Management of displaced posterior cruciate ligament avulsion fractures using arthroscopic suture fixation technique versus Burks and Schaffer approach

Mohamed H. Khalil

Department of Orthopedic Surgery, Faculty of Medicine, Cairo University Teaching Hospitals, Cairo, Egypt

Correspondence to Mohamed H. Khalil, MD, Department of Orthopedic Surgery, Faculty of Medicine, Cairo University Teaching Hospitals, Cairo, 002, Egypt. Tel: +20 3797 6272; fax:02 37494579;
E-mail: mohamedhussein1980@gmail.com

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Purpose
The purpose of this study was to analyze and compare the results of management of displaced posterior cruciate ligament (PCL) avulsion fractures using cannulated screws through the Burks and Schaffer open approach versus the arthroscopic suture technique.
Patients and methods
Forty patients with PCL avulsion fractures were included in this randomized prospective study. Twenty patients in group A were treated using the arthroscopic suture technique, whereas 20 patients in group B underwent open reduction and internal fixation of the avulsed PCL fragment by a 4-mm cannulated screw using the Burks and Schaffer approach. The mean follow-up period was 26.75 and 28.55 months for group A and B, respectively.
Functional assessment was done using the Lysholm and International Knee Documentation Committee scores. Radiographic evaluation was done by plain radiographs and computerized tomography to assess the rate and time for bone union. Clinical examination compared the regained flexion range of motion and degree of posterior laxity.
Results
All patients were available at the final follow-up. All patients in both groups achieved bone union at 7–10 weeks postoperative. The Lysholm and International Knee Documentation Committee scores in both groups increased significantly at the final follow-up.
There was no statistically significant difference between both groups apart from the operative time for the arthroscopic group being longer than the open group and the regained flexion range in the arthroscopic group was higher than the open group. Eight (40%) patients in the arthroscopic had associated meniscal pathologies, which were treated during the arthroscopic procedure. No neurovascular, nonunion or wound complications were reported in either group.
Conclusion
Displaced tibial PCL avulsion fractures can be successfully managed using both the open and arthroscopic techniques. Arthroscopic management required a longer operative time than the open approach; however, the regained flexion range was better than the open technique and concomitant pathologies were managed during the arthroscopic procedure.
Level of evidence: Level III; prospective comparative study.

Keywords:
arthroscopic, posterior cruciate ligament, tibial avulsion

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Introduction

The overall incidence of traumatic posterior cruciate ligament (PCL) prejudice is 38.3%, with avulsion injuries measuring only 2.4% [1]. The PCL has a vital role in knee stability and is considered the primary restraint to posterior tibial translation and the secondary restraint to external rotatory forces over the knee [2,3]. Dashboard collision is the most prevalent mechanism of injury responsible for tibial PCL avulsion fractures, in which a posteriorly directed force is exerted on the proximal aspect of the tibia with the knee in flexion [4]. In sports-related injuries, sudden extravagant flexion of an extended knee or fall over a flexed knee is the most common mode of injury [5].

Early presentations of PCL avulsion fractures include pain, swelling, and tenderness deep in the popliteal fossa with positive posterior drawer test. Patients with

untreated or overlooked PCL avulsion fractures commonly complain of anterior knee pain increased by activity, difficulty in climbing stairs, knee effusion, and instability [6]. Degenerative arthritis of medial and patellofemoral compartments and higher risk of meniscal injuries may occur in PCL-deficient knees [7].

Surgical fixation of displaced PCL avulsion fractures was highly recommended by Griffith *et al.* [8] to preclude the complications of knee instability and nonunion associated with PCL avulsion fractures. Although several open approaches [9–11] were used for treatment of PCL avulsion fractures, the simplified approach described by Burks and Schaffer [12] is considered the most reliable and most commonly used open approach for management of PCL avulsion fractures with good functional results and accelerated postoperative rehabilitation achieved.

The complicated deep location of the PCL in conjunction with the complexity of the anatomy resulted in evolvement of the minimally invasive arthroscopic techniques, which proved to be a successful method for management of avulsed PCL injuries [13–16].

The aim of this study was to compare the functional and radiological outcomes of arthroscopic suture fixation and open reduction and internal fixation (ORIF) using cannulated screws through Burks and Schaffer approach for management of tibial PCL avulsion fractures.

The hypothesis is that arthroscopic management of PCL avulsion fractures is a safe, reliable method of treatment with excellent results comparable to the Burks and Schaffer approach.

Patients and methods

This research design was as a single-center prospective randomized study. This study was approved by the ethical committee in orthopedic department in Cairo university teaching hospital. The study encompassed 40 patients having tibial PCL avulsion injuries between September 2014 and June 2016.

Inclusion criteria

The following were the inclusion criteria:

(1) Isolated PCL avulsion fractures displaced more than 3 mm.
(2) Skeletally mature patients.
(3) Patients must realize the risks and benefits of the procedure to be performed and be capable of giving informed consent.
(4) Compliance of the patients throughout the whole study duration.

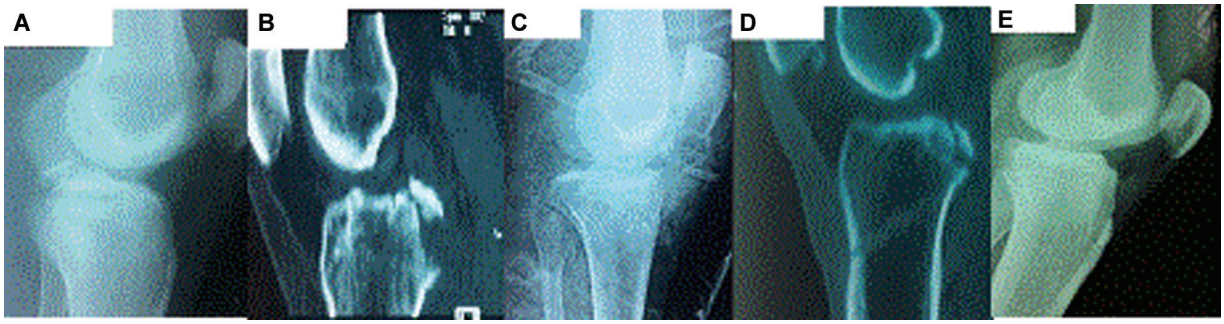
Exclusion criteria

The following were the exclusion criteria:

(1) Less than 3-mm displacement or severe comminution of the avulsed PCL fragment.
(2) Multiligamentous knee injuries or advanced osteoarthritis of the involved knee.
(3) Concomitant neurovascular injury or long bone fractures.
(4) Neglected or chronic cases of PCL avulsion injuries (>1 month).
(5) Skeletally immature patients.
(6) History of previous surgery to the affected knee.
(7) Open fractures.

Preoperative radiographic evaluation included standard plain radiographs of the injured knees including anteroposterior and lateral views (Fig. 1a). All patients underwent computerized tomography to

Fig. 1



(a) Preoperative lateral radiography showing the avulsed PCL fragment, (b) sagittal CT showing a displaced PCL tibial avulsion fracture, (c) postoperative lateral radiography, (d) postoperative sagittal CT showing a reduced PCL fragment and tibial tunnels, and (e) postoperative radiography showing united PCL fragment at final follow-up. CT, computed tomography; PCL, posterior cruciate ligament.

assess the amount of displacement and the severity of comminution of the avulsed PCL fragment (Fig. 1b).

The random assignment of all patients to enter either group was computerized using simple randomization. Informed consent was obtained from all patients. Patients in group A had arthroscopic reinsertion of the avulsed PCL fragment, whereas patients in group B underwent ORIF of the avulsed PCL fragment by a 4-mm cannulated screw using the Burks and Schaffer [12] approach.

Follow-up was conducted in the outpatient clinic and involved suture removal in the first visit 2 weeks postoperative. Subsequently, follow-up was done at regular intervals of 4 weeks. Radiographic assessment included immediate postoperative plain radiographs and computerized tomography of the injured knee to detect reduction of the avulsed PCL fragment and position of the screw or tunnels according to the carried out procedure (Fig. 1c, d). Plain radiographs only were done in the subsequent visits until bony union was achieved (Fig. 1e). Clinical examination and functional assessment using the Lysholm and Gillquist [17] and International Knee Documentation Committee (IKDC) [18] scores were done at 3, 6, 12, and 24 months after surgery. All patients were available at the final follow-up period.

This study was composed of two groups:

(1) Group A: arthroscopic group (AG) included 20 patients, with 16 males and four females. Their mean age was 31.5±6.12 (range: 22–42) years. The right knee was involved in 17 patients, whereas injury affected the left knee in three patients. The mean time from injury to surgery was 7.9±1.25 (range: 7–11) days. Road traffic accident was the mechanism of injury in 15 patients, whereas five patients were injured during practicing sports.
(2) Group B: open group (OG) included 20 patients, with 17 males and three females. Their mean age was 29.55±5.55 (range: 20–41) years. The right knee was affected in 16 patients whereas the left knee was injured in four cases. The mean time from injury to surgery was 7.5±1.79 (range: 4–12) days. A total of 16 patients had road traffic accident, whereas four patients were injured during participation in sports (Table 1). There was no preoperative statistically significant difference between both groups.

All statistical calculations were done using computer program IBM SPSS (statistical package for the social sciences, version 25; SPSS Inc., Chicago, Illinois, USA) release 22 for Microsoft Windows. Data were statistically expressed in the form of mean±SD, range, frequencies, and percentages when appropriate. Numerical variables were compared between the two groups using the Student *t*-test for independent samples for comparing normally distributed data, whereas Mann–Whitney *U*-test was used for independent samples for comparing not normal data. χ^2-test or Fisher's exact test were used to analyze categorical data as appropriate. *P* values less than 0.05 was considered statistically significant.

Table 1 Patient demographics

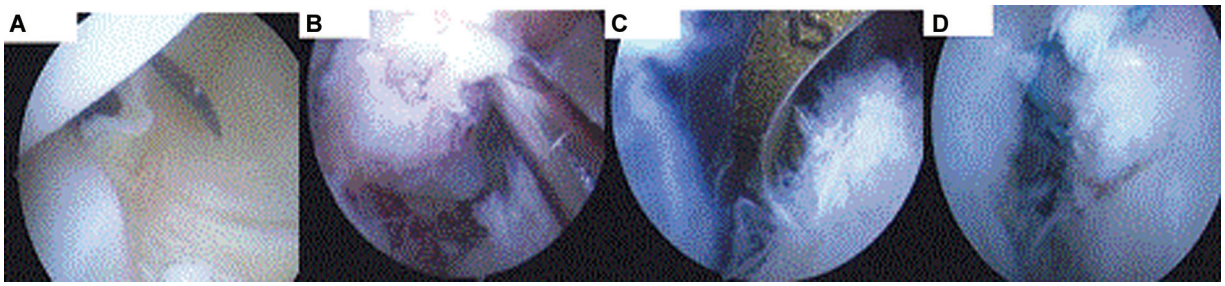
	Group A: arthroscopic group (*n*=20) [*n* (%)]	Group B: open group (*n*=20) [*n* (%)]	*P* value
Age at trauma in years			
Mean±SD (average)	31.5±6.12 (22–42)	29.55±5.55 (20–41)	0.298
Sex			
Male	16 (80)	17 (85)	1
Female	4 (20)	3 (15)	
Side			
Right	17 (85)	16 (80)	1
Left	3 (15)	4 (20)	
Mechanism of injury			
Road traffic accident	15 (75)	16 (80)	1
Sports injury	5 (25)	4 (20)	
Time from injury to surgery in days			
Mean±SD (average)	7.9±1.25 (7–11)	7.5±1.79 (4–12)	0.418

Surgical technique

Group A: AG

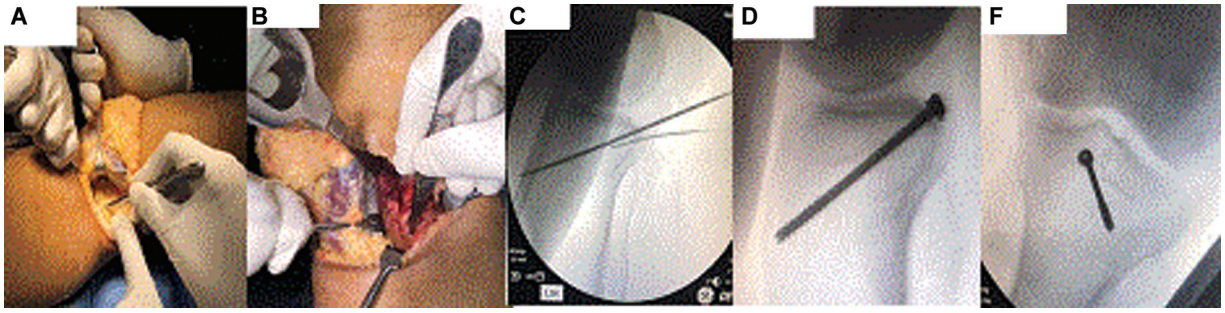
All patients were placed supine with the involved knee flexed 90° and the ipsilateral hip abducted, and a tourniquet was applied. A high anterolateral portal was first established followed by hemarthrosis evacuation. A high anteromedial portal was then done, through which the plane between the anterior cruciate ligament and PCL was developed, and management of associated pathologies was done. The arthroscope was passed to the posterior knee compartment between the medial femoral condyle and the PCL, where high and low posteromedial portals were created under direct arthroscopic visualization followed by insertion of a 6-mm cannula (Fig. 2a). The arthroscope was then shifted to the high posteromedial (visualizing) portal, and a shaver was introduced through the low posteromedial (working) portal (Fig. 2b). The shaver was used to develop the plane between the PCL and the posterior knee capsule followed by debridement of the PCL fragment bed.

Fig. 2



Arthroscopic images showing (a) the high and low posteromedial portals, (b) debridement of the fragment bed using a shaver, (c) tibial guide wire drilled using a PCL guide, and (d) the suture loop around the osseotendinous junction of the PCL reducing the avulsed PCL bony fragment. PCL, posterior cruciate ligament.

Fig. 3



(a) Blunt dissection of the plane between the medial head of gastrocnemius muscle and semimembranosus tendon, (b) reduction of the avulsed PCL fragment after incision of the posterior knee capsule, (c) intraoperative guide wire insertion using image intensifier, (d) intraoperative lateral view showing reduction of the PCL avulsed fragment by the cannulated screw, and (e) intraoperative anteroposterior view showing cannulated screw using image intensifier. PCL, posterior cruciate ligament.

Care was taken to keep the shaver blade away from the posterior knee capsule to avoid popliteal vascular injury. Two tibial tunnels (medial and lateral to the base of the avulsed fragment bed) were done using the PCL tibial guide introduced through the anteromedial portal under arthroscopic visualization (Fig. 2c). A sliding knot at the osseotendinous junction of the PCL using a NO. 5 Ethibond was done followed by three half hitches to secure the knot. Each limb of the knot suture was then shuttled through the corresponding tibial tunnel reducing the avulsed PCL fragment under direct arthroscopic visualization (Fig. 2d). Both shuttled limbs of the Ethibond suture were tightened over the anteromedial tibial cortex while applying an anteriorly directed force to the tibia with the knee flexed at 70–90°.

Group B: OG

All procedures were done under spinal anesthesia and application of a tourniquet. All patients were placed in the prone position with the affected knee kept at 20° of flexion. A vertical skin incision was made over the medial aspect of the gastrocnemius muscle and was slightly curved laterally at the knee joint crease. Incision of the deep fascia was done over the medial head of the gastrocnemius muscle. Blunt dissection was carried out through the interval between the semimembranosus tendon and the medial head of the gastrocnemius muscle (Fig. 3a). The posterior knee capsule could be reached by retracting the medial head of the gastrocnemius muscle laterally. This kept the popliteal neurovascular bundle safe and away from the surgical field. Incision of the posterior knee capsule was then made exposing the PCL avulsed fragment (Fig. 3b). Debridement of the fragment bed was done. Anatomical reduction followed by 4-mm cannulated screw and a washer fixation with washer was achieved under image intensifier guidance (Fig. 3c–e). Finally, wound closure in layers over a suction drain was done.

Both groups followed the same rehabilitation protocol. A well-padded long knee brace locked in full extension was applied for all patients in the first 2 weeks after surgery. Straight leg raising exercises were allowed immediately postoperatively followed by gradual increase in the range of motion under supervision of physiotherapist. Full weight bearing was allowed 4–6

weeks postoperatively. Open chain quadriceps exercises were not allowed before 6 weeks after surgery. Return to the previous full activities was achieved at the end of 4 months after surgery.

Results

The mean follow-up period was 26.75 (range: 24–31) months for the AG and 28.55 (range: 24–37) months for the OG.

The arthroscopic group

Statistical analysis of the AG data showed that the mean Lysholm score increased from 30.25 ±5.15 preoperatively to 92.65±4.28 at final follow-up, whereas the IKDC score improved from 31.05±4.2 to 93.8±2.02, respectively. This was found to be statistically significant ($P<0.001$). Clinical examination showed that 17 patients had grade I, two patients had grade II, whereas one patient had grade III posterior laxity. Nineteen patients were grades A and B, whereas one patient was grade C according to IKDC subjective evaluation. The mean operative time was 57.5 min, and the mean regained flexion range of motion was 130.5°.

The open group

Statistical analysis of the OG data showed that the mean Lysholm score improved from 32.2±4.94 preoperative to 92.2±4.96 at the final follow-up, whereas the IKDC score improved from 32.3±5.54 to 93.65±2.39, respectively. This proved to be statistically significant ($P<0.001$). Clinical examination showed that 16 patients had grade I, three patients had grade II, whereas one patient had grade III posterior laxity. Nineteen patients were grades A and B, whereas one patient was grade C according to IKDC subjective evaluation. The mean operative time was 47.5 min and the mean regained flexion range of motion was 124.5°.

All patients in both groups achieved bone union 7–10 weeks after surgery.

Comparison of both group showed that there was no statistically significant difference between both groups in terms of final IKDC, Lysholm scores, posterior laxity, and rate and time of bone union. However, the AG showed statistically significant longer operative time ($P=0.002$) and achieved statistically significant higher regained flexion range of motion ($P=0.009$) than the OG (Table 2).

Table 2 Comparison of the results between arthroscopic and open groups

	Group A: arthroscopic group ($n=20$) [mean±SD (average)]	Group B: open group ($n=20$) [mean±SD (average)]	*P* value
Lysholm score			
Preoperative	30.25±5.15 (26–40)	32.2±4.94 (24–42)	0.229
Postoperative	92.65±4.28 (79–96)	92.2±4.96 (76–95)	0.76
IKDC score			
Preoperative	31.05±4.2 (25–41)	32.3±5.54 (26–42)	0.426
Postoperative	93.8±2.02 (89–98)	93.65±2.39 (88–96)	0.831
Time of union in weeks	8.55±0.94 (7–10)	8.4±0.88 (7–10)	0.607
Flexion range of motion	130.5±5.6° (115–135°)	124.5±7.93° (105–135°)	0.009
Follow-up period in months	26.75±2.57 (24–31)	28.55±3.2 (24–37)	0.057
Operative time in minutes	57.5±11.53 (45–90)	47.5±5.26 (40–60)	0.002
Posterior laxity grade [*n* (%)]			
Grade 1 (0–5 mm)	17 (85)	16 (80)	1
Grade 2 (6–10 mm)	2 (10)	3 (15)	
Grade 3 (>10 mm)	1 (5)	1 (5)	
IKDC grade [*n* (%)]			
A (normal)	16 (80)	15 (75)	1
B (near normal)	3 (15)	4 (20)	
C (abnormal)	1 (5)	1 (5)	
D (severely abnormal)	0	0	

IKDC, International Knee Documentation Committee.

Discussion

Controversy exists regarding whether to use the open or the arthroscopic approach and the utilized method of fixation [13–16,19,20].

Open surgical approaches have the advantages of adequate visualization of the avulsed PCL fragment and its bed, allowing complete reduction and providing rigid fixation [21]. However, these approaches have demerits including diminished range of motion as a result of large soft tissue scar following dissection to access the deeply located insertion site of the PCL within the popliteal fossa. Furthermore, the open surgery is deemed to be a high-risk procedure owing to the closeness of the popliteal neurovascular bundle [22,23].

In this study, the mean IKDC and Lysholm scores were 93.65 and 92.2, respectively, in the OG at final

follow-up, and 19 patients were grades A and B, whereas only one patient was grade C according to IKDC subjective evaluation. All patients achieved bone union after 7–10 weeks. The results of the open group in this study were comparable to several studies in the literature [19,20,23].

The arthroscopic approach has several merits including less postoperative pain and scaring owing to smaller wounds [24]. Furthermore, management of associated injuries like meniscal tears is another factor for the preference of the arthroscopic approach [1,4]. However, the arthroscopic technique is a more complex surgical procedure requiring advanced instrumentation and longer operative time and learning curve [25].

The results of the AG in this study showed that 19 patients were grades A or B and one patient was grade C according to IKDC subjective evaluation. The mean IKDC and Lysholm scores were 93.8, 92.65, respectively, at final follow-up, and all patients achieved bone union after 7–10 weeks. The results of the arthroscopic group in this study are in line with various studies in literature [13,14,16].

Comparison of the outcomes in both groups of this study showed no significant statistical difference regarding the IKDC, Lysholm, clinical posterior laxity, IKDC subjective evaluation and union rate and time at final follow-up. However, the mean of the regained flexion range of motion in the arthroscopic group was 130.5° and 124.5° in the open group. In addition, the operative times were 57.5 and 47.5 min for the arthroscopic group and open group, respectively. Both the regained flexion range of motion and operative time showed statistically significant differences (P=0.009 and 0.002, respectively).

The results of this study are in line with the results reported in the literature comparing open and arthroscopic management of PCL avulsion fractures.

Pardiwala *et al.* [26] proved in a comparative prospective randomized study including 50 patients that there was no statistically significant difference in the results following management of PCL avulsion fractures through the traditional posterior approach and a 4-mm cannulated screw versus the arthroscopic pull-through suture technique. The previous study documented that clinical grading of PCL laxity, arthrometer testing, stress radiography, and functional outcomes using IKDC showed no significant statistical difference between the open and arthroscopic groups at a minimum of 2 years of follow-up. However, this study documented that 12% of the cases in the open group had subsequent operative intervention to manage the associated intra-articular injuries.

Furthermore, Sabat *et al.* [27] in a retrospective comparative study including 47 patients compared the results of the open posterior approach and arthroscopic fixation of avulsed PCL injuries. At 1-year follow-up, the mean Lysholm score was 95.3 and 94.8 for the open and arthroscopic group, respectively, with no significant statistical difference. In addition, the Tegner activity level and IKDC score showed no statistically significant differences, and union of the avulsed fragment occurred 3 months postoperatively. However, 85% of the patients in the arthroscopic group achieved 0–3 mm laxity compared with 74% in the open group using KT-2000 arthrometer.

Eight (40%) patients in the AG in this study had associated meniscal injuries, which were treated by either meniscectomy or repair, emphasizing the advantage of the arthroscopic technique in management of concomitant lesions associated with PCL avulsion fractures.

In this study, the time interval from injury to surgery was 4–12 days and chronic or neglected cases were excluded, as Torisu [28] stated that poor outcomes are associated with delayed or neglected cases of PCL avulsion injuries. In addition, arthroscopic management was not carried out except after 1 week from injury to allow for capsular healing and to avoid compartment syndrome owing to fluid extravasation.

Hence, Singla *et al.* [29] mentioned that the IKDC score was favored over the Lysholm score in functional outcome evaluation of patients with PCL avulsion injuries. Therefore, functional outcome assessment in this study was done using both the IKDC and Lysholm scores.

Although in this study, five patients (two in the arthroscopic group, one in the ORIF group) had grade II posterior laxity and two patients (one in each group) had grade III laxity measured by the posterior drawer test, this reported laxity did not influence the patients' subjective knee evaluation at the final follow-up. This is explained by several authors [30,31] who proved the absence of direct relationship between the grade of PCL laxity and the subjective knee evaluation.

The arthroscopic management of avulsion fractures using sutures proved to be biomechanically sound as Eggers *et al.* [32] assessed the initial strength of various fixation methods in a biomechanical study and concluded that fixing tibial eminence factures using sutures achieved a higher fixation strength when compared with screws.

No neurovascular, nonunion, or wound complications were observed in all patients in both groups. The main limitation in this study is the relatively small sample size in each group, although this is attributed to the relatively uncommon incidence of isolated PCL avulsion fractures.

Conclusion

Displaced tibial PCL avulsion fractures can be managed through both the open and arthroscopic techniques. Comparable results were obtained after both techniques, apart from the longer operative time required for the arthroscopic technique and the higher regained flexion range achieved after arthroscopic management. Finally, associated intra-articular pathologies can be successfully managed during the arthroscopic procedure.

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Conflicts of interest
There are no conflicts of interest.

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