Semitendinosus tendon graft ingrowth in tibial tunnel following ACL reconstruction

A histological study of 2 patients with different types of early graft failure

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Case 1

Due to a previous trauma, a 26-year-old man had an initial ACL reconstruction of his left knee in November, 1996, utilizing a quadruple semitendinosus tendon graft fixed with an endobutton on the femoral side and 2 screws with washers on the tibial side, as described by Rosenberg (1992) and Barrett et al. (1995). He was rehabilitated according to a standard protocol, which includes full weight bearing and early motion training. He had a functionally and clinically stable knee 3 and 6 months after surgery. He was able to start playing soccer again 6 months postoperatively. Unfortunately, he sustained another trauma in the same knee 7 months postoperatively. Arthroscopy showed a distal intra-articular substance tear of the ACL graft (Figure 1). Despite adequate physical therapy, he suffered from his ACL instability and subsequently underwent revision surgery. 1 year after the primary reconstruction, he underwent revision with a bone-patellar tendon-bone graft taken from the ipsilateral knee. Since the primary tibial tunnel had been in adequate position, it allowed us to core out a tunnel, 10 mm in diameter and approximately 40 mm in length, containing the old tendon graft with its surrounding bone. The graft remnant was approximately 25 mm in length and located in the proximal part of the tunnel. Thus the biopsy specimen consisted of a full-thickness graft remnant and the surrounding bone of the tibial tunnel. The specimen was fixed in formalin, decalcified and embedded in paraffin. It was cut into transverse and longitudinal 5-micron sections in different parts and stained according to standard techniques with hematoxylin and eosin and van Gieson's trichrome stain. Standard light and polarization microscopy were used.

Macroscopically, the tendon appeared to be integrated with the surrounding bone around the whole circumference of the tunnel. The 4 strands of the tendon were fused into one tendinous cord.

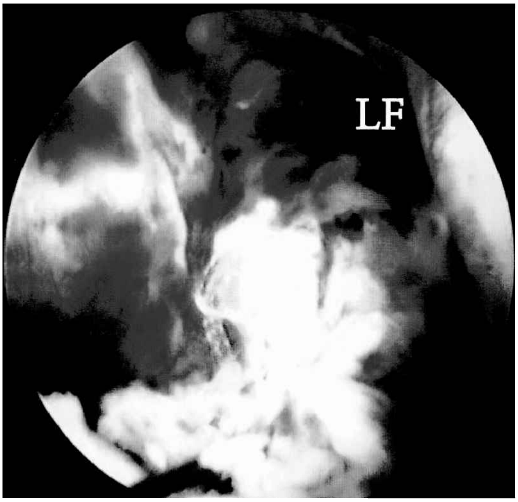

Figure 1. Arthroscopic view (case 1) of an intra-articularly torn ACL graft (quadruple semitendinosus) close to its tibial insertion. Note the bleeding from the synovial sheet. Lateral femoral condyle (LF) indicated for orientation.

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No obvious signs of degeneration were noted. Microscopically, the quadruple semitendinosus graft, examined at various levels in longitudinal and transverse sections, was found to have fused into one tendinous cord with a normal tendinous structure and normal vasculature. Thus the distribution and parallel arrangement of collagen fibers were normal (Figure 3). The tendon graft was entirely integrated with the surrounding bone tunnel, as illustrated by continuity between tendon tissue and the surrounding bone with an interface zone containing hyaline and fibrous cartilage. In polarized light, the continuity of the tendon tissue with the bone was even more obvious; continuous collagen fibers, resembling Sharpey's fibers, extended from the tendon into the bone (Figure 3).

Case 2

A 24-year-old man had his initial ACL reconstruction performed in January 1998. A quadruple semitendinosus with the same endobutton technique was used. No complications were reported at the time of surgery and postoperative radiographs showed no inadequacy of the implants (endobutton proximally and screws distally below the tibial tunnel). No obvious malpositioning of the tibial tunnel was noted. The same rehabilitation protocol as in case 1 was used. 3 months after surgery, his knee was found to be extremely unstable in the Lachman and anterior drawer tests. There was no history of postoperative trauma. Clinically, instability was of the same degree as before surgery. He continued physical therapy, but the functional instability was so severe that a diagnostic arthroscopy was performed 11 months after surgery. The whole graft was found to be severely degenerated intra-articularly and most of it was virtually gone. The suture material used for the initial fixation remained in the form of a "graft skeleton" that hung between the femoral and tibial insertions (Figure 2). No other pathological condition, except slight synovitis, was noted intra-articularly. The sutures were removed with a shaver and revision surgery of the ACL was planned. During this procedure, which was done using a bone-patellar tendon-bone graft from the contralateral knee, the earlier tibial tunnel was harvested in the same way as in case 1. The specimen was prepared and examined in the same way. In addition, an immunocytochemical analysis employing monoclonal antibodies for CD 68 (a macrophage marker) was performed to assess some of the histological findings better.

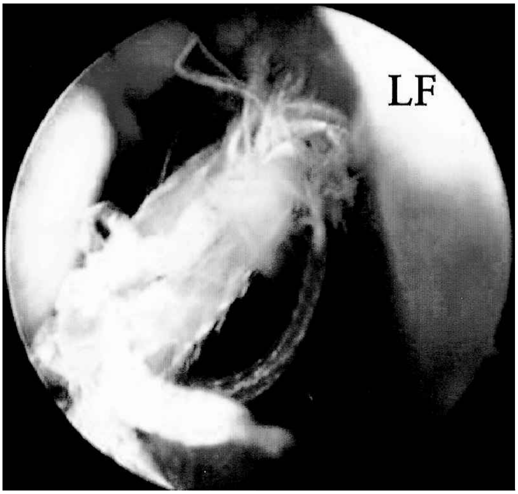
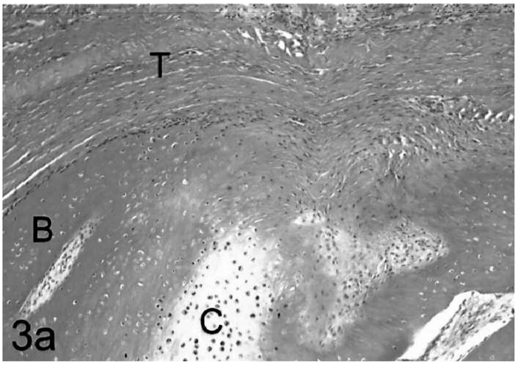
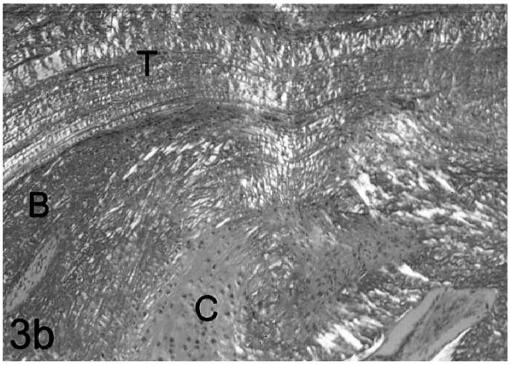
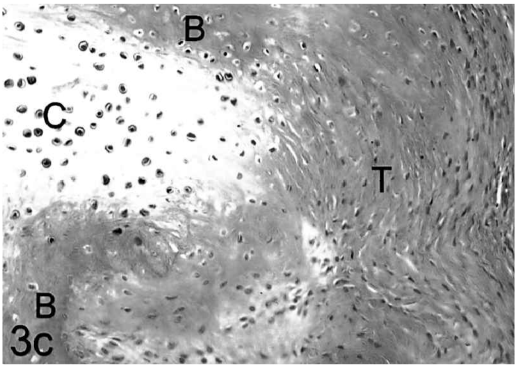


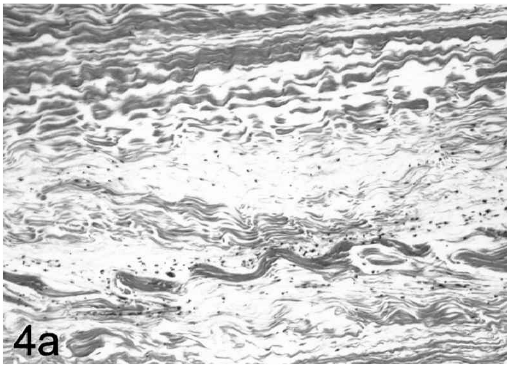
Figure 2. Arthroscopic view (case 2) of a degenerated ACL graft (quadruple semitendinosus) in which the non-resorbable ethibond sutures, used as whip stitches, are still in place while the graft material is missing. Lateral femoral condyle (LF) indicated for orientation.

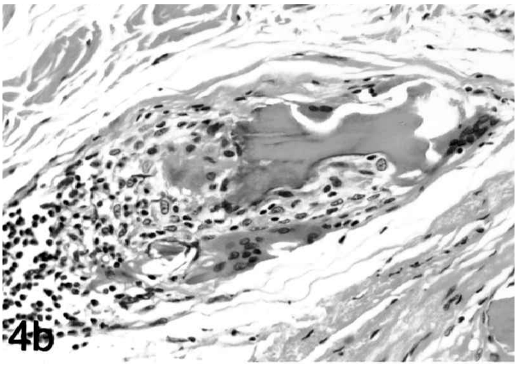
Clinically, the patient had persistent swelling of the knee, a sign of chronic synovitis. Macroscopically the specimen looked degenerated and "spongy" in its tendinous part and the transition zone between the tendon and surrounding bone was not well defined, before or after it was cut into longitudinal and transverse sections. In some parts, however, the macroscopic impression was that the tendon tissue had "fused" with the bone. Microscopically, the tendon tissue showed severe degenerative changes, the collagen fibers in many parts being dissolved and replaced by loose myxoid tissue and areas of resorption with clusters of macrophages (Figure 4). In contrast to the macroscopic appearance of at least partial integration of the tendon graft and bone in some areas, the microscopic picture revealed extensive resorption of the surrounding bone. Lymphocytes, macrophages and numerous osteoclasts surrounded small islands of degenerated or necrotic bone. The immunocytochemical stains for CD 68 highlighted the macrophages and osteoclasts.











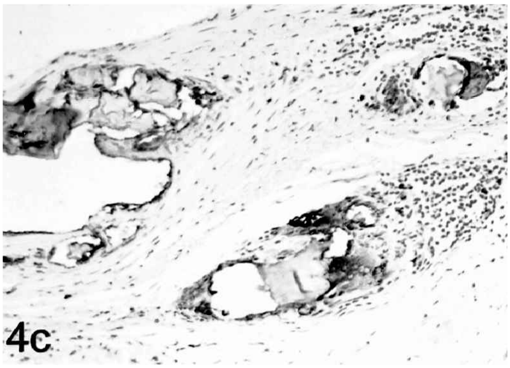


Figure 3. Case 1.
A. The tendon graft (T) has a normal appearance and is attached to the bone (B) of the tunnel wall. Focally, the tendon is continuous with bone and areas of cartilage (C). (HE, ×90).
B. Same area as in A examined under polarized light, which enhances the normal structure of the tendon and the fusion between tendon, bone and cartilage. (HE, ×90).
C. High power illustration of the area presenting features of normal tendon insertion. (HE, ×200).

Figure 4. Case 2.
A. Tendon graft with severe myxoid degeneration, loss of collagen fibers, marked reduction in cellularity and focal accumulation of macrophages. (HE, ×120).
B. Resorption of necrotic bone fragments; the bone is surrounded by macrophages, multinucleated osteoclast-like giant cells, and lymphocytes. (HE, ×200).
C. Immunostaining for CD 68 highlights the macrophages surrounding bone fragments within the periphery of the bone tunnel. (HE, ×120).

Discussion

One of the crucial factors in successful anterior cruciate ligament (ACL) reconstruction is the potential for graft integration with the bone tunnels. In a dog model, Rodeo et al. (1993) found a gradual ingrowth of the long digital extensor tendon into the surrounding bone in a drilled hole in the proximal tibia. They concluded that, by 8–12 weeks, the tendon-bone interface gradually sembled that of a normal tendon-to-bone insertion. However, Hausman and Rubin (1989) found no evidence of osseous ingrowth into the transplanted tendon in a goat model and they suggested that metaphyseal bone could not heal and fuse with tendon tissue. Very few studies have analyzed these matters in humans.

In our material of 110 consecutive patients, we found 2 cases of early mechanical ACL graft failure, one traumatic and the other with no history of trauma. They illustrate different fates of the semitendinosus tendon graft intra-articularly in the knee and intraosseously in the tibial tunnel. In case 1 complete osseointegration of the graft had taken place, with continuity of the collagen fibers of the tendon and bone and with formation of an interface resembling that of a normal tendon-to-bone insertion, i.e., a transition zone with hyaline and fibrous cartilage as well as continuous collagen fibers, resembling Sharpey's fibers. In a case report, Pinczewski et al. (1997) emphasized the importance of the interference screw for creating direct contact of the tendon with the bone to stimulate tendinous ingrowth. They also described continuity of the collagen fibers and the surrounding bone. In our study (case 1), osseointegration took place without an interference screw, and it seems that so long as the tunnel diameter corresponds to the graft, this is possible without fixation with an interference screw. These findings are also in line with animal studies in which tendons became integrated with the surrounding bone in predrilled holes (Kernwein 1942, Whiston and Walmsley 1960, Forward et al. 1963, Rodeo et al. 1993, St Pierre et al. 1995, Liu et al. 1997). Another difference between our findings and those of Pinczewski et al. (1997) is the histological appearance of the tendon in the tunnel. In their 2 cases, the tendon was dense and acellular centrally while in our case 1, it closely resembled normal tendon tissue. What implications this may have on the pull-out strength, graft survival, or the ingrowth potential of the graft remain to be investigated. Judging from the reported graft failure rate in the interference screw series of Pinczewski et al. (1997) and ours, both techniques seem adequate for graft fixation. However, with the development of a dense, acellular graft in the tibial tunnel, the conditions for optimal vascularization of the graft may be jeopardized.

In case 2, the clinical picture even at 3 months after surgery indicated failure of graft function and severe laxity of the knee in the sagittal plane. There were no clinical signs of infection and the patient had not suffered another injury. The lack of tendinous ingrowth on histological examination may be related to compromised vascularization of the graft-bone interface. Previous animal studies of the blood supply and revascularization of ACL grafts indicate that the tibial bone insertion does not contribute to vascularization of the intra-articular parts of the graft and that the main blood supply of the ACL comes from the infrapatellar fat pad and the synovial tissue dorsally in the knee (Arnoczky et al. 1979, Arnoczky et al. 1982, Arnoczky 1983, Arnoczky 1985). According to these findings, the vascularization of the intra-articular portion of the graft would not be hampered by inadequate tendon-to-bone healing in the tibial tunnel. The reasons for failure, as in our case, remain unclear. In other reports, early clinical signs within 6–12 weeks provide a good assessment of the stability, ingrowth potential and function of the graft (Rodeo et al. 1993 and Pinczewski et al. 1997), indicating that impaired revascularization of the graft might explain the failure in case 2.

Our 2 cases differ from the study in dogs by Rodeo et al. (1993) as their tendon implants cannot be considered free grafts since the distal insertion of the long digital flexor muscle in their cases was left intact. Moreover, their implants were not stretched across a joint with more or less continuous motion and exposure to synovial fluid as in our cases. Despite these differences, the graft in our case 1 healed, integrated itself with the surrounding bone and gave a stable knee.

The reason for failure in case 2 can only be speculated on. Several factors, such as mismatch in graft and bone tunnel diameter, revascularization disturbances by excessive suture tension on the tendinous strands of the graft and a synovial fluid pump effect in the bone tunnel, might be involved. High suture tension could also jeopardize the microcirculation in the graft and thus cause graft degeneration.

In conclusion, our findings and those of previous animal studies indicate that a four-stranded semitendinosus tendon graft can promote normal tendon-to-bone ingrowth. Moreover, the four-stranded graft can fuse into one histologically normal appearing tendinous cord inside the bone tunnel in contrast to that observed after the interference screw fixation procedure of Pinczewski et al. (1997). Our study also shows that ingrowth failure presents with early clinical signs of instability and persistent synovitis.

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