Effects of aggressive early rehabilitation on the outcome of anterior cruciate ligament reconstruction with multi-strand semitendinosus tendon

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Summary. *To evaluate the effects of aggressive early rehabilitation on the clinical outcome of anterior cruciate ligament reconstruction using semitendinosus (and gracilis) tendon, 103 of 110 consecutive patients who underwent ACL reconstruction using multi-strand semitendinosus tendon (ST) or the central one-third of patellar tendon with bony attachments (BTB) were analyzed prospectively. Subjectively, the Lys-holm score was not different among the groups. The Lachman test indicated a trend of less negative grade in the ST men's group than that in the BTB men's group. On the patellofemoral grinding test, only women patients of both groups showed pain, with less positive crepitation in the ST group than in the BTB group. KT measurements at manual maximum showed more patients with more than 5 mm differences in the ST group than in the BTB group. The results of this study suggest that aggressive early rehabilitation after the ACL reconstruction using the semitendinosus (and gracilis) tendon has more risk of residual laxity than with the BTB.*

Résumé. *Pour évaluer les effets d'une réhabilitation agressive précoce sur le résultat clinique d'une reconstruction de ligament croisé antérieur, quand un tendon demi-tendineux (et gracile) est utilisé, 103 des 110 patients consécutifs qui subirent une reconstruction ACL par l'utilisation d'un tendon semi-tendineux (ST) multifibre ou un tiers central d'un tendon rotulien avec attaches osseuses (BTB) ont été analysés prospectivement. Pour comprendre les résultats cliniques dans le détail, l'évaluation a été effectuée en prenant en considération les différences de sexe dans chaque groupe. Subjectivement, le résultat de Lys-*

holm ne s'est pas différencié parmi les groupes. Le test de Lachman a indiqué une tendance à des degrés négatifs moindres dans le groupe d'hommes ST que dans le groupe d'hommes BTB. Avec le grinding test rotulo-fémoral, seules les patientes de sexe féminin des deux groupes montrèrent des douleurs, tandis qu'on constatait une crépitation moins marqué dans le groupe ST par rapport au groupe BTB. Les mesures KT au maximum manuel montrèrent une tendance à un plus grand nombre de patients avec des différences de plus de 5 mm dans le groupe ST que dans le groupe BTB. Les résultats de cette étude suggèrent que la réhabilitation agressive précoce après une reconstruction ACL avec un tendon semitendineux (et gracile) induit un plus grand risque d'hyperlaxité résiduelle que le BTB.

Introduction

Reconstruction of the anterior cruciate ligament (ACL) using one third of the patella tendon with bony attachments (BTB) is recognised in the United States and Europe as being the optimum method because of its mechanical strength and the bony fixation [2, 3, 17, 24]. Anterior knee pain, flexion contracture of the knee, and delayed recovery of the strength of knee extension may occur after this procedure. To avoid these problems the semitendinosus tendon, combined with that of gracilis (STG), has been used as an alternative procedure. Several comparative studies of ACL reconstruction using BTB and STG have been reported [1, 4, 5, 7, 13, 18]. Marder et al. [13] did not find any significant difference between the two methods in a prospective randomised study of 80 consecutive patients. Their postoperative management was moderately progressive with a brace being used for six weeks, and active knee ex-

tension from 0–40° banned until after six months. Aglietti et al. [1] reported a more speedy return to athletic activities following the BTB procedure, but the differences were not significant. They allowed full weight bearing by the end of the second month, and leg extension against resistance from 0–45° was not allowed until six months.

Holms [7] reported excellent/good results in only 50% of STG procedures five years after operation. Feagin et al. [4] reported slightly better results through BTB reconstruction but they were not statistically significant. Tolin and Friedman [26] allowed the use of the two kinds of graft according to age, size, athletic activity and the length of time of mobilisation for each patient, and found that the STG operation showed slightly less favourable results.

Recently, Maeda et al. [12] describe good results using multi-strand semitendinosus tendon and had a better recovery of knee extension compared with the BTB operation. Howell and Taylor [8] used double strands of STG, aggressive early rehabilitation and no bracing. Their well designed study showed no deterioration of the results at 24 months compared with 4 months after operation.

ACL reconstruction using the STG technique needs improvements in the technique of operation before it can be considered as a true alternative to BTB reconstruction [26, 27]. However, it is uncertain as to how the two compare. Which is better for patients with low activity, which has a better operative morbidity, which is more suited to the older patient and which is best in the acute phase?

We have performed a prospective study to assess the outcome of reconstruction of the ACL using multi-strand semitendinosus tendon compared with the BTB technique using aggressive early rehabilitation. We assessed any factors which were associated with the sex of the patient.

Patients and methods

Out of 110 consecutive patients who underwent ACL reconstruction between June 1992 and June 1994 using the multi-strand semitendinosus tendon (ST), or the central one third of the patellar tendon with bony attachment, 103 had a full review at least 20 months after operation and are included in this study. The BTB group consisted of 51 patients and the ST group of 52. There were no differences between the two groups as regards the sex, preoperative period, level of sporting activity and accompanying meniscal injuries. We excluded patients who required repair or reconstruction of the collateral ligaments (Table 1). Bilateral ACL injuries were found in 2 patients, one man in the BTB group and a woman in the ST group.

Technique of operation

In the ST group, the semitendinosus tendon was harvested with a tendon stripper (3M, St. Paul, Minnesota) through a 3 cm incision on the anteromedial aspect of the tibia from the level of the tibial tubercle. A triple or quadruple multi-strand semitendinosus graft was tied in a bundle like fashion 6 to

Table 1. Preoperative patients' data

Graft tissue	BTB	ST
Patient number	51	52
Sex: Men	22	21
Women	29	31
Age at operation (years)	24±7	25±8
Preoperative period (months)	37±59	28±32
Acute operation <6 wks	21	15
Preoperative Tegner activity score	6.1±1.4	6.1±1.1
Follow-up period (months)	28±5	31±8
Accompanying meniscal injuries:		
Medial	25	18
Lateral	13	15

8 cm long, using three No. 5 non absorbable polyester braided sutures at each end [12]. The diameter of the graft tissue obtained was at least 7 mm, and the tendon of gracilis was added if the semitendinosus was too short or too thin. Four patients required this reinforcement. In the BTB group the central one third of the patellar tendon with bony attachments was harvested through a central incision of about 6 cm in length.

The reconstructions were performed using the arthroscopically assisted outside-in two-incision technique. The ST graft was fixed by tying the sutures over a button or staple in the femur and a screw in the tibia under tension in 30° of flexion. The BTB graft was secured with interference screws in the femur and the tibia, again in 30° of flexion.

Postoperative management

The knee was immobilised for three days in a plaster splint in 30° of flexion for the ST group and in a simple knee brace in extension for the BTB group. The patients were then encouraged to move the knee and bear as much weight as they could tolerate. Crutches were used for walking as long as required, usually about three to four weeks. We encouraged working out on an exercise bicycle, swimming the crawl or backstroke, and performing halfsquat exercises after one month. Jogging was allowed three months after operation if the muscle power had reached 65% of the opposite side. The patients returned to their original sporting activities by six months after operation, when each was carefully assessed so as not to be pushed too hard.

Assessment

The maximum extension and flexion of the knee. The maximum extension was assessed using a lateral radiograph in hyperextension [15]. Maximum knee flexion was measured with a goniometer.

Manual knee laxity tests. These were graded for each limb as negative, +, ++, or +++.

Patellofemoral grinding test. This assessment was done to assess pain and crepitation in the patellofemoral joint.

Anterior knee laxity using the KT-100. Anterior laxity was measured with the KT-1000 arthrometer (Medmetric Corp., San Diego, California) at 20 pounds and manual maximum anterior pull strength.

Measurements of knee muscle strength. Cybex II (Cybex Co., Division of Lumex, Ronkonkoma, New York) was used to test the strength of flexion and extension of the knee.

Lysholm knee score and Tegner activity score. A subjective evaluation was performed for a Lysholm knee scoring scale [10]. Sporting activity was graded according to the Tegner activity score [25] before and after operation.

Each assessment was based on the difference between the operated and uninjured limb.

Analysis

Physical analysis was performed using the ANOVA and the Bonferroni/Dunn tests, with the Mann-Whitney U-test and chi-square test. All data were analysed using Statview 4 (Abacus Concepts, Inc., Berkeley, California). Significance was assumed with a *P*-value smaller than 0.05.

Results

An ANOVA and the Bonferroni/Dunn tests failed to show any statistical differences in any parameters when the patients were divided into four groups, according to sex and operation.

Range of knee movements

The extension deficit was significantly smaller in the ST group than in the BTB group, averaging 1° and 1.8° respectively. However, the extent was small and there were two patients in the BTB group and one in the ST group who had more than 5° of flexion contracture.

The limitation of flexion in the ST group, $0.6 \pm 3.1^\circ$, tended to be smaller than in the BTB group, $1.2 \pm 2.4^\circ$ (*P*=0.06).

Manual knee laxity tests

A positive Lachman test was seen more frequently in men in the ST group than in men in the BTB group. However, there was no difference in the two groups with regard to the anterior drawer or pivot shift tests (Table 2).

Patellofemoral grinding test

Only women complained of pain on this test. There was no difference in the two groups as regards pain, but those in the BTB group had more crepitation than those in the ST (*P*=0.07) (Table 3).

KT-1000 test

There was no difference between the ST group and the BTB group as regards the average anterior knee laxity as measured by the KT-1000 apparatus. In the ST group the measurements were 2.3 ± 2.4 mm in men and 1.8 ± 2.3 mm in women, while in the BTB group the measurements were 1.5 ± 2.0 mm in men and 1.7 ± 2.0 mm in women. According to the IKDC

form for KT measurements [6], there tended to be more patients who showed more than 5 mm of anterior laxity in the ST group than in the BTB group (*P*=0.07) (Fig. 1).

Cybox testing

There were no differences among the patients in any group with regards to knee extension and flexion as tested by the Cybex II (Table 4). The results of the Cybex testing were then divided into three groups: more than 80%, between 80 and 65%, and less than 65% recovery compared to the uninjured limb [21]. Significantly more patients showed a strength of knee extension of less than 65% in the BTB group than those in the ST group (Fig. 2).

Table 2. Manual knee laxity tests; m=male, f=female

		BTBm	BTBf	STm	STf
Lachman	−	91%	76%	59%	77%
	+	9%	21%	36%	17%
	++	0%	3%	5%	6%
BTBm vs. STm, <i>P</i> =0.1					
ADT	−	82%	79%	73%	90%
	+	5%	17%	27%	10%
	++	3%	3%	0%	0%
Pivot-shift	−	80%	55%	68%	57%
	+	10%	38%	23%	43%
	++	10%	7%	9%	0%

Table 3. P-F grinding tests; m=male, f=female

		BTBm	BTBf	STm	STf
Pain	−	100%	93%	100%	93%
	+	0%	7%	0%	7%
Male vs. female: <i>P</i> =0.06					
Crepitus	−	73%	69%	86%	80%
	+	27%	31%	14%	20%
BTB vs. ST: <i>P</i> =0.07

Fig. 1. There was a tendency for more patients in the ST group than in the BTB group to show more than 5 mm anterior laxity in the KT measurements at maximum pull, that is, categorized as abnormal in the IKDC form (*P*=0.07)

Table 4. Cybex testing; m=male, f=female (side-to-side %, 0 degrees/s)

	BTBm	BTBf	STm	STf
Average extension	89	90	88	87
Average flexion	102	99	92	93

Fig. 2. The results of the Cybex testing were divided into three groups: more than 80%, between 80 and 65%, and less than 65% recovery compared to the uninjured limb. Significantly more patients showed knee extension strength of less than 65% in the BTB group than in the STG group**Table 5.** Tegner activity score; m=male, f=female

	BTBm	BTBf	STm	STf
Preoperative	6.3	6.0	6.9	5.7
Postoperative	5.6	5.8	6.3	5.7

Lysholm knee scoring scale

There were no differences for the overall score between the two groups, averaging 92 points in the ST men, 93 points in the ST women, 95 points in the BTB men and 94 points in the BTB women. There were no differences among the four groups for the instability score or the pain score.

Tegner activity score

Both before and after operation the Tegner scores in the men were significantly greater than the women: 6.6 points in men and 5.8 points in women before operation, and 6.0 points in men and 5.7 points in women after. A statistically significant decrease in the Tegner score was noted for the men after operation (Table 5).

Discussion

The current trend on the postoperative management following reconstruction of the ACL is aggressive early rehabilitation, with minimal immobilisation of the knee, early active mobilisation and as much weightbearing as can be tolerated. Running is started

as early as 6 weeks and full athletic activity may be assumed as early as 4 months after operation, depending on the individual patient [20]. These concepts have been applied, principally, to the BTB operation, and rehabilitation using the multi-strand technique has been less aggressive [1, 8, 13]. We have carried out a prospective comparative study of these two methods based on aggressive early rehabilitation. The patients with a BTB procedure showed a tendency for a deficit in residual knee extension and less favourable recovery of extensor power than in the ST group [16]. However, the ST group showed greater residual anterior laxity and less negative Lachman tests.

The technique adopted by Maeder et al. [12] was very similar to ours except that they fixed their graft in 90° of knee flexion as opposed to our 30°, and used different sutures. Our patients showed more residual laxity after surgery than those of Maeder et al., probably due to differences in postoperative management or in tensioning of the graft [28].

The volume of the STG graft is greater than that of the BTB [12, 17, 27], but the difference in the procedures appears to be in the healing which takes place within the bony tunnel. In the STG procedure anchoring begins at the interface of the tendon and the bone and experience has suggested that tendon anchoring takes longer to become sound than bone to bone fixation [14].

There is a risk of a diminution of the residual tension in the tendon graft after cyclic loading compared with that in the BTB graft [19, 24]. Experiments with the tendon of beagle dogs showed similar levels of failure with three different methods of fixation [11, 27, 28], with the grafts always failing at the interface between the tendon and the fixation material.

Steiner et al. [23] compared four methods of fixation of the graft using human semitendinosus and gracilis tendons in cadaver knees. They did not test the same method of fixation which we had used, but they found that fixation of the hamstring tendons was less stiff than that achieved by BTB grafts using interference screws.

The method of fixation for the tendon graft needs improvement. The long distance between the femoral and tibial sites of fixation causes more creep in the graft. The method reported by Howell and Taylor [8] has some advantages over fixation with buttons and screw posts.

Patellofemoral pain is said to have been one of the most frequent problems found after BTB construction but we encountered this only in women in both of our groups subjected to aggressively early rehabilitation. More frequent deterioration of the patellofemoral particular surface has been reported after moderate postoperative rehabilitation [22].

Reconstruction of the ACL using the semitendinosus tendon, in association with gracilis if needed, needs further improvement in both technique and post-operative management before it can be considered as a replacement for the patella bone procedure.

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