to cooperate and mobilize the graft.

There is not much we can do about the extent of the initial injury, but by means of correct initial treatment, ensurance of primary healing, improved surgical technique, both at the time of surgery and in the postoperative phase, the results can be vastly improved upon and be gratifying to both patient and surgeon.

Finally the name accorded by the famous Sterling Bunnell, 'no-man's land', should be regarded as 'hand-man's land', since *it is by carrying out the initial treatment in whatever form is indicated, that the future of the finger rests*, for it is conceivable that initial primary repairs will in the final analysis yield the best results.

REFERENCES

1. White, W. L. (1960): *Surg. Clin. N. Amer.*, **40**, 432.
2. Bunnell, S. (1918): *Surg. Gynec. Obst.*, **26**, 103.
3. Littler, W. J. (1947): *Amer. J. Surg.*, **74**, 315.
4. Boyes, J. H. (1955): *Ibid.*, **89**, 1116.
5. Pulvertaft, R. G. (1956): *J. Bone Jt Surg.*, **38B**, 175.
6. White, W. L. (1956): *Amer. J. Surg.*, **91**, 662.
7. Brand, P. (1959): *J. Bone Jt Surg.*, **41B**, 208.
8. Harrison, S. H. (1958 - 59): *Brit. J. Plast. Surg.*, **11**, 106.
9. Flynn, J. E. (1953): *J. Bone Jt Surg.*, **35A**, 132.
10. Verdan, C. (1960): *Ibid.*, **42A**, 647.
11. McCash, C. R. (1961): *Brit. J. Plast. Surg.*, **64**, 53.
12. Van't Hoff, A. (1958): *J. Bone Jt Surg.*, **40A**, 256.
13. Wakefield, A. R. (1960): *Surg. Clin. N. Amer.*, **40**, 267.