TENDON GRAFTS AND IMPLANTS

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Injuries of tendons and ligaments are frequently seen by the podiatric physician. Management of these injuries can often be difficult. Their disruptive nature frequently leaves inadequate tissue with which to effect repair. Use of autologous structures for such reconstruction is the common solution. However, sacrificing a normal functioning units to act as a donor may itself produce difficulty. If the procedure utilizing autologous graft fails or is inadequate, the patient may be left with multiple compromised areas. Such considerations have fostered the search for prosthetic ligaments and tendons. Various materials such as silk, wire, silicone rubber, polytetrafluoroethylene (teflon), and synthetic polyesters have been used. However, their utilization has been limited due to their biological reactivity and lack of strength (1). The body recognizes these materials as foreign leading to undesirable inflammatory reactions. These early implants frequently failed when put under physiologic loads. The development of carbon fiber and xenograft implants has significantly decreased these complications.

Carbon Fiber Implants

In the early 70s, Benson (2) and von Fraunholer (3) suggested the use of carbon as an implantable material. Carbon was both biomechanically and biochemically compatible with living tissue. Investigations by Jenkins and associates, Wolter and associates, Claes and associates, Nurgebaurer and associates, and Forster have demonstrated that carbon can be used for tendon and ligament implants (4-8).

Originally there were three types of carbon implants available: pure carbon reinforced carbon, epoxy-based carbon, and filamentous carbon. Pure carbon has fallen into disuse because of its tremendous expense and extremely brittle nature. Epoxy-based carbon is similar to reinforced concrete in that the epoxy acts as the concrete and the carbon as the metal struts. The advantage of this formulation is that Young's modulus of elasticity can be altered by combining different proportions of carbon to epoxy. This material has both good biological and biomechanical acceptance. However, its use is limited due to the fact that it cannot be molded well and will not allow any twisting or bending. Epoxy-based carbon is still under investigation (9).

The most widely used carbon implant is the filamentous type. The carbon filaments are approximately 6-10 u in diameter. The actual tow or bundle is composed of approximately 10,000 fibers. The carbon filaments have a moderate degree of flexibility. These materials can therefore be bent and turned allowing easier implantation. The tows are coated with a polylactic acid polymer to protect the fiber on implantation. When multiple tows are utilized, the tensile strength is extremely good (10).

The carbon fibers have a special affinity for living tissue (4). Forster and associates (8) have described the carbon filament as acting like a scaffold. This material provides a matrix for the ingrowth of fibroblasts and for the deposition of new collagen. The composite provides mechanical strength until the new tissues mature. As the tissues develop there is a gradual mechanical degregation of the carbon fibers. This allows for proper orientation of developing tissues as the load is gradually transferred. In contrast, normal cicatrixation is initially disorganized. Gradually, realignment occurs during the remodeling phase in reaction to stress forces. The final result, when utilizing carbon fiber, is the stronger neotendon as compared to primary repair tendon (10). A shorter recovery period has also been associated with the use of carbon fibers (1).

The principle problem associated with carbon implants is their extreme brittleness leading to premature fragmentation. Alexander and associates (12) recognized this problem and began coating the carbon bundles with polylactic acid. This does tend to reduce handling problems but does not reduce the premature fragmentation. In sheep, carbon particles could be detected in the regional lymph nodes (13, 14). There was no associated tumor formation, no gross inflammation, and no disadvantage to the animal. These results have not been demonstrated in any other species including humans (9).

Intra-articular fragmentation of the carbon fibers produces a staining of the cartilage and synovium. Parsons and associates (15) suggested that these free carbon particles in the joint cause a mild reactive synovitis. However, early fragmentation in extra articular tissues does not cause any reaction within the tissue. The theory is that the minute carbon particles act much like talc, causing irritation to the articular tissues. The reaction initiated by the carbon however, is less intense than that of the talc. A further problem that may be encountered is tissue hypertrophy. The original mass of the carbon implant may be increased up to four times its original size (8). No mechanical disadvantage has been associated with this hypertrophy.

Bovine Zenograft

The first successful use of nonautogenous tissue was in replacement of human heart valves (16). The same formulation of collagen stabilized with glutaraldehyde (a five carbon dealdehyde) has been utilized for tendon and ligament implants. Collagen is one of the unique molecules of the body that can maintain a significant amount of structure and function after its removal from the organism. Chemical composition and function is quite similar from species to species. The combination of these characteristics allows collagen to be a successful prosthetic material (9). Tendon and ligament bioprotheses from bovine sources have produced an implant which is morphologically preserved, biomechanically competent and biocompatible. Fixation of the collagen with glutaraldehyde rendered the xenograft stronger, slightly stiffer, resistant to crude collagenase digestion, and storable at room temperature (17). Xenografts serve as a passive scaffold for the host tissue ingrowth. Electron microscopy has shown this ingrowth to be orderly, unlike that found in normal scar formation. Human and animal studies have proven this material to be biomechanically and biochemically compatible (16). Experiments have shown that on a size basis zenograft material is stronger than the ligamentous tissue it is replacing (17). More time, however, is necessary to determine if these results remain consistent.

Complications associated with the use of bovine zenografts have been few and are decreasing with increased utilization (9). The majority of the early complications were secondary to infection. They were hospital acquired and most likely related to intraoperative contamination. There were no infections that could be attributed to lack of graft sterility (9). In all cases to date that have resulted in infection, the implants were subsequently removed. This is due to the fact that the graft material can easily be infected, and with its impermeable nature it would be very hard to receive adequate levels of antibiotics. In recent work no additional cases of infection have been noted (16).

The second most common complication was a chronic non-specific synovitis. Although this appeared in a low number of cases, there were a few grafts that had to be removed to reduce the joint effusion (9). A final point is stressed that excessive slack or tension applied to the graft can lead to joint restriction of motion or inadequate stabilization.

Indications

Implants may be used following most tendon and ligament injuries in the leg and foot. The greatest experience is following tendo Achillis ruptures (acute or chronic) and medial or lateral ankle ligament disruption. In 1981, Aragona and associates (10) reported excellent results, utilizing filamentous carbon fiber to repair large deficits in rabbit achilles tendons. When compared to autogenous tendon grafts, shorter time and more efficient repair was obtained when using the carbon fiber implants. In reports published by Parsons and others, repair of Achilles tendon ruptures in humans with filamentous carbon implants have been quite successful (9, 11, 14, 18, 19). Following implantation, the patient's convalescent period was reduced, postoperative strength was increased and the incidence of reoccurrence was decreased (9).

The procedure described by Weiss and associates (19) utilizes four carbon bundles. Initially, the carbon tow is pulled halfway through the proximal end of the Achilles tendon, about 2-3 inches proximal to the rupture site (Fig. 1). One half of the tow is then woven distally through the length of the tendon using a locking stitch technique. The end is brought out through the rupture site, across the gap into the distal portion of the tendon (Fig. 2). The tow is then woven 4-5 times in the distal portion using the locking stitch technique (Fig. 3). The remaining half of the tow is then woven distally in the same manner (Fig. 4). The ends should be cut to the tissue level and secured with a locking suture. This process is repeated three more times (one proximally, two distally) completing eight passes across the defect with excellent tensile strength (3200 N). The patient is placed in a below knee cast non-weightbearing for approximately 3-6 weeks depending on the extent of the injury and age of the patient. Over the next four weeks the patient is gradually rehabilitated (11).

Ligament implants have been used rather extensively in repairing chronic ankle instability. The advantage over autogenous graft is that it does not involve the use of the peroneal tendons and provides versatility of the repair. By the utilization of carbon or bovine xenografts one can actually replace a particular disrupted ligament. In lateral ankle instability, the talofibular component can be stabilized without compromising the subtalar joint. An example of this repair is demonstrated in Figure 5. Procedures currently utilized for correction of this deformity cross an otherwise stable subtalar joint leading to restriction of motion.

When using carbon implant in ligament repairs some precautions must be remembered. The carbon tows are brittle and therefore should not be submitted to sharp turns, twisting or frequent knotting (19). Entrance and exit holes in bones should be smooth to prevent fraying. Metal anchoring devices should not be employed. Metal reacts with the carbon causing a degredation in the metal. Special instrumentation and carbon fasteners as described by Strover should be utilized (20).

Studies reveal excellent results when carbon fibers are used for medial and lateral ankle ligament complex repairs (9, 14). The majority of patients obtain stabilization without a reduction in motion. Failures have mainly been related to irritation by shoe gear over the carbon implant. This has not been a factor with the use of xenografts.

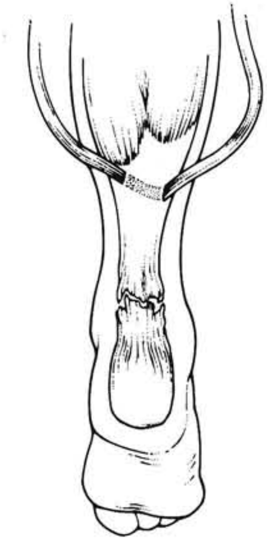

Fig. 1. Initially carbon tow is pulled halfway through proximal end of injured achilles tendon. (Adapted from Weiss AB, Hatam M, Alexander H: Surgical protocols for PLA-carbon ligament implants. *Contemporary Orthopedics* 7:41, 1983.)

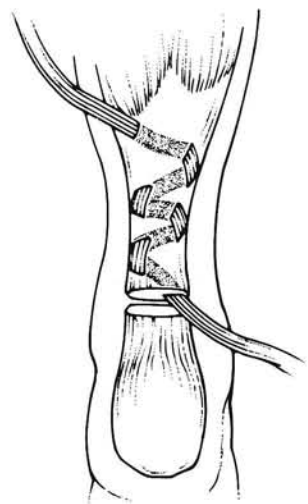

Fig. 2. Half of carbon tow is woven distally using locking stitch technique.

Fig. 3. Tow crosses the defect and is woven through distal end of torn Achilles tendon.

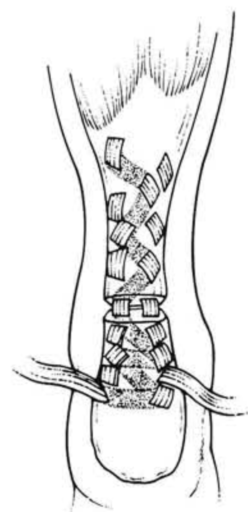

Fig. 4. Remaining half of carbon tow is woven through proximal and distal portions of tendon.

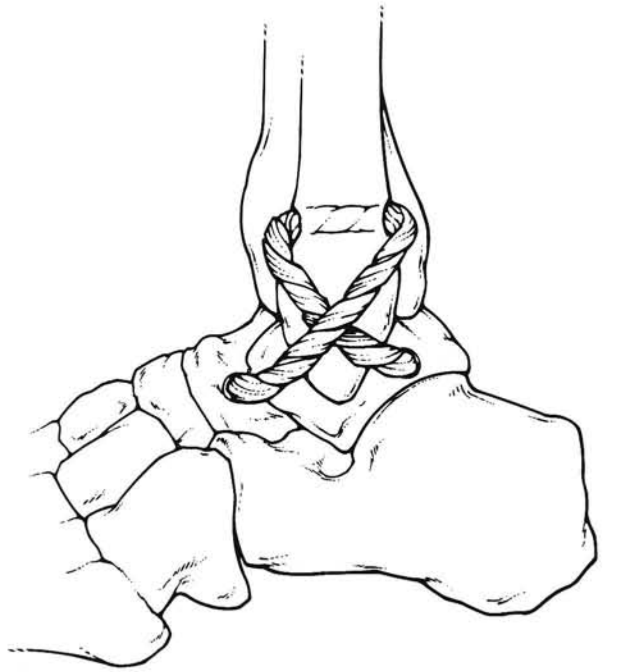

Fig. 5. One method of repair for lateral ankle instability. Carbon tow is passed through lateral malleolus from anterior to posterior and is anchored into lateral talar body. (Adapted from Jenkins DHR: *Ligament Injuries and Their Treatment.* Rockville, MD, Aspen Publications, 1985, p 240.

Summary

Obviously, implants are not indicated in all tendon and ligament injuries. However, in extremely disruptive or chronic injuries, graft materials can be utilized. Many materials have been investigated, but carbon fibers and Bovine xenografts seem to be the most applicable. These implants are biochemically and biomechanically acceptable. A few indications and procedures have been discussed. Studies have indicated these substances have been well tolerated and have provided excellent results. Further time and increased utilization is necessary to determine the full potential of these implantable materials.

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