MRI AND MORPHOLOGY OF THE INSERTION OF THE PATELLAR TENDON AFTER GRAFT HARVESTING

STEPHEN H. LIU, DAVID W. HANG, AMICARE GENTILI, GERALD A. M. FINERMAN

From UCLA School of Medicine, Los Angeles, USA

We performed MRI on 16 patients who had had reconstruction of the anterior cruciate ligament (ACL) with a mid-third bone-patellar-tendon-bone autograft. Our aim was to assess the tendon and the site of its insertion at an average of seven years after the original operation. In four of these patients biopsies were taken from the donor site when they had revision of their original operation.

MRI showed reconstitution of the tendon into the patellar defect with no evidence of bone formation. Six patients had a persistent defect in the patellar tendon itself. Histological examination of the biopsies of the donor site showed an indirect pattern of insertion with absence of the normal fibrocartilage zone. These morphological changes may adversely affect the biomechanical properties of the healed donor site and we suggest that another graft taken from this site may not be suitable for use in a further operation for reconstruction of the ACL.

J Bone Joint Surg [Br] 1996;78-B:823-6.

Received 12 April 1996; Accepted after revision 11 June 1996

The bone-patellar-tendon-bone (BPTB) autograft is commonly used for reconstruction of the anterior cruciate ligament (ACL), but problems with the patella have been reported subsequently (Bose and Chong 1976; Bonamo, Krinick and Sporn 1984; Paulos et al 1987; Huegel and Indelicato 1988; Lambert and Cunningham 1988; Sachs et al 1989; Christen and Jakob 1992; Kleipool, Van Loon and Marti 1994; Rubinstein et al 1994; Tria, Alicea and Cody 1994). Histological and imaging studies of the donor site after graft harvesting have shown evidence of progressive healing (Berg 1992; Coupens et al 1992; Koblik and Free-

man 1993; Kamps et al 1994; Karns et al 1994; Rubinstein et al 1994; Shelbourne et al 1994; Adriani et al 1995; Cerullo et al 1995; Nixon et al 1995). The structural integrity of the healed donor site, however, may be compromised at the tendon itself and also at its site of insertion into bone.

A recent MRI study has investigated the integrity of the infrastructure of the tendon (Koblik and Freeman 1993) and others using MRI combined with gadolinium diethylenetriaminepenta-acetic acid (Gd-DPTA) have been able to grade the vascularity of the connective tissue to a degree comparable with that of histological studies (Tosch et al 1993; Jerosch et al 1994; Howell et al 1995). Most studies on the healing of the donor site have focused on the tendon rather than on its site of insertion. Using MRI we have studied the morphology of the donor site after healing, examining specifically the site of insertion of the tendon.

PATIENTS AND METHODS

We assessed 16 patients (15 men and 1 woman) with a mean age of 26 years (21 to 33) who had had ACL reconstruction at a mean of seven years (1 to 13) previously at the University of California at Los Angeles Wadsworth Veteran Hospital. All had had a BPTB autograft using the central third of the patellar tendon. Eight of the group had been seen again with symptoms of knee instability after the operation (the instability group); four subsequently had revision of their ACL reconstruction. The other eight formed an asymptomatic age-matched control group and were also matched for the length of follow-up after the original operation.

With the exception of one patient who had a medial arthrotomy, all patients underwent an arthroscopically-assisted technique. None had bone graft placed in the bony defect of the patella. Reapproximation of the tendon defect and the paratenon was performed in six patients but the others did not have such closure.

MRI. We performed MRI on the knee using a 1.5 Tesla unit (Magnetom: Siemens, Erlangen, Germany) with a dedicated extremity coil. In all patients we obtained sagittal multiecho acquisition (TR 1500 to 2500; TE 20, 70 to 90) and coronal T1-weighted (TR 400 to 500; TE 20 to 30) or multiecho acquisition images (TR 1500 to 2500; TE 20, 70 to 90). At the final follow-up we obtained T1-weighted images (TR 400 to 600; TE 20 to 30) with and without Gd-

S. H. Liu, MD, Assistant Professor
D. W. Hang, MD, Fellow
A. Gentili, MD, Assistant Professor
G. A. M. Finerman, MD, Professor
Department of Orthopaedic Surgery, UCLA School of Medicine, 10833 Le Conte Avenue, 76-119 CHS Los Angeles, California 90095, USA.

Correspondence should be sent to Dr S. H. Liu.

©1996 British Editorial Society of Bone and Joint Surgery
0301-620X/96/51276 \$2.00

Fig. 1

MRI showing defects in the tendon donor site. Figures 1A and 1B – Coronal and axial views (arrows point to the defect). Figure 1C – Hypertrophic connective tissue inserting directly into the defect in the patellar bone without evidence of bone formation (arrows point to the patellar bone defect). Figure 1D – Hypertrophy of the regenerated patellar tendon at the donor site (thickened tendon between the arrows).

DTPA. Assessment was undertaken by a skilled MRI radiologist (AG).

Histological examination. Biopsies of the site of insertion of the patellar tendon were obtained during revision operations on the ACL in four patients at a mean follow-up of five years (3 to 9) after their initial operation. The specimens included the patellar tendon and the site of its bony insertion and were obtained from a palpable spot at the previous donor site. The average size of the specimen was 15 mm in length, 5 mm in width, and 10 mm in depth, including the regenerated patellar tendon and its attached bone. The specimens were preserved in 4% paraformaldehyde solution containing 0.1 M Sorensen's phosphate buffer for 72 hours at 4°C. The tissue was then decalcified in 10% formic acid at 4°C for 21 days, followed by cryoprotection in 20% sucrose solution. It was then dehydrated and embedded in paraffin. Sections of 5 µm were obtained longitudinally and mounted on Super-Frost Plus slides for histological examination. Haematoxylin and eosin staining was used to determine the maturity of the collagen fibres within the tendon and to distinguish the morphological zones at the site of insertion.

RESULTS

MRI. Compared with the unaffected knee, ten patients (6 from the control and 4 from the instability groups) showed no defects at the tendon donor sites. The other six patients had persistent defects in the tendon. Their periods of

follow-up ranged from 13 to 158 months (13, 22, 40, 40, 80, 158 months respectively) (Figs 1A and 1B). Four of the six patients in whom the tendon had been closed had no defect, but the other two showed inadequate healing. Attempted closure of the tendon did not affect the presence of persistent defects or their size.

The sagittal images were examined for signal intensity and tendon thickness at the inferior pole of the patella. We obtained axial and coronal views to assess the defects in the patellar tendon and in the bone. The reconstituted connective tissue within the previous donor site was found to extend into the defect in the patellar bone (Fig. 1C). On the sagittal views the thickness of the patellar tendon at the inferior pole of the patella was found to be increased compared with the other knee in 14 patients and to be similar in two (Fig. 1D). Closure of the tendon did not affect its thickness. The central third of the patellar tendon showed significant heterogeneity with no consistent pattern and an increased signal on the T1-weighted and proton-density images. There did not appear to be significant mature healing of the tendon at the donor site even at a mean time of seven years after harvesting of the graft.

Histological examination. The specimens obtained from the site of insertion of the patellar tendon showed three zones: adjacent to the bone, at the interface zone of mature collagen fibres aligned obtusely towards the bone, and at the tendon (Fig. 2). This arrangement differed from the normal transitional structure found in the tendon insertion in that the fibrocartilage zone did not reconstitute after

Fig. 2

Photomicrograph showing site of insertion of the patellar tendon after repair. There is direct transition from the bone zone (solid white arrow) to the tendon zone (open white arrow) and no evidence of a tidemark or of fibrocartilage transitional zones indicating interdigitation of tendon fibre into the bone trabeculae (haematoxylin and eosin $\times 20$).

healing following excision of the graft. There was also no evidence of a tidemark at this interface.

DISCUSSION

Several studies have described the characteristics of the donor site of the patellar tendon as seen on MRI after removal of the graft (Berg 1992; Coupens et al 1992; Koblik and Freeman 1993; Kamps et al 1994; Rubinstein et al 1994; Shelbourne et al 1994; Cerullo et al 1995; Nixon et al 1995). Although many MRI studies have shown gradual maturation of the donor site of the patellar tendon there is no information on the appearance at its insertion after removal of the graft.

There is controversy as to the biological behaviour of the donor site after harvesting of the patellar tendon graft. Some have identified scar tissue in the central one-third of the tendon, while others have demonstrated progressive healing of the defect with time. Cerullo et al (1995) showed that in patients in whom the defect had been repaired at operation scar tissue was present not only in the central third but also in the medial and lateral thirds in more than 50% six months after the graft had been taken. In those without tendon closure, however, scar tissue was present only in the central third. Coupens et al (1992) studied patellar tendon defects in 20 patients by MRI between four weeks and 18 months after operation. They demonstrated a progressive decrease in the high signal intensity of the tendon with total resolution by 18 months, and concluded that the closed tendon defects had the potential to remodel. Nixon et al (1995) using MRI noted a progressive decrease in the size of the unsutured tendon cleft and also showed sequential remodelling of the collagen fibres to a more normal orientation on histological examination although the specimens were from different patients. Karns et al (1994)

reported complete regeneration of the site of the patellar tendon defect on MRI four years after ACL reconstruction, and he re-used the central third as a BPTB graft for revision of an ACL reconstruction.

We were not able to show complete healing of the donor site in all our patients; six of the 16 had persistent tendon defects. One patient with the longest follow-up (13 years) had the largest defect with persistent fatty infiltrate and no evidence of ingrowth of connective tissue. Tendon closure did not influence the development of a defect in the tendon.

In all of our patients the bone defect became filled with connective tissue interposed between the tendon and bone as a continuous band, but there was a diverse pattern of high-intensity signals at the insertion site. The various patterns seen in the patellar tendon may be related to the techniques of closure, but we did not find any correlation between the type of closure and the MRI appearance.

Berg (1992) examined histological specimens eight months after removal of the graft without closing the defect. He postulated that the linear arrangement of the collagen suggested that the regenerated tissue had been subjected to tensile stress. He did not comment on the appearances at the site of insertion of the tendon. Our study has shown absence of the fibrocartilage zone at this site. Alteration of the structure at the insertion of the tendon may explain the patellofemoral morbidity often observed in these patients and makes reharvesting of the graft for revision operations undesirable.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES

- Adriani E, Mariani PP, Maresca G, Santori N. Healing of the patellar tendon after harvesting of its mid-third for anterior cruciate ligament reconstruction and evolution of the unclosed donor site defect. *Knee Surg Sports Traumatol Arthrosc* 1995;3:138-43.
- Berg EE. Intrinsic healing of a patellar tendon donor site defect after anterior cruciate ligament reconstruction. *Clin Orthop* 1992; 278:160-3.
- Bonamo JJ, Krinick RM, Sporn AA. Rupture of the patellar ligament after use of its central third for anterior cruciate reconstruction: a report of two cases. *J Bone Joint Surg [Am]* 1984;66-A:1294-7.
- Bose K, Chong KC. The clinical manifestations and pathomechanics of contracture of the extensor mechanism of the knee. *J Bone Joint Surg [Br]* 1976;58-B:478-84.
- Cerullo G, Puddu G, Gianni E, Damiani A, Pigozzi F. Anterior cruciate ligament patellar tendon reconstruction: it is probably better to leave the tendon defect open! *Knee Surg Sports Traumatol Arthrosc* 1995;3:14-7.
- Christen B, Jakob RP. Fractures associated with patellar ligament grafts in cruciate ligament surgery. *J Bone Joint Surg [Br]* 1992;74-B: 617-9.
- Coupens SD, Yates CK, Sheldon C, Ward C. Magnetic resonance imaging evaluation of the patellar tendon after use of its central one-third for anterior cruciate ligament reconstruction. *Am J Sports Med* 1992;20:332-5.
- Howell SM, Knox KE, Farley TE, Taylor MA. Revascularization of a human anterior cruciate ligament graft during the first two years of implantation. *Am J Sports Med* 1995;23:42-9.

- Huegel M, Indelicato PA.** Trends in rehabilitation following anterior cruciate ligament reconstruction. *Clin Sports Med* 1988;7:801-11.
- Jerosch J, Castro WH, Muller U, Assheuer J.** Does intravenous gadolinium-DTPA administration have advantages in magnetic resonance imaging of acute injuries or chronic damage to the knee joint? *Sport Verletz-Sportschaden* 1994;8:178-85.
- Kamps BS, Linder LH, Decamp CE, Haut RC.** The influence of immobilization versus exercise on scar formation in the rabbit patellar tendon after excision of the central third. *Am J Sports Med* 1994;22:803-11.
- Karns DJ, Heidt RS, Holladay BR, Colosimo AJ.** Case report: revision anterior cruciate ligament reconstruction. *Arthroscopy* 1994;10:148-51.
- Kleipool AE, Van Loon T, Marti RK.** Pain after use of the central third of the patellar tendon for cruciate ligament reconstruction: 33 patients followed 2-3 years. *Acta Orthop Scand* 1994;65:62-6.
- Koblik PD, Freeman DM.** Short echo time magnetic resonance imaging of tendon. *Invest Radiol* 1993;28:1095-100.
- Lambert KL, Cunningham RR.** Anatomic substitution of the ruptured ACL using a vascularized patellar tendon graft with interference fit fixation. In: Feagin JA Jr, ed. *The crucial ligaments*. New York, etc: Churchill Livingstone, 1988:401-8.
- Nixon RG, SeGall GK, Sax SL, Cain TE, Tullos HS.** Reconstitution of the patellar tendon donor site after graft harvest. *Clin Orthop* 1995;317:162-71.
- Paulos LE, Rosenberg TD, Drawbert J, et al.** Infrapatellar contracture syndrome: an unrecognized cause of knee stiffness with patella entrapment and patella infera. *Am J Sports Med* 1987;15:331-41.
- Rubinstein RA Jr, Shelbourne KD, Van Meter CD, McCarroll JC, Rettig AC.** Isolated autogenous bone-patellar tendon-bone graft site morbidity. *Am J Sports Med* 1994;22:324-7.
- Sachs RA, Daniel DM, Stone ML, Garfein RF.** Patellofemoral problems after anterior cruciate ligament reconstruction. *Am J Sports Med* 1989;17:760-5.
- Shelbourne KD, Rubinstein RA Jr, Van Meter CD, McCarroll JR, Rettig AC.** Correlation of remaining patellar tendon width with quadriceps strength after autogenous bone-patellar tendon-bone anterior cruciate ligament reconstruction. *Am J Sports Med* 1994;22:774-8.
- Tosch U, Hertel P, Bernard M, Lais E, Felix R.** Gadolinium-DTPA enhanced MRI in the evaluation of the healing of autologous patellar ligament transplants for anterior cruciate ligament reconstruction. *Radiologe* 1993;33:40-5.
- Tria AJ Jr, Alicea JA, Cody RP.** Patella baja in anterior cruciate ligament reconstruction of the knee. *Clin Orthop* 1994;299:229-34.