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ACL reconstruction using bone–patella tendon–bone autograft: press-fit technique vs. interference screw fixation

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Abstract
Purpose The gold standard in ACL reconstructions has been the bone–patellar tendon–bone autograft fixed with interference screws. This prospective, randomized clinical trial aimed to compare two methods of fixation for BPTB grafts: press-fit fixation vs. interference screw, over a 12-month follow-up interval.
Methods 158 patients with an average age of 29.8 years, between 2011 and 2012, were treated for torn ACL. 82 patients underwent reconstruction with BPTB autograft with a press fit fixation technique, and in 76 cases an interference screw was used. At the time of final follow-up, 71 patients in press-fit group and 65 patients in interference screw group were evaluated in terms of return to pre-injury activity level, pain, knee stability, range of motion, IKDC score and complications.
Results At 12-month follow-up, 59 (83 %) and 55 (85 %) in press-fit and screw group, respectively had good-to-excellent IKDC score ($p > 0.05$). The mean laxity assessed using a KT-1000 arthrometer improved to 2.7 and 2.5 mm in press-fit and screw group, respectively. Regarding Lachman and pivot shift test, there was a statistically significant improvement in the integrity of the ACL in both the groups, but no significant differences was noted between groups. There were no significant differences in terms of femur circumference difference, effusion, knee range of motion, pain and complications.
Conclusions The press-fit technique is an efficient procedure. Its outcome was comparable with the interference screw group. Furthermore it has unlimited bone-to-bone healing, no need for removal of hardware, ease for revision and cost effectiveness.

Keywords Anterior cruciate ligament reconstruction · Bone-patellar tendon-bone graft · Press fit fixation · Interference screw · Outcome

Introduction

The anterior cruciate ligament (ACL) is regarded as critical to the normal functioning of the knee [1]. Disruption of ACL is a common ligamentous injury of the knee that causes significant disabilities among athletes. Strategies exist for patients with this injury are controversial between conservative rehabilitation and reconstruction, and between methods of reconstruction [2].

Reconstruction of the ACL allows the patient to resume sporting activities and delays the onset of osteoarthritis, which is associated with loss of meniscal function [3–5]. Currently, ACL reconstruction is most often performed using an arthroscopically assisted technique [6].

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For the past years, the gold standard in ACL reconstructions has been the central third bone–patellar tendon–bone autograft fixed with interference screws [7–9].

Multiple fixation techniques are currently available, most of which use hardware or resorbable material for fixation of the graft inside or outside the bony tunnel, including screws cross-pins, staples, or small plates [10].

The use of interference screws has been associated with the risk of intraoperative graft damage as well as that of a secondary graft damage caused by screw misplacement [11–18].

Besides the biomechanical questions bone, defects are a severe problem in cases of revision [19].

To avoid difficulties related to internal fixation devices, a hardware-free ACL reconstruction method was developed. This technique uses the bone plugs on either end of the patella tendon graft for press-fit fixation in marginally undersized bony tunnels.

This technique was first introduced in 1987 for femoral press-fit fixation and in 1989 for tibial press-fit fixation [20]. Several biomechanical studies have been conducted in order to compare the press-fit fixation with commonly used implant fixations. The press-fit fixation has been shown to have a similar pull-out strength and stiffness [21–23].

This prospective, randomized clinical trial aimed to compare two methods of fixation for bone–patella tendon–bone grafts in patients with a complete tear of the anterior cruciate ligament: press-fit fixation vs. interference screw. Comparisons were made over a 12-month interval and consisted of return to pre-injury level of sporting activity, pain, knee stability, range of motion, IKDC score (International Knee Documentation Committee), complications and costs.

Methods

Patients

Between 2011 and 2012, 158 patients, 131 men and 27 women with anterior cruciate ligament tearing were selected for the study. Exclusion criteria included previous injury or operation on either knee, a concurrent fracture, osteoarthritis in either knee, or significant injury to other ligament structures (including posterior cruciate ligament, lateral collateral ligament, medial collateral ligament, or posterolateral corner of the knee). The study design was approved by our ethics committee and all patients gave informed consent prior to inclusion in this trial.

This patient population was randomly placed in two groups, by a computer-generated list, regarding to the treatment. In the first group (Group A; $n = 82$) the press fit fixation technique was used; while in the second group (Group B; $n = 76$) an interference screw was used.

Table 1 Descriptive data for patients in this study

	Press-fit group	Interference screw group
Age		
Mean	28.4	30.5
Range	17–42	18–42
Sex		
Male	68	63
Female	14	13
Injured leg		
Left	35	37
Right	47	39

The average patient age was 29.8 years (range 17–42 years). The right knee was injured in 86 patients and the left in 72 patients (Table 1). The time between injury and surgery ranged from 5 weeks to 25 months (median 10 months), and it was similar for the two groups.

Surgical technique

All reconstructions were performed by a single surgeon (MM Sarzaeem). Patients were initially placed in a program of physical therapy emphasizing techniques to regain motion and decrease swelling preoperatively.

At the time of arthroscopy, the knee was examined, associated joint pathology was documented, and irreparably torn meniscal fragments were removed.

Bone–patellar tendon–bone grafting using interference screw

The bone–patellar tendon–bone graft was constructed from the central third of the tendon of the ipsilateral knee. The graft was 10 mm wide and harvested with 20–28 mm of bone from the patella and tibial tubercle. The femoral guide pin was placed 5 mm anterior to the posterior cortex to allow for a 1–2 mm posterior cortical rim after reaming at the ten-thirty position (for right knees) or one-thirty position (for left knees). The tibial guide pin was placed through the footprint of the ACL adjacent to the anterior horn of the lateral meniscus and the tibial tunnel was reamed. All tunnels were reamed to an appropriate size depending on the width of the autograft bone blocks. The graft was pulled through the tunnels so that the patella bone block was within the femoral tunnel and the tibial bone block was within the tibial tunnel. The graft was positioned so that no bone protruded into the joint. An interference-fit screw was used in the femoral tunnel to fix the bone block. Tension was then placed on the distal part of the graft, and impingement was excluded by range of motion maneuvers. Next, the graft was secured under an appropriate tension

Fig. 1 The graft was 10 mm wide and harvested with 20–28 mm of bone from the patella and tibial tubercle. The femoral bone blocks is formed to a pyramidal shape using an oscillating saw

within the tibial tunnel with use of an interference screw. The tibia was loaded with a maximal posterior force during fixation on the tibial side to minimize graft laxity present at the time of surgery.

Bone-patellar tendon-bone grafting using femoral press fit fixation

The tunnels were placed in the same manner as the tunnels for the interference screw fixation method, but the femoral tunnel was reamed 2 mm undersized. The femoral bone block was formed to a pyramid shape using an oscillating saw (Fig. 1). The patella bone block must be sized so that its basis can pass through a tunnel of 10 mm diameter and only about 5 mm of its tip can pass through a tunnel of 8 mm diameter so it allows 15 mm of bone block for press fitting (Fig. 2). One 1.5 mm hole was drilled into each bone block. The graft was then passed into the knee from outside-in using a pull-through suture and the bone blocks positioned in their tunnels by pulling and assisted with hammering using impactor inserted through arthroscopic portal. After press fit fixation of the patella bone block, 300 N tension during 30 s was applied distally to the graft at the 30° position of the knee to confirm press fit fixation. Then under appropriate tension the tibia bone plug was secured in the tibial tunnel with a staple (Fig. 3) (see the supplementary video).

Postoperative rehabilitation

The rehabilitation protocol was identical for both groups with passive range of motion exercises instituted immediately and progression to active closed chain exercises

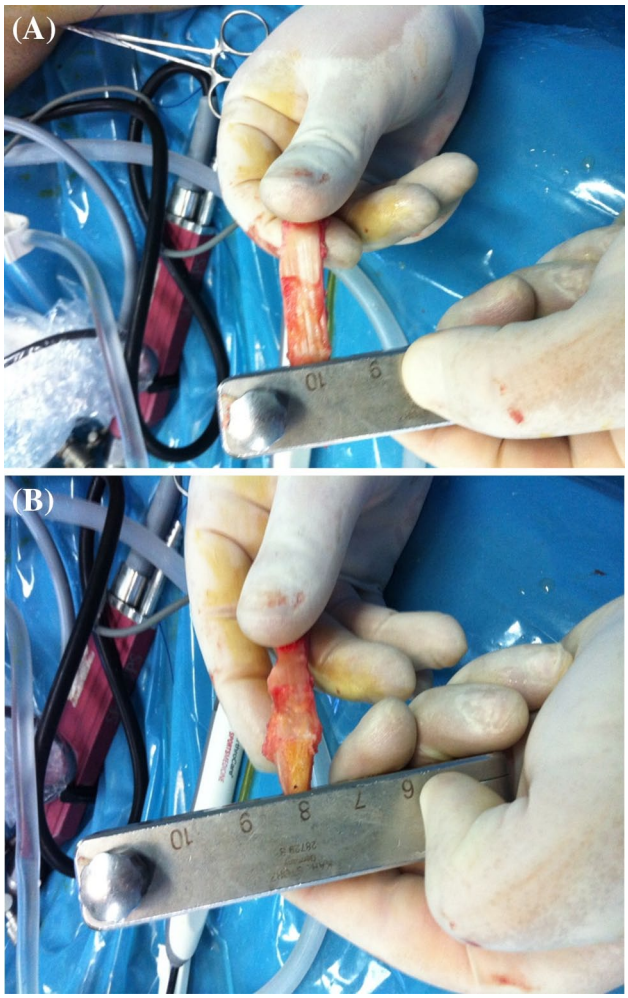

Fig. 2 The patella bone block must be sized so that its basis can pass through tunnel of 10 mm diameter (**a**) and about 5 mm of the tip of the bone block can pass through tunnel of 8 mm diameter (**b**), so it allows 15 mm of bone block for press fitting

Fig. 3 The tibia bone block is fixed to the tibial tunnel with a staple

achieved by 6 weeks postoperatively. Patients were allowed full weight bearing 3 weeks postoperatively and returned to running at 3 months. Return to sports participation was allowed at 6 months.

Follow-up evaluations

All patients were examined and postoperative data were collected at 3, 6 and 12 months after surgery.

Objective parameters used for evaluation included the presence of effusion, Lachman and pivot-shift testing, KT-1000 arthrometer side-to-side differences, modified IKDC knee function scores and Tegner activity scores [24].

Ranges of knee motion, locking of the knee, and patellofemoral pain were also recorded. Quadriceps bulk was measured 20 cm above the joint line and compared with that of the contralateral extremity.

Anterior–posterior knee laxity was recorded using maximum-manual KT-1000 arthrometer at 20° of knee flexion and with the Lachman test. Grading of the Lachman examination was defined as normal, 1+(increased excursion with an end point), or 2+(increased excursion without an end point). Pivot-shift examination was graded as normal, 1+(mild difference between the knees or glide), 2+(moderate difference or subluxation), or 3+(gross subluxation).

Activity level was determined with the use of the International Knee Documentation Committee (IKDC) preoperatively and at latest follow-up. The Tegner activity scale was used to quantitate patient activity levels before injury and at 1 year follow-up.

Knee function was assessed with the ability to bear weight, difficulty with climbing stairs, ability to run and difficulty with squatting.

Post-operative complications including deep infection, wound infection, patella fracture were recorded at follow up visits.

One-year follow-up was completed for 136 patients (86.1 %): 71 patients of the first group (press fit group) and 65 patients of the second group (screw group).

Statistical methods

Statistical analyses were carried out using SPSS (SPSS statistic package, version 21.0.0) statistical software. The Pearson Chi square test and the *t* test were used to determine whether there were any significant differences. The level of significance was set at $p < 0.05$.

Results

There were no significant differences between the two groups in the number of meniscal or osteochondral lesions.

Table 2 The IKDC score

	Press-fit group[a]	Interference screw group[a]
Pre-operation		
A and B	49 (69 %)	47 (72 %)
C and D	22 (31 %)	18 (28 %)
12-month follow up		
A and B	59 (83 %)	55 (85 %)
C and D	12 (17 %)	10 (15 %)

There was no significant difference in activity levels between the groups at the preoperative and 1-year interval.

[a] The values are given as the number of patients with the percentage in parentheses

At the 12-month follow-up 59 patients (83.1 %) in group A and 55 patients (84.6 %) in group B had good-to-excellent IKDC score (grade A or B), showing statistically insignificant differences between two groups ($p > 0.05$) (Table 2). The activity levels as measured with the Tegner scale at the 1-year follow-up was a median of 6 points (range 4–9 points) in the press fit group and a median of 5 points (range 3–9 points) in the interference screw group ($p > 0.05$).

The mean laxity assessed using a KT-1000 arthrometer improved from 6.6 preoperatively to 2.7 mm at the last follow-up in group A ($p < 0.05$) and from 6.5 mm preoperatively to 2.5 mm at the last follow-up in group B, but no statistically significant difference between the two groups was observed. Postoperatively for Lachman test, In press fit group, 43 patients were graded as normal, 23 patients were graded as 1+and 5 patients as 2+; comparing with interference screw group, including 39 patients graded as normal, 21 patients graded as 1+and 5 patients graded as +2, the differences was not statistically significant ($p > 0.05$, $\alpha = 0.05$, $\beta = 10$ %) (Table 3).

Regarding the pivot shift test, there was a statistically significant improvement in the integrity of the ACL in both the groups, but no significant differences was noted between the groups ($p > 0.05$) (Table 4).

There were no significant differences with regard to femur circumference difference, effusion, or range of motion between the two groups. At the end of 12 months follow up, 8 patients (11.3 %) in group A and 7 patients (10.8 %) in group B had extension deficit between 3° and 5° ($p > 0.05$). 7 patients (9.9 %) in group A and 5 patients (7.7 %) in group B had flexion loss more than 5° ($p > 0.05$).

3 patients (4.2 %) in group A, and 4 patients (6.1 %) in group B showed post-operative complications ($p > 0.05$) (Table 5). 9 patients (12.7 %) in group A and 10 patients (15.3 %) in group B had mild patellofemoral pain at 1-year follow up, showing no significant differences between the two groups ($p > 0.05$).

Table 3 Lachman Test

	Press-fit group[a]	Interference screw group[a]
Pre-operation		
Normal	0 (0 %)	0 (0 %)
1+	10 (14 %)	6 (9 %)
2+	61 (86 %)	28 (81 %)
12-month follow-up		
Normal	43 (61 %)	39 (60 %)
1+	23 (32 %)	21 (32 %)
2+	5 (7 %)	5 (8 %)

There was no difference between the groups preoperatively and at the 12 months follow up.

[a] The values are given as the number of patients with the percentage in parentheses

Table 4 Pivot Shift examination

	Press-fit group[a]	interference screw group
Pre operation		
Normal	0 (0 %)	0 (0 %)
1+	6 (9 %)	8 (12 %)
2+	23 (32 %)	18 (28 %)
3+	42 (59 %)	39 (60 %)
12 month follow up		
Normal	59 (79 %)	57 (88 %)
1+	10 (16 %)	5 (8 %)
2+	2 (5 %)	3 (4 %)
3+	0 (0 %)	0 (0 %)

There was no difference the groups preoperatively and at the 1-year follow up.

[a] The values are given as the number of patients with the percentage in parentheses

Table 5 Reported complications

	Deep infection	Wound infection	Patella fracture
Press-fit group	1 (1 %)	2 (3 %)	0 (0 %)
Interference screw group	2 (3 %)	2 (3 %)	0 (0 %)

There was no difference between the treatment groups

Discussion

The choice of the graft influences the success of ACL reconstruction. Bone–patella tendon–bone (BPTB) is the most common currently used autograft; it is a stable graft with long-term biomechanical properties [9, 25–28]. The stability of the graft depends on its strength and also on its fixation method. There are some studies presenting the results of ACL reconstruction with the press-fit fixation technique [11, 19, 20, 29, 30] and to our knowledge, our study is one of the small number of clinical trials, which compared interference screw fixation with press-fit patella tendon bone for ACL reconstruction.

In this study the clinical results of press-fit group compare well with the interference screw group. At 12-month of follow-up, normal to nearly normal IKDC scores were reported in 83 and 85 % of group A and B, respectively, it was in accordance with previous studies [20, 27, 31–35].

In our study the median Tegner score was 6 and 5 points in press-fit and interference screw group, respectively. These results are comparable to observations reported by others [9, 25, 27, 36].

At the time of last follow-up the mean laxity assessed using a KT-1000 arthrometer improved to 2.7 mm in group A and to 2.5 mm in group B patients. Regarding the Lachman and pivot shift test, there was a statistically significant improvement in the integrity of the ACL in both the groups, but no significant differences was noted between the groups. Similar results have been noted in the literature after ACL reconstruction [19, 25, 36].

The donor site morbidity seems to be a major concern of all BPTB graft techniques. It include complications such as damaging the knee extensor apparatus, the potential for subsequent patellofemoral joint pain or crepitation, patella fracture, patella tendon rupture, infra-patella contraction, numbness caused by damage of the infra-patellar branch of the saphenous nerve and possible loss of quadriceps strength [9, 28, 37]. In our study anterior knee pain was noted in 14 % the of patients. Some authors [26] suggested accelerated rehabilitation programs to decrease the incidence of anterior knee pain. Fracture of the patella is an uncommon complication and occurs in 0.1–3 % of patients [38, 39]. In this study, no patella fracture was reported.

The clinical outcome of the two groups of our study did not differ significantly with regard to return to pre-injury level of sporting activity, knee stability, range of motion, IKDC score, prevalence of knee-locking, femur circumference difference and complications. On the other hand, the press-fit fixation method is a very cost-effective technique. Taking this into account, it seems reasonable to consider the most inexpensive graft for ACL reconstructions due to limited economy.

Healing of the bone-to-bone interval with secure osseous incorporation could be observed as early as 6 weeks post-ACL reconstruction [33, 34]. This supports early functional rehabilitation in press fit fixations grafts [15]. Nonetheless, no group in our study underwent an aggressive postoperative rehabilitation protocol and running delayed until 3 months postoperatively. This protocol was applied to allow for adequately healing of the interference screw fixed grafts within the bone tunnels while maintaining similarity for both groups.

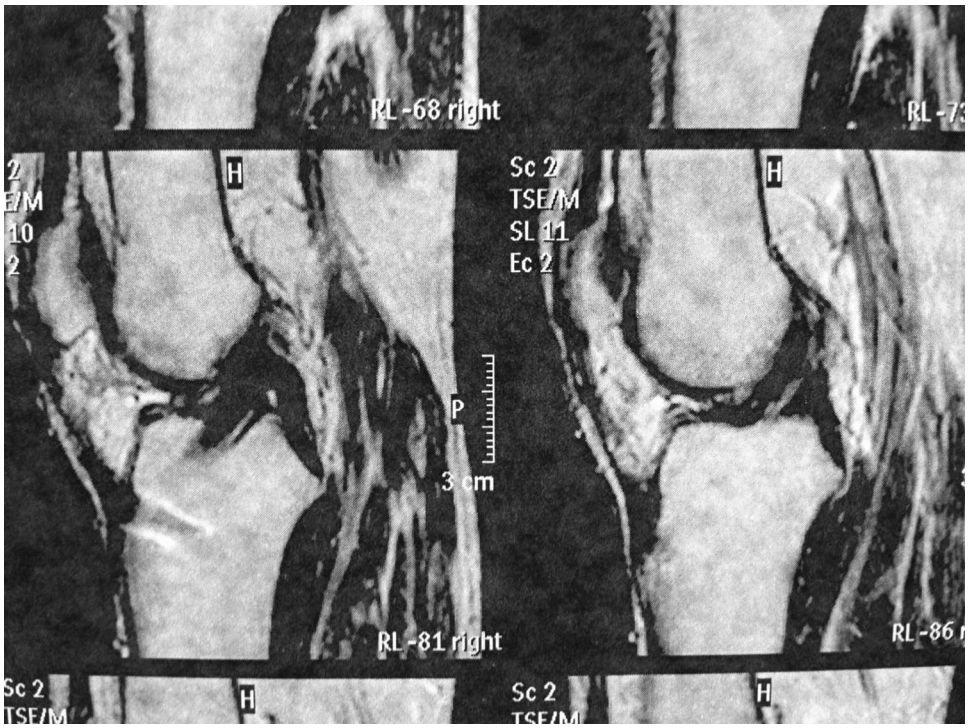

Fig. 4 The MRI after 6 months, only few signs of the tibia channel can be detected. The graft is stable and in correct anatomic position

Press-fit fixation depends on the quality of bone, so a more protective rehabilitation protocol is rational in some patients with osteopenic bone and for this group of patients. Felmet [40] suggests a reduced range of motion in a brace from 30° to 90° knee flexion for the first 3–4 weeks. In his cohort study, the long-term follow-up showed no difference between the osteopenic group and the patients with normal bone quality.

The press-fit fixation has been worked well in most of our cases and it had low rate of complications. The use of interference screws was only necessary in two cases because of insufficient stability due to poor bone quality (after applying 300 N tension to the graft in distal direction, the patella bone block dislodged, so it was fixed to the femoral tunnel with an interference screw). We think this technique is usable in every case.

The press-fit fixation of the graft close to the native insertion is useful [41]. This minimizes the risk of tunnel enlargement [20, 42], it causes a stable fixation and a direct bone-to-bone healing (Fig. 4) and it has a similar pull-out strength and stiffness when compared to hard-ware fixations [21, 23]. Another important feature of this fixation technique is easier revision of ACL reconstruction [20, 40]. Also press-fit fixation reduces the number of disadvantages associated with hardware fixation including screw divergence with a resultant decrease of pullout strength, intraoperative graft violation, damage to the dorsal cortical bone of the femur 6–9, inadvertent graft advancement, bone resorption, chronic synovitis, bio incompatibility, biodegradability or allergic reactions [11, 23, 43].

Limitations of this technique include a certain degree of technical difficulty and limited applicability in patients with poor bone quality. However in our study we did not observe any complications related neither to bone quality nor to technical site.

Conclusions

Arthroscopic reconstruction of the ACL with a bone–patellar tendon–bone graft in the press-fit technique is an efficient procedure. Its outcome was comparable with the interference screw group. Furthermore its advantages include unlimited bone-to-bone healing, high primary stability and thus early functional rehabilitation. It has no disadvantages associated with an implant, no need for the removal of hardware, ease for revision surgery and cost effectiveness. We think the BPTB femoral press-fit fixation method can be safely used and lets patients to return to pre injury activities.

Conflict of intrest None.

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