# Anterior cruciate ligament reconstruction with bone-patellar tendon bone graft by hour-glass technique

Tarek Abdel Aziz Mahmoud

Department of Orthopaedic Surgery, Suez Canal University, Ismailia, Egypt

Correspondence to Tarek Abdel Aziz Mahmoud, MD, Department of Orthopaedic Surgery, Suez Canal University, Ismailia, Egypt. Tel: +20 122 415 6281; e-mail: tareksh64@yahoo.com

**Received** 11 December 2018
**Accepted** 27 December 2018

**The Egyptian Orthopaedic Journal** 2018, 53:266–273

**Background**
Torn anterior cruciate ligament (ACL) is a major cause of knee instability, and reconstruction by hour-glass technique is an effective method of treatment.
**Aim of the study**
This study evaluated the clinical and functional outcomes after using bone-patellar tendon bone graft for ACL reconstruction through hour-glass technique.
**Patients and methods**
This prospective study was done on 20 patients, all males, attending the Saudi German Hospital in Saudi Arabia between May 2011 and January 2013, and the mean age was 28 (range, 21–42) years at the time of surgery. The patients included in the study had posttraumatic knee instability with torn ACL. Clinical and functional evaluation was done after 1 year of follow-up using the Gillquist Lysholm score. Grading of the results was based on clinical evaluation using Lysholm score, and radiological evaluation using Kellgren score was done also after 1 year of follow-up.
**Results**
Patients who presented late after trauma (3–12 months) represented 75% of patients included in the study, and the main complaint of almost all patients was knee instability and pain. Other associated complaints were limping in 80%, locking of the knee in 20%, and difficulty in climbing stairs in 15% of patients. During arthroscopy, 14 (70%) patients had ACL torn at femoral attachment, four (20%) patients had mid substance torn ACL, and only two (10%) patients had torn ACL at tibial attachment. Moreover, meniscal lesions were found in four (20%) patients, and partial meniscectomy was done through arthroscopy. In addition, 90% of patients had excellent and good results, and the average Lysholm score was increased from preoperative of 42 (22–65) to postoperative of 95 (75–98) after 1-year follow-up. Radiological evaluation of osteoarthritis was done with comparison of the operated knee and the contralateral side according to Kellgren classification. In the current study, 30% of patients decreased by one grade and 45% of patients decreased by two grades, and in 25% of patients, there is no change. Only one (5%) patient had marked retropatellar pain, and this patient had degenerative changes before surgery owing to late presentation. Moderate graft pain with tenderness was found in two (10%) patients. No other complications were found except one (5%) patient who developed superficial infection and improved with frequent dressing and antibiotics.
**Conclusion**
ACL reconstruction by bone-patellar tendon bone graft by hour-glass technique is an effective method to restore knee stability with early weight-bearing and high satisfactory results.

**Keywords:**
anterior cruciate ligament reconstruction, bone graft, hour-glass

Egypt Orthop J 53:266–273

1110-1148

## Introduction

The anterior cruciate ligament (ACL) is an important stabilizing structure of the knee joint that prevents anterior translation and rotation of the tibia in relation to the femur [1]. Instability of the knee after ACL rupture may lead to recurrent attacks of giving way and increased risk of meniscal tear with development of degenerative changes [2,3].

Many studies have proved that a torn ACL will not heal with conservative treatment and repair alone. Consequently, reconstruction has become the standard method of treatment for patients with rupture of the ACL [4,5].

Surgical treatment of ACL rupture by reconstruction are divided into three methods, intra-articular

reconstruction, extra-articular reconstruction, and combined both intra-articular and extra-articular reconstruction using either autogenous or synthetic material. The most commonly used autograft for intra-articular reconstruction of the ACL is the central one-third of the patellar tendon [3].

Many authors confirm that reconstruction of the ACL ligament by bone-patellar tendon-bone (BPTB) autografts has become the gold standard procedure and gives good clinical results [6–9].

Isometric positioning of the graft, use of strong and well-prepared graft, adequate graft fixation, staged rehabilitation with early passive extension, and arthroscopic technique can be expected to improve the outcome of ACL reconstruction and reduce associated complications [10,11].

Many studies reported that harvesting the patellar ligament for ACL reconstruction can be a source of anterior knee pain and hyposthesia of the lateral side of the knee [12].

## Patients and methods

This prospective study was done on 20 patients, all males, attending Saudi German Hospital in Saudi Arabia between May 2011 and January 2013, and the mean age at the time of surgery was 28 (range, 21–42) years. This study was approved by ethical committee of Seuiz Canal University. All patients signed an informative consent form. The patients included in the study had posttraumatic knee instability with torn ACL. Patients having other ligamentous injuries or open knee injuries were excluded from the study. Clinical and functional evaluation was done after 1 year of follow-up using the Gillquist Lysholm score [13] (Table 1). They developed a scoring scale for evaluating athletes after knee ligament surgery. This subjective scoring for examination for ACL injury and any associated injuries of meniscus and knee ligaments was done for each patient.

The Lysholm knee score [14] for grading the patient's satisfaction of operation based on clinical evaluation was done at 1-year follow-up (Table 2). In addition, radiological evaluation for the grade of osteoarthritis (OA) was evaluated after 1 year of follow-up using Kellgren score [15] (Table 3).

**Table 1 Lysholm and Gillquist score**

| Parameters | Total 100 points |
|---|---|
| Limp | 5 points |
| Support | 5 points |
| Stair climbing | 10 points |
| Squatting | 5 points |
| Walking running and jumping – instability | 30 points |
| Walking running and jumping – pain | 30 points |
| Walking running and jumping – swelling | 10 points |
| Atrophy of thigh | 5 points |

**Table 2 Lysholm knee score**

| Knee score | Points |
|---|---|
| Excellent | 95–100 |
| Good | 84–94 |
| Fair | 65–83 |

### Surgical technique

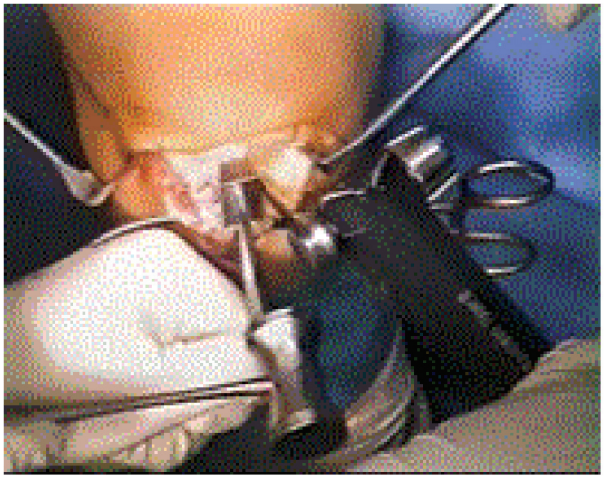
All patients were given spinal anesthesia, and clinical examination was done for meniscus, ACL, and other ligamentous injuries to confirm diagnosis. Then through anterolateral portal using 30° arthroscopy and under tourniquet, the joint was examined, and any associated meniscal lesions were managed by partial meniscectomy. With the knee in 90° flexion, an 8-cm midline anterior skin incision starting at the middle of the patella and extending distally to the tibial tuberosity was done. Then subcutaneous dissection was done to expose the patella and tendon. A straight midline incision through the peritenon and a mid-third wide graft 8–10 mm in size was harvested from the central portion of the patella and tendon and extending proximally from the middle of the patella to the tibial tuberosity. An oscillating saw was used for bone cuts and was run initially parallel to the anterior cortex of the patella and then run oblique to complete the bone cuts, and the cut was 8 mm in depth (Fig. 1). It is very important to keep the saw in oblique direction to avoid fracture of the patella. The patellar bone fragment was approximately 9-mm wide and 25-mm long and then graft was released by dissection and osteotomy. Tibial bone fragment was released in the same way, and its size was 12–13 mm width and 20 mm length with keeping the saw in oblique direction to release the bone safely (Fig. 2).

**Table 3 Kellgren score**

| Grade of OA | Findings |
|---|---|
| Grade I (doubtful) | Minute osteophyte |
| Grade II (minimal) | Definite osteophytes, unimpaired joint space |
| Grade III (moderate) | Moderate diminution of joint space |
| Grade IV (severe) | Joint space greatly impaired with sclerosis of subchondral bone |

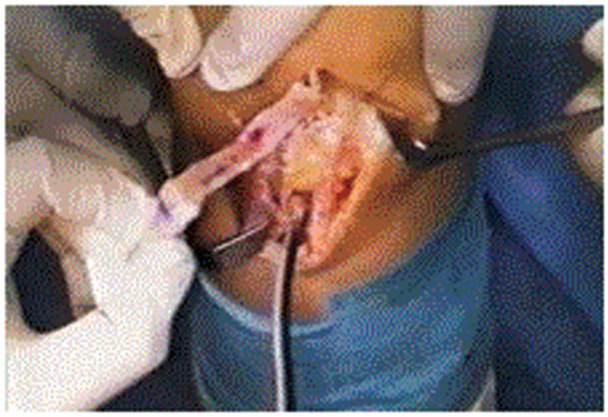
OA, osteoarthritis.

**Figure 1**



Sizing and cutting of the patellar part of the graft.

**Figure 2**



Release of the graft patellar part of the graft.

After that, preparation of the graft was done by making two drill holes in tibial and patellar bone fragment, and a thick nylon thread passed into the holes to help traction of the graft through the femoral and tibial tunnels. Then adjusting the size of patellar bone fragment by graduated sizer block and the size of the fragment was adjusted at size 8 mm. In the same way, the tibial bone fragment was adjusted into two sizes, the proximal part into size 8 mm and the distal part into sizes 11–12 mm. The size of the patellar bone fragment and the distal part of the tibial bone fragment should be the same size to pass through the tibial tunnel and proximal part of the femoral tunnel.

Tibial tunnel was prepared by directing a 2-mm K-wire at ~30° angle, with tibia beginning just medial to the tibial tuberosity and 25–30 mm below the joint surface. K-wire was inserted with the help of a C-angle guide wire entering the joint at the tibial attachment of the ACL. Tibial tunnel was prepared

**Figure 3**

Femoral guide was hooked on the posterior cortex of femoral condyle, and K-wire was inserted to prepare femoral tunnel.

**Figure 4**

Femoral guide was hooked on the posterior cortex of femoral condyle, and K-wire was inserted to prepare femoral tunnel.

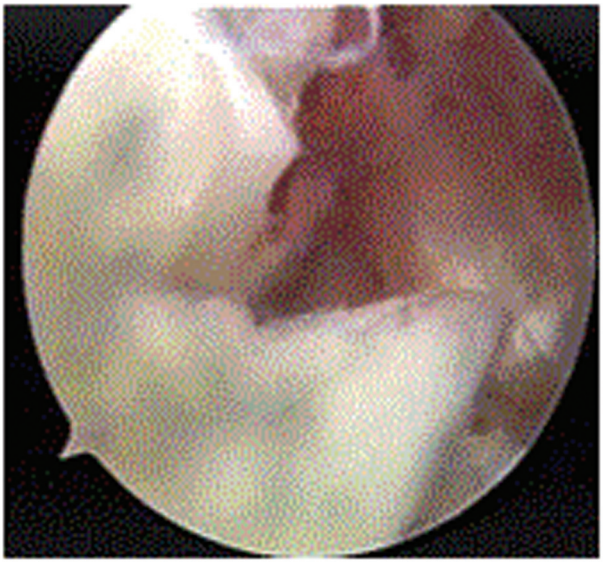
by drilling with graduated cannulated drills and reamers [6–9] over the K-wire, and the final size used in all patients is 9.

With the knee in 90° flexion, notchplasty was done and the K-wire was passed through the tibial tunnel and advanced into the intercondylar notch at isometric point (posterior-superior part of lateral surface of intercondylar notch) using femoral guide and passed outside through the lateral part of the distal femur (Figs 3 and 4). Skin

**Figure 5**

Graduated reamer was inserted.

**Figure 6**



After insertion of the graft, prepare the hour-glass femoral tunnel.

incision was done near the projecting K-wire, and muscles were cut through the skin incision. Then bone was exposed subperiosteally around the wire. Femoral tunnel was done by cannulated reamer size 9 and passed through the outer cortex of the femur and kept in position, and graduation of the reamer was clear through arthroscopy. Then K-wire was introduced through the outer lateral part of the distal femur and another reamer size 12–13 was used to prepare femoral tunnel with different size and pushed slowly under arthroscopy control and pushing the reamer inside the femoral tunnel size 9 until length 25 mm was clear (Fig. 5). Then both reamers get outside and the femoral tunnel size was now the proximal part is 9 mm and the outer distal part is 12–13 according to size of the distal part of tibial bone fragment prepared before.

Finally, guide wire was attached to nylon threads of the patellar bone fragment and passed through the femoral tunnel and pulled outside through the tibial tunnel, and the tibial bone fragment was plugged into the femoral tunnel and the patellar bone graft into the tibial tunnel. Now the femoral graft was fitted completely inside the femoral tunnel and fixed without metal fixation or screws as the two different sizes of the femoral plug are fitted well in the hour-glass tunnel (Fig. 6). With the knee kept in 30° flexion for keeping the tension of the graft, the tibial bone graft was fixed by biodegradable screw size 9 mm. Tension on the graft was evaluated by using probe and traction on the tendinous part of the graft.

Then wash was done, and closure of the patellar tendon and sheath and wound was done in layers over suction drain. Moreover, the skin over the outer distal part of femur was closed in layers. Dressing, cotton, and crepe bandage were applied and limb elevated. Suction drain was usually removed after 2 days, and stitches were removed after 2 weeks.

Physiotherapy protocol was aimed for early restoration of full extension and strengthening exercises. Continuous passive motion began the next day after surgery for 2 h twice a day, and patients started continous passive motion (CPM) between 0° and 45° and increased 10° per day as tolerated to a maximum of 120°. Knee brace was applied, and progression of weight-bearing using crutches or canes was allowed for partial weight bearing as pain was tolerated. Functional activities including walking and running were allowed after 6 months postoperatively.

### Statistical analysis

Analysis of data was performed by using statistical package for the social sciences (version 16; SPSS Inc., Chicago, Illinois, USA) for analysis, for describing these data (mean and SD), and for comparison of quantitative parameters before and after the surgical procedure ($t$ test). A 95% confidence interval had been calculated, and a $P$ value less than 0.05 had been considered significant.

## Results

A total of 20 patients having posttraumatic torn ACL were included in the study, and 65% of them were

**Table 4 Distribution of clinical signs after anterior cruciate ligament injury**

| Clinical sign | Number of patients [*n* (%)] |
|---|---|
| Tenderness of joint line | 12 (60) |
| Effusion | 18 (90) |
| Flexion deformity ≤10° | 1 (5) |
| ROM <100° flexion | 2 (10) |
| Positive special tests[a] | 20 (100) |

[a]Special tests (Anterior Drawer test, Pivot shift test, and Lachman test).

following sporting injury. The average time between injury and time for ACL reconstruction was 3–12 months in 75% of patients included in the study and 15% before 3 months and only 10% after 12 months of the injury, and the mean interval was 6 months. The chief complaint of almost all patients was knee instability and pain. Other associated complaints were limping in 80%, locking of the knee in 20%, and difficulty in climbing stairs in 15% of patients.

The Gillquist Lysholm score was used to evaluate knee function [13]. On clinical evaluation, right knee was involved in 12 (60%) patients. Because all patients were presented late after trauma, there is wasting of the quadriceps muscle that ranged from 1 to 3 cm and 90% of patients had quadriceps wasting of 1 cm in comparison with the uninjured side. Additional clinical signs were identified and are shown in Table 4.

During arthroscopy, 14 (70%) patients had ACL torn at femoral attachment, four (20%) patients had mid substance torn ACL, and only two (10%) patients had torn ACL at tibial attachment. Meniscal lesions were found in four (20%) patients, and partial meniscectomy was done through arthroscopy. In addition, 90% of patients had excellent and good results, and the average Lysholm score was increased from preoperative of 42 (22–65) to postoperative of 95 (75–98) after 1-year follow-up.

Radiological evaluation for OA was done with comparison of the operated knee and the contralateral side according to Kellgren classification [15]. In the current study, 30% of patients decreased by one grade and 45% of patients decreased by two grades and in 25% of patients, there is no change. Only one (5%) patient had marked retropatellar pain, and this patient had degenerative changes before surgery owing to late presentation. Moderate graft pain with tenderness was found in two (10%) patients. No other complications were found except one (5%) patient developed superficial infection and improved with frequent dressing and antibiotics.

## Discussion

Authors have different opinion about ACL reconstruction if it is mandatory or not. MacDaniel and Dameron [16] and Balkfors [17] have presented patients with ACL rupture who resumed normal life without surgical intervention. In contrast, Johnson *et al.* [18] reported high incidence of meniscal tears and degenerative arthritis with ACL-deficient knee, and the incidence of articular cartilage erosion and OA owing to ACL rupture and instability is more than 70%.

According to Noyes *et al.* [19], the main aim of ACL reconstruction is to restore knee instability and to restore its function and allow patient to return to normal activities. Another aim is to prevent the early degenerative arthritis.

Failure of tension of the graft of various donor tissues have confirmed that BPTB graft has the strongest mean of strength of 163–175% of that normal ACL, and it is the gold standard method for ACL reconstruction [20]. Moreover, interference fit fixation of the bone of the physioTherapy (PT) graft has been known to be superior to other types of fixation. Another advantage that the bone peg unites in approximately 6 weeks allows early rehabilitation of the knee [21,22]. In addition, early weight bearing after ACL reconstruction with the PT graft and interference screw fixation was discussed and accepted by many authors [23,24].

The average age in the present series was 28 (range, 21–42) years. In Kevin [25], the average age was 46 years (40–65 years), and in Pathania *et al.* [20], the average age was 27.8 years (20–39 years).

In our series, the most common cause of injury was sporting injury in 65% of the patients included in the study followed by fall after slipping in 20%. In Pathania *et al.* [20], the most common modality of injury was football and basketball sports (44%), next to that fall from a height (16%), and fall after slipping (16%). In Kevin [25], the primary cause of injury was accidents that occurred during skiing (40%), tennis (20%), and soccer (8%).

The average time between injury and time for ACL reconstruction in our series was 3–12 months in 5% of patients included in the study and 15% before 3 months and only 10% after 12 months of the injury, and the

mean interval was 6 months. In Kevin [25], the mean interval between injury and operation was 25 months, and in Pathania *et al.* [20] was 12 months.

In the current study, meniscal lesions were found in four (20%) patients and partial meniscectomy was done through arthroscopy. In the study of Pathania *et al.* [20], 20% of patients had meniscal lesions. In Kevin [25], 28.2% had meniscal tear, and partial meniscectomy was done for all of them.

For evaluation of postoperative knee instability, anterior drawers, Lachman, and pivot shift tests were done after 1-year follow-up, and the negative results in our series were as follows: Lachman test in 95%, anterior drawer test in 90%, and pivot shift test in 95%. In Al-Zarahini [26], negative results of Lachman test in 94%, of anterior drawer test in 60%, and of pivot shift test in 96%. In Pathania *et al.* [20], negative results of tests were as follows: Lachman test in 84%, anterior drawer test in 72%, and pivot shift test in 88%. In the study of Kang *et al.* [27], negative results of Lachman test were found in 81.6%, anterior drawer test in 84.2%, and pivot shift test in 93.4%. In a series of Jonathan [28], negative results of tests were as follows, Lachman test in 81%, anterior drawer test in 99%, and pivot shift test in 91%. In Kevin series, [25] negative results of Lachman test were seen in 80%, Anterior Drawer test in 66%, and Pivot shift test in 80%. In the study of Samir *et al.* [29], negative results of tests were as follows: Lachman test in 87.5%, anterior drawer test in 90%, and pivot shift test in 87.5%. Another study of Shuzhen *et al.* [30] reported that Lachman test was negative in 73% of patients and pivot test was negative in 83% of patients included in the study. These variations of results may be related to different time for follow-up evaluation at 1 and 2 years and different techniques used for reconstructions.

In the current study, in comparison with the uninvolved knee, 90% of patients had full range of movements, 5% of patients had restriction of last 10° of flexion, and 5% of patients had extension deficit of 5°. These results are comparable with the results of Pathania *et al.*, [20] as in their series 92% of patients had full range of movements, 8% of patients had restriction of last 10° of flexion, and 8% of patients had extension deficit of 5°.

In the study of Samir *et al.* [29], 5% of patients had a loss of 10° of extension and 12.5% of patients had loss of flexion up to 15°. In Kevin series [25], the average postoperative knee flexion was 136°. Only one patient had knee flexed to less than 125° postoperatively. In Al-Zarahini [26], 92% of patients had full range of movements and 4% had an extension deficit. In the series of Jonathan [28] at 2-year follow-up, 99% of patients had full flexion or lacked less than 5° of flexion and 1% lacked less than 7° of flexion. Overall, 97% of the patients had full extension or lacked less than 3° and only 3% were lacking 4°–5° of full extension. The study by Shuzhen *et al.* [30] reported that 9% of patients has extension loss of more than 5°.

In the current study, 90% of patients had excellent and good results and average Lysholm score increased from preoperative of 42 (22–65) to postoperative of 95 (75–98). In Pathania *et al.* [20] 19 (76%) patients were rated as good or excellent result. Moreover, the average Lysholm score increased from preoperative of 47 (27–75) to postoperative of 87 (68–95). In the study by Al-Zarahini [26], 41 (82%) patients were rated good and excellent after an average follow-up of 24 months. In the series of Jonathan [28], 90% of patients scored good or excellent result. Moreover, the average Lysholm score was increased from preoperative of 61 (6–95) to 95 (70–100) at 12 months of follow-up, and these results are comparable to the results of the current study.

In the study of Kevin [25], the average preoperative Lysholm score was 63 (11–100) and the average postoperative improved to 94 (69–100). In Kang *et al.* [27], the mean preoperative Lysholm score was 59 (33–78), and the mean postoperative scores at 12 months were 90 (69–100). In the study by Dejour *et al.*, [31], excellent and good results were seen in 85% of patients after reconstruction. In the study of Samir and colleagues, the average postoperative Lysholm knee score after 1-year follow-up was 91.6 (79–96).

Several studies have reported that after ACL reconstruction, the progressing rate of OA increased [32,33]. In another study of Daniel *et al.* [4], the possible explanations for the development of OA in the reconstructed knee related to joint injury occurring at the time of surgery were prolonged joint inflammation after surgery and abnormal joint mechanics after surgery. In addition, the age of the patient, the time from injury to surgery, the procedure of ACL reconstruction, and meniscectomy could increase the incidence of OA. In the study of Kang *et al.* [27], the surgical procedure for reconstruction of the ACL may be of importance regarding the risk of OA that finally developed through maintaining knee stability, which results in a lower frequency of repeated injuries of the meniscus and cartilage.

On the contrary, in the study of O'Brien *et al.* [3], ACL reconstruction will cause balance of the uneven load of the knee, with reduction of the incidence of meniscal degeneration and prevention of osteoarthritic changes. Radiological evaluation for OA was done with comparison of the operated knee and the contralateral side according to Kellgren classification [15]. In the current study, 30% of patients decreased by one grade and 45% of patients decreased by two grades, and in 25% of patients, there is no change. In the study of Kang *et al.* [27], 38% of patients decreased by one grade and 9% of patients decreased by two grades, and in 53% of patients, there was no change. In the study of Samir *et al.* [29], postoperative moderate patellofemoral OA with osteophytes was developed after 1 year in 20% of patients (grade II) and 15% of patients developed moderate degenerative changes of the medial compartment (grade III).

Postoperative complications of retropatellar pain and crepitus in the current study were noted in only one (5%) patient, and this patient had degenerative changes before surgery owing to late presentation. No other complications were found except one (5%) patient who developed superficial infection and improved with frequent dressing and antibiotics. In AL-Zarahini [26], 8% of patients had retropatellar pain and crepitus. In Pathania *et al.* [20], 8% had also retropatellar pain, and these were the cases presented late and had some degenerative changes before surgery. These results are nearly similar to the results in the current study. In Kevin series [25], patellofemoral crepitus was noted in 33% of patients and no patients had retropatellar pain. In the study of Samir *et al.* [29], 27% of patients had developed retropatellar pain. In the study of Holmes *et al.* [34], the incidence of patellofemoral pain was 16%. In another study, Marder *et al.* [35] reported that 15% of patients complained of anterior knee pain with activity. Shaieb *et al.* [36] reported that 42% of patients had patellofemoral pain on activity. The study of Shuzhen *et al.* [30] found anterior knee pain in 21% of patients.

In this study, 18 (90%) patients did not have any tenderness or irritation of the graft, and moderate graft pain with tenderness was noted in two (10%) patients. In Pathania *et al.* [20], 70% of patients did not have any tenderness or irritation of the graft, 14% of patients had slight symptoms, 9% had moderate symptoms, and 4% had severe symptoms. In the series of Jonathan [28], 56% of patients did not have any symptoms, 34% had slight, 9% had moderate, and 1% had severe symptoms. These results are comparable with the study of Bach [37] as only 8% of patients had moderate tenderness and crepitus. Another series of O'Brien *et al.* [38] shows good results using a patellar tendon graft through a medial arthrotomy, but one-third of the patients had retropatellar pain and tenderness owing to displacement of the patella during operation.

In the current study, 90% of patients had quadriceps wasting of 1 cm compared with the uninjured side, 5% had wasting of 1–2 cm, and 5% had 3 cm of thigh wasting. In Pathania *et al.* [20], 80% of patients had quadriceps wasting of 1 cm compared with the uninjured side, 16% had wasting of 1–2 cm and 4% had 3 cm of thigh wasting. In series of Jonathan [28], 86% of patients had wasting 1 cm, 13% had 1–2 cm wasting, and 1% had 3-cm wasting. These results are comparable to the results of the current study.

In this series, a good rehabilitation program was done to retain full movement, decrease patellofemoral pain, and prevent muscle wasting. In addition, successful ACL reconstruction that performed before any significant joint deterioration can preserve joint function and high activity level.

## Conclusion

ACL reconstruction by BPTB graft by hour-glass technique is an effective method to restore knee stability with early weight-bearing and high satisfactory results.

#### Financial support and sponsorship

Nil.

#### Conflicts of interest

There are no conflicts of interest.

## References

1 Marrale J, Morrissey MC, Haddad FS. A literature review of autograft and allograft: anterior ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 2007; 15:690–704.

2 Arnold JA, Cokes JP, Haeton LM, Park JP. Natural history of anterior cruciate tears. Am J Sports Med 1979; 7:305–313.

3 O'Brien SS, Warren RF, Let P. Reconstruction of the chronically insufficient ACL with central third of patellar ligamant. J Bone Joint Surg 1991; 73A:140–151.

4 Daniel DM, Stone ML, Dobson BE. Fate of the ACL-injured patient: a prospective outcome study. Am J Sports Med 1994; 22:632–644.

5 Engebresten L, Benum P, Fasting Q. A prospective, randomized study of three surgical techniques for treatment of acute ruptures of anterior cruciate ligament. Am J Sports Med 1990; 18:585–590.

6 Fu FH, Bennett CH. Current trends in anterior ligament reconstruction. Part II: operative procedures and clinical correlations. Am J Sports Med 2000; 28:124–130.

7 Chang SKY, Egami DK, Shaib MD, Kan DM, Richardson AB. Anterior cruciate ligament reconstruction: allograft versus autograft. Arthroscopy 2003; 19:453–462.

**8** Han HS, Seong SC, Lee S, Lee MC. Anterior cruciate ligament reconstruction. Quadriceps versus patellar autograft. Clin Orthop Relat Res 2008; 466:198–204.

**9** Gorschewsky O, Klakow A, Mahn H. Clinical comparison of the autologous quadriceps tendon (BQT) and the autologous patella tendon (BPTB) for the reconstruction of the anterior cruciate ligament. Knee Surg Sports Traumatol Arthrosc 2007; 15:1284–1292.

**10** Burks R, Daniel DM, Loss G. The effect of continuous passive motion on anterior cruciate ligament stability. Am J Sports Med 1984; 12:323–327.

**11** Sachs RA, Daniel DM, Stone ML, Garfein RF. Patellofemoral problems after anterior cruciate ligament reconstruction. Am J Sports Med 1989; 17:760–765.

**12** Ioncu A, Mader R, Bonin N, Ternamian PJ, Dejour D. Bone-patellar tendon-bone graft via a single minimally-invasive approach versus a classical approach in anterior cruciate ligament reconstruction: a prospective study. Orthop Traumatol Surg Res 2012; 98:426–431.

**13** Lysholm J, Gillquist J. Evaluation of knee ligament surgery results with special emphasis on useful scoring scale. Am J Sports Med 1982; 10:150–154.

**14** Tenger Y, Lysholm J. Rating system in evaluation of knee ligament injuries. Clin Orthop 1985; 198:43–49.

**15** Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis 1957; 16:494–502.

**16** MacDaniel WJ, Dameron TB. Untreated ruptures of anterior cruciate ligament. A follow up study. J Bone Joint Surg 1980; 62-A:696–705.

**17** Balkfors B. The course of knee ligament injuries. Acta Orthop Scand 1982; 53:7–99.

**18** Johnson RJ, Beynnon BD, Nicholas CE. Current concepts review. The treatment of injuries of the anterior cruciate ligament. J Bone Joint Surg 1992; 74-A:77–84.

**19** Noyes FR, Butler DL, Paulos LE, Grood ES. Intra-articular cruciate reconstruction, perspective on graft strength, vascularization and immediate motion on replacement. Clin Orthop 1980; 172:71–77.

**20** Pathania VP, Gupta SL, Joshi LC. Anterior cruciate ligament reconstruction with bone patellar tendon bone graft through a mini arthrotomy. MJAFI 2004; 60:15–19.

**21** Lambert KL. Vascularized patellar tendon graft with rigid internal fixation for anterior cruciate ligament insufficiency. Clin Orthop 1983; 172:85–89.

**22** Kurosaka M, Yoshiya S, Andrish JT. A biomechanical comparison of different surgical techniques of graft fixation in anterior cruciate ligament reconstruction. Am J Sports Med 1987; 15:225–229.

**23** Shebourne KD, Nitz P. Accelerated rehabilitation after anterior cruciate ligament reconstruction. Am J Sports Med 1990; 18:292–299.

**24** Ibrahim SA. Anterior cruciate ligament reconstruction by combined intra-articular (K-Lmbert method) and extra-articular iliotibial band tenodesis (Macintosh method) autologous grafts. Med Prince 1999; 8:1–5.

**25** Kevin D. Reconstruction of the anterior cruciate ligament. J Bone Joint Surg 1998; 80-A:184–194.

**26** Al-Zarahini S. Anterior cruciate ligament reconstruction by mini arthrotomy. Int Orthop 1997; 21:161–163.

**27** Kang S, Shao-Qi T, Ji-hua Z, Chang-suo X, Cai-long Z, Teng-bo Y. Anterior cruciate ligament reconstruction with bone-patellar tendon-bone autograft versus allograft. J Arthroscopic Relat Surg 2009; 25:750–759.

**28** Jonathan M. Endoscopic reconstruction for isolated anterior cruciate ligament rupture. J Bone Joint Surg 1998; 80-B:288–294.

**29** Samir AI, Ibrahim MA, Abdul Rahman KA, Hussein QA, Sami A, Tarek A. Clinical evaluation of arthroscopically assisted anterior cruciate ligament reconstruction: patellar tendon versus gracilis and semitendinosus autograft. Arthroscopy 2005; 21:412–417.

**30** Shuzhen L, Jinmin Z, Yinglong X, Zhandong B, Xiaofei D, Qingjun W. A meta-analysis of hamsting autografts versus bone-patellar-tendon-bone autografts for reconstruction of the anterior cruciate ligament. Knee 2011; 18:287–293.

**31** Dejour H, Walch G, Narget PH. The result of operation for chronic anterior knee laxity. French J Orth Surg 1988; 2:520–534.

**32** Ferretti A, Conteduca F, DeCarli A, Fontana M, Mariani PP. Osteoarthritis of the knee after ACL reconstruction. Int Orthop 1991; 15:367–371.

**33** Van der Hart CP, Van den Bekerom MPJ, Patt TW. The occurrence of osteoarthritis at a minimum of ten years after reconstruction of the anterior cruciate ligament. J Orthop Surg 2008; 3:1749–1759.

**34** Holmes PF, James SL, Larson RL, Singer KM, Jones DC. Reconstructive direct comparison of three intra-articular anterior cruciate ligament reconstruction. Am J Sports Med 1991; 19:596–600.

**35** Marder RA, Raskind JR, Carroll ME. Prospective evaluation at arthroscopically assisted anterior cruciate ligament reconstruction. Am J Sports Med 1991; 19:478–484.

**36** Shaieb MD, Kan DM, Chang SK, Marumoto JM, Richardson AB. A prospective randomized comparison of patellar tendon versus semitendinosus and gracilis tendon autograft for anterior cruciate ligament reconstruction. Am J Sports Med 2002; 30:214–220.

**37** Bach Br Jr. Arthroscopy assisted patellar tendon substitute for anterior cruciate reconstruction. Am J Knee Surg 1989; 2:3–20.

**38** O'Brien SJ, Warren RF, Pavlov H. Reconstruction of the chronically insufficient anterior cruciate ligament with the central third of patellar ligament. J Bone Joint Surg 1991; 73A:278–286.