Anterior cruciate ligament graft fixation: clinical and radiological effects on anterior cruciate ligament reconstruction with hamstring tendon graft

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Received 9 September 2013
Accepted 5 October 2013

The Egyptian Orthopaedic Journal
2016, 51:323–328

Aim of the study
The aim of this study was to compare the results both clinically and radiologically in patients undergoing anterior cruciate ligament (ACL) reconstruction using two different methods of graft fixation.
Patients and methods
In a retrospective way, at Mansoura knee surgery unit, 120 patients underwent ACL reconstruction with hamstring graft with the use of an interference screw fixation in both the femoral and the tibial tunnel in 60 patients (group A) and rigid fix fixation in the femoral tunnel and screw and washer fixation distal to the tibial tunnel in another 60 patients (group B). The evaluation included International Knee Documentation Committee ratings, Lysholm score, and standardized radiographs, MRI. The diameter of the tunnel on MRI was compared with the tunnel diameter obtained from the operative sheet.
Results
No significant difference in clinical results was found with using Lysholm score and International Knee Documentation Committee between the two groups. Radiologically, in group A, eight patients had developed femoral tunnel widening and four had developed tibial tunnel widening. In group B, 12 patients had tunnel widening in the femur and 20 in the tibia. There was a significant reduction of tunnel widening in the tibia using interference screw fixation compared with the fixation by screw and washer distal to the tibial tunnel.
Conclusion
The position of the fixation sites and type of fixation device are major factors in the development of tunnel widening after ACL surgery, but they do not significantly affect the clinical results.

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

Egypt Orthop J 51:323–328

1110-1148

Introduction

From anterior cruciate ligament (ACL) reconstruction until graft incorporation, there is an actual challenge. Immediate full range of motion, muscle strengthening, neuromuscular coordination, and early weight bearing are critical. Graft strength and method of fixation should withstand the stresses of this early rehabilitation [1].

Laboratory studies demonstrate avulsion of the graft from the tunnel. However, as biologic incorporation is allowed to proceed, increasing failure strength is demonstrated, indicating histological incorporation and a shift of the weak link from the graft-fixation–tunnel interface to the bone/ligament interface and then to the interstitial portion of the graft [2].

Graft fixation secures soft tissue or bone plugs, either within the tunnel or extracortical by compression, expansion, or suspension [3]. A variety of methods for fixation of tendon grafts have been introduced. In our study, we compare between graft fixation using two absorbable interference screws (group A) and graft fixation using rigid fix in femoral tunnel and metal screw fixation with washer in the tibial tunnel (group B).

Many factors may affect graft fixation: the mechanism of fixation, site of fixation, correct placement of the method of fixation, bone density around the tunnel [4], angle of stress relative to fixation, and screw length and diameter. The ideal fixation technique provides rigid fixation (abundant strength and stiffness) at the anatomic footprint of the native ACL at the articular surface, provides no inflammatory response, facilitates biologic incorporation of the graft into the tunnel, and does not hinder future procedures or investigative techniques [1].

Patients and methods

In a retrospective way, 120 patients with ACL-deficient knees were treated by ACL reconstruction at Mansoura knee surgery and arthroscopy unit in the period between March 2006 and April 2008.

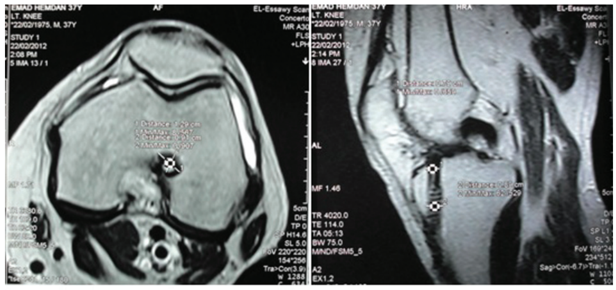
According to graft fixation, the patients were classified into two groups (each group contains 60 patients): group A (graft fixation using two absorbable interference screws) and group B (graft fixation using rigid fix in femoral tunnel and metal screw and washer fixation in the tibial tunnel).

Transtibial single-bundle ACL reconstruction technique was performed using the autologous quadrupled hamstring graft in all the patients. For group A, two bioabsorbable interference screws were used to fix the hamstring graft at both the femoral and tibial tunnels. For group B, a bioabsorbable rigid fix was passed transversally through the femoral tunnel and 4-mm cortical screw with a plastic washer just distal to the tibial tunnel.

The combined injuries were meniscus tear (44 and 40 cases in groups A and B, respectively), grade II medial collateral ligament injury (six and four cases in groups A and B, respectively), and chondral flap (eight and four cases in groups A and B, respectively). For meniscal tears, partial meniscectomy was performed in 34 and 36 cases in groups A and B, respectively. Suture repair were performed in 10 and four cases in groups A and B, respectively. For the medial collateral ligament injuries, full range of motion was obtained with conservative treatment before ACL reconstruction. Regarding the chondral flaps, patients were treated with debridement.

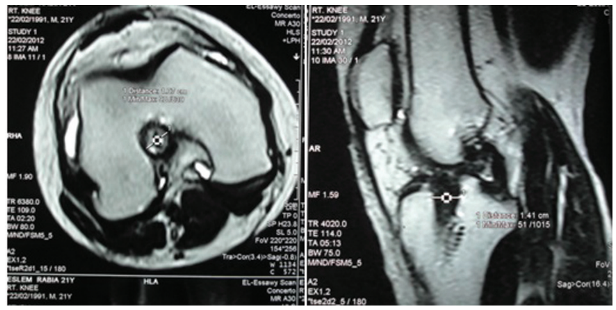
Clinical assessment included the anterior drawer test, Lachman test, Pivot shift test, one-leg hop test, International Knee Documentation Committee score, and Lysholm score (Table 1). For assessment of the tunnel diameter, intraoperative tunnel diameter was recorded. Follow-up MRI was done to measure tunnel diameter and to assess tunnel healing (Figs 1–3).

Figure 1



From group A, in a 37-year-old male patient, the intraoperative tunnel diameter was 0.8 cm, showing an increase mainly in the femoral tunnel diameter (1.29 cm). The tibial tunnel diameter is 0.89 cm.

Figure 2



From group A, in a 21-year-old male patient, the intraoperative tunnel diameter was 1 cm, showing an increase mainly in the tibial tunnel diameter (1.41 cm). The femoral tunnel diameter is 1.07 cm.

Table 1 Patient findings

	Preoperative findings		Post-operative findings	
	Group A	Group B	Group A	Group B
ADT (G 0/1/2/3)	0/0/8/52	0/0/4/56	54/4/2/0	52/4/4/0
Lachman (G 0/1/2/3)	0/0/6/54	0/0/4/56	56/2/2/0	56/4/0/0
Pivot shift (G 0/1/2/3)	0/0/40/20	0/0/46/14	54/4/2/0	50/6/4/0
One-leg hop (G 0/1/2/3)	4/20/16/20	6/16/14/24	40/10/6/4	40/10/6/4
Meniscus tear	44	40	–	–
MCL injury	6	4	–	–
Chondral flap	8	4	–	–
Mean femoral tunnel diameter	8.6 mm	8.2 mm	8.5 mm	8.6 mm
Mean tibial tunnel diameter	8.6 mm	8.2 mm	8.4 mm	9.2 mm
Lysholm score	59.2	60.4	95.8	90.2
IDKC score	70.2	65.2	95.4	88.5

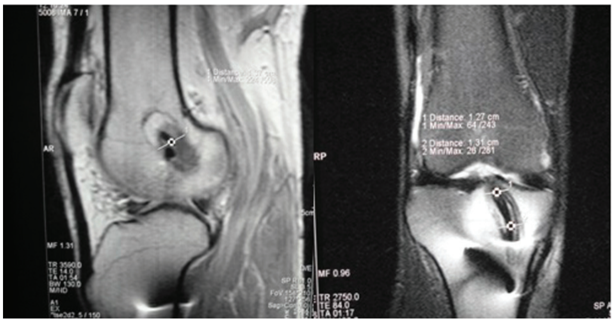
Results

The mean age of the patients was 27.2 years (range: 20–32 years) in group A and 25.4 years (21–34 years) in group B. The male–female ratio was 52/8 in group A and 56/4 in group B. The mean follow-up period was 38.3 months (12–60 months) in group A and 42.5 months (12–48 months) in group B. The cause of injury was sports injury in 48, traffic accident in eight, and activities of daily living in four patients in group A and sports injury in 44, traffic accident in 12, and other causes in four patients in group B.

As shown in Table 1, regarding the anterior drawer test in group A, there were eight cases of grade II and 52 cases of grade III preoperatively and 54 cases of grade 0, four cases of grade I, and two cases of grade II at the last follow-up postoperatively. Regarding the anterior drawer test in group B, there were four cases of grade II and 56 cases of grade III preoperatively and 52 cases of grade 0, four cases of grade I, and four cases of grade II at the last follow-up postoperatively.

Regarding the Lachman test in group A, there were six cases of grade II and 54 cases of grade III preoperatively and 56 cases of grade 0, two cases of grade I, and two cases of grade II at the last follow-up postoperatively. Regarding the Lachman test in group B, there were four cases of grade II and 56 cases of grade III preoperatively and 56 cases of grade 0 and four cases of grade I at the last follow-up postoperatively.

Figure 3



From group B, in a 35-year-old male patient, the intraoperative tunnel diameter was 1 cm, showing an increase in both the tibial tunnel diameter (1.27 cm) and the femoral tunnel diameter (1.37 cm).

Table 2 Post-operative radiological findings

	Group A	Group B
Tibial tunnel widening	4 (6.6%)	20 (33%)
Femoral tunnel widening	8 (13%)	12 (20%)
Tibial tunnel healing	22 (36%)	16 (26%)
Femoral tunnel healing	26 (43%)	22 (36%)

Regarding the pivot shift test in group A, there were 40 cases of grade II and 20 cases of grade III preoperatively and 54 cases of grade 0, four cases of grade I, and two cases of grade II at the last follow-up postoperatively. For the pivot shift test in group B, there were 46 cases of grade II and 14 cases of grade III preoperatively and 50 cases of grade 0, six cases of grade I, and four cases of grade II at the last follow-up postoperatively

Regarding the one-leg hop test in group A, there were four cases of grade 0, 20 cases of grade I, 16 cases of grade II, and 20 cases of grade III preoperatively and 40 cases of grade 0, 10 cases of grade I, six cases of grade II, and four cases of grade III at the last follow-up postoperatively. For the one-leg hop test in group B, there were six cases of grade 0, 16 cases of grade I, 14 cases of grade II, and 24 cases of grade preoperatively and 40 cases of grade 0, 10 cases of grade I, six cases of grade II, and four cases of grade III at the last follow-up postoperatively.

The mean International Knee Documentation Committee subjective score increased from 70.2 preoperatively to 95.4 at the last follow-up in group A and from 65.2 preoperatively to 88.5 at the last follow-up in group B, but no significant difference was found between the two groups. There was a significant improvement in the mean Lysholm score from 59.2 preoperatively to 95.8 at the last follow-up in group A and from 60.4 preoperatively to 90.2 at the last follow-up in group B, but no significant difference was noted between the two groups. All patients were evaluated at final follow-up with MRI for tibial tunnel diameter, femoral tunnel diameter, tunnel healing, graft size, and implant complications. Table 2 shows significant tunnel widening in group B.

There was a significant improvement in clinical results of group A and a significant improvement in clinical results of group B; however, there is no significant difference in final clinical results between group A and group B. Also, there is a significant reduction of tunnel widening in the tibia in group B compared with group A using MRI measurement (Figs 1–3).

Discussion

Graft incorporation is a process of collagen-fiber growth between bone and tendon and histological anchorage of the graft in the bone tunnel and hence biologic fixation. The process involves neochondrification, neo-ossification, and Sharpey's fibers identification. It also involves intra-articular neovascularization, ligamentization, and junctional ossification. The time required for completion of this process in humans is unclear. Animal studies showed different times for graft incorporation. It differs according to type of the graft and the graft fixation method [5,6].

At 6 weeks, histological evidence of complete healing of bone plug occurred; however, soft tissue graft incorporation had not yet occurred. Grafts with bone plugs achieve histological incorporation earlier than soft tissue grafts [6]. Once biologic incorporation of the graft in the tunnel has occurred, the rigidity of the ligament substitute depends on the intraarticular portion of the graft itself [2]. Graft strength required to endure daily activities is ~454 N. Different graft substitutes provide different strength and stiffness (Table 3) [7].

Mechanism of fixation

The tendon grafts may be fixed by compression (e.g. bioscrew), expansion (e.g. rigid fix), or suspension (cortical, e.g. end-button or cancellous, e.g. Linx-Ht) [4]. Compression fixation mechanism has a relatively low failure load [8]. Expansion fixation mechanism obtains secure fixation because two cross pins inserted transversely through a graft provide a centrifugal pressure on the femoral tunnel. Although the treatment results depend on the press-fit of the graft, bone density around the femoral tunnel, and correct placement of the cross pins through the graft tendon [7], expansion fixation has been reported to render satisfying results in biomechanical and clinical studies [4]. Cortical suspension fixation has been associated with biomechanical instability and graft–tunnel motion including bungee cord effect [9] and windshield wiper effect [10]. Cancellous suspension fixation allows the least elongation and accordingly provides the greatest fixation strength and stability among various available methods and has the lowest cyclic amplitude [11].

Site of fixation

Extracotical graft fixation (e.g. endobutton for femoral tunnel or metal screw and plastic washer for tibial tunnel) may be associated with biomechanical instability [9,10], which may lead to delayed biological incorporation and tunnel enlargement. Also the synovial fluid may escape through the tunnel to the bone affecting tunnel healing and causing fluid collection at the proximal tibia. Synovial fluid within bony tunnels causes osteolysis and eventually tunnel enlargement [12].

Table 3 Graft strength

Tendon graft	Strength	Stiffness
Native ACL	2160 N	242 N/mm
Patellar tendon	2977 N	455 N/mm
Quadrupled hamstring tendon	4140 N	807 N/mm
Quadriceps tendon	2353 N	326 N/mm

Intratunnel fixation (e.g. interference screws) provides rigid aperture fixation, which increases knee stability and graft isometry and avoids suture stretch and graft–tunnel motion [13]. Also, it seals the tunnel preventing escape of synovial fluid.

Bone density around the tunnel

Graft fixation in bone is improved with increased bone mineral density. The distal femur has a greater bone mineral density than the proximal tibia, and hence, fixation of the graft in the femoral tunnel provides greater strength than fixation in the tibial tunnel [14].

The force applied to the tibial fixation is in line with the intraosseous portion of the graft, whereas it is oblique and sometimes perpendicular in the femoral bone tunnel, that is, more stresses on the tibial fixation [1]. Owing to the inherent inferior fixation strength of the tibia, and the in-line direction of pull in the tibial tunnel compared with the wedge effect in the femoral tunnel, much attention should be given to tibial fixation, and avoidance of screw divergence on fixation is more critical on the tibial side than the femoral side [15].

Method of fixation

Interference screw is the gold standard for fixation of a graft with bone plug. Regarding metal versus bioabsorbable screws, there was no difference in healing of bone plugs in the tunnel between biodegradable and metal screws [2]. Currently, bioabsorbable interference screws have been used for graft fixation. Their potential advantages are implant degradation [2], no distortion on MRI, removal not require in cases of arthroplasty or revision, and good results [16], although lower fixation strengths have been reported with them. Newer interference screws have been created specifically for soft-tissue grafts. These screws have blunted threads to decrease the risk of soft-tissue graft laceration and have been shown to provide similar fixation to interference screws with bone plugs [1]. The potential disadvantages are screw breakage during insertion [17], an inflammatory response and cyst formation that weakens the fixation [18], and inadequate fixation after partial degradation before biologic incorporation. The time required for degradation of bioabsorbable screws is dictated by the chemical composition of each screw [1]. Dissolution of the bioabsorbable implant may be shown on MRI at 6 months [17], on computed tomography at 12 months [16], and may remain evident on scans up to 24 months [19]. Others show complete dissolution of the bioabsorbable implant and replacement with new bone by MRI at 5 years [20].

Screw length and diameter

A 35-mm screw had significantly improved strength and stiffness over a 28-mm length screw in tibial fixation of a soft-tissue graft [21]. Fixation strength and stiffness are increased with larger diameter screws in the femur and tibia when using a graft with a bone plug [22]. Increasing screw length provides a greater improvement in fixation of soft-tissue grafts whereas, increasing screw diameter provides a greater improvement in fixation of graft bone plugs [13].

With a soft-tissue graft, screw diameter should approximate that of the osseous tunnel to ensure adequate strength [23]. When using a soft-tissue graft, Weiler has recommended a screw diameter 1 mm larger than the graft diameter, especially at the tibial site, and/or 5-mm longer screw [13]. Also sizing tunnels to 0.5 mm increments improved load to failure compared with tunnels sized using 1 mm increments [24]. Gap size (tunnel–graft diameter) has also found to be a significant factor when considering interference screw fixation [15].

Correct placement of the method of fixation

Screw divergence of 15°–30° dramatically decreases the fixation strength of the graft. Although laboratory significance has been demonstrated, screw divergence has not been correlated with laxity clinically [15]. To prevent divergence, notching the anterior edge of the femoral tunnel before screw insertion, flexing the knee 100°–120°, and placing the screwdriver through the tibial tunnel may be helpful [23].

Insertion torque of the screw has been positively correlated with pullout strength in the laboratory [13,14]. Insertion torque may be altered by increasing screw diameter, decreasing gap size, and performing tunnel dilation. Underdrilling by 2 mm and dilating the final 2 mm diameter compresses the adjacent cancellous bone, increasing the relative bone mineral density and compressive stiffness, with subsequent increased fixation strength [21].

Effects of weak fixation

The weak fixation may lead to graft slippage and early reconstruction failure, graft tunnel motion, tunnel dilatation, tunnel nonunion, graft laceration, and graft rupture at the junction between intraarticular and intratunnel parts of the graft. There are two types of graft–tunnel motion including superior–inferior motion [9] and anterior–posterior motion [10], which may lead to delayed biological incorporation and tunnel enlargement.

Many clinical studies have not found any correlation between tunnel widening and clinical outcomes [12,25–27]; however, tunnel enlargement has been considered an early sign of graft failure by some authors. There are also some studies that found some effect of tunnel widening on clinical results. A significant positive association between sagittal tibial tunnel enlargement on radiography and anterior knee laxity after primary ACL reconstruction was reported [28].

Fauno and Kaalund [25] believed that extracortical fixation was associated with increased laxity and significantly more tunnel enlargement compared with aperture fixation. Although it is still controversial whether tunnel enlargement would affect the clinical outcome, it has been accepted that tunnel widening might be a problem in cases of revision because a new tunnel may be difficult to obtain. Therefore, it would be beneficial to find a way to reduce tunnel enlargement in ACL reconstruction.

Tunnel enlargement is a multifactorial process [8]. It may be caused by mechanical factors and/or biological factors. The mechanical factors include motion of the graft within the tunnel, fixation methods, and devices; stress shielding of the graft; improper graft placement; and accelerated rehabilitation. The biological factors include graft swelling during the remodeling process, the use of allograft tissue, synovial fluid within bony tunnels, and increased cytokine levels within the knee [12].

Conclusion

The site of graft fixation and type of fixation device are major factors in the development of tunnel widening after ACL surgery, but they do not significantly affect the clinical results.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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