An Original Study

Intraosseous and Extraosseous Attachments of Flexor Tendon to Bone: A Biomechanical In Vivo Study in Rabbits

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Abstract

There are 2 popular methods of repairing flexor tendons to the distal phalanx and attaching a free tendon graft to bone: intraosseous, by implanting the tendon into a bony tunnel, and extraosseous, by suturing the tendon to the cortical surface after elevating the periosteum. An in vivo study was designed to determine whether one method is stronger than the other.

The profundus flexor of the third and fourth toes of the hind paw of adult rabbits was divided and reattached to the middle phalanx using either an intraosseous tunnel or an extraosseous suture. Half the rabbits were killed after 3 weeks, the other half after 8 weeks. Repairs were then tested to failure, using an Instron device, and compared with the same tendons in the nonoperated limbs. The repaired tendons demonstrated similar strength 3 weeks and 8 weeks after surgery but were significantly weaker than the nonoperated tendons.

The importance of this study is that it gives equal credence to these usual methods of tendon attachment.

Attachment of a flexor tendon to the distal phalanx after an acute laceration or avulsion and reconstruction with an autogenous graft are common surgical procedures. Popular methods are *intraosseous*[1,2] (inserting tendon into trough in bone) and *extraosseous*[3,4] (suturing tendon to bone surface). The rationale for the intraosseous method is that it promotes formation of Sharpey fibers, the normal pattern by which tendons attach to bone, and therefore provides a more secure fixation than with extraosseous fixation. Although numerous studies have compared tendon–tendon suture techniques, few have analyzed the tendon–bone interface after repairs or reconstructions.

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Materials and Methods

In this study, the right hind paw of 20 skeletally mature adult male New Zealand white rabbits was used with institutional review board approval. The skin on the plantar surface of the second and third toes was incised and the underlying flexor digital sheath exposed. The sheath in both digits was then incised, and the flexor digitorum profundus was severed at its insertion. In one toe, the profundus was repaired by inserting the tendon into bone (intraosseous method); in the other toe, the tendon was attached to the surface of the bone (extraosseous method). The middle rather than distal phalanx was used because in rabbits it is a significantly wider bone and therefore less likely to fracture when the trough is made.

For the intraosseous method, a hole was made in the volar cortex of the middle phalanx distal to the insertion of the superficialis flexor. Nylon 5-0 was sutured into the end of the tendon using the Lister[5] modification of the Kessler[6] method, and each end of the sutures was passed dorsally through the hole using Keith needles. Traction on the suture pulled the tendon into the bone, and then the suture ends were tied over a cotton pad to avoid any pressure irritation of the dorsal skin. A similar suture was placed in the tendon of the other toe, but, instead of a hole being drilled into the middle phalanx, the periosteum was elevated and the bony surface roughened with a scalpel blade, and each limb of the suture was then passed around the side of the phalanx, through the dorsal skin, and tied over a cotton pad.

The animals were divided into 2 groups of 10 each (groups A and B). In group A, the intraosseous method was used for the second toe, and the extraosseous method for the third toe; in group B, the intraosseous method was used for the *third* toe, and the extraosseous method for the *second* toe. After each repair, the skin was closed, a sterile dressing was applied, and the limb was casted with the hock joint in 90° of flexion. Three weeks after surgery, 5 animals from each group were killed, and the remaining rabbits were relieved of their casts (these rabbits were allowed to move freely in their cages until 8 weeks after surgery, at which point they were also killed). At time of sacrifice, both operated and nonoperated limbs were harvested and frozen.

The limbs were defrosted 24 hours before dissection. All the flexor tendons were exposed in the region of the hock joint, and the flexor digitorum flexor tendons of the first and fourth toes were divided. The common muscle belly of the profundus was then split longitudinally, leaving half of the muscle connected to the profundus tendon of the second toe and the other half connected to the tendon of the third toe. The same procedure was carried out on the nonoperated hind limbs. The limb was then disarticulated at the hock joint, and a 0.062-inch Kirschner wire (K-wire) was inserted transversely into the middle phalanges distal to the sites of tendon repair and into the middle phalanges of the nonoperated second and third toes. There was no visible evidence that any of the repairs had failed. The proximal end of the second and third profundus tendons (normal and reattached) was fixed to a pneumatic grip with 2 serrated plates. With use of an Instron machine digitally linked to a microprocessor, each tendon was loaded at 5 mm/s until failure.

The specimens were not preconditioned before loading to failure. Ultimate loads were documented. Statistical analysis was performed with analysis of variance (ANOVA) and the Levene test.

Results

All animals survived the surgery and remained healthy until sacrifice. There were no infections and no loss of immobilization. At testing, 38 of the 40 repaired tendons failed at the suture site, and there were 2 bony avulsions. Failure of the control tendons occurred because of tendon avulsion (28), bony avulsion (6), midsubstance tendon rupture (3), fracture at K-wire (1), and rupture at lower Instron grips (2). For both tendon repair groups, mean load to failure was considerably less 3 weeks after surgery (16 N) than 8 weeks after surgery (51.5 N). Mean load to failure of the nonoperated second and third control tendons was 91 N (SD, 16 N) 3 weeks after surgery and 100 N (SD, 20 N) 8 weeks after surgery. Mean load to failure 3 weeks after suture was slightly greater with the intraosseous method (17 N; SD, 4 N) than with the extraosseous method (15 N; SD, 5 N). At 8 weeks, mean load to failure was 45 N (SD, 16 N) with use of the intraosseous suture and 58 N (SD, 19 N) with use of the extraosseous method. The differences between the 2 methods of tendon suturing at both 3 and 8 weeks after surgery were not statistically significant when analyzed using both ANOVA and the Levene test.

Discussion

Controversy persists regarding the biology of tendon-to-bone healing, and there is no consensus regarding the optimal method of fixation of tendon to bone. Few in vivo studies have compared intraosseous and extraosseous techniques. Kerwein[7] wrote, “Experience has demonstrated that firm anchorage is best obtained when a tendon is implanted into bone,” and the “anchorage is due to the gradual ossification and incorporation of the tendon in bone.” His observations were based primarily on clinical experience. Rodeo and colleagues[8] arrived at the same conclusions after transplanting the long digital extensor tendons of mongrel dogs into holes made in the proximal tibia: “Collagen fibers that attached the tendon into bone resembled Sharpey’s fibers with remodeling of the trabecular bone at the tenorraphy site.” They observed that pleuripotential cells originating from the bone marrow were responsible for the initial healing of the tendon and that, with time, bone eventually grew into the tendon. The findings of Liu and colleagues,[9] who studied the healing of rabbit hallucis longus tendons inserted into calcanei, were similar. They reported that the tendon–bone attachment consisted of type III collagen resembling Sharpey fibers. They also acknowledged that they could not conclusively demonstrate the formation of these fibers. Other investigators have had conflicting findings. Brooks[10] and Jones and colleagues[11] concluded that, when a tendon was inserted into bone, healing occurred at the periosteal surface rather than by osseous integration—an opinion shared by Hausman and colleagues[12] based on their in vivo experiments. St Pierre and colleagues[13] studied the effects of repairing the infraspinatus tendon in goats using both intraosseous and extraosseous methods. They noted no differences in stiffness or load to failure 6 and 12 weeks after surgery. Histologic evaluation of both types of repair showed similar healing through an array of collagen fibers extending from bone to tendon. They concluded that these fibers are identical to Sharpey fibers. Shaieb and colleagues[14] also studied both methods of tendon repair, using the Achilles tendon in rabbits, and noted no difference in tensile strength. They found that, after the intraosseous method was used, the portion of the tendon within the bone gradually resorbed.

The purpose of our study was to determine whether there is any difference in load to failure between the intraosseous and extraosseous methods of attaching rabbit digital flexor tendons to bone. These methods yielded similar results both 3 and 8 weeks after surgery. In 38 of the 40 repairs, failure was at tenorraphy, a figure that is greater than for the controls, where there were 28 insertional avulsions. This difference is consistent with the significant differences in load to failure between repairs and controls. The similarity of the results of the 2 surgical techniques suggests that these methods would produce similar results in humans and reinforces the comment made by Forward and Cowan[15]: “The differences in the results of various methods may depend more on the skill and experience of the individual surgeon than on a particular advantage of the method used.”

An obvious weakness of this study is that we used an animal model and results might be different in humans. We chose not to sacrifice and to test the strength of nonoperated rabbit flexor tendons, as the main purpose of this study was to compare methods of tenorraphy. Therefore, we cannot report what the “normal” load to failure is for such animals. The force required to cause rupture of the 8-week control tendons did average 9 N more than the force for the 3-week controls, indicating that the extra weight carried by the nonimmobilized limb may have led to stronger tendon attachment. However, this difference was much less than the differences between controls and repairs.

Authors' Disclosure Statement

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