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Posterior cruciate ligament injuries managed with internal bracing

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ABSTRACT

Background: Synthetic augmentation in the form of an internal brace is increasingly used to stabilize injured knee ligaments. This study aimed to evaluate the clinical and radiological outcome of patients with knee dislocations treated with a posterior cruciate ligament (PCL) internal brace.

Methods: Synthetic suture tape drilled into the femoral and tibial PCL footprints was performed in patients with multiple knee ligament injuries. PCL tears were either repaired or left in situ if not repairable. Patients with chronic injuries, contraindications to magnetic resonance imaging (MRI) scans, or cognitive impairment were excluded. Patient-reported outcome measures (PROMs), range of motion, stress X-Rays, and MRI scans were assessed. An acceptable outcome was defined as a Lysholm score of 84 or more, grade II laxity or less on stress radiographs and a range of motion from full extension to 90° or more of flexion.

Results: Eight patients were included with a median age of 38 years, five were female. No patients had knee flexion less than 90° or an extension deficit of more than 10°. PROMs showed a median Lysholm score of 87. Stress radiographs showed less than 7 mm (Grade I) of posterior translation laxity in all patients. In six patients a follow up MRI scan was obtained, which revealed no healing of the PCL in one patient and only partial healing in three patients.

Conclusion: All patients had stable knees and acceptable PROMs, despite tunnel widening or reaction to synthetic material on MRI in five of the six patients. Factors such as anisometric tunnel position and the absence of PCL tear repair may have contributed to the tunnel widening.

1. Introduction

Knee dislocations are rare but devastating injuries [1–3]. The assessment and comparison of surgical results in these injuries is challenging due to the presence of other confounding variables. Other injuries can contribute to long-term disability, such as associated popliteal artery and peroneal nerve injuries, fractures, and meniscal or chondral injuries [4,5]. Proposed treatment philosophies include conservative management, primary early repair, and early or delayed ligament reconstruction, although many aspects of these strategies remain controversial [2,3,6–8]. Studies involving knee dislocations often have small numbers of patients and short follow up periods [9]. Especially in low-resource settings, access to high-quality allo-

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grafts is rare and autograft options are often limited by contralateral injuries. This has increased the use of synthetic tapes or sutures to reconstruct or augment ligament repairs, also known as internal bracing. The theoretical advantage is additional strength and protection of the repair in early stages of healing allowing early mobilisation with improved recovery. Internal bracing is thought to act as a check rein to extremes of motion, rather than a load-sharing construct. Donor site morbidity and surgical time needed to harvest graft is reduced and smaller tunnel sizes are needed [10]. Other advantages of repair and internal bracing vs. reconstruction are preservation of the native tissue and proprioception and faster recovery from surgery [11]. Current literature on internal bracing with synthetic material focuses mainly on augmentation of repair, anterior cruciate ligament (ACL) reconstruction or ACL bracing. There are few reports on its use for posterior cruciate ligament (PCL) injuries [12]. The use of suture tape for internal bracing has been described for the medial collateral ligament of the knee, but no large prospective studies are available to evaluate outcomes [13].

2. Materials & methods

This was an observational descriptive study evaluating patient reported outcome measures (PROMs), knee stability and magnetic resonance imaging (MRI) features in patients treated with a PCL internal brace following knee dislocations. The study centre manages approximately 40 patients with knee dislocations per year for whom a prospective database is maintained. The hospital is a tertiary-level teaching hospital affiliated with a university. It is a level 1 trauma centre and a large trauma referral centre with a high burden of motor vehicle accidents and interpersonal trauma. Most patients are from low-income households. Exclusion criteria were patients under 18 years of age, those with chronic injuries, cognitive impairment, psychiatric conditions, or contraindications for an MRI scan. All injuries were diagnosed with an MRI on admission. Demographic data and injury details were collected. After surgery, patients underwent standard clinical follow up procedures, including range of motion and radiographic stress views. Additionally, patients underwent MRI using a 1.5- or 3-T system with standard sequences. Lysholm scores were used to evaluate PROMs. The Lysholm score is one of the most commonly used knee scores in studies for multi-ligament knee injuries, and is proposed by experts as patient-specific outcome metric for knee dislocations [2,7,14]. It has various questions on knee function regarding limping, pain, locking, stair-climbing, support, instability, swelling and squatting, which can be rated. An overall score is given, and less than 65 is considered poor, 65–83 is fair, 84–90 is good, and more than 90 points represent excellent knee function. In the normal population the average Lysholm score is 94 [15]. Ethics approval as well as institutional permission was obtained prior to data collection and Informed consent was obtained from all patients included in this study.

2.1. Surgical technique

A full examination under anaesthesia was performed to confirm the injuries and to evaluate the extent of concomitant ligamentous tears. Patients were positioned supine with a foot and side bolster and a high tourniquet on the thigh. After sterile preparation and draping, a diagnostic arthroscopy was performed to evaluate intra-articular injuries. Damage to the ACL, meniscus, and cartilage were addressed as necessary. Concomitant posterolateral corner injuries were addressed using a reconstruction method described by Arciero et al. [16]. Medial-sided injuries were repaired by directly reattaching the avulsed femoral or tibial-sided insertion with armed 5-mm suture anchors.

2.2. PCL repair

The PCL remnant was carefully mobilized around the femoral footprint, and a grasper was used to reduce the ligament on to its footprint, allowing assessment of adequate tissue length. To achieve maximum PCL length during this evaluation, an anterior drawer force was applied to counteract any posterior tibial subluxation. A single stitch with an Ultrabraid #2 suture (Smith & Nephew), placed within the ligament using a FIRSTPASS MINI Suture Passer (Smith & Nephew), was initially used to apply traction and test ligament integrity. This traction then facilitated deeper bites into the tissue, with a second suture placed more proximally to maximize pullout strength by utilizing the high-quality distal tissue. Both sutures were then passed outside the knee through the anteromedial portal and tied over the far cortex, utilizing the same cortical fixation device as for the internal brace. If the suture cut out or ripped through the tissue, the remnant was not debrided, and the suture tape was placed without completing a PCL repair.

2.3. Tunnel placement of internal brace

For the PCL internal brace tunnels were drilled free hand into the PCL anterolateral bundle footprint on the femur as well as the central tibial PCL footprint using a specific tibial tunnel PCL aiming device. For the tibial tunnel placement, a posteromedial portal was established to enhance visualization and to protect the neurovascular bundle in case the PCL remnant obstructed the view via anterior portals. An eyelet passing pin was then over-drilled with a cannulated 4 mm drill bit. An illustration of PCL repair is shown in Figure 1.

Figure 1. Illustration of posterior cruciate ligament repair and internal brace.

2.4. Tensioning and fixation

A doubled 2-mm synthetic suture tape made of a polyester weave and ultra-high molecular weight polyethylene (FiberTape® from Arthrex) was then inserted with a passing suture in a retrograde fashion into the tibial tunnel via the medial portal. The repair sutures were then inserted into the femoral cortical fixation device for the suture tape (button from Smith & Nephew). This button was then drawn antegrade into the femoral tunnel and flipped. A 2-cm incision over this button and blunt dissection to its cortical location allowed us to tie the PCL sutures over the far cortex. Similarly, a button was used for cortical fixation to the tibia. In cases where the PCL was repaired, the suture was secured with the knee in 90° while an anterior drawer manoeuvre was applied on the tibia by the assistant. Following this, the tape was fastened without the manoeuvre, with careful attention to avoid over-tensioning. For cases without native PCL repair, the knee was brought to 90° flexion, an anterior drawer manoeuvre was applied, and the tape was tensioned similarly to a PCL graft fixation. Postoperatively patients were placed in a range of motion brace with motion restricted to between 0° and 90° of flexion. Range of motion exercises were started from Day 1, ideally in prone position. Weight bearing was allowed after 6 weeks. No standardized physiotherapy protocol was followed as access to these services are very limited.

2.5. Outcome measures

Stress radiography involved the application of a standardized posterior force of 150 N using a Telos® device (Telos®, Marburg, Germany) at a knee flexion angle of 90° (Figure 2). An experienced orthopaedic knee surgeon assessed the disparity in posterior tibial translation (PTT) between the surgically treated knee and the contralateral side, using the measuring technique described by LaPrade. The side-to-side difference of the stress views was graded as follows – Grade 1: 0–7 mm; Grade 2: 8–11 mm; Grade 3: $\geq$12 mm [17].

MRI scans were evaluated by a subspecialist orthopaedic knee surgeon. They were assessed for synovitis, homogeneity and healing of the PCL, as well as tunnel widening of the synthetic tape. Healing was evaluated using the grading scale proposed by Gross et al. in which Grade 0 has a continuous, low-intensity signal that corresponds to a normal PCL, Grade I has areas of increased signal within the ligament but with intact borders indicating an intrasubstance injury, Grade II has areas of increased signal with 1 border intact indicating a partial tear and Grade III shows complete disruption of the ligament [18].

Figure 2. Stress view of knee at 90° of flexion to assess posterior tibial translation.

Presence of tunnel widening was defined as more than 150% widening, i.e., a 4-mm tunnel was defined as widened when increased to 6 mm. Tunnel width was measured at its widest point on the MRI scan then divided by the size of the original drill bit to calculate widening [19].

Synovitis was assessed using the MRI Osteoarthritis Knee Score (MOAKS) system as follows: 0 = normal/ no hyperintensity, 1 = mild, 2 = moderate and 3 = severe for Hoffa-synovitis, and 0 = physiological amount, 1 = small, 2 = medium and 3 = large for effusion-synovitis [20]. The Lysholm score was used to evaluate patient-reported outcome [21].

Patients were categorized as objective copers, objective non-copers, and subjective copers based on predefined criteria (Table 1). An acceptable outcome was defined considering Lysholm score, laxity, and range of motion.

3. Results

Eight patients with a median age of 38 (interquartile range (IQR) 9) were included. Median time to surgery was 11 days (IQR 23) after injury. Patients were followed up at a median of 23 months, range 22–30 months (IQR 7). Their Lysholm score reached a median of 87 (IQR 7.5).

No patient had flexion of less than 90° (mean 103.8°) in the treated knee or an extension deficit more than 10° (mean 1.3°). All patients had posterior translation of less than 7 mm with stress views, mean 3 mm (IQR 4) with three of eight patients demonstrating 0 mm of PTT. All patients in the study were thus categorized as 'objective copers'. The specific outcomes of internal bracing only versus internal bracing with repair can be seen in Table 2.

Six patients underwent postoperative MRI evaluation (Figure 3). Of these six patients, three had tunnel widening defined as at least 150% of original tunnel width, three showed mild or moderate synovitis and a large cyst was found in one patient (Table 3). All patients with tunnel widening showed the greatest enlargement at the articular-sided cortex resulting in a funnel-shaped appearance. Timing of the MRI scan did not influence the shape of the tunnel widening in the cases where it occurred. MRI scans were taken after a median period of 23 months (IQR 5). The MRI scans of the three patients with enlargement namely patients 2, 5 and 6 were taken in month 30, month 23 and month 28, respectively.

Table 1
Patient categorization as coper, non-coper and subjective coper.

Category	Objective coper (good outcome)	Objective non-coper (suboptimal outcome)	Subjective coper
	No or moderate knee instability (grade II or less) on stress views or clinical exam A maximum of one reported giving-way episodes since injury Knee flexion of 90° or more	Persistent grade III instability on stress views or clinical exam Multiple giving-way episodes since injury	Patients who are coping with their knee function in their daily life and/or decline surgery

Table 2
Patient demographics, injuries and outcomes.

ID	Age	Sex	KD	ACL	PCL	LCL/PLC	MCL	Internal brace	PTT (mm)	ROM (°)	Lysholm score
1	36	M	III L	X	X	X		Only	0	0–90	99
2	27	M	III L	X	X	X		Only	4	0–110	81
3	59	F	III M	X	X		X	Only	4	0–90	86
4	35	F	IV	X	X	X	X	With repair	0	10–110	85
5	39	F	III L	X	X	X		Only	3	0–120	79
6	41	M	IV	X	X	X	X	Only	4	0–120	91
7	39	F	III L	X	X	X		With repair	5	0–90	88
8	26	F	III M	X	X		X	With repair	0	0–100	93

ACL, anterior cruciate ligament; F, female; KD, knee dislocation according to Schenck [22]; LCL, lateral collateral ligament; M, male; MCL, medial collateral ligament; PCL, posterior cruciate ligament; PLC, posterolateral corner; PTT, side-to-side difference in posterior tibial translation on stress-radiographs; ROM, range of motion.

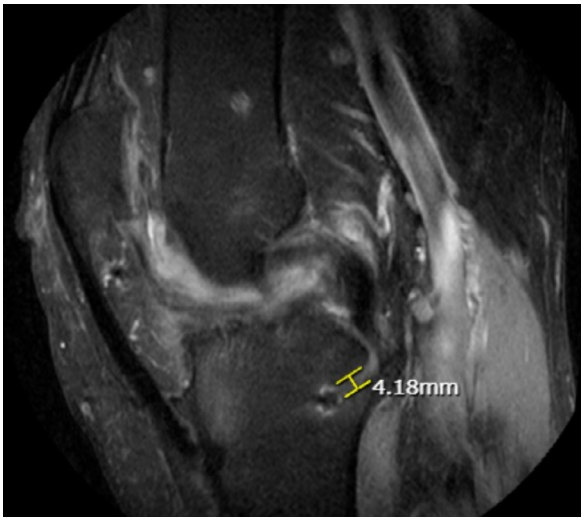

Figure 3. Magnetic resonance imaging (MRI) evaluation of tunnel widening by comparing MRI tunnel size to diameter of original drill used to drill tunnel. The dotted white line indicates the funnel-shaped morphology of the enlarged tunnel.

4. Discussion

The use of internal bracing to augment suture repair has been well-established in ACL tears, with significantly higher loads to failure documented compared with repair alone [23]. Some studies have shown improved pain, motion and quality of life with PCL repair and internal bracing versus conventional PCL reconstruction [24]. However, there is a paucity of high-quality evidence when comparing internal bracing of the PCL with other surgical techniques. Our study demonstrated overall satisfactory clinical outcomes with internal bracing of the PCL in multi-ligament knee injuries. All patients were 'objective copers' with good PROMs, stable knees, and acceptable range of motion. However, three of the patients with follow up MRI scans had significant tunnel widening, and only two showed high-grade healing of the PCL.

Table 3
Grading of posterior collateral ligament (PCL) healing, Hoffa synovitis and tunnel widening on magnetic resonance imaging (MRI)scan.

Patient identifier	Tibial tunnel widening	Femoral tunnel widening	PCL healing grade [18]	MOAKS grading of Hoffa synovitis [20]
2	175%	175%	II	0
3	100%	75%	II	I
4	100%	113%	I	II
5	150%	225%	II	0
6	183%	230%	I	II
7	130%	133%	III	0

MOAKS, MRI Osteoarthritis Knee Score (MOAKS).

4.1. Clinical outcomes

In a systematic review of synthetic devices for cruciate reconstruction (not augmentation) including 85 articles with 5140 patients, less than 6% of cases involved PCL surgery. The failure rates of internal bracing ranged from 1% to 33.6% for ACL and 1% to 16.7% for PCL. Materials such as Dacron had higher failure rates than others (i.e., Ligament Advanced Reinforcement System – LARS®, Arc-Sur-Tille, France) [12].

With this in mind, we found acceptable PROMs and stability (mean PTT 3 mm) in our patients. These were similar to other studies on PCL internal bracing in multi-ligament knee injuries. One study of 14 patients with PCL tears treated with internal bracing reported a mean Lysholm score of 69.1, average flexion of 120° degrees with no extension deficit. The mean PTT was 5.5 mm greater compared with the contralateral knee and good PCL healing and continuity was seen on MRI [25]. However, Rosteius et al. in a study that treated both ACL and PCL injuries with repair and ligament bracing reported good results with stable joints and good range of motion via gait analysis and a mean Lysholm score of 82 [26]. Another study assessed 69 knee dislocations treated with internal bracing of ACL and PCL tears using FibreWire (Arthrex, Naples, FL, USA), the mean Lysholm score was 81, with 91% of patients having excellent to fair outcomes. On stress views, the mean PTT was 2.1 mm [27]. In a study of 22 patients with knee dislocations that underwent suture repair and internal bracing of the cruciate ligaments, Hecker et al. concluded that satisfactory mid-term clinical results are obtainable with this technique despite persistent radiological instability and a significant increase in osteoarthritis [28].

Hopper et al. reported good results in 17 patients with PCL repair and suture augmentation according to the Knee Injury and Osteoarthritis Outcome Score (KOOS) and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores, however exact details for ultimate range of motion and radiographic findings were not reported [29]. The use of the LARS synthetic ligament (Surgical Implant and Devices, Arc-sur-Tille, France) was evaluated previously in 111 patients with ACL and PCL tears, and showed a median Lysholm score of 79.5 with a median range of motion of 0–124°. Here a mean side-to-side difference of the PTT reached 8.2 mm on average, which is consistent with grade II PCL laxity [30].

4.2. Complications

Compared with these studies, our cohort showed some limitations in knee flexion, with a mean range of motion of 1–104°. A likely contributing factor is that most of our patients did not receive regular physiotherapy. Arthrofibrosis, though poorly defined, is one of the most common challenges for surgeons treating multi-ligament knee injuries with rates reported in *meta*-analyses ranging from 2.8% to 57% [31,32]. Patients experiencing limited flexion may benefit from manipulation under anaesthesia or arthroscopic arthrolysis [33]. While none of our patients required this intervention, it is offered to those unable to achieve 90° of flexion or who experience significant limitations in important activities due to restricted flexion. Additionally, we observed no perioperative complications, such as deep vein thrombosis, compartment syndrome, or surgical site infection. One patient with limited knee flexion did develop mild heterotopic ossification.

4.3. Radiological outcomes

Although the clinical outcome of our patients was acceptable, the MRI evaluation showed a high incidence of reaction to synthetic material with either tunnel widening or synovitis observed in 83.7% (five of six patients) of the cohort. Three of the six patients had an MRI Osteoarthritis Knee Score (MOAKS) Hoffa synovitis grade ranging from one to two. Tunnel widening of over 150% occurred in three of the six patients and was present in both the femoral and tibial tunnels in all three patients. In one patient a cyst was found around the tape, which was probably caused by tissue reaction to the synthetic material. The tunnel widening in the other patients was funnel-shaped with greatest enlargement around the articular-sided cortex. This was most probably due to anisometry and the fact that the tape was not fixed at these cortices. But it may also be caused by a foreign body reaction especially in the case with cystic morphology of the tunnel erosion [10]. In terms of PCL healing on MRI, the median grade was 2 (IQR 1). This was similar to the median score of 2.5 by Otto et al. [25]. These radiographic findings do not necessarily correlate with poor clinical outcomes, as the authors also reported good results despite low rates of complete PCL healing on MRI. It can however point towards a potential risk of stress shielding of the healed ligament. The study by Otto et al. represents the only other available study assessing MRIs of PCL repairs augmented with internal bracing. Here, no findings were included on tunnel widening [25]. Research on MRI findings after ACL repair with internal brace augmentation has also shown stable knees despite absence of features of radiographic healing [34].

Our study had some limitations. Firstly, there was variance in the injury pattern of our cohort which could influence PROMs, range of motion and stability. This is an inherent challenge in knee dislocation research and commonly described as one of the major limitations to interpret data in these patients. Also, a follow up of just 2 years is short to evaluate for potential longer-term reaction to the synthetic material, but targets such as range of motion, stability and healing are unlikely to change with longer followup. Even with the relatively small sample size without a control group, we showed radiographic evidence of complications related to synthetic materials despite acceptable clinical outcomes.

5. Conclusions

Acceptable stability and clinical outcome could be achieved with the use of a PCL internal brace, even in cases where PCL remnants were irreparable. Although significant tunnel widening and cyst formation is a concern, it did not result in specific clinical symptoms or instability. This calls for adjustments of techniques with fixation points on the near cortex to avoid subsiding of the tape into bone. Most importantly, this should trigger research into materials with biomechanical properties similar to ligaments, ideally without the formation of unwanted tissue reaction. Although the use of tape augmentation for PCL surgery is promising, autograft reconstruction should still be seen as the gold-standard and is favoured in our practice whenever possible.

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by all authors. The first draft of the manuscript was written by A.A., then W.S. and M.H. commented on all versions of the manuscript. All authors read and approved the final manuscript.

CRediT authorship contribution statement

Ashley Arakkal: Writing – review & editing, Writing – original draft, Investigation, Formal analysis. **Waldo Scheepers:** Writing – review & editing. **Michael Held:** Writing – review & editing, Supervision, Methodology, Investigation, Data curation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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