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ORIGINAL RESEARCH

Patient Reported Clinical Outcomes Following PCL Suture Augmentation in Patients with Multiligamentous Knee Injury: A Retrospective Observational Study

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Purpose: To compare the patient-reported outcomes between patients with posterior cruciate ligament (PCL) reconstruction or repair alone versus PCL reconstruction or repair with internal bracing (IB) in the context of multi-ligament knee injuries (MLKI).

Methods: All patients who underwent surgical management of MLKI at two institutions between 2006 and 2020 were retrospectively identified and offered participation in the study. Patient reported outcomes were measured via three instruments: Lysholm Knee score, Multiligament Quality of Life (ML-QOL), and the Patient-Reported Outcomes Measurement Information System (PROMIS) computer adaptive testing (CAT). The postoperative outcomes and reoperation rates were compared between the internal bracing and non-internal bracing groups.

Results: Fifty-two patients were analyzed; 34 were included in the IB group (17.6% female; age 33.1 ±1.60 years), and 18 were included in the non-IB group (11.1% female; age 34.1 ±3.72 years). Mean follow-up time of the entire cohort was 1.44 ± 0.22 years (IB: 1.21 ± 0.18; non-IB: 2.1 ±0.65). There were no significant differences between PROMIS CAT [PROMIS Pain (54.4 ±1.78 vs 51.7 ±1.70, p=0.319), Physical Function (44.3 ±2.27 vs 47.9 ±1.52, p=0.294), Mobility (44.0 ±1.71 vs 46.1 ±2.10, p=0.463)], ML-QOL [ML-QOL Physical Impairment (40.7 ±4.21 vs 41.7±5.10, p=0.884), Emotional Impairment (49.2 ±4.88 vs 44.7±5.87, p=0.579), Activity Limitation (43.5 ±4.56 vs 31.5±3.62, p=0.087), Societal Involvement (44.9 ±4.96 vs 37.5 ±5.30, p=0.345)] and Lysholm knee score (61.8 ±4.55 vs 61.0 ±4.95, p=0.916) postoperatively compared to the non-IB group.

Conclusion: In this group of patients, function and patient-reported outcomes between patients treated with PCL reconstruction and repair without internal brace versus those with additional internal brace augmentation were not significantly different. Further research encompassing a larger patient sample is necessary to investigate the efficacy of the internal brace for PCL injury in the context of MLKI injuries.

Keywords: knee, tissue augmentation, multiligament, suture augmentation, posterior cruciate ligament, internal brace

Introduction

Ligamentous knee injuries are a common occurrence in active populations, with some estimates that 36.6% of all sports injuries involve the knee.[1] Among the knee ligaments, isolated posterior cruciate ligament (PCL) injuries are uncommon, with an annual incidence around 1–6%.[2] PCL tears more often occur concomitantly with other knee ligament injuries including the posterolateral corner (PLC), anterior cruciate ligament (ACL), and medial collateral ligament (MCL). Multi-ligament knee injuries are commonly recognized as the tear of at least two of four major knee ligament structures: PCL, ACL, MCL, and PLC.[3,4] Among multi-ligament knee injuries, around 41% involve a PCL tear.[5]

The PCL functions as a restraint to posterior tibial translation.[6] Insufficient posterior stability resulting from a PCL tear can lead to increased contact pressure between the patellofemoral compartment and the medial tibiofemoral

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compartment, increasing the risk for subsequent injury.[7,8] Considering these risks, it is important to evaluate the current interventions to determine what might produce the best patient outcomes. Currently, PCL reconstruction surgery remains the most popular technique for treating complete tears.[8–11] However, 5–21% of patients who undergo PCL reconstruction require revision surgery, and graft failure has been reported to be very high.[12–14]

Internal bracing is a technique that uses high strength suture tape to enhance a ligament repair and act as a secondary stabilizer.[15] Internal bracing was recently proposed to augment PCL reconstruction, and several studies have demonstrated satisfactory posterior stability and clinical outcomes when compared to isolated PCL reconstruction both in physical tests and magnetic resonance imaging (MRI) scans.[16–18] Current literature on PCL tears has focused largely on isolated PCL tears in evaluating the efficacy of internal bracing.[16] Therefore, the purpose of this study was to compare the patient reported outcomes between patients with isolated PCL reconstruction or repair versus PCL reconstruction or repair with internal bracing in the context of multi-ligament knee injuries.

Methods

A retrospective review was performed to identify adult patients who underwent surgical management of multi-ligament knee injuries (MLKI) – defined as at least 2 major knee ligaments torn – at two institutions between 2006 and 2020. Patients were contacted via email and/or telephone and offered participation in the study via the collection of post-operative functional outcomes using validated instruments for MLKI. Our inclusion criteria included: 1) age ≥18 years at the time of injury 2) surgical reconstruction or repair of MLKI involving the PCL, 3) at least 1 year of follow-up and 4) patient willingness to participate. Patients were excluded if they had previous surgery on the operated knee or were neither English nor Spanish speaking, or refused to participate. The study was approved by the University of Southern California Institutional Review Board (HS-17-00301) and complies with the Declaration of Helsinki.

Patient Evaluation and Data Collection

After being described the study design via telephone by 2 authors (AF, SK), participants gave verbal consent to participate in the study. At the time of interview, 3 outcome measures were administered – the 8-item Lysholm, the 52-item ML-QOL (Multiple-Ligament Quality of Life), and the Patient-Reported Outcomes Measurement Information System (PROMIS) computer adaptive testing (CAT) Pain Interference, Physical Function, and Mobility instruments.[19] After telephone interview, additional data was collected via electronic medical record (EMR), including patient demographic information (sex, age, and body mass index), Schenck Classification of MLKI, intra-operative procedures performed, and reoperation rate. Reoperation rate was defined as any additional surgery to the same knee requiring general anesthesia.

Data Collection Instruments

The primary outcome was the measurement of patient-reported quality of life as measured by three distinct instruments. The Multiple Ligament Quality of Life instrument was introduced in 2014 and had the goal of measuring several variables that may be more unique to MLKI including both social and sports participation but also the emotional burden that these severe injuries may place on patients.[20] The instrument asks patients a total of 52 questions across 4 larger domains: Physical Impairment, Emotional Impairment, Activity Limitations, and Societal Involvement.[20]

The PROMIS Computer Adaptive Testing is a software-based instrument that adapts to each of the patient's antecedent responses. It has previously been demonstrated that this instrument correlated to previously existing instruments for measuring patient reported outcomes following MKLI injuries including the MLQOL and Lysholm knee score.[19] The instrument encompasses three domains: Pain, Physical Function, and Mobility categories.

The Lysholm Score was first described in the literature in 1982 to assist clinicians in measuring outcomes after surgical intervention of ligamentous knee injuries.[21] The assessment is a condition-specific outcome measure comprised eight domains: limp, locking, pain, stair-climbing, use of supports, instability, swelling, and squatting.[22] With the exception of the Lysholm knee scores and PROMIS Physical Function and PROMIS Mobility, higher numerical scores on these instruments represented a worse outcome.

Surgical Technique and Postoperative Rehabilitation

In order to assess the extent of ligamentous injuries, the patients' knee underwent stress testing under general anesthesia, with the goal of assessing which structures (PCL, ACL, LCL, PLC, MCL or PMC) would require surgical correction. In order to determine whether repair or reconstruction was indicated, the senior author assessed both MRI findings and the overall tissue quality of the injured ligaments.

The practice of the senior author is primarily focused on the management of MLKI, and in 2016 he began implementing the use of internal bracing in his surgical intervention of MLKI injuries. Prior to this, the senior author's PCL technique utilized a single bundle with Achilles tendon allograft with a trans-tibial technique, with interference screw fixation on the femur and interference screw plus screw and washer fixation on the tibia.[23,24] The senior author's repair prior to internal brace consisted of a suture repair for proximal injuries of the PCL without a spanning internal brace.

After 2016, the determination on whether a repair with internal bracing or reconstruction with internal bracing was utilized relied on both the location of injury and the quality of the PCL tissue. All attempts were made to repair proximal and distal avulsions with a spanning internal brace. Primary repairs and/or reconstructions were augmented with suture tape, or a construct composed of two separate tight-rope fixation devices. The brace spanned the entire length of the repaired ligament and was secured on the femoral side over a suspensory button and on the tibial side over a suspensory button, and often backed up with a supplementary anchor on the tibia. In 2016, the reconstruction technique changed from a transtibial technique with interference screw fixation to an all-inside technique with suspensory fixation. Two FiberTapes (Arthrex, Naples, FL) were used for PCL reconstruction.

Statistics

Statistics were performed with Stata (v 13.0; StataCorp). In order to compare continuous variables between different groups, a two-tailed *t*-tests was performed. For comparison of categorical variables, chi-squared testing or the Fisher's exact test (if n<5) was used. The level of statistical significance was set at <0.05.

Results

A total of 52 patients who underwent surgical management of MLKI involving the PCL were included in this analysis. Of the 52 total patients, 16 underwent PCL reconstruction without internal bracing and 2 underwent PCL repair without internal bracing (total of 18; Non-IB group). Within the internal bracing group, 13 patients underwent PCL repair and 21 underwent reconstruction with the use of suture augmentation (total of 34; IB group). The Non-IB group included 13 males and 2 females (2 patients with unknown demographics) with an average age of 34.1 years +-3.72, average BMI of 28.5+-1.8, and average follow-up time of 760.5 days +-230.94. The IB group included 28 males and 6 females with an average of 33.1 years ± 1.6, average BMI of 28.8± 0.90, and average follow-up time of 440.0+-64.63 (Table 1).

Patient reported outcome scores are presented in Table 2. With regard to the PROMIS instrument, there was no statistically significant difference in all three subcategories: Pain, Physical Function, and Mobility. The findings from the

Table 1 Demographic and Injury Classification for Both the Internal Brace (IB) and Non-Internal Brace (Non-IB) Participants

		Internal Brace	Non-Internal Brace	Total
Demographics	n	34	18	52
	Average Age at Surgery	32.6+-2.00	34.1+-3.72	33.1+-1.63
	Average Follow-up (days)	440+-64.63	760.5+-230.94	527.6+-79.90
	Average Time to Surgery	251.8+-299.40	1031.5+-1864.47	459.7+-1065.29
	Average BMI	28.9+-1.00	28.5+-1.83	28.8+-0.90
	Gender	28 Male (82.35) 6 Female (17.65%)	13 Male (72.22%) 3 Female (16.67%) 2 Undisclosed (11.11%)	41 Males (78.85%) 9 Females (17.31%) 2 Undisclosed (3.71%)

(*Continued*)

Table 1 (Continued).

		Internal Brace	Non-Internal Brace	Total
Schenck Type	KDI	9 (26.47%)	5 (27.78%)	14 (25.93%)
	KDII	1 (2.94%)	5 (27.78%)	6 (11.11%)
	KDIII	19 (55.88%)	8 (44.44%)	27 (50.0%)
	KDIV	5 (14.71%)	0 (0%)	5 (9.26%)
	KDV	0 (0%)	0 (0%)	0 (0%)

Notes: The internal brace group had a shorter follow up time, though this value did not reach statistical follow up. The internal brace group demonstrated a higher percentage of high-grade Schenck injuries (KDIII and KDIV).

Table 2 Comparisons of Three Different Instrument Outcomes Scores in the Post-Operative Evaluation of Both the Internal Brace (IB) and Non-Internal Brace (Non-IB) Groups

Instrument	PCL w/o Internal Bracing	PCL w/ Internal Bracing	Total	p value
PROMIS-Pain	51.7+-1.70	54.4+-1.78	53.5+-1.31	0.3193
PROMIS- Physical Function	47.9+-1.52	44.3+-2.27	45.6+-1.58	0.294
PROMIS- Mobility	46.1+-2.10	44.0+-1.71	44.7+-1.33	0.4626
MLQOL- Physical Impairment	41.7+-5.10	40.7+-4.21	41.0+-3.24	0.8836
MLQOL- Emotional Impairment	44.7+-5.87	49.2+-4.88	47.6+-3.76	0.5788
MLQOL- Activity Limitation	31.5+-3.72	43.5+-4.56	39.3+-3.32	0.087
MLQOL- Societal Involvement	37.5+-5.30	44.9+-4.96	42.4+-3.73	0.3447
Lysholm Knee Score	61.0+-4.95	61.8+-4.55	61.5+-3.40	0.9161

Notes: Higher numerical scores for the Patient-Reported Outcomes Measurement Information System (PROMOS)-Pain, all Multiple-Ligament Quality of Life (MLQOL), represent a worse outcome. For the Lysholm knee scores, PROMIS-Physical Function and Mobility, higher numerical scores represent a good result. There were no significant differences between the IB and non-IB groups.

ML-QOL questionnaire were also not statistically significant in all subcategories: Physical Impairment, Emotional Impairment, Activity limitation, and Societal Involvement. Finally, the Lysholm Knee instrument was not significantly different between the non-IB group and IB-group.

Reoperations rates for both the internal brace and non-internal brace groups are presented in Table 3. A total of 15 patients underwent a collective total of 22 reoperations following their initial surgeries. Of these 15 patients, 5 (33.3%)

Table 3 Indications for and Number of Re-Operations Following Initial Surgery for Both the Internal Brace and Non-Internal Brace Groups

Reoperation Procedures	Non-IB (n=18)	IB (n=34)
Manipulation under Anesthesia	3	5
Removal of Hardware	1	2
Internal bracing revision	0	3
Irrigation and Debridement	2	0
Neurolysis of Peroneal nerve	0	1

(*Continued*)

Table 3 (Continued).

Reoperation Procedures	Non-IB (n=18)	IB (n=34)
LCL Revision w/IB	0	1
PCL revision	0	1
Total Knee Arthroplasty	0	1
Adductor Canal Block	0	1
Multiligament Knee revision	1	0
Total	7 (38.9%)	15 (44.1%)

belonged to the non-internal brace group while the remaining 10 patients (66.7%) belonged to the internal brace group. Collectively, the most commonly cited reasons for re-operation were manipulation under anesthesia (n=8, 36.4%), removal of hardware (n=3, 13.6%), and revision of internal bracing (n=3, 13.6%).

Discussion

In the present study, patients who underwent internal brace augmentation during the surgical repair and/or reconstruction of multi-ligament injuries with PCL involvement showed similar patient-reported outcomes and physical function compared to those without internal brace augmentation at short-term follow-up. While these findings are preliminary, our results suggest that suture augmentation may be a viable treatment for PCL ruptures in the context of MLKI injuries.

Suture augmentation has been an area of recent interest within the orthopaedic literature. Many studies have demonstrated the viability of internal bracing within the context of Anterior Cruciate Ligament injuries.[25,26] The protection and stabilization that internal bracing provides may allow for increased mobilization during the early-phase healing process.[27,28] Still, the current literature on suture augmentation for both isolated and multi-ligament PCL injuries is limited. However, preliminary studies suggest a potentially promising future for the use of suture augmentation for PCL tears. Biomechanical studies by Grotting et al and Trasolini et al have demonstrated reduced posterior tibial translation in cadavers with PCL suture augmentation when compared to PCL reconstruction.[17,29] Additionally, Otto et al analyzed a cohort of 14 patients with multi-ligament PCL tears and found that suture augmentation provided adequate restoration of posterior tibial translation when followed for 20 months.[18] Recently, Zhao et al expanded on these findings to demonstrate satisfactory posterior stability and patient reported outcomes at two-year follow-up in 33 patients with isolated or multiligament PCL tears.[16]

Given both the acuity and rarity of these injuries, there is a paucity of high level of evidence studies regarding their treatment. It is unsurprising, then, that there lacks a consensus in the optimal surgical approach. When a surgical approach is indicated, variations in techniques exist. Historically, a two-staged approach was a more common technique. Bin et al described a technique where the medial or lateral ligament complexes were initially addressed followed by a second operation months later where the ACL or PCL was reconstructed.[30] Conversely, Ohkoshi et al's two-stage approach involved with reconstructing the PCL initially followed by reconstructions of the ACL, MCL, and LCL.[31] More recently, a single-stage approach has been favored, since it has been demonstrated to result in fewer complications and costs.[32] This may be particularly beneficial for MLKI's with PCL involvement, as it has been demonstrated that early reconstruction of the PCL (less than or equal to 12 weeks since onset of injury) can prevent the development chondral injuries.[33] Repair for MLKI has also recently demonstrated viability, especially in the setting of internal bracing, and offers specific advantages over the use of a graft such as preserving native tissues, reducing incidence of osteoarthritis, and minimizing recovery time.[34] Though our findings do not reveal any significance between repair and/or reconstruction with and without internal brace, it does highlight that continued research is needed in this area of orthopaedic research and that future studies should continue to explore the treatment of these high-risk injuries.

We reported a total of 22 reoperations across 15 patients. Of these 22 reoperations, 7 belonged in the non-internal brace group while the remaining 15 belonged to the internal brace group. In both the internal brace and non-internal brace group, manipulation under anesthesia (MUA) was the most commonly cited reason for a re-operation. Arthrofibrosis is

a common complication that has been estimated to occur with rates as high as 57% for patients after a MLKI.[35] However, MUA has been demonstrated to result in high rates of both satisfaction and improved functional outcomes in patients suffering from arthrofibrosis following MLKI.[35] Given the complexity of MLKI and their mechanism of injury, it is unsurprising that the post-operative recovery is often influenced by multiple factors such as the mechanism of injury, concomitant injury, and the patients baseline level of activity. A systematic review by Everhart et al revealed that return to work rates varied depending on several factors including whether or not job-related modifications were implemented, the presence of vascular injuries, or Schenck classifications.[36] With regard to return to sports, the level of preinjury play may also play an important factor as competitive athletes often have a much lower return to sport rate.[36] Post-operative rehabilitation may play a crucial role in both return to work and return to sport. However, given that there lacks a standardized treatment protocol for MLKI, it is also unsurprising that their seems to be a lack of a standardized post-operative rehabilitation protocol.[37] Still, with proper rehabilitation protocol, patients can often return to sport. Monson et al describe their post-operative rehabilitation protocol with the implementation of return to sport testing at various time points and report that patients at their center are educated in a return to sport timeline between 12 and 18 months.[37] Given the variability of MLKI injuries, there is a strong need for further research to explore and improve rehabilitation protocols to optimize return to sport and work rates.

Limitations

Given the rarity and heterogeneity of multiligament knee injuries, it is difficult to obtain a substantial-matched cohort comparing IB patients with non-IB patients.[38] This is particularly true when including only MLKIs involving the PCL. Our study is similarly limited and is clearly underpowered to detect an effect of the internal brace. Due to the small number of patients given this extremely rare injury, we decided to combine repair and reconstruction groups, which admittedly introduces bias into the results. In addition, the traumatic nature of these injuries poses a substantial challenge in creating a uniform treatment protocol, which explains the large imbalance in follow-up duration and time to surgery. The average follow-up period between these groups also differed drastically, since internal bracing was only recently implemented in the senior author's practice. This might introduce some additional confounding factors, particularly as many of the instruments utilized in our study require participants to describe the effect of their knee injury on daily activity. It is plausible that a longer follow-up time may have conferred an advantage in answering these questions. Moreover, some patients may have received additional care at separate institution, which may not have been disclosed to us. Despite these inherent constraints, one of the strengths of our study is that we had a single surgeon perform both the IB and non-IB procedures with the same protocol, reducing the possibility of bias that may result from differences in surgeon technique. Additionally, both the IB and non-IB patient cohorts had a similar average age, BMI, and percentage of males and females, limiting the likelihood of these confounding variables on the results of our study.

Conclusion

In this subset of patients, differences in outcomes and function between patients treated with isolated PCL reconstruction or repair versus those with additional internal brace augmentation were not significant. Further research encompassing a larger patient sample is necessary to investigate the efficacy of internal brace augmentation for the PCL in MLKI injuries.

Disclosure

Dr George F Hatch III reports grants, personal fees from Arthrex, outside the submitted work. The authors report no other conflicts of interest in this work.

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