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Anterior cruciate ligament reconstruction: the diagnostic value of MRI

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Summary. *A prospective study was carried out in order to evaluate the predictive value of MRI in the early postoperative course after cruciate ligament replacement. Twenty patients who had undergone anterior cruciate ligament reconstruction using autologous patellar tendon/bone grafts were examined clinically and with contrast enhanced MRI at 2, 12 and 24 weeks, and 1 and 2 years after operation. The clinical findings were evaluated according to the scores established by Lysholm, OAK and IKDC. The MRI scans (SP 63, 1.5 Tesla) were assessed in terms of the quality and signal intensity of the reconstructed ligaments. During the first postoperative year there was a significant increase of signal intensity and in homogeneity of the neoligament on in the MRI. Seventeen patients had an average value for signal/noise of 1.1 at two weeks after surgery, which had increased to 7.1 at 1 year. In 14 patients the reconstructed ligament could not be evaluated in MRI scans after 1 year but clinical instability was not suspected in any of these patients. Two years after operation the MRI signal intensity of the neoligament was again decreasing.*

Résumé. *Une étude prospective a été faite, afin d'estimer la valeur de pronostic de l'IRM dans la phase postopératoire précoce du remplacement des ligaments croisés. 20 patients, avec des ligaments croisés antérieurs remplacés (transplantation autologue du tendon rotulien) ont été examinés cliniquement et à l'aide d'IRM de contraste, la 2e, 12e, 24e semaine post-opératoire et, 1 et 2 ans post-opératoires. Les examens cliniques ont été évalués selon le score de Lysholm, OAK et IKDC. Les imageries IRM (SP 63, 1.5 Tesla) ont été évaluées et mettant en évidence la qualité et l'intensité du signal du ligament reconstitué. Pendant la première année post-opératoire, on a noté à l'IRM une augmentation significative de l'intensité du signal et de la non-homogénéité du nouveau ligament chez 17 patients, avec une valeur moyenne du signal/écho allant de 1.1, 2 semaines postopératoire, jusqu' à 7.1, un an post-opératoire. Chez 14 patients dans la première année post-opératoire, le ligament reconstitué a pu être visualisé à l'IRM, bien qu'aucun de ces patients n'ai eu un examen clinique suspect, quand à l'instabilité. A l'IRM post-opératoire de la deuxième année, l'intenstié du signal du nouveau ligament a à nouveau diminué, selon une constatation régulière.*

Introduction

In patients with reconstructed cruciate ligaments only clinical examination and mechanical techniques such as KT 1000 arthrometer testing are of use in confirming the stability of the neoligament. Moreover, in persons with recent trauma, it can be very difficult to reach conclusions concerning the integrity of the neoligament.

Magnetic resonance imaging (MRI) offers very good imaging quality for knee ligaments with a specificity of about 80% and a sensitivity up to 99% for the diagnosis of a ruptured cruciate ligament [1, 4]. Some authors have reported good visibility of the neoligament on MRI and have recommended it for follow-up examination [2, 5, 6, 17, 21]. Others have observed significant changes in the signal intensity of the reconstructed ligament following operation and have concluded that the neoligament cannot be evalu-

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ated with MRI [12, 18, 20, 22]. Most of the studies were retrospective and merged the results of several MRI examinations undertaken at different intervals following surgery. The indication for MRI in most of the patients has been acute trauma, persistent symptoms or instability. In the majority of reported studies the results were not correlated with the clinical outcome.

The aim of this prospective study was to study the normal appearance of a reconstructed cruciate ligament on MRI during the first two postoperative years. The focus was on the time-dependant signal behaviour of the neoligament, in order to determine if there were any changes in signal intensity as potential sequelae of revascularisation.

Materials and methods

The study was designed prospectively and consent for participation was obtained from 20 patients, in whom reconstruction of the anterior cruciate ligament had been carried out by free patellar tendon bone (PTB) graft. The mean age of the 12 male and 8 female patients was 30 years (17–59 years). These individuals were examined clinically and with MRI at 2, 12 and 24 weeks and then at 1 and 2 years after operation. The procedures were performed arthroscopically in eight patients and with a minimal arthrotomy in 12. The PTB block was fixed with titanium interference screws. In this way, the MRI examinations could be carried out with a minimised likelihood of artefacts.

Using a standard rehabilitation programme, mobilisation was started on the second post-operative day. Partial weight-bearing and a limited range of motion of 0/90 for extension and flexion in a knee brace (Goldpoint®, Don-Joy Inc.) was employed. Full weight-bearing and a full range of movement of the knee joint were permitted 4–6 weeks post-operatively.

The examinations were carried out using a high resolution MRI with a special knee coil. In acccordance with a standardised protocol, the knee was positioned in 20 degrees of flexion during the investigation. Native T-1 and T-2 weighted spin echo sequences were obtained in sagittal, parasagittal and coronal projections. The parasagittal slices were adjusted to the course of the neoligament. After intravenous injection of Gadolinium-DTPA as contrast medium (0.1 mmol/kg body weight) dynamic gradient echo (GE) turbo flash sequences, T-1 weighed spin echo (SE) and FAT-SAT sequences were obtained. The signal intensity of the neoligament was measured in the ROI (region of interest) in the areas of proximal and distal insertion, as well as in the middle one third, and compared with the values of the remaining patellar tendon. For signal intensity the signal/noise value was calculated:

$$C / N = \frac{\text{signal (reconstructed ligament)} - \text{signal (patellar tendon)}}{\text{signal (background)}}$$

The MRI scans were evaluated by an expert radiologist without knowledge of the clinical results.

The clinical follow-up examinations were performed according to a standardised protocol, which facilitated calculation of the most common knee scores as defined by Lysholm [16], OAK [19] and IKDC [9]. Subjective symptoms were recorded and measurements of circumference and range of motion obtained. Clinical and mechanical stability tests were performed (Lachman, pivot-shift, KT 1000). The results of the clinical examinations were then compared with the MRI findings.

Results

Seventy-nine MRI examinations were performed in the study. The average deviation from the dates of the postoperative MRI investigations were 3 days for the 2 weeks study, 17 days for the 3 months, 42 days for the 6 months and 49 days for the 1 year. The 2 year follow-ups were performed in an interval of ±56 days. On average, 4 MRI examinations were undertaken in each patient.

Two weeks after operation the reconstructed ligament was visualised in 18 out of 20 instances as a broad band with a low signal intensity along its full course. In the T-1 sequences the signal/noise ratio as a value for signal intensity was 1.1; after intravenous injection of Gd. 1.5. in the T-2 sequences, the average C/N value was 0.1.

In two patients without any clinical abnormalities the neoligament could not be visualized in any MRI sequence.

By three months the complete course of the reconstructed ligament could be visualised with MRI in 11 of 16 patients and the ligament was rated as being intact. The C/N value in the middle area of the neoligament was 4.4 in the T-1 sequences before and 4.6 after injection of gadolinium. In 3 patients it was difficult to evaluate the neoligament by MRI due to the increased signal intensity. In 2 patients without clinical abnormality the neoligament could not be visualised in any MRI sequence.

At six months 11 patients considered that their operated knee was nearly normal. One patient experienced a decreased range of motion and intermittent pain. Examination by the Lachman test, drawer test and pivot-shift showed no evidence of instability in any patient. In KT 1000 arthrometer testing the affected side was below 4 mm in every subject.

In 10 patients with increasing signal intensity and inhomogeneity, accurate assessment of the reconstructed ligament was only possible in the post-con-

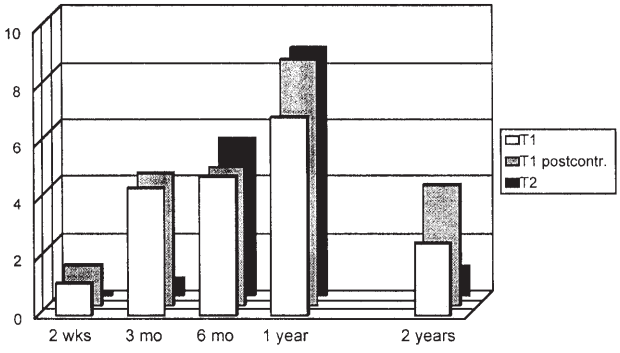

Fig. 1. Average C/N value of the neoligament at the different times in the various MRI sequences

$$C / N = \frac{\text{signal (reconstructed ligament)} - \text{signal (patellar tendon)}}{\text{signal (background)}}$$

T1, T1 sequence; *T1 postcontr.*, T1 sequence after administration of Gadolinium as contrast media; *T2*, T2 sequence; *2 wks*, 2 weeks postoperatively; *3 mo*, 3 months postoperatively

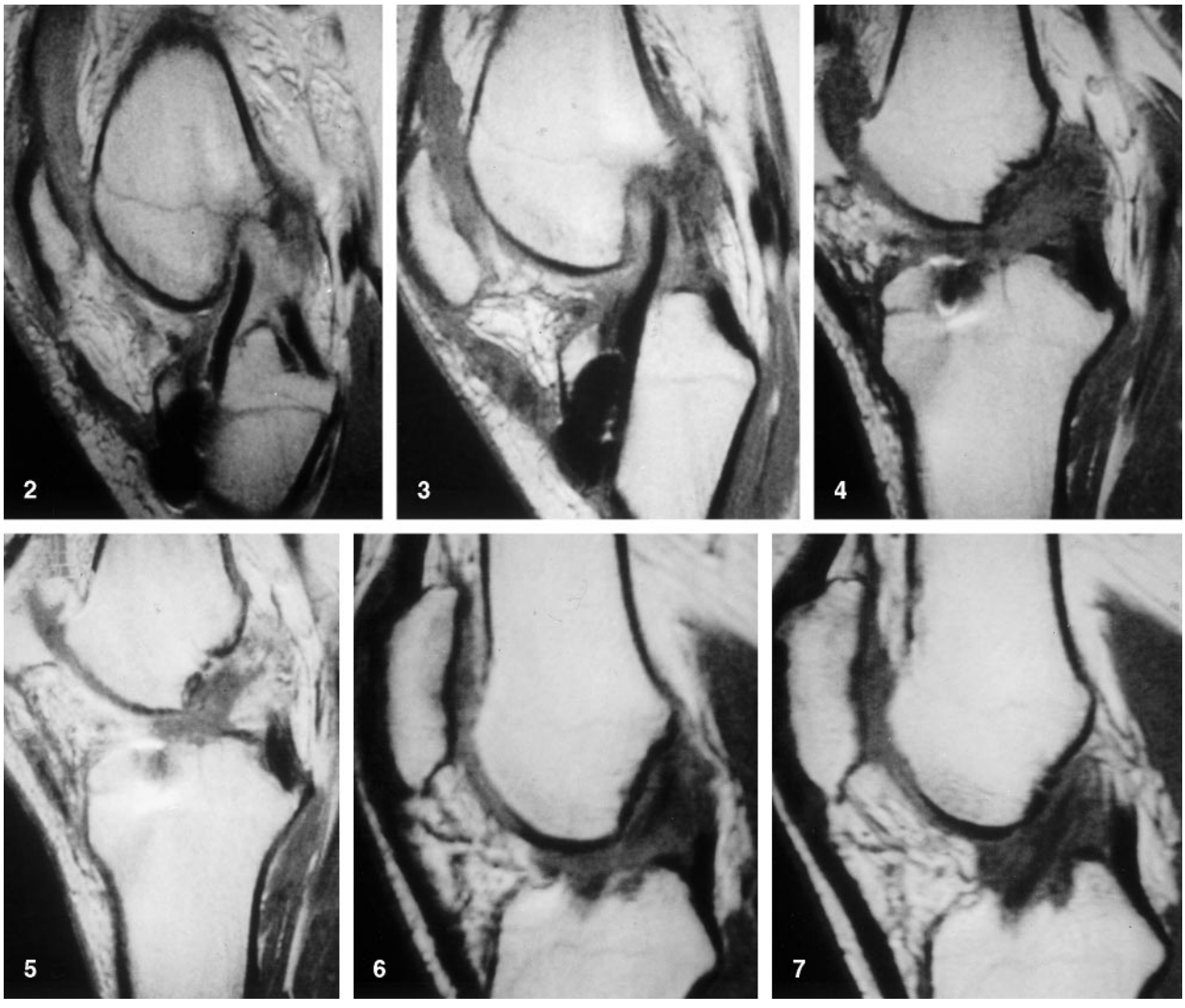

Fig. 2. Two weeks after operation (patient 16, T-1 sequence): the reconstructed cruciate ligament is seen in continuity with a low signal intensity comparable to the normal ligament

Fig. 3. Twelve weeks after operation (patient 16, T-1) the neoligament shows increased signal intensity. Evaluation is possible along its complete course

Fig. 4. Six months after operation (patient 4, T-1): In the natural MRI sequence the signal intensity of the neoligament is markedly increased. Assessment is not possible

Fig. 5. Six months after operation (patient 4, T-1): After administration of Gadolinium DTPA the reconstructed ligament is visualized as a broad structure. The potential for assessment is limited

Fig. 6. One year after operation (patient 16, T-1): The continuity of the neoligament cannot be judged

Fig. 7. Two years after operation (patient 16, T-1): The reconstructed ligament is visualized as a broad band with a similar low signal intensity as in the first examination. The continuity can again be assessed

trast images. The average C/N value was 4.9 in the T-1 and 5.5 in the T-2 sequences. In 2 patients the neoligament could not be demonstrated by MRI.

One year after operation there was no clinical suspicion of instability in any of the 17 patients. The side difference in KT 1000 arthrometer testing was again below 4 mm in all patients. There was no extension deficit and the average flexion deficit was 5°. According to the OAK score, there were 13 excellent and 4 good results. The IKDC scores were slightly worse, with 5 B, 11 C and 1 D results.

With significant increase of signal intensity in T-1 sequences and consecutive inhomogeneity, evaluation of the neoligament even after Gd. injection was not possible in 14 out of 17 patients. The average C/N value was 7.1 (post-contrast 8.6). In T-2 weighted sequences a continuous enhancement could be observed up to a C/N value of 8.7.

By two years there was a clear decrease of signal intensity in MRI in 11 of 14 patients as compared to the 1 year follow-up. This resulted in an average C/N value of 2.7 (post-contrast 4.2) in T-1 and 1.0 in T-2 weighted sequences. In 10 patients the neoligament was very obvious and its continuity could be evaluated. In two patients the quality of visualisation was impaired and in another two the ligament could not

Table 1. Patient data

Average age (years)	29.9
Sex (m/f)	12/8
Surgical procedure	12 Mini arthrotomy 8 Arthroscopic
Graft	20 Autologuous lig. patellae

Table 2. Clinical score results 1 and 2 years postoperatively

Score	1 year postop.		2 year postop.	
Lysholm	13	>90	10	>90
	2	80–90	3	80–90
	2	70–79	1	70–79
OAK	13	Excellent	10	Excellent
	4	Good	4	Good
IKDC	5	B	1	A
	11	C	6	B
	1	D	7	C
∅ KT 1000 (mm)		2.35		2.3

∅ KT 1000=average side difference in KT 1000 testing with manual maximum

be assesed, although clinically there was no suspicion of instability. There was a slight improvement of the clinical scores, with 1 A, 6 B and 7 C results, according to the IKDC.

Discussion

Information about the timing of remodelling and revascularisation of autologous tendon transplants is currently available only from animal studies [3, 8].

The aim of our prospective study was to demonstrate the normal post-operative course of the neoligament by means of MRI. We wanted to assess whether the appearance of the reconstructed cruciate ligament differs from that of the original cruciate ligament in MRI, and if it is possible to analyse the integrity of the neoligament.

For patients with a ruptured cruciate ligament, the standard management is reconstruction with a free autologous patellar tendon graft [10, 11, 15]. Operation is performed either arthroscopically or with an additional small arthrotomy after diagnostic arthroscopy. These different surgical techniques do not influence the healing of the transplant or the clinical outcome and the functional results are similar [15].

During the first year after operation there was a significant change in signal intensity of the neoligament in 17 patients (Fig 1). The reconstruction could be seen as a continuous structure of low signal intensity in all sequences after 2 weeks. The signal intensity was only slightly higher than that of the patellar tendon, which served as a reference. By three months thinning of the reconstructed ligament was evident with increased signal intensity. The continuity of the ligament could be assessed in the natural, and even better, in the contrast enhanced sequences. At 6 months in several instances the neoligament could not

Table 3. C/N values (T-1) in the middle third of the neoligament and the quality of evaluation at different times

Pt. Nr.	2 weeks		3 months		6 months		1 year		2 years	
	C/N	Q	C/N	Q	C/N	Q	C/N	Q	C/N	Q
1	1.1	+	3.2	+	4.0	0			3.0	+
2	0.9	+	3.8	+	4.8	0	7.8	–		
3	0.8	+	4.9	+			7.6	–	2.0	+
4	1.5	+	4.8	+	5.3	0	6.3	0	2.0	+
5	1.3	–	6.2	–	7.4	–	7.5	–	5.0	–
6	1.0	+	4.6	+			8	–	2.5	0
7	1.0	+	3.1	+	3.9	+	7.8	–		
8	1.2	+					7.3	–	2.2	+
9	1.4	+	4.8	+			7.8	–		
10	0.7	+	3.9	+	4.1	+	6.5	0	2.0	+
11	1.0	+	1.3	+	2.9	+	2.2	+	1.1	+
12	1.1	+	4.8	+	5.0	0				
13	1.1	+	5.2	0	5.5	0	7.3	–	1.9	+
14	1.4	+	5.3	0			7.8	–	1.8	+
15	0.9	+			5.6	0			2.0	+
16	1.1	+	3.8	+			6.9	–	2.4	+
17	1.2	–	4.8	–	5.0	–	7.4	–	5.0	–
18	1.2	+					7.4	–	5.1	0
19	0.8	+	5.4	0			7.2	–		
20	1.1	+			5.1	0	7.1	–		

$$C/N = \frac{\text{Signal (reconstructed ligament)} - \text{Signal (patellar tendon)}}{\text{Signal (background)}} \text{ in native T-1 sequence}$$

Q=quality of evaluation of the neoligament: "+"=neoligament well visualised and can be assessed throughout its length; "0"=reduced but of sufficient quality for visualisation and evaluation; "–"=insufficient quality of visualisation for evaluation

be evaluated in the natural sequences due to further increase of signal intensity and inhomogeneity. Even after injection of Gadolinium the reconstructed ligament could not be seen in 2 of 12 patients but clinically there was no evidence of instability. One year after operation, in most of the patients the signal intensity of the neoligament was so high that differentiation between synovium and ligament was not possible. The appearance of the reconstruction was comparable to that of a ruptured cruciate ligament, thus raising the possibility of a false diagnosis. The controls, 2 years post-operatively, again showed significant reduction of signal intensity, with consequent improvement of potential for evaluation (Fig. 2–7).

The patients included in this study all had an uneventful postoperative course and there was no suspicion of instability or of extension deficit due to notch impingement. Visualisation of the neoligament by MRI reflects the normal post-operative course. During the first year there is significant increase of signal intensity with a peak at the end of this period. Evaluation of the reconstructed ligament is difficult after 6 months. However, even without a parallel histological study it can be concluded that the changes in signal intensity reflect the different stages of revascularisation of the neoligament [3, 8]. After about 18 months, when revascularisation is complete, the neoligament again gives a low signal intensity with improved potential for assessment.

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