CHAPTER 5

MUSCLE-TENDON TRANSFERS OF THE LOWER EXTREMITY

Stephen J. Miller, D.P.M.

The manipulation and the transfer of tendon is a recent development in surgery, just a little over 100 years old. Nicoladoni of Vienna was the first to record a tendon transfer. He corrected a dropfoot with a peroneus longus transfer in 1881. Many ideas and procedures were then developed by German authors such as Lange, Biesalski, Vulpius, and Stoffel.[1] However, Mayer stands out as the investigative and clinical father of the modern concepts of tendon transfer.[2-7] Mayer brought his ideas to America where Bernstein, Steindler, Ober, Bunnell, and others added to his work.[8]

McGlamry and his colleagues were the first in the podiatric community to implement the concept of major tendon surgery. They reported on the applications, theory, experience and results of such procedures as the split tibialis anterior tendon transfer, Young's tendosuspension for weak foot, Jones metatarsal suspension, and correction of the equinus foot.[9-15]

DESCRIPTION

A tendon is the non-stretchable portion of the musculotendinous unit that connects the muscle to bone. It is responsible for transferring the large tensile forces produced by contraction of the muscle, so that distant movement or torque can occur about joint axes. To function properly requires smooth gliding along its course, as well as flexibility of the associated joints.

A tendon is usually cord-like, flat or round, but may also form as a sheet-like aponeurosis. It is stronger than muscle, with a tensile strength as great as that of bone, although it is flexible and slightly extensile. Tendon fibers resist tension, so that muscle contractile energy is not lost during transmission to insertion. The flexibility of tendons enables them to be angulated around bone surfaces or deflected beneath retinacula (Fig. 1).

The metabolic needs of tendon are very small, yet it is a dynamic tissue composed of three fibrous proteins: collagen (86%), reticulin, and elastin. In addition, it contains ground substance and fibroblasts in connective tissue. The fibroblasts become active when the tendon is injured, but they also replace all of the collagen in the tendon every six months.[16]

ANATOMY

The collagen forms into *fibrils* which are bundled into *fascicles* surrounded by *endotenon,* the internal supportive areolar connective tissue. Together, the fascicles form the tendon, which is covered with a thin supportive layer of connective tissue know as the *epitenon*. The fibrils and fascicles have a wave, crimp, or zig-zag pattern along their course, which disappears when the tendon is placed under tension. This provides modest shock absorption during function.[17,18]

External to the tendon are two types of significant connective tissue. The loose and areolar *paratenon* surrounds the tendon when it is in a

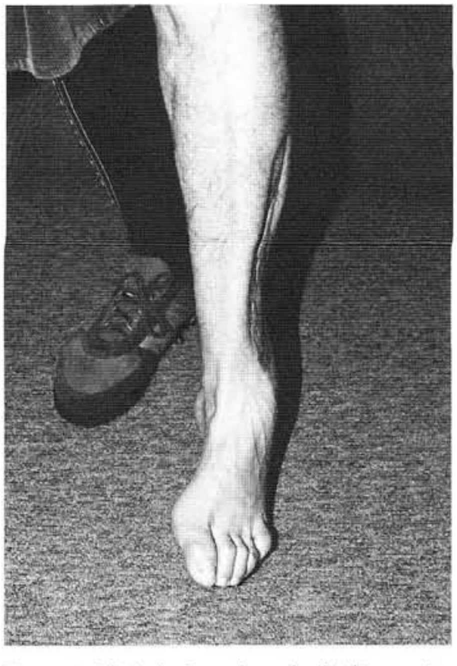

Figure 1. Clinical view of weak tibialis anterior tendon. Note its course underneath the extensor retinaculum.

straight course. It carries a neurovascular network which enters via the *mesotenon* situated on the side of least pressure. The second type of external support is the *synovial sheath* (not tendon sheath). It is basically a "tubular bursa" surrounding the tendon, and made up of a visceral and parietal layer sandwiching a synovial membrane lining. Synovial sheath is present where the tendon curves under retinacula or around bones and protects against friction. It too takes its neurovascular supply via the mesotenon.

Tendons receive their vascular supply from three sources. Approximately 30% is derived proximally from the arterioles via the musculotendinous junction, plus distally from the capillaries at the osteotendinous insertion.[19] The majority supply is derived through the paratenon and synovial sheath.

There are three types of nerve found in tendons, Paciniform (touch), Golgi tendon organ (stretch), and free nerve endings (pain).[20,21] These nerve endings take part in proprioception, reflexes and pain reception.

Tendon is attached to bone by way of transitional fibers that pass through the periosteum, and convert from collagen, to fibrocartilage, to bone as they penetrate the cortex. These have been termed "perforating fibers of Sharpey" (Fig. 2).[22]

TENDON HEALING

The fibroblast for tendon healing arises out of the supportive connective tissue in the area adjacent to the injury: paratenon, synovial sheath, epitenon, endotenon. When the majority migrate from the epitenon, the least amount of adhesions form.[23]

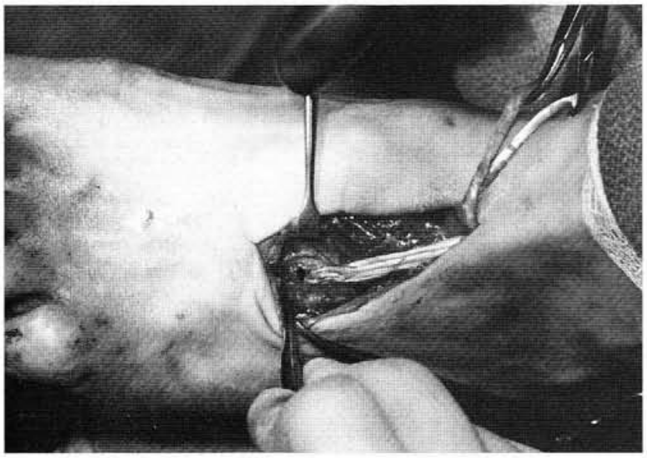

Figure 2. Cuneiform drill hole for insertion of a transferred tendon. This must duplicate the natural attachment of tendon to bone.

Tendons heal by progressive fibrosis and reconstitution of tendon, a process called "cicatrization and tendonization". The chronology of tendon healing is as follows. During the first week, there is an inflammatory reactive phase with cell exudate forming a jelly-like "fibroblastic splint". During the second week, there is increased vascularity and proliferation of fibroblasts, but still no tensile strength. Only the sutures hold the tendon ends together. Through the third week, there is vigorous production of collagen fibers, and moderate bond strength allows the starting of gentle exercises. During week four, the maturation or remodeling phase allows for collagen fiber alignment and cleavage from local tissues. There is a gradual return to slightly less than full strength. Progressive muscular force can now be applied.

The scar formed in a tendon repair is interpositional. It remodels, but does not return to the original histo-anatomy of tendon. Therefore, it does not blend with the undamaged portions of tendon, as is the case when ligament repairs remodel.

RESTORATION OF FUNCTION

Recent research has demonstrated that early motion, as opposed to long-term immobilization results in stronger tendon repairs, as well as less adhesions. Early activity stimulates the fibroblasts from the epitenon to conduct the majority of the healing.[23,24] When the suture repair is deemed strong enough, motion should start between one and two weeks; otherwise, no later than the end of the third week. Also important to preserve the gliding function is preservation or repair of the paratenon. Allowance for proper healing is followed by vigorous therapy to increase muscle strength.

SURGICAL CONSIDERATIONS

Several factors and principles should be observed that contribute to the success of tendon transfer surgery (Table 1). It is important not to damage the gliding surface of the tendon by rough handling, drying, manipulation with gauze, or grasping with toothed forceps. In order to preserve gliding function and blood supply, as well as to prevent adhesion formation, damage to the paratenon and synovial sheath should be avoided (Fig. 3).

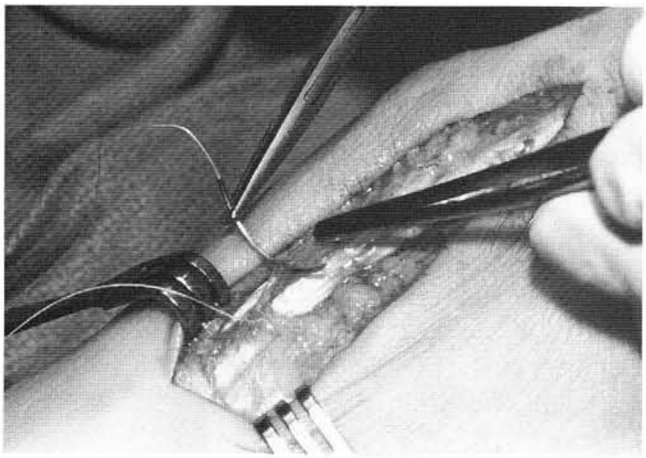

Figure 3. Repair of damaged paratenon will help restore gliding function.

Table 1

PRINCIPLES OF TENDON TRANSFERS

1. Select suitable cases.
2. Understand the anatomy and physiology involved.
3. Correct the local tissues for suppleness.
4. Correct fixed or structural deformities first.
5. Select proper timing for the transfer.
6. Select a suitable tendon(s).
7. Provide a direct or mechanically efficient line of pull.
8. Perform stabilizing procedures if necessary.
9. Preserve the gliding mechanism.
10. Utilize atraumatic technique at all times.
11. Preserve blood supply and innervation.
12. Provide adequate muscle-tendon tension on fixation.
13. Use secure fixation techniques.
14. Provide detailed postoperative management.

Fixation of tendon transfer can be performed by tendon-to-tendon suturing, (usually side-to-side anastomosis) (Fig. 4) or by a variety of tendon-to-bone techniques. These include the trephine plug, the periosteal flap, the buttress and button anchor, the three-hole suture technique, a screw and cleated washer, or the newer soft tissue bone anchors.

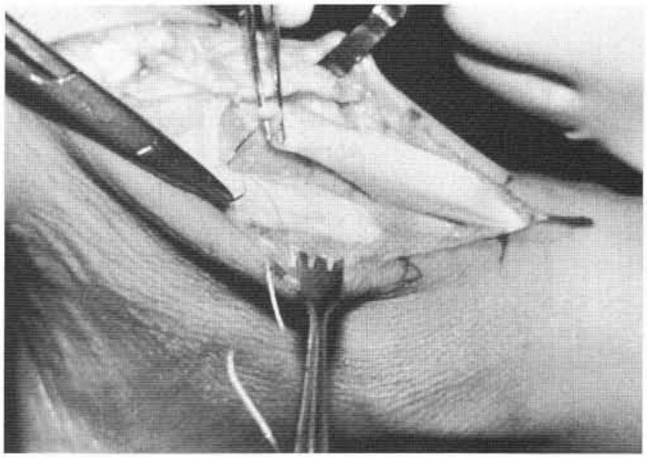

Figure 4. Suture of the transferred tendon by side-to-side anastomosis.

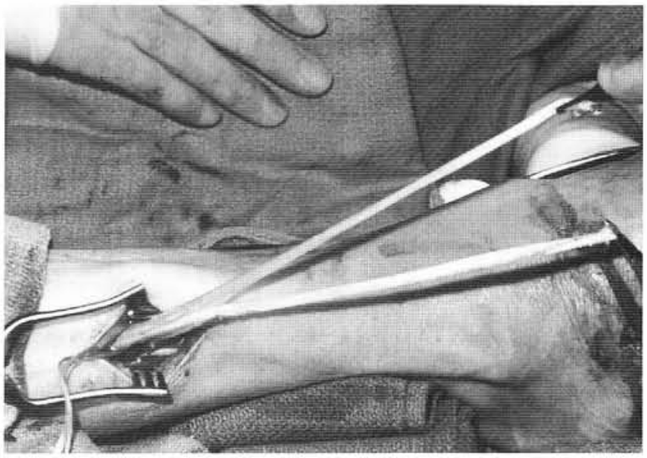

Figure 5. Split peroneus longus tendon to achieve dynamic muscular balance.

DEFINITIONS

Tendon transfer refers to the detachment of a tendon of a functioning muscle at its insertion and then relocating it to a new insertion or attachment.

Tendon transposition is the rerouting of the course of a normal muscle tendon without detachment, to assist other functions, sometimes known as a "tendon translocation".

Tendon suspension denoted those tendon procedures designed to support a structure, also known as a "tendosuspension".

Muscle-tendon transplantation is the detachment of a muscle tendon at both its origin and its insertion, and moving it to a new location along with its neurovascular support structures.

TENDON TRANSFER APPLICATIONS IN FOOT AND ANKLE SURGERY

The greatest application of tendon transfers is in the case of flexible deformities, where there is a dynamic muscular imbalance (Fig. 5). The following are some applications for tendon transfer surgery.

Flexor Digitorum Longus Tendon Transfer

Indications: Correction of flexible hammertoe deformities where rectus alignment is important, as well as when plantarflexory function and toe purchase needs to be maintained, improved, or enhanced.

Technique: Involves releasing the long flexor tendon at a digit and transferring it either by splitting it and passing it around the proximal phalanx or through a drill hole in the neck of the proximal phalanx and suturing it into the extensor tendon dorsally to itself or the periosteum.

Goals: Release digital flexion contracture forces and provide plantarflexion at the proximal phalanx and metatarsophalangeal joint to keep the digit rectus and functional.

Jones Tendosuspension

Indications:

A. Flexible cavus foot.
B. Flexible plantarflexed first ray, with or without hammered hallux.
C. Prophylaxis, when both sesamoid bones are removed.

Technique: The EHL tendon is rerouted through the neck of the first metatarsal and sutured back on itself. Usually the hallux IPJ is also fused.

Goals: Used to correct a cocked-up hallux and eliminate retrograde force at the metatarsophalangeal joint, which may be causing plantarflexion of the first metatarsal.

Hibb's Tendosuspension

Indications:

A. Flexible forefoot or metatarsal equinus, with or without clawtoes.
B. Flexible cavus deformity with clawtoes secondary to extensor substitution.

Technique: The long extensor tendons, (including the EHL if desired) are released, bound together, and transferred into the midfoot. The stumps of the longest tendons are then sutured into the existing brevis tendons.

Goals: Release of the contracting, retrograde buckling forces at the metatarsophalangeal joints, and reduction of plantarflexion on the forefoot. The transferred tendon improves dorsiflexion at the ankle.

Young's Tibialis Anterior Weakfoot Suspension

Indications: Symptomatic flexible flatfoot, usually in conjunction with other procedures.

Technique: The tibialis anterior is rerouted plantar medially through a posteriorly-directed slot in the navicular bone so as to provide a sling support mechanism.

Goals: To provide a sling support mechanism that helps to stabilize and partially realign the medial column for symptom relief.

Kidner Posterior Tibial Tendon Advancement

Indications: Used primarily when removing an os tibiale externum or cornuted navicular as well as to augment medial arch reconstruction in flexible flatfoot correction.

Technique: Involves detaching the larger portion of the posterior tibial tendon insertion at the navicular and advancing it either beneath the navicular or distally into the cuneiform or base of the first metatarsal.

Goals: To maintain or improve tension on the posterior tibial muscle-tendon complex, maintaining the foot in adduction across the midtarsal joint.

FDL Transfer for PT Dysfunction

Indications: Stage I or Stage II posterior tibial dysfunction when the deformity is still relatively flexible.

Technique: The FDL tendon is rerouted from its second compartment under the laciniate ligament into the compartment containing the tibialis posterior tendon. There it is advanced and sutured to the tibialis posterior tendon providing better tension on the tendon, and adduction on the foot.

Goals: To augment repair of a posterior tibial tendon rupture and increase the amount of tension on the posterior tibial tendon. Also to stabilize the foot across the midtarsal joint.

Split Tibialis Anterior Tendon Transfer (STATT)

Indications:

A. Spastic rearfoot varus.
B. Fixed equinovarus.
C. Excessive invertor power relative to evertor power.
D. Forefoot equinus with swing phase extensor substitution and clawtoes.
E. Flexible cavovarus deformity.
F. Excessive supination in gait.
G. Dorsiflexory weakness.

Technique: One-half of the tibialis anterior tendon is transferred, to be inserted laterally on the foot. It can be sutured to the peroneus tertius tendon or inserted in bone.

Goals: To create increased true dorsiflexion of the foot, and counters forces causing a varus or cavovarus position of the foot. Also to rebalance tendon function across the ankle joint.

Tibialis Anterior Tendon Transfer

Indications:

A. Recurrent clubfoot.
B. Flexible forefoot equinus.
C. Dropfoot.
D. Charcot-Marie-Tooth deformity.

Technique: Release tibialis anterior tendon from insertion, draw it up through its sheath and reroute it through the long extensor sheath to be reinserted dorsally in the midfoot area.

Goals: Reduce supinatory forces in the foot and increase strength or replace lost dorsiflexion power. Also to rebalance tendon function across the ankle joint.

Tibialis Posterior Tendon Transfer

Indications:

A. Weak or paralyzed anterior muscle group.
B. Equinovarus deformity.
C. Recurrent clubfoot deformity.
D. Dropfoot.
E. Charcot-Marie-Tooth disease deformities.
F. Permanent peroneal nerve palsy.

Technique: There are three different techniques used to reroute the tibialis posterior from its insertion medially to the dorsum of the foot either through the interosseus membrane, or around the medial malleolus subcutaneously.

Goals: To provide dorsiflexory power at the ankle joint when replacement is needed and other tendons are unavailable.

Peroneus Longus Tendon Transfer

Indications:

A. Anterior muscle group weakness.
B. Dropfoot deformity.

Technique: After the tendon is released near the cuboid, it is drawn up the lateral aspect of the leg, passed through the anterolateral muscular septum into the anterior compartment and delivered down the extensor pathway to the dorsum of the midfoot.

Goals: Effective treatment of loss of dorsiflexory muscle power at the ankle joint.

Murphy Procedure (Heel Cord Advancement)

Indications: Used primarily for young patients with cerebral palsy, or when spasticity of the triceps surae is causing an equinus deformity at the ankle. Weakens plantarflexory equinus forces by almost 50%.

Technique: The Achilles tendon is released from its insertion, and moved anteriorly into the superior surface of the calcaneus. It is usually rerouted anterior to the FHL tendon. This prevents the tendon from progressing back to its original insertion.

Goals: Shortens the lever arm about which the Achilles tendon must function, and thereby weakens the plantarflexory power of the Achilles tendon.

Peroneus Brevis Ankle Stabilization

Indications:

A. Lateral ankle instability.
B. Subtalar joint instability.

Technique: Can be used almost exactly in the same manner as the peroneus longus technique. Used in ankle stabilization procedures such as the Watson-Jones procedure, with the tendon passing through the fibular and sutured to itself more proximally than posterolateral leg. Another common ankle stabilization procedure involves rerouting the peroneus brevis or longus or portion thereof through the fibula to replace the ATFL and CFL.

Goals: The goals are similar to those of the peroneus longus technique. Otherwise used in stabilizing the lateral ankle.

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