Clinical and radiological outcome of Endobutton versus cross-pin femoral fixation in hamstring anterior cruciate ligament reconstruction

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Background
The selection of a graft and the method of graft fixation are critical in anterior cruciate ligament (ACL) reconstruction surgery. ACL reconstruction with the hamstring tendon provides sufficient strength for early rehabilitation and activity; the tendon to bone healing and the fixation method can become an issue with the hamstring tendon, which affects the functional outcome.

Aim of the work
The aim of this study was to compare the clinical and radiological outcome of Endobutton femoral fixation and cross-pin femoral fixation for primary ACL reconstruction using quadrupled hamstring tendons with a minimum follow-up of 2 years.

Type of study
Retrospective study.

Patients and methods
Forty-five patients were evaluated 2 years after arthroscopic ACL reconstruction. Two methods of graft fixation were compared: in group 1 (20 patients, EB group), an indirect graft fixation was achieved utilizing the Endobutton with a manually knotted polyester tape for proximal femoral fixation combined with bicortical suture and post-tibial fixation. In group 2 (25 patients, TF group), a direct graft fixation was achieved utilizing cross-pin femoral fixation (TransFix II Pin) with an additional autograft bone plug inserted into the femoral tunnel. Tibial fixation of the graft was performed with a bioabsorbable interference screw and an additional staple on the graft. All cases were operated using a transtibial technique.

Results
According to the IKDC evaluation form, the clinical outcome of the TF group was better than that of the EB group. Radiographs of the EB group showed a higher degree of divergence of the osteosclerotic lines indicating the bone tunnels in comparison with the TF group. The entrance diameters of the drilled femoral bone tunnels were 12.5 and 10.5 mm in the EB group and the TF group, respectively ($P < 0.05$).

Conclusion
We conclude that avoiding tapes and sutures and using a surgical technique with direct graft fixation minimizes movement of the tendon graft for ACL reconstruction and improves the clinical results.

Keywords:
anterior cruciate ligament reconstruction, graft fixation, hamstring tendon, tunnel widening

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Introduction

Anterior cruciate ligament (ACL) reconstruction surgery is one of the most common procedures in sports traumatology. The selection of the graft depends on the surgeon's preference and the available tissues. Among the autogenous tissues, the most commonly used grafts currently are the patellar tendon and the quadrupled hamstrings [1–3].

Several studies have shown that the bone–tendon ingrowth after hamstring tendon reconstruction remains questionable [4]. Enlargement of the bone tunnel and permanent elongation of grafts after cyclic loading led to increasingly greater interest in the type of hamstring tendon fixation [5]. Nowadays, several methods of direct tendon–bone fixation are available to minimize the elongation of the construct. A large number of femoral tunnel fixation systems have been introduced and used in ACL reconstruction surgery with autogenous hamstring tendon. In general, three types of ACL graft fixation mechanisms for the femoral tunnel exist, and these can be classified according to the amount, application site, and distribution: compression, expansion, and suspension. Compression fixation is achieved with interference screws. A typical example of expansion devices is the cross-pin system and that of a cortical suspension device is the Endobutton system, which has been used widely as a fixation device for a quadruple hamstring graft [6]. However, there is a certain elasticity in the graft–implant complex and the fixation point of the Endobutton system is relatively far from the joint line, resulting in graft–tunnel motion of up to 3 mm under physiologic load. It has been reported that this intratunnel motion has been associated with tunnel widening [7].

Patients and methods

The clinical and radiographic outcomes of patients after ACL reconstruction were evaluated retrospectively. The indication for reconstruction was chronic ACL deficiency. Quadrupled hamstring tendon grafts were used in all patients using a transtibial technique. In the first group (EB group), femoral fixation was carried out using a manually knotted connector tape (Mersilene 5 mm; Ethicon) and a flipping plate (Endobutton; Acufex, Mansfield, Massachusetts, USA). Tibial fixation was performed with eight strands of sutures (Ethibond No. 5; Ethicon) manually knotted over an AO screw as a post. In the second group (TF group), the femoral graft fixation was performed by looping the graft over a rectangular inserted pin (Transfix; Arthrex, Naples, Florida, USA), which fixed both loops inside the femoral canal. An autologous bone plug was harvested from the femoral tunnel using a 6-mm AIT-tube harvester (Arthrex) and inserted into the femoral drill hole by a cannulated bone plug impactor (Arthrex) through the anteromedial portal with distal tensioning of the graft. The bone core was advanced until flush with the tunnel rim. Tibial fixation was carried out using a biodegradable interference screw (Arthrex) and an additional staple on the distal portion of the graft. The surgical techniques of the EB group and the TF group are considered as representatives of indirect and direct graft fixation, respectively.

Demographic data

Between January 2005 and April 2009, 50 ACL reconstructions were performed at Tanta University Hospital. In all of them, a quadrupled hamstring graft with either Endobutton–Mersilene or Transfix fixation was used on the femoral side. Patients with osteoarthritis at the time of surgery and those with multiligament injury were excluded from the study.

Five patients were lost to follow-up examination. Overall, 45 patients were available for the present study.

There were 25 patients in the TF group, 20 men and five women, 11 right sided and 14 left sided. The follow-up time after surgery was on average 26 months (range 24–30 months). During arthroscopy, a partial meniscectomy was necessary in 11 patients; meniscal repair of a longitudinal meniscal tear was performed in four cases. The EB group included 17 men and three women, nine right sided and 11 left sided. Partial meniscectomy was performed in 17 patients. In two cases, meniscal repair was performed using an inside-out technique. The follow-up time after surgery was on average 27 months (range 24–32 months). All patients who were included in the study were operated on at least 6 weeks after injury.

Chondral and meniscal pathology and the detailed operative procedure were recorded from the 45 patients.

Assessment of the results

The clinical assessment was based on the International Knee Documentation Committee (IKDC) evaluation form [8] and the Tegner-activity score [9]. Furthermore, a detailed evaluation was performed of a radiographic examination at follow-up.

Clinical assessment

According to the IKDC evaluation form, symptoms (pain, swelling, and giving way), motion, stability, crepitus in each knee compartment, and harvest site pathology were evaluated. Each category was graded as normal (A), nearly normal (B), abnormal (C), and severely abnormal (D). Knee stability was tested clinically (Pivot-shift test, anterior drawer). The level of activity was categorized in each patient before injury and 2 years after surgery. The assessment was performed on the basis of four levels: strenuous activities including sports that require jumping, pivoting, and hard cutting maneuvers such as football, soccer, and basketball (first level), moderate activities including heavy manual work, skiing, tennis, baseball, and volleyball (second level), light activities characterized by light manual work, jogging, running, and cycling (third level), and sedentary activities including housework or a desk job with no sports participation (fourth level).

Radiographic evaluation

The radiographic evaluation included the anteroposterior and lateral radiographs. The measurement was performed perpendicular to the long axis of the tunnels. The tunnel widening was measured on the immediate postoperative radiographs and the last follow-up radiographs. The average data of three measurements were used for statistical analysis. The radiographs that were taken at the follow-up examination were scanned using a special radiographic scanner. The bone tunnels of the graft at the femoral and tibial side were measured in the anteroposterior and lateral views. Thin sclerotic lines indicating the diameter of the bone tunnels were used for determination of their size and shape. The measurement of all visible canals was performed directly on the screen. As shown in Figs 1 and 2, the apertures at the intra-articular side of the tunnels were measured and their shapes were described. Furthermore, the tibial and femoral angles created between the superior and inferior (lateral view) and medial and lateral wall (anteroposterior view) of the canal as visualized by osteosclerotic lines were determined (opening angle, Fig. 2).

Results

No significant differences were found between the two groups in age, sex, or associated pathologies ($P > 0.05$).

International Knee Documentation Committee evaluation [8]

When patients were asked 'On a scale from 0 to 3, how does your knee affect your activity level?' Eight patients (41.6%) in the EB group and 18 patients (73%) in the TF group answered '0' ($P < 0.01$). Eleven patients (53.4%) in the EB group and 21 patients (86.5%) in the TF group considered their knee function as normal. Group 2 (symptoms) of the IKDC evaluation assessed pain, swelling, and partial or complete giving way. Between the two groups, significant differences were found ($P < 0.05$).

The range of motion also showed differences in both groups. An extension deficit of more than 3° was found in 20% of the patients in the EB group and in 5.8% of patients in the TF group. Loss of flexion between 6 and 15° was observed in 18.3% of the patients in the EB group and in 9.6% of the patients in the TF group. On the basis of the IKDC evaluation, anterior drawer of 1–2 mm showed 62% of the patients in the EB group and 77% in the TF group (Table 1).

Two patients of both groups showed unstable knees at follow-up examination. Despite correctly positioned bone tunnels, an anteroposterior translation of 5–12 mm was observed. One case of the unstable knees in the EB group presented thin and parallel tunnels and the other three cases showed tunnel diameters within the normal range.

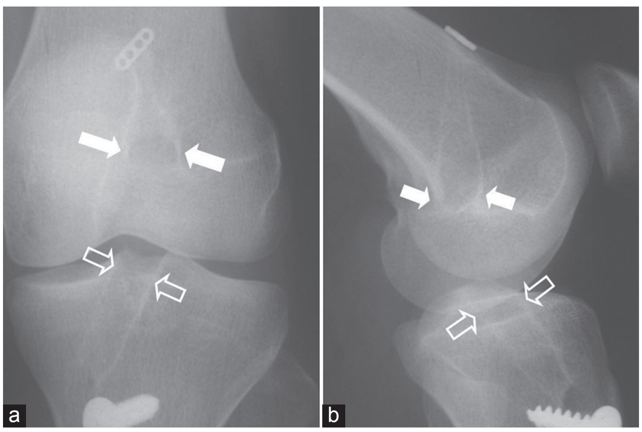
Evaluation of activity according to the Tegner-activity score [9]

The preinjury average Tegner level was 7.38 in the TF group and 7.66 in the EB group. Two years postoperatively, the TF group reached an average of 6.37 and the EB group reached an average of 6.68. Both the preinjury and the postoperative activity level were not significantly different in both groups.

Radiographic evaluation

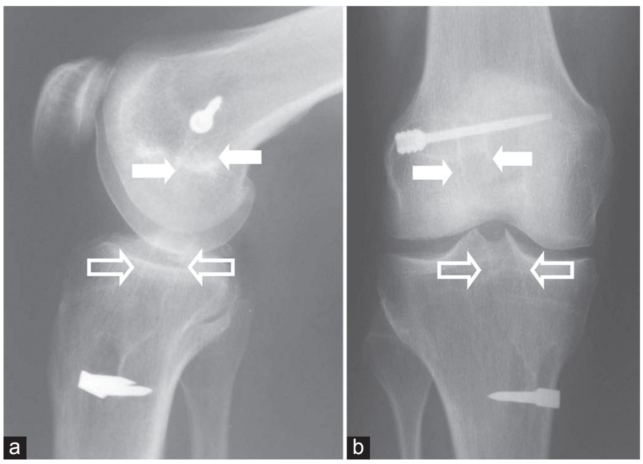
In all cases, we could detect the bone tunnels for the measurements as described above. Figure 1 shows a typical example of a patient of the EB group 2 years after operation. The margins of the femoral and tibial bone tunnels are divergent and the entrances to the joint are widened. In contrast, the patient of the TF group showed almost parallel bone tunnels as shown in Fig. 2. All averaged entrance widths and opening angles of the tibial and femoral side are presented in Table 2. The entrance of the femoral canal to the joint was significantly larger

Figure 1



Radiographs 2 years after anterior cruciate ligament reconstruction using a quadruple semitendinosus graft, which was fixed with a polyester tape and a flipping plate (Endobutton) on the femoral side and sutures with a post on the tibial side. On the anteroposterior view (a), the filled arrows mark the diameter of femoral tunnel and the empty arrows mark the tibial tunnel. Lateral radiographs are shown in (b).

Figure 2



Radiographs 2 years after anterior cruciate ligament reconstruction using a quadruple semitendinosus/gracilis graft with an rectangular inserted pin on the femoral side (Transfix) and a staple and a biodegradable interference screw on the tibial side. On the anteroposterior view (a), the filled arrows mark the diameter of femoral tunnel and the empty arrows mark the tibial tunnel. Lateral radiographs are shown in (b).

in the EB group in comparison with the TF group as determined on the lateral radiographs. Measurement of the opening angles between both the tunnels (indicated by osteosclerotic lines) showed significant differences between both groups.

In the EB group, six patients developed an irregular bone tunnel enlargement on the femoral side. In contrast, this phenomenon was found only in one patient in the TF group.

Discussion

Among the autogenous tissues, the most commonly used grafts currently are the patellar tendon and the quadrupled hamstrings. Each of these grafts has been shown to have sufficient load-to-failure strength and stiffness to replace the ACL [10]. Graft fixation is also important. To promote an early return to daily life and sports activities, a strong graft with fixation that can endure the strain placed on the knee during early rehabilitation is essential. ACL graft fixation mechanisms can be classified according to the amount, application site, and distribution of forces that resist graft pullout [11]. To *et al.* [12] reported in a cadaver study that the stiffness of a graft–graft fixation complex is largely dependent on the fixation method and less on the graft itself, and that the close-to-joint transcondylar fixation method in that respect was superior to the Endobutton system. During biomechanical analysis of hamstring grafts, it was found that more than 90% of the permanent elongation of the hamstring graft occurred in the regions of the polyester tape or the sutures. If there is 10 times more creep in the sutures and the tape in comparison with the autologous graft, the mere point of fixation does not seem to be the major factor. Avoidance of creep biomechanical properties of the connectors seems to be important. Supporting this view, we found in our study improved stability and clinical results using a method with fixation closer to the joint line. A cross-pin was used for the proximal fixation in sizes as long as possible to confer stability. A cancellous bone block after graft fixation was inserted into the femoral tunnel to provide additional anatomical fixation of the graft and to prevent synovial fluid from entering the bone tunnel. Milano *et al* [13] used nine different kinds of femoral fixation methods and showed that the greatest failure loads were reported for Transfix (Arthrex). Rigidfix and Endobutton were included in an intermediate subset. In another animal experiment, the interference screw and the Rigidfix fixation showed inferior fixation biomechanics compared with the Bio-Transfix (Arthrex) and Endobutton techniques.

Several theories have been developed to account for tunnel widening following ACL reconstruction, including mechanical and biological contributions.

Table 1 International Knee Documentation Committee evaluation of symptoms, stability, and loss of motion and final evaluation

	Endobutton	Transfix
Symptom evaluation [*n* (%)]		
A	10 (53.4)	22 (88.7)
B	6 (30)	2 (6.8)
C	3 (13.3)	1 (4.5)
D	1 (3.3)	0 (0)
Anterior drawer [*n* (%)]		
A (1+)	12 (61.7)	18 (75)
B (2+)	7 (35)	6 (20.4)
C (3+)	1 (3.3)	1 (4.6)
D (4+)	0 (0)	0 (0)
Lack of flexion [*n* (%)]		
A	16 (81.7)	23 (93.2)
B	4 (18.3)	2 (6.8)
C	0 (0)	0 (0)
D	0 (0)	0 (0)
Loss of extension [*n* (%)]		
A	16 (80)	24 (95.5)
B	3 (15)	1 (4.5)
C	1 (5)	0 (0)
D	0 (0)	0 (0)
Final evaluation [*n* (%)]		
A	4 (20)	14 (56.8)
B	9 (46.6)	8 (34.1)
C	5 (21.7)	3 (9.1)
D	2 (11.7)	0 (0)

Table 2 Evaluation of radiographic parameters of the bone tunnels: the diameter at the entrance to the joint and the divergence of the tunnel indicating osteosclerotic lines were measured

	AP view				Lateral view			
	Tibia		Femur		Tibia		Femur	
	DJE	Angle	DJE	Angle	DJE	Angle	DJE	Angle
EB group (*N* = 20)								
Six trumpet deformations	12.19	4.43	12.99	14.29	12.35	7	12.85	10.87
TF group (*N* = 25)								
One trumpet deformation	12.04	4.47	12.17	4.98	12.74	4.53	10.93	3.9
t-Test	NS	NS	NS	<0.01	NS	<0.01	<0.05	<0.01

Angle, measured angle between both lines indicating the drilled canal, 0° means that the lines were parallel; AP, anteroposterior; DJE, diameter of the canal just at the entrance of the joint.

Within the tunnel, up and down motion (a bungee effect) and side to side motion (the motion of windshield wipers) can occur. Extravasation of synovial fluid that contains various cytokines into the tunnel around the graft may be increased by this motion and this interferes with the soft tissue-to-bone healing. In the suspensory fixation system, these interactions are likely to occur [14].

Fauno and Kaalund [15] reported that tunnel widening is influenced by the mechanical properties of the implants and more patients with increased knee laxity were in the extracortical fixation (Endobutton fixation) group compared with the close-to-joint fixation (Transfix) group. However, the clinical results were considered successful in both groups.

In the present study, we compared two different fixation systems and each had its own characteristics. One is a cross-pins system called Transfix and the other is a suspensory system called Endobutton. According to previous studies, significantly more femoral tunnel widening developed with the use of a suspensory system compared with that of the cross-pin system for quadrupled hamstring grafts [16]. In the current study, we attempted to verify this phenomenon and its relationship with the clinical results obtained in our patients.

There are disagreements on the timeline of tunnel widening. Some authors reported that tunnel widening is an acute phenomenon that occurs during the first 6 weeks after surgery, whereas others reported that it continues to develop over the first 1–2 years following ACL reconstruction. Simonian *et al*. [17] observed that tunnel widening did not develop between the first 3 and 12 months. Fink *et al*. [18] reported that tunnel widening peaked at 6 weeks following graft fixation. Pinczewski *et al*. [19] observed that tunnel widening progressed up until 2 years after reconstruction. The difference in the tunnel shape between the groups is the second important finding to be discussed. On the lateral radiographs, the width of the entrance into the joint was significantly larger in the EB group (Table 2), whereas on anteroposterior radiographs, no differences could be identified. Differences in the aperture seem to be related to a tunnel widening in the anteroposterior direction. This widening might be caused by the stress that is elicited by the ACL graft during flexion and extension motion of the joint.

In this study, we used two different graft fixation methods for the tibial tunnel for each group. Although there have been disagreements on the relationship between tibial tunnel widening and fixation methods, the difference in the tibial tunnel fixation method could have affected the development of femoral tunnel widening. The main finding of the study is that the type of graft fixation has a major influence on the clinical outcome, ligament stability, and bone tunnel widening 2 years after ACL reconstruction.

Conclusion

We conclude that avoiding tapes and sutures and using a surgical technique with direct graft fixation minimizes movement of the tendon graft for ACL reconstruction and improves the clinical results.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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