Autodigestion of a Hamstring Anterior Cruciate Ligament Autograft Following Thermal Shrinkage

A Case Report and Sentinel of Concern*

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Thermal and laser heat shrinkage of collagen recently has been proposed as a means of treating selected cases of shoulder instability[12]. While such treatment is controversial, clinical reports of capsular shrinkage procedures involving the shoulder have shown limited but promising results[1,2,9,10]. Thermal technology also has been applied to the treatment of anterior cruciate ligament laxity in the knee[11]. Basic-science investigators have elucidated the macroscopic and molecular changes that occur in the collagen fibrils following thermal shrinkage[3-7]. However, long-term clinical follow-up to determine the integrity of these structures following thermal shrinkage is still lacking.

We present the case of a patient in whom an endoscopic reconstruction of the anterior cruciate ligament was performed with a hamstring autograft, which, following reinjury, underwent thermal shrinkage. The findings at arthroscopy, both during the initial thermal shrinkage and at fifteen weeks postoperatively, are discussed.

Case Report

A sixteen-year-old female athlete sustained an anterior cruciate ligament tear while twisting her left knee during a basketball game. She subsequently underwent an arthroscopically assisted reconstruction of the anterior cruciate ligament with a semitendinosus-gracilis graft and a partial lateral meniscectomy. The graft, a four-bundle construct, was secured to the femur with endobutton fixation (Smith and Nephew, Memphis, Tennessee), and it was secured to the tibia with a soft-tissue interference screw and suture fixation. Following the reconstruction, the intraoperative Lachman test was negative.

Postoperatively, the patient followed a regimented, physical-therapist-monitored protocol that included progressive range-of-motion and strengthening exercises. Four months postoperatively, physical examination revealed a negative pivot-shift test and a grade of 1+ (less than five millimeters of side-to-side difference), with a firm end point, on the Lachman test. Evaluation of laxity with a KT-2000 arthrometer (MEDmetric, San Diego, California) revealed that the value on the affected side was within three and one-half millimeters of that on the normal side on maximum manual testing. Testing with a dynamometer (Biodex, Shirley, New York) revealed quadriceps and hamstring torques of 83 and 41 percent of body weight, respectively, on the involved side compared with 95 and 47 percent of body weight, respectively, on the contralateral side. On the basis of these parameters, the patient was allowed to progress to full activity.

Five months following the initial reconstruction, the patient sustained a twisting reinjury to her left knee and felt a pop, with immediate pain and swelling. Clinical examination suggested an injury to the anterior cruciate ligament graft as well as a medial meniscal tear. Magnetic resonance imaging revealed a medial meniscal tear and showed the anterior cruciate ligament graft to be in continuity. An examination with the patient under anesthesia revealed a grade of 2+ on the pivot-shift-test and a grade of 2+ (five to ten millimeters of increased anterior-posterior translation compared with the normal side) on the Lachman test. Arthroscopy demonstrated an irreparable bucket-handle tear of the medial meniscus and showed that the anterior cruciate ligament graft was in continuity but had severe laxity (Fig. 1). The medial meniscal tear was debrided, and, since the anterior cruciate ligament graft appeared to be intact with no evidence of bleeding, a thermal heat probe (ORATEC; ORATEC Interventions, Menlo Park, California) with radiofrequency current to induce collagen shrinkage was used to tighten the graft. This procedure was performed at 65 degrees Celsius and forty watts of energy, as recommended by the manufacturer. The intra-articular portion of the anterior cruciate ligament graft shrank (Fig. 2); it then was probed to verify that appropriate tension had been achieved. Following the shrinkage procedure, an intraoperative Lachman test revealed no increased anterior tibial translation compared with the uninjured side.

Postoperatively, the patient participated in an active rehabilitation program with protection of the thermally treated graft for twelve weeks. Physical examination of the knee at twelve weeks revealed a negative pivot-shift test and a grade of 1+ on the Lachman test, and the patient was allowed to progress to full activity. One week later, she sustained a noncontact reinjury to her left knee, which produced functional instability. Physical examination revealed a grade of 3+ (greater than fifteen millimeters of anterior translation of the tibia on the femur), with no appreciable end point, on the Lachman test.

Approximately two weeks following the reinjury, a revision anterior cruciate ligament reconstruction with use of a bone-patellar tendon-bone autograft and a medial meniscal repair were performed arthroscopically. During the procedure, no remnant of the previous hamstring autograft was identifiable in the notch between the tibial and femoral tunnels (Figs. 3-A and 3-B). Following the reconstruction, an intraoperative Lachman test was negative. Nine months following the revision, the patient had no subjective instability and the Lachman test was negative.

Discussion

Thabit reported using a monopolar device to treat native and reconstructed anterior cruciate ligaments that were lax but in continuity[11]. He recommended leaving

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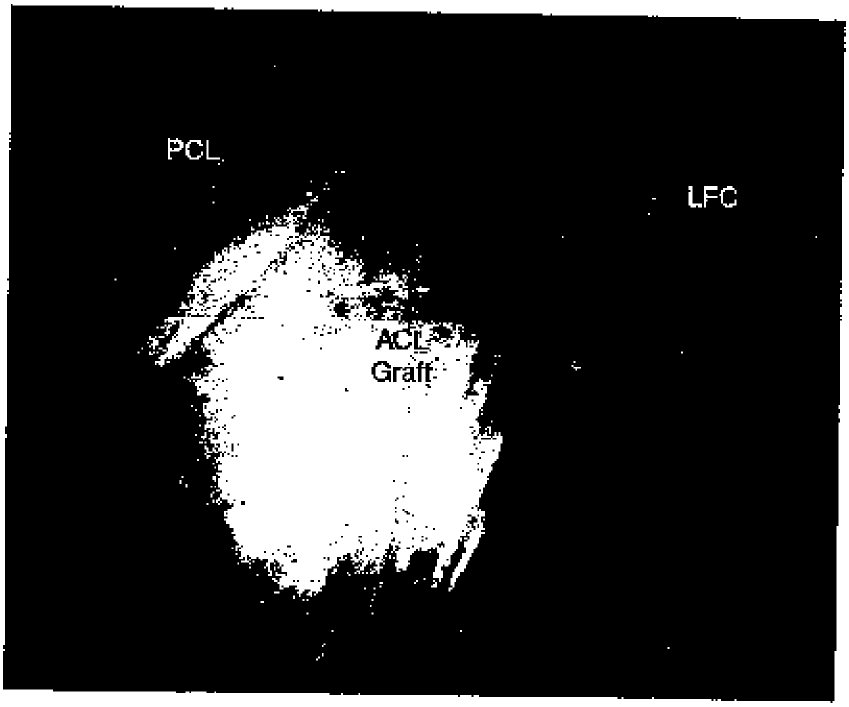

FIG. 1

Figs. 1 through 3-B: Arthroscopic views of the left knee.
Fig. 1: The hamstring anterior cruciate ligament autograft (ACL Graft) is shown after the reinjury. Although the graft had severe laxity, it was in continuity. PCL = posterior cruciate ligament, and LFC = lateral femoral condyle.

the posterior aspect of the ligament untreated to allow for revascularization and suggested a three to six-month period of activity modification and rehabilitation after radiofrequency treatment of the anterior cruciate ligament, prior to return to full activity. In an anecdotal report on twenty-five patients who were thus treated and

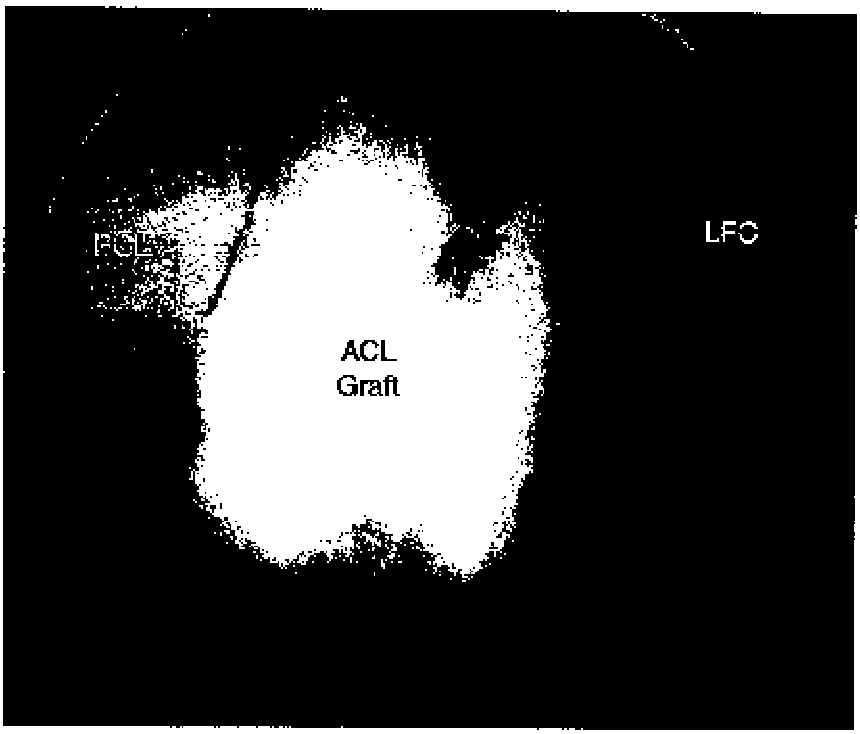

FIG. 2

The hamstring anterior cruciate ligament autograft (ACL Graft) is shown after heat-probe treatment. PCL = posterior cruciate ligament, and LFC = lateral femoral condyle.

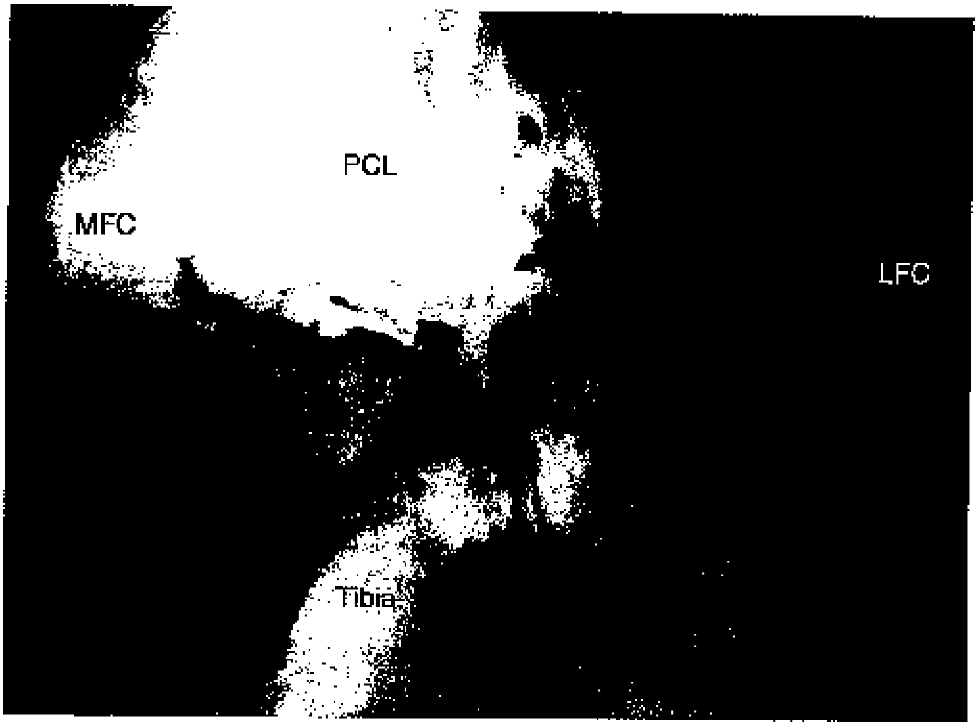

FIG. 3-A

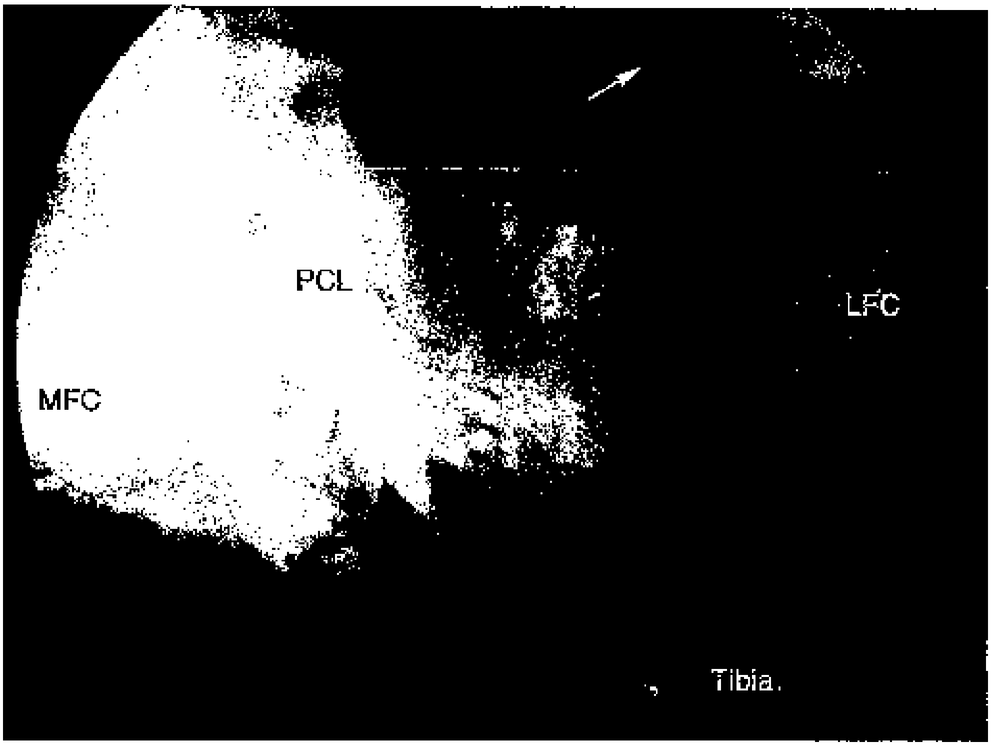

FIG. 3-B

Figs. 3-A and 3-B: Fifteen weeks after thermal shrinkage of the autograft and two weeks after the reinjury. Nothing resembling an anterior cruciate ligament graft was seen in the notch between the tibial and femoral tunnels. (The arrow points to the femoral tunnel.) PCL = posterior cruciate ligament, LFC = lateral femoral condyle, MFC = medial femoral condyle, and tibia = tibial plateau.

were followed for a maximum of 1.5 years, Thabit reported gross ligamentous failure in one patient and increased laxity (as measured with the KT-1000 arthrometer) in another. The other twenty-three patients had KT-1000 arthrometer values that were within two millimeters of those for the contralateral, normal knee[11].

Several basic-science studies have elucidated the macroscopic and molecular changes that occur in the collagen fibrils following thermal shrinkage[3,4,12]. On the basis of both cadaveric and animal models, these reports suggest that thermal energy results in denaturation of the collagen microstructure[3,4,6]. The long-term effects of these structural changes on the biomechanical properties of collagen are unknown.

Schaefer et al. demonstrated, in a rabbit model, that laser-induced patellar tendon shrinkage (an average of 6.6 percent) resulted in the tendons stretching out beyond pretreatment lengths over an eight-week period[8]. Biomechanical testing revealed that the tendons were significantly less stiff compared with the pretreatment values ($p = 0.03$) and that marked histological changes were present. However, the rabbit limbs were not immobilized during the postoperative period, so activity was essentially unrestricted.

In our patient, laxity developed after injury to a hamstring anterior cruciate ligament autograft. After heat shrinkage of the graft, two mechanisms for failure seem plausible, and both may have been contributory. First, biomechanical alteration of the graft may have predisposed the graft to failure when the patient returned to sports activity. Wall et al., in a study of bovine tendons, showed that shrinkage of greater than 15 to 20 percent resulted in substantial material property changes and denaturation of the fibrillar microstructure[12]. The amount of shrinkage required to decrease anterior-posterior translation from greater than ten millimeters to less than three millimeters (assuming that the anterior cruciate ligament in our patient was thirty millimeters in length) would be on the order of 40 percent. Therefore, the estimated degree of shrinkage required in this case was markedly greater than what is recommended in the literature.

Second, complete resorption of the graft occurred, suggesting that alteration in the collagen structure of the graft and heat-related necrosis may have led to immune-mediated autodigestion. While other mechanisms may have been responsible for this phenomenon, none are apparent to us.

We acknowledge the limitations of a single case report; however, on the basis of our findings, we caution against the use of thermal shrinkage in the treatment of a lax anterior cruciate ligament graft. We believe that additional work is necessary to characterize the response of host and graft collagen tissue to laser and thermal energy before this modality can be safely applied to such ligament grafts.

References

1. **Abelow, S. P.:** Laser capsulorrhaphy for multidirectional instability of the shoulder. *Op. Tech. Sports Med.*, 5: 244-248, 1997.
2. **Fanton, F. S.:** Arthroscopic electrothermal surgery of the shoulder. *Op. Tech. Sports Med.*, 6: 139-146, 1998.
3. **Hayashi, K.; Markel, M. D.; Thabit, G., III; Bogdanske, J. J.;** and **Thielke, R. J.:** The effect of nonablative laser energy on joint capsular properties. An in vitro mechanical study using a rabbit model. *Am. J. Sports Med.*, 23: 482-487, 1995.
4. **Hayashi, K.; Thabit, G., III; Bogdanske, J. J.; Mascio, L. N.;** and **Markel, M. D.:** The effect of nonablative laser energy on the ultrastructure of joint capsular collagen. *Arthroscopy*, 12: 474-481, 1996.
5. **Hayashi, K.; Thabit, G., III; Massa, K. L.; Bogdanske, J. J.; Cooley, A. J.; Orwin, J. F.;** and **Markel, M. D.:** The effect of thermal heating on the length and histological properties of the glenohumeral joint capsule. *Am. J. Sports Med.*, 25: 107-112, 1997.
6. **Naseef, G. S., III; Foster, T. E.; Trauner, K.; Solhpour, S.; Anderson, R. R.;** and **Zarins, B.:** The thermal properties of bovine joint capsule. The basic science of laser- and radiofrequency-induced capsular shrinkage. *Am. J. Sports Med.*, 25: 670-674, 1997.
7. **Obrzut, S. L.; Hecht, P.; Hayashi, K.; Fanton, G. S.; Thabit, G., III;** and **Markel, M. D.:** The effect of radiofrequency energy on the length and temperature properties of the glenohumeral joint capsule. *Arthroscopy*, 14: 395-400, 1998.
8. **Schaefer, S. L.; Ciarelli, M. J.; Arnoczky, S. P.;** and **Ross, H. E.:** Tissue shrinkage with the holmium:yttrium aluminum garnet laser. A postoperative assessment of tissue length, stiffness, and structure. *Am. J. Sports Med.*, 25: 841-848, 1997.
9. **Thabit, G., III:** Therapeutic heat: a historical perspective. *Op. Tech. Sports Med.*, 6: 118-119, 1998.
10. **Thabit, G., III:** The arthroscopically assisted holmium:YAG laser surgery in the shoulder. *Op. Tech. Sports Med.*, 6: 131-138, 1998.
11. **Thabit, G., III:** The arthroscopic monopolar radiofrequency treatment of chronic anterior cruciate ligament instability. *Op. Tech. Sports Med.*, 6: 157-160, 1998.
12. **Wall, M. S.; Deng, X. H.; Torzilli, P. A.; Doty, S. B.; O'Brien, S. J.;** and **Warren, R. F.:** Thermal modification of collagen. *J. Shoulder and Elbow Surg.*, 8: 339-344, 1999.