TENDON SURGERY; PRINCIPLES AND TECHNIQUES

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Introduction

Tendon surgery in the lower extremity ranges from transfer procedures for restoration of motor balance to reconstruction of traumatic ruptures or lacerations. Regardless of the actual procedure, certain principles and techniques apply to all tendon surgery. Proper handling, suturing, and attachment techniques will help to ensure a successful result.

Principles

In 1921 Sterling Bunnell coined the term "atraumatic technique" (1). According to Bunnell the greatest obstacles of reconstructive surgery are fibrosis and infection. He formulated a method of surgical technique to overcome those obstacles which is the basis of tendon surgery as well as all reconstructive surgery.

Obviously, absolute asepsis is essential. However, Bunnell emphasized other factors which may determine infection such as dead spaces, buried foreign bodies (including excessive suture material and ligature), closure with insufficient hemostasis, excessive separation of tissue layers, drying of tissues, and long surgical exposure of tissues.

Of equal importance in limiting complications is the reduction of tissue trauma. Careful, gentle retraction and limited, purposeful sponging (gauze irritates tissue) are essential to preserve tissue integrity. Tissue forceps should hold more by retracting than by grasping to prevent crushed or torn tissue.

More specifically, the tendon, its sheath or paratenon, and its gliding mechanism must be preserved. The field and the tendons must not become dry. Additionally, the tendon should never be grasped by an instrument. Tendon anastomoses should be placed in a sufficient tissue bed. Thus, subcutaneous tissue must be preserved to protect gliding function. When considering tendon transfers, route the tendon through normal tendon sheaths which are not diseased, fibrosed, or lacerated. This will prevent fibrosis and poor gliding.

Incision planning must be carefully considered to reduce wound trauma and prevent fibrosis. A thorough knowledge of the anatomy is required so that nerves and large vessels may be avoided. Incisions over joints should be gently curved to prevent joint contracture during wound healing. Incisions are placed so that tendon junctures are beneath skin flaps away from skin edges and thus free from cutaneous scar.

Instrument handling of a tendon will traumatize the delicate fibroblastic covering of the tendon known as epitenon. Adhesions which bind a tendon to the surrounding tissue arise from the injured epitenon as well as the sheath or paratenon. Lindsay and Thompson demonstrated that the mere passage of a suture needle through a tendon produced sufficient trauma to cause local adhesions (2).

Tendon tension is crucial for appropriate joint motion. Too little tension produces weak joint motion and poor stability. Excessive tension reduces the end range of motion and more importantly produces degeneration of the muscle unit. Mayer in 1916 demonstrated degeneration in the gastrocnemius of the dog when the tendon repair was placed under excessive tension (3). The tendon should be sutured in a neutral position under normal tension. In some instances, a tendon repair may be performed under local anesthesia so that the tendon may be actively moved to access tension.

Techniques

Handling/Harvesting

As described previously, preservation of the epitenon is essential to limit fibrosis and prevent adhesions which limit gliding. Avoid instrument handling of the tendon whenever possible. When retraction of a tendon is necessary a moistened penrose drain or moistened umbilical tape is appropriate.

In the approach to a tendon for harvesting when transferring is the goal, the tendon sheath should be preserved as much as possible. This provides a path of transfer as well as an environment for gliding. Once the tendon has been harvested and removed from its insertion the free end should be tagged with either zero or 2-0 non-absorbable suture in an over and over fashion. The tendon should never be tagged with an instrument (Fig. 1).

Transfer Techniques

Prior to elective tendon surgery hemostasis of the

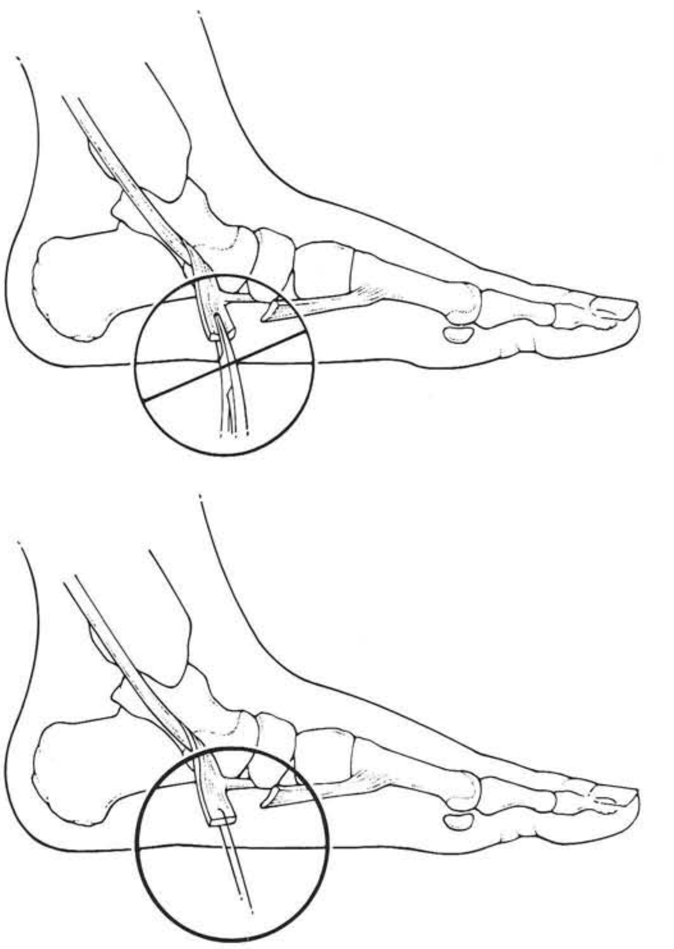

Fig. 1. Tendon should never be tagged with instrument. Free end should be secured with suture tag.

extremity should be established. The skeletal structure should be stable and adequate joint range of motion should be present. Where joint instability or degenerative joint changes exist arthrodesis should be considered to promote stability and increase lever advantage. Tendon transfers should never be performed across bony nonunion sites as telescoping will result, preventing normal tension necessary for motion. Soft tissue should have adequate vascularity and be free of fibrosis. Obviously, unhealed or chronic open wounds are contraindications to surgery.

Timing of the transfer is variable and depends on the clinical situation. Traumatic nerve injuries producing paralysis require time to evaluate axonotmesis and potential recovery. Neuromuscular disorders require evaluation of the disease state and its progression potential.

Selection of a muscle to be transferred is determined by the clinical situation and the desired function one wishes to achieve. Technical consideration of muscle selection begins with voluntary muscle testing of all active muscles in the extremity. Highet's clinical scale is the standard for grading muscle strength and should be utilized as follows:

0 — total paralysis
1 — muscle flicker
2 — muscle contraction
3 — contraction against gravity
4 — contraction against gravity and resistance
5 — normal

Once familiarity with muscle testing is achieved, plus or minus grades may be used to achieve further accuracy (example 4 +). The muscle unit selected should be more than strong enough for its proposed new task since the muscle may lose one grade of strength on Highet's scale secondary to the postsurgical healing process. However, this is not always the situation since the new tendon position may place the motor-tendon unit in an advantageous lever position thereby negating the effect of postsurgical strength loss and produce a muscle of equal or greater effective strength.

As stated, normal sheath should be utilized whenever possible. An adequate bed of subcutaneous tissue should be present. The tendon should not cross raw bone as adhesions will occur.

Muscle-tendon unit transfers (i.e. tibialis posterior) that act through fascial planes such as the tibiofibular interosseous membrane, should have as large a fascial opening as possible. The muscle unit should actually be placed through the opening since exterior muscle fibers will adhere to the opening allowing interior fibers to move. If tendon contact the fascial opening fibrosis can result with restriction of tendon gliding.

The direction of pull of the transferred tendon should be as close to a straight line as possible. Since most muscles are parallel to bone, this relationship should be preserved. The angle of approach between the transferred tendon and its original insertion should be small. If the insertion of the transferred tendon is split (as in the STATT), the muscle unit will act primarily on the tendon under greatest tension. Thus appropriate tension is effected depending on the desired force.

Suture Materials

Prior to discussing suture techniques a discussion of suture materials is appropriate. The most common materials utilized almost a century ago were silk, cotton, and cat gut. Through the 1950s silk and to a lesser extent cotton were popular. In the 1940s and 1950s stainless steel gained popularity due to its strength and non-reactivity. Today stainless steel is used very little because of difficult handling properties, bulky knots, and in vivo electrolysis which significantly reduces tensile strength in approximately one month. Nylon was the first synthetic suture to be used being introduced in the 1950s and is still commonly utilized today. Mersilized dacron/polyester and polypropylene are non-absorbable sutures which now compete with nylon. All are relatively non-reactive with nylon being the least reactive. Although these sutures all handle far better than stainless steel, nylon tends to be springy and requires four knots to prevent untying.

Synthetic absorbable sutures of the polyglycolic acid (PGA) family were introduced to tendon surgery with the advent of other synthetic sutures. The PGA (dexon) family is absorbed by hydrolysis versus cat gut which is phagocytized. Consequently, there is less inflammatory reaction around the tendon juncture than with cat gut. Although reactivity is low, Ketchum reports a 50% reduction in PGA tensile strength at one month compared to polyester fiber (4).

Presently, non-absorbable synthetic sutures such as Merceline, Tevdek, and Prolene are most desirable. Absorbable sutures used alone may become weakened too soon to be reliable for tendon anchor.

Suture Technique: Tendon to Tendon Anastomosis

Although strength of the suture material contributes to the overall strength of the tendon repair the technique utilized is even more important. Early tendon surgeons discovered interrupted sutures placed parallel to the tendon fibers pulled through the tendon repair when tension was placed on it (Fig. 2A). This fact encouraged Bunnell to develop the now classic criss-cross stitch to prevent the shearing of suture through the tendon (Fig. 2B) (1). Since that time a variety of suture techniques have been described. The strongest tendon repair techniques of the hand and finger are the Bunnell (Fig. 3), Kessler (Fig. 4), and Mason-Allen (Fig. 2C). However, the Bunnell stitch is more strangulating to the microcirculation of the tendon than

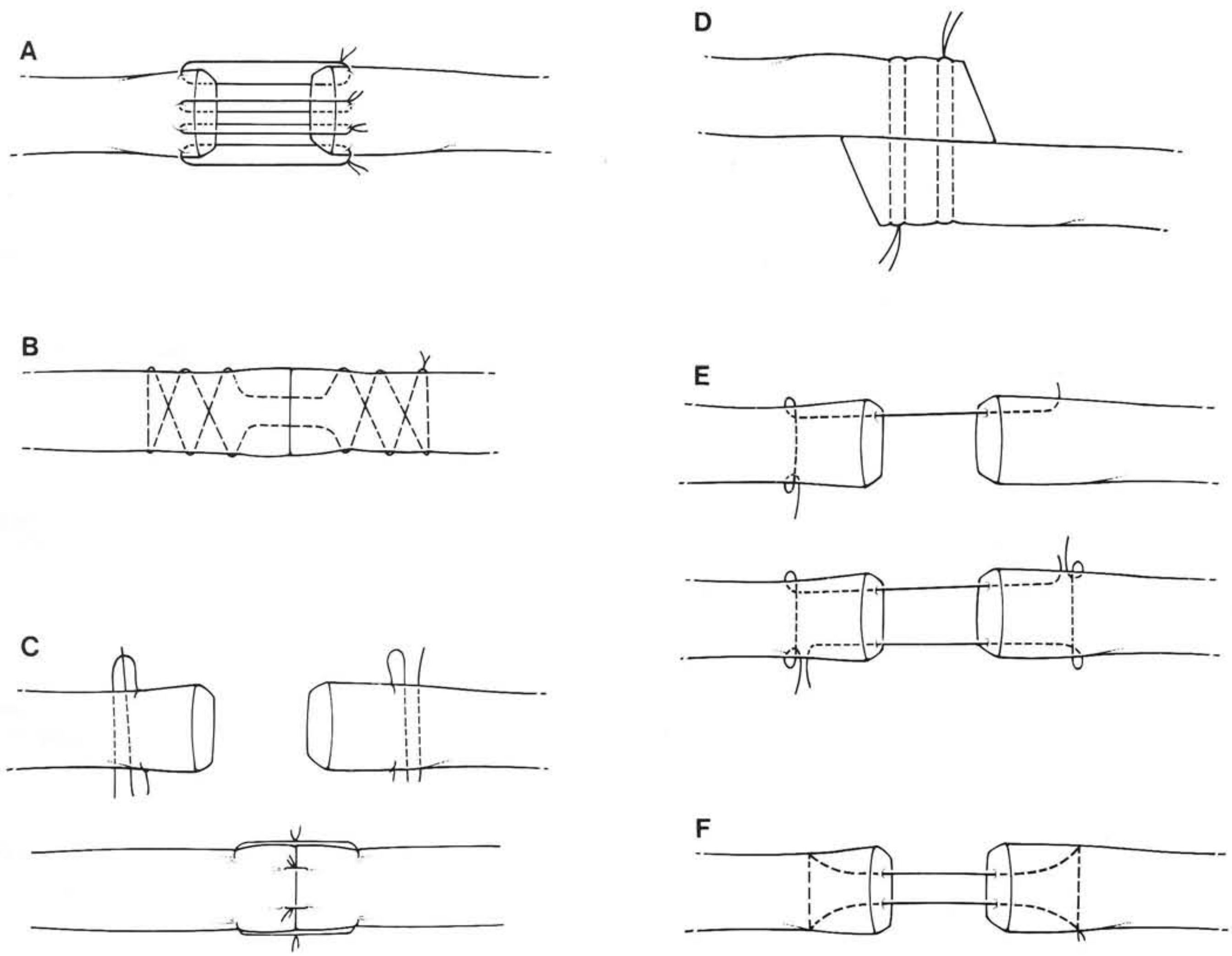

Fig. 2. A. Interrupted sutures. **B.** Bunnell suture. **C.** Mason-Allen suture. **D.** Side to side suture. **E.** Kessler grasping suture. **F.** Nicoladoni technique.

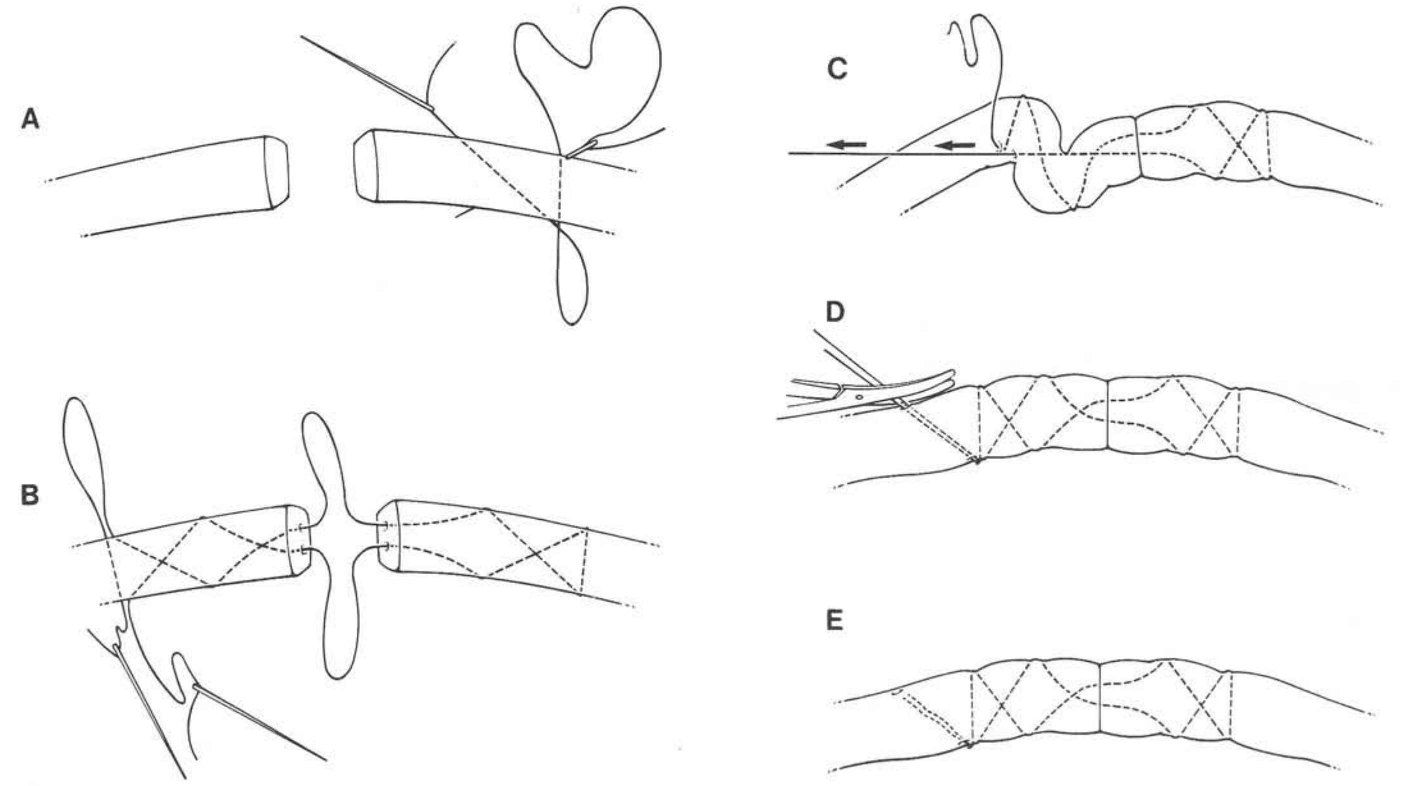

Fig.3. Bunnell suture. **A.** Suture with needle on each end is passed through distal end of tendon. **B.** Needles then criss-cross and exit from middle of tendon. They are then passed through proximal tendon and criss-crossed as in the distal tendon. **C.** Tendon ends are then pulled so that bunching results. **D.** Suture is tied and then passed into body of tendon for about 2 cm. **E.** Suture ends are cut flush allowing them to retract into the substance of the tendon.

the later two resulting in tendomalacia (softening of the tendon) and gap formation. Hand repair techniques can be assumed to be of similar strength when utilized in the foot, even though weightbearing adds an additional force.

The simplest and least traumatic suture technique, though weakest initially, will allow tendon healing to proceed most rapidly. Thus adequate immobilization and splinting is required to prevent rupture. In approximately three to six weeks the suture technique and material become secondary to tendon healing as the prime provider of strength to the tendon repair.

At Doctors Hospital the Bunnell (1) and Kessler (5) suture techniques have been utilized most often for tendon laceration or rupture repair. Side to side or interrupted techniques are utilized for extensor tendon repair following digital arthroplasty or arthrodesis (Fig. 2D). Although contrary to classical tendon principles, in the digit these techniques are successful because of minimal tension placed on the repair secondary to bony resection, internal fixation (with Kirschner wire (K-wire)) when utilized, and dressing immobilization.

One should maintain appropriate tension on the tendon repair so that a neutral position is achieved. At times this may be difficult to attain due to tendon tension and instability. To stabilize a tendon during suturing an 18 gauge needle may be passed transversely through the proximal and distal tendon ends (Fig. 5). This will prevent retraction of the tendon into its sheath, assist with tendon stabilization, and facilitate wound retraction. The trauma to the tendon is insignificant and the ease of repair is considerably enhanced.

Once repair is complete excess tendon should be excised to limit fibrosis formation since adhesions grow directly from exposed or injured tendon ends. Extensor tendons transected during digital repair may become instrument traumatized; however fibrosis and limitation of motion are minimal due to resection of excess and damaged tendon.

Suture Technique: Tendon to Bone Attachment

A variety of methods have been described for tendon to bone attachment. These include:

1. trephining (Fig. 6),
2. intraosseous drill holes with suture attachment (Fig. 7),
3. AO screw with polyacetyl washer (Fig. 8)

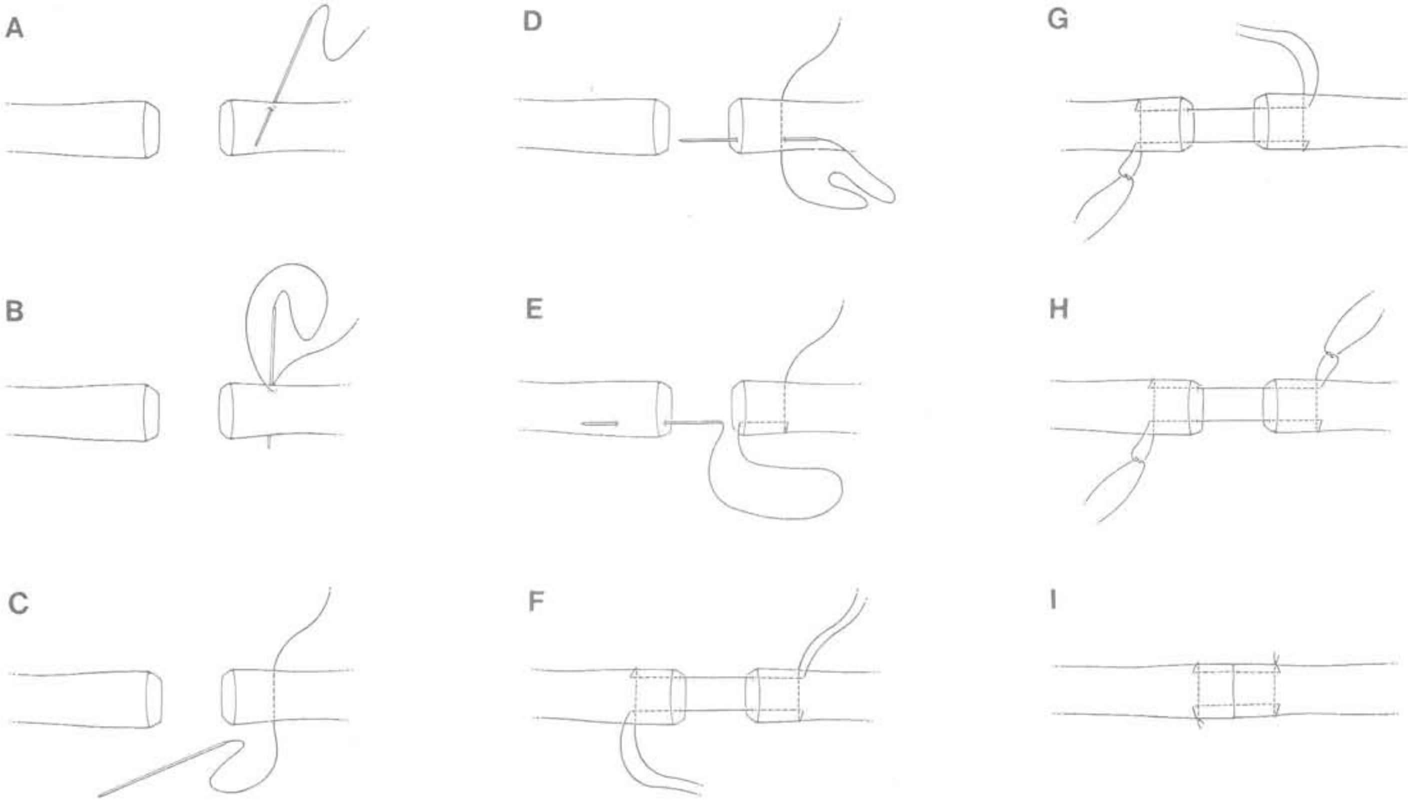

Fig. 4. Kessler grasping suture. **A.** Needle is passed through one border of tendon. **B.** Knot is then tied and, **C.** needle is passed across tendon. **D.** Needle is then passed through body of tendon once a knot has been tied on opposite border. **E.** Needle is then passed into substance of other tendon end. **F.** Same sequence is then performed in reverse direction. **G—I.** Suture ends are then tied producing completed suture.

4. pull out button (Fig. 9),
5. trap-door techniques (Fig. 10).

Presently the most commonly utilized methods at Doctors Hospital are the first three and these will be described in more detail.

Trephining requires the use of a Michele Trephine available in a variety of diameters. A sawtooth rim allows penetration of the cortex by a rapid axial rotation of the instrument. A bony plug remains in the barrel of the trephine which is removed with a stylet. Approximately one-half to three-quarter inches of tendon is placed in the hole under appropriate tension (Fig. 6A). The tendon is sutured to the surrounding periosteum and deep fascia. A plug of bone is replaced in the hole and then compressed with a stylet (Fig. 6B). The soft cancellous bone when compressed fixes the tendon in place. The bony plug is covered by reapproximating the periosteum and deep fascia over it (Fig. 6C). The tendon becomes firmly incorporated after approximately six weeks of immobilization.

Intraosseous drill holes with suture attachment provides a second standard technique. Periosteum is freed from the area of planned insertion and the osseous surface is drilled.

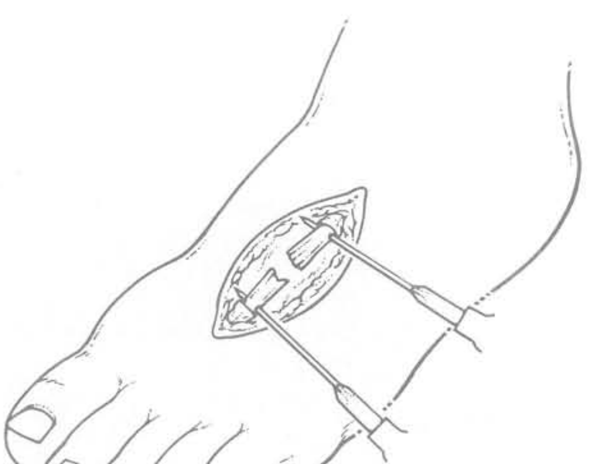

Fig. 5. Tendon stability may be obtained by passing 18 gauge needle through tendon ends.

Drilling is done in such a way as to create a three-eights to one-half semi-circle thereby allowing the passage of a suture needle. The suture is then passed through the tendon and then anchored onto the osseous surface. Although a successful technique, this method is less stable than a modification known as the three-hole suture technique (Fig. 7). This variant involves anchoring a tendon into a large drill hole with a double-armed suture. A suture is then passed out of the hole through two small drill holes and tied.

Screw fixation utilizes a cleated polyacetyl washer. This technique is useful where minimal soft tissue exists to allow tendon to tendon reinsertion or bony anchoring is not possible. Posterior tibial tendon transfers or repair of tendo achillis avulsions are possible indications for this method (Fig. 8).

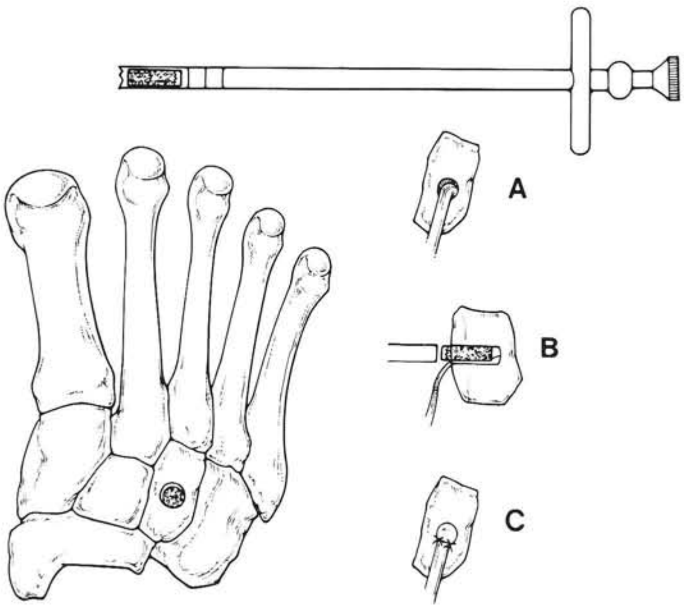

Fig. 6. Michele trephine. **A.** Tendon is placed in trephine hole. **B.** Once plug is placed in hole compression is applied. **C.** Periosteum and deep fascia are then closed over plug.

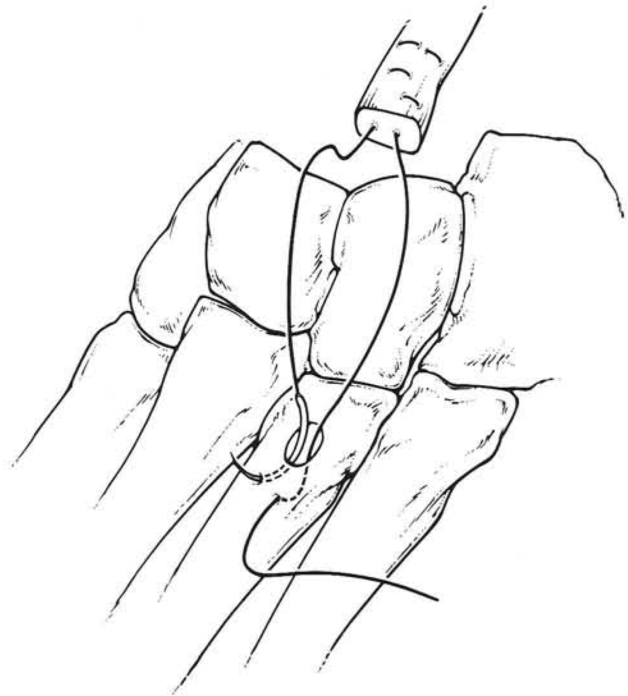

Fig. 7. Modification of intraosseous technique known as three-hole suture method.

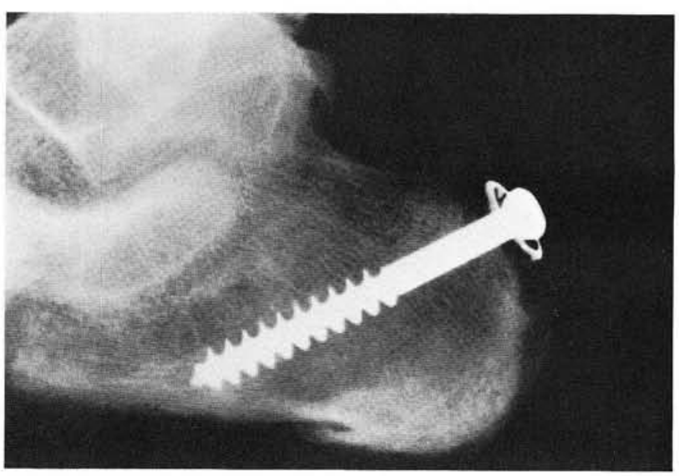

Fig. 8. AO screw with polyacetyl washer utilized to attach tendo achilles to calcaneus following avulsion type rupture.

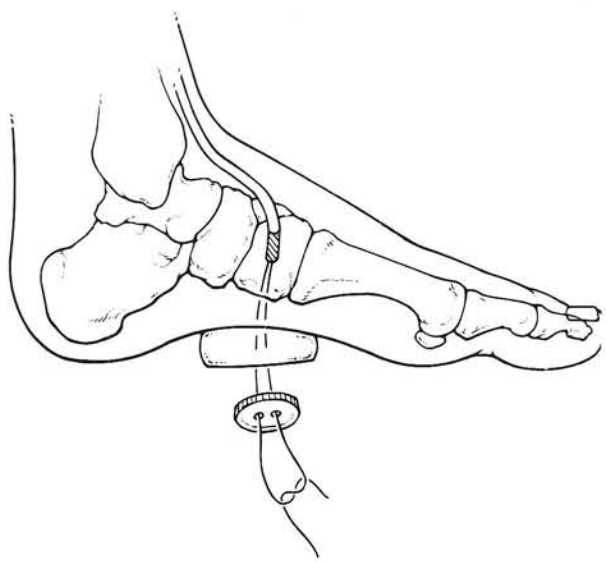

Fig. 9. Pull-out button utilized with buttress to secure suture.

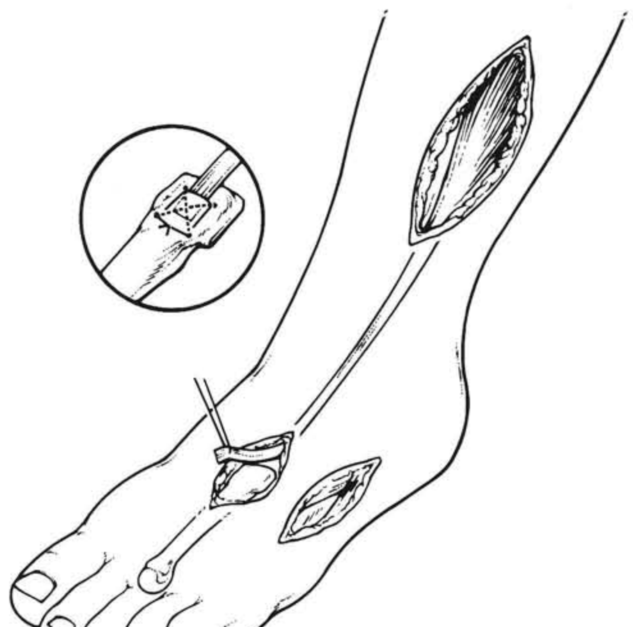

Fig. 10. Trap-door technique; periosteum is raised allowing tendon to be inserted and sutured.

Summary

The principles and basic techniques of tendon surgery have been reviewed. Utilization of these fundamentals and their application to the described techniques are crucial to the attainment of successful surgical results.

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