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Intraoperative and Postoperative Outcomes of Patients Undergoing Total Knee Arthroplasty With Prior Anterior Cruciate Ligament Reconstruction: A Matched Cohort Analysis

Bahar Entezari, BMSc[a, b, *], Johnathan R. Lex, MBChB, MASc[c], Jonathan Peck, MD, FRCSC[c], Emmanuel N. Igbokwe, HBSc, MD[c], Jeremy F. Kubik, MD, FRCSC[c], David J. Backstein, MD, MEd, FRCSC[a, c], Jesse I. Wolfstadt, MD, MSc, FRCSC, FAAOS[a, c]

[a] *Granovsky Gluskin Division of Orthopaedics, Mount Sinai Hospital, Toronto, ON, Canada*
[b] *Queen's University School of Medicine, Kingston, ON, Canada*
[c] *Division of Orthopaedic Surgery, Department of Surgery, University of Toronto, Toronto, ON, Canada*

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ABSTRACT

Background: Previous anterior cruciate ligament (ACL) injury is a risk factor for the development of knee osteoarthritis. Despite advances in ACL reconstruction (ACLR) techniques, many patients with history of ACLR develop end-stage osteoarthritis necessitating total knee arthroplasty (TKA). The purpose of this study was to investigate the impact of prior ACLR on intraoperative and postoperative outcomes of TKA.
Methods: This was a single-centre matched cohort study of all patients with prior ACLR undergoing primary TKA from January 2000 to May 2022. Patients were matched 1:1 to patients undergoing TKA with no prior ACL injury based on age, sex, and body mass index. Outcomes investigated included TKA procedure duration, soft-tissue releases, implant design, and complications requiring reoperation.
Results: Forty-two ACLR patients were identified and matched to controls. Mean follow-up was 6.8 years and 5.0 years in the ACLR and control cohorts, respectively ($P = .115$). ACLR patients demonstrated longer procedure durations (122.8 minutes vs 87.0 minutes, $P < .001$) and more frequently required soft-tissue releases (40.5% vs 14.3%, $P = .007$), stemmed implants (23.8% vs 4.8%, $P = .013$), and patellar resurfacing (59.5% vs 26.2%, $P = .002$). There were no significant differences in postoperative clinical or surgical outcomes between groups. Ten-year implant survivorship was 92% and 95% in the ACLR and control cohorts, respectively ($P = .777$).
Conclusions: TKA is an effective procedure for the management of end-stage osteoarthritis with prior ACLR. The care team should be prepared for longer operative times and the utilization of advanced techniques to achieve satisfactory soft-tissue balance and implant stability.

Introduction

The anterior cruciate ligament (ACL) is a critical stabilizing structure of the knee joint that functions to limit anterior tibial translation and excessive knee rotation [1–3]. It is one of the most commonly injured ligaments in the knee, with an annual incidence of ACL tears approaching 70 per 100,000 person-years in the United States [4–7]. Affected individuals are generally young, with a peak incidence between 19 and 25 years in men and between 14 and 18 years in women [4,8]. When the ACL is torn, it results in instability of the knee joint, leading to functional impairment and predisposing to cartilage degeneration in the long term [1,2,9]. While some individuals are candidates for nonoperative management with rehabilitation and physical therapy, an increasing proportion of patients undergo surgical management with ACL reconstruction (ACLR) [4,10]. The goals of management include restoration of stability and function of the knee joint, allowing patients to return

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* Corresponding author. Queen's University School of Medicine, 15 Arch Street, Kingston, ON, Canada K7L 3N6. Tel.: +1 647 866 8729.
E-mail address: bentezari@qmed.ca

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to their preinjury level of activity while reducing the risk of further injury and joint degeneration [1,2,11].

Despite advances in ACLR techniques and postoperative rehabilitation protocols, it has been well documented that compared to patients with no known history of ACLR, patients who have undergone ACLR are at an increased risk of undergoing subsequent total knee arthroplasty (TKA) secondary to osteoarthritis in the knee joint [12–14]. The cumulative incidence of TKA following ACLR has been documented to be up to 7 times greater than the cumulative incidence of TKA among the general population (1.4% vs 0.2%, respectively) [15]. Many mechanisms may contribute to the increased risk of degeneration among patients who have undergone ACLR, including failure to restore normal ACL tension and joint kinematics, chondral or meniscal damage from the initial trauma, or secondary to the surgery itself [1,15–22]. These same factors, as well as postoperative scarring and presence of hardware such as screws or staples, may affect intraoperative and postoperative outcomes of patients undergoing subsequent TKA [14,23].

A handful of retrospective studies have investigated the intraoperative and postoperative outcomes associated with TKA in patients with prior ipsilateral ACLR [14,16,23–27]. Several of these studies have noted significant intraoperative and postoperative challenges related to TKA in this population, including increased operative times, higher rates of postoperative periprosthetic joint infections (PJIs), postoperative stiffness refractory to physiotherapy, and revision surgeries [14,23,25–27]. Conversely, several studies have noted no significant differences in these and other outcomes related to TKA in this patient population when compared to the general population [14,24,25,27]. Furthermore, many studies do not provide a comprehensive overview of preoperative clinical and radiographic data describing ACLR patients undergoing TKA which may affect postoperative outcomes. The aims of this study were to thus investigate the impact of prior ACLR on intraoperative and postoperative outcomes following TKA in extensive clinical and radiographic context and to contribute to the resolution of the existing controversy in the literature.

Material and methods

This was a single center matched cohort study of all patients with known history of ACLR undergoing unilateral primary TKA from January 2000 to May 2022 for a primary indication of knee osteoarthritis (OA). Patients were identified by filtering of a prospectively maintained institutional arthroplasty database. Patients were matched 1:1 to patients undergoing TKA with no prior ACL injury or ACLR based on age, sex, and body mass index. A minimum of 1-year follow-up from date of primary TKA was required for study inclusion. Only patients over the age of 18 years undergoing unilateral TKA were included. For patients in the ACLR group, only those with isolated ACL tears who underwent ACLR were included – those with a history of multiligamentous knee injury and those with ACL tears managed nonoperatively were excluded.

The database was queried for demographic patient data including age at time of TKA, sex, body mass index, diabetes status, smoking status, American Society of Anesthesiologists classification, and Charlson comorbidity index classification. Clinical preoperative data collected included OA severity as graded by radiographic examination using the Kellgren-Lawrence (KL) system, radiographic coronal alignment, and range of motion (ROM) and stability in the anterior-posterior (AP) plane based on physical examination. Coronal alignment was measured on weight-bearing, full-length AP lower limb radiographs as the hip-knee-ankle angle, defined as the angle between the mechanical axes of the femur and tibia. The mechanical axis of the femur was drawn as a line extending from the center of the femoral head to the femoral intercondylar notch, and the mechanical axis of the tibia a line extending from the tibial interspinous point to the tibial midplafond. Neutral alignment was defined as a hip-knee-ankle angle within 2 degrees of neutral. Valgus and varus alignment were defined as a hip-knee-ankle angle of greater than 2 degrees of valgus or varus deformity, respectively [28]. Stability in the AP plane was assessed by anterior drawer testing, with anterior translation of <6 mm with the knee flexed to 90 degrees with the foot stabilized. Intraoperative data were collected from operative reports and included procedure duration (defined using operation start and stop times), any soft tissue releases, removal of hardware, patellar resurfacing, and inserted implant type including level of constraint, need for femoral or tibial stems, and polyethylene insert thickness. Postoperative data collected included ROM and stability in the AP plane as determined on physical examination, and any complications requiring revision. Duration of follow-up from time of primary TKA was documented for all patients.

Surgical technique

TKAs were performed by 5 fellowship trained arthroplasty surgeons. Existing midline, paramedian, or curved medial scars were used for skin incisions wherever possible, followed by a standard medial parapatellar arthrotomy. Upon visualization of the patellar articulating surface, patellar resurfacing was performed if significant patellar wear was noted. Otherwise, patelloplasty and lateral facetectomy were undertaken to ensure a smooth articulating surface. Manual instrumentation was used to guide bone resection and implant positioning for all cases. Femoral hardware removal was performed in cases where the previous hardware was obstructing the femoral intramedullary guide rod. Trial implants were used to assess joint stability and ROM, and to determine the need for any additional releases. Definitive implants were all implanted using antibiotic-impregnated cement. Joint stability and ROM were evaluated again before primary closure of the wound.

Statistical analysis

Statistical analyses were performed using GraphPad Prism, version 9 (GraphPad software, San Diego, CA). Differences in continuous data were assessed using unpaired t-tests and one-way analysis of variance where applicable. Differences in categorical data were assessed using Pearson's Chi-squared test or Fisher's exact test where applicable. Kaplan-Meier survival analysis with log-rank test was performed for complications requiring reoperation. Statistical significance for all analyses was set at $\alpha = 0.05$.

Ethical considerations

Institutional research ethics board (REB) approval was granted (20-0073-C). All patient data were deidentified.

Results

Forty-eight patients with a history of ACL injury undergoing primary TKA were identified from the arthroplasty database during the study period. Two patients were excluded due to having multiligamentous knee injuries. Three patients were excluded as their ACL injuries were managed nonoperatively. One patient was excluded for undergoing simultaneous bilateral TKA following ACLR. The remaining 42 patients were matched 1:1 to 42 controls, yielding a total study population of 84 patients. Patients with a history of ACLR accounted for 1.6% of all patients undergoing primary TKA during the study period. Compared to the general population, ACLR patients were significantly younger at the time of primary TKA (59.3 standard deviation [SD]: 7.5 years vs 66.2 SD: 10.1 years, $P < .001$) and included a smaller proportion of women (33.3% vs 62.2%, $P < .001$). All patients in both groups had a minimum follow-up of 1 year, with a mean follow-up of 6.8 years (range: 1.0 to 15.3 years) in the ACLR cohort and 5.0 years (range: 1.0 to 19.0 years) in the control cohort ($P = .115$). Mean time from ACLR to TKA was 28.7 years (range: 6.3 to 46.0 years).

Following matching, baseline characteristics including age, sex, body mass index, diabetes status, smoking status, and Charlson comorbidity index score was similar between groups ($P > .05$ for all) (Table 1). The ACLR cohort consisted of a higher proportion of American Society of Anesthesiologists 1 patients (14.3% vs 2.4%, $P = .048$) and a lower proportion of American Society of Anesthesiologists 3 patients (40.5% vs 64.3%, $P = .029$). On preoperative radiographic films, both groups showed similar distributions of KL OA grades ($P > .05$ for all). Preoperative coronal alignment differed significantly between groups, with the ACLR cohort consisting of a higher proportion of patients in valgus alignment (26.2% vs 6.1%, $P = .022$) and a lower proportion of patients in varus alignment (61.9% vs 87.9%, $P = .012$). On clinical examination, patients in both groups demonstrated similar ROM, but patients in the ACLR group were less likely to demonstrate stability in the sagittal plane compared to control (64.3% vs 92.9%, $P < .001$).

A total of 11 patients representing 26.2% of the ACLR cohort required removal of hardware at the time of TKA, 7 of which had hardware removed from the tibia alone and 4 of which had hardware removed from both the tibia and femur (Table 2). Compared to the control cohort, ACLR patients experienced longer procedure durations (122.8 SD: 30.8 minutes vs 87.0 SD: 19.5 minutes, $P < .001$) and more frequently required additional soft tissue releases (40.5% vs 14.3%, $P = .007$), tibial stems (23.8% vs 4.8%, $P = .013$) and patellar resurfacing (59.5% vs 26.2%, $P = .002$) (Table 3). Femoral stem lengths ranged from 100mm to 200mm in the ACLR cohort while only 100mm femoral stems were used in the control cohort. Tibial stem lengths ranged from 75mm to 145mm in the ACLR cohort compared to 30 mm to 100 mm in the control cohort. There were similar proportions of patients in both groups requiring implants with low (cruciate retaining, cruciate sacrificing, medial congruent), intermediate (posterior stabilized, constrained posterior stabilized), and high (condylar constrained knee, rotating hinged knee) degrees of constraint ($P > .05$ for all). No significant differences were observed in any postoperative clinical outcomes between groups, including range of motion and AP stability on physical examination, or postoperative surgical complications requiring reoperation (Table 4). Two patients in the ACLR cohort and 2 in the control cohort required revision for stiffness. One patient in the ACLR cohort required reoperation for pain, entailing irrigation and debridement and polyethylene liner exchange, patellar debridement, and excision of a loose osseous fragment. No patients in either group required revision for PJI (acute or chronic), instability, or any other indication. Implant survivorship at 10 years was 92% and 95% in the ACLR and control cohorts, respectively, and similar between groups ($P = .777$) (Fig. 1).

Table 1
Preoperative demographic and clinical characteristics of patients with and without history of ACLR undergoing primary TKA.

Characteristic	ACLR cohort	Control cohort	*P*-value
Number of patients, N	42	42	-
Age, mean ± SD	59.3 ± 7.5	60.1 ± 8.1	.636
Females, N (%)	13 (33.3)	13 (33.3)	1.000
BMI, mean ± SD	29.7 ± 6.2	32.8 ± 8.0	.052
BMI >35, N (%)	7 (16.7)	7 (16.7)	1.000
Diabetes, N (%)	4 (9.5)	6 (14.3)	.500
Current smoker, N (%)	2 (4.8)	5 (11.9)	.236
ASA classification			
1, N (%)	6 (14.3)	1 (2.4)	.048
2, N (%)	19 (45.2)	14 (33.3)	.264
3, N (%)	17 (40.5)	27 (64.3)	.029
4, N (%)	0 (0.0)	0 (0.0)	1.000
CCI score			
0-1, N (%)	16 (38.1)	14 (33.3)	.768
2-3, N (%)	22 (52.4)	21 (50.0)	.827
>3, N (%)	4 (9.5)	6 (14.3)	.500
KL OA grade			
0, N (%)	0 (0.0)	0 (0.0)	1.000
1, N (%)	0 (0.0)	0 (0.0)	1.000
2, N (%)	3 (7.1)	1 (2.4)	.306
3, N (%)	23 (54.8)	21 (50.0)	.662
4, N (%)	16 (38.1)	20 (47.6)	.378
Radiographic coronal alignment			
Neutral, N (%)	5 (11.9)	2 (6.1)	.388
Valgus, N (%)	11 (26.2)	2 (6.1)	.022
Varus, N (%)	26 (61.9)	29 (87.9)	.012
ROM arc >90°, N (%)	36 (85.7)	36 (85.7)	1.000
Stable in AP plane, N (%)	27 (64.3)	39 (92.9)	<.001
Time from ACLR to TKA in years, mean ± SD	28.7 ± 9.5	-	-
Follow-up in years, mean ± SD	6.8 ± 3.9	5.0 ± 6.4	.115

ACLR, anterior cruciate ligament reconstruction; AP, anterior-posterior; ASA, American Society of Anesthesiologists; BMI, body mass index; CCI, Charlson comorbidity index; KL OA, Kellgren and Lawrence osteoarthritis; ROM, range of motion ; SD, standard deviation; TKA, total knee arthroplasty.

Table 2
Mean procedure duration by extent of hardware removal among patients with history of ACLR undergoing primary TKA. One-way ANOVA analysis revealed no statistically significant differences in procedure duration between groups ($P = .497$).

Removal of hardware	Sample size, N (%)	Mean procedure duration, min ±SD
None	31 (73.8)	122.0 ± 33.4
Tibia only	7 (16.7)	126.3 ± 27.9
Femur only	0 (0.0)	-
Tibia and femur	4 (9.5)	160.0 ± 14.1

ACLR, anterior cruciate ligament reconstruction; ANOVA, analysis of variance; SD, standard deviation.

Discussion

The purpose of this study was to investigate the impact of prior ACLR on intraoperative and postoperative outcomes following TKA. The findings of this study highlight the intraoperative difficulties that can be anticipated when planning TKA for patients with a history of ACLR. Compared to controls, ACLR patients had longer operative times and more frequently required additional soft tissue

Table 3
Operative data of patients with and without history of ACLR undergoing primary TKA.

Outcome	ACLR cohort	Control cohort	*P* value
Procedure duration, min ±SD	122.8 ± 30.8	87.0 ± 19.5	<.001
Additional release(s), N (%)	17 (40.5)	6 (14.3)	.007
Stemmed implant, N (%)	10 (23.8)	2 (4.8)	.013
Femoral stem, N (%)	4 (9.5)	2 (4.8)	.397
Tibial stem, N (%)	10 (23.8)	2 (4.8)	.013
Implant liner design			
CR/CS/MC, N (%)	22 (52.4)	29 (69.0)	.118
PS/CPS, N (%)	16 (38.1)	12 (28.6)	.355
CCK/RHK, N (%)	4 (9.5)	1 (2.4)	.167
Polyethylene insert >12 mm, N (%)	4 (9.5)	5 (11.9)	.724
Patellar resurfacing, N (%)	25 (59.5)	11 (26.2)	.002

ACLR, anterior cruciate ligament reconstruction; CCK, constrained condylar knee; CPS, constrained posterior stabilized; CR, cruciate retaining; CS, cruciate sacrificing; MC, medical congruent; PS, posterior stabilized; RHK, rotating hinge knee; SD, standard deviation; TKA, total knee arthroplasty.

Table 4
Postoperative clinical and surgical outcomes of patients with and without history of ACLR undergoing primary TKA.

Outcome	ACLR cohort	Control cohort	*P*-value
ROM arc >90°, N (%)	41 (97.6)	41 (97.6)	1.000
Stable in AP plane, N (%)	37 (88.1)	42 (100.0)	.055
Complications requiring revision, N (%)	3 (7.1)	2 (4.8)	.645
PJI, N (%)	0 (0.0)	0 (0.0)	1.000
Stiffness, N (%)	2 (4.8)	2 (4.8)	1.000
Instability, N (%)	0 (0.0)	0 (0.0)	1.000
Pain, N (%)	1 (2.4)	0 (0.0)	1.000
Others, N (%)	0 (0.0)	0 (0.0)	1.000

ACLR, anterior cruciate ligament reconstruction; AP, anterior-posterior; PJI, periprosthetic joint infection; ROM, range of motion; TKA, total knee arthroplasty.

releases, patellar resurfacing, and stemmed implants. Despite these intraoperative challenges, postoperative outcomes of ACLR patients were similar to those of patients with no known history of ACLR.

Perhaps the most consistently reported finding presented here and in the existing literature is prolonged operative times among patients undergoing TKA with history of ACLR. In their 2018 matched case-control study of 101 patients with prior ACLR and 202 controls, Chong et al. [14] reported operative time to be prolonged by an average of 14 minutes in the ACLR group. Lizaur-Utrilla et al. [25] and Watters et al. [23] both reported similar findings in their matched case-control studies of 37 and 122 patients with prior ACLR, respectively. Magnussen et al. [26] reported prolonged tourniquet time for patients in their ACLR group compared to controls; however, this did not achieve statistical significance. Several factors may contribute to prolonged TKA operative times for ACLR patients, including removal of preexisting hardware to allow for passage of intramedullary instruments and placement of TKA components. Magnussen et al. [26], Watters et al. [25], and Chong et al. [14] reported 45%, 50%, and 84% of patients in their ACLR groups required implant removal during TKA, respectively, and suggest implant removal contributes to prolonged operative times among ACLR patients. Furthermore, Chong et al. [24] conducted subgroup analysis and found that operative times were greater for patients requiring ACLR hardware removal from both the tibia and the femur as compared to those requiring ACLR hardware removal from the tibia alone, suggesting more extensive removal procedures contribute to greater increases in operative time. In this present study, over a quarter of patients in the ACLR cohort underwent hardware removal at the time of TKA, potentially contributing to prolonged operative times.

Effects of a dysregulated inflammatory response among ACLR patients may also contribute to prolonged TKA operative times. It has been demonstrated that inflammatory and chondrodegenerative biomarkers are elevated following both ACL injury and ACLR [29]. Arthrofibrosis, or the formation of adherences and fibrous tissue secondary to inflammatory processes and associated intra-articular effusions, occurs commonly after ACLR [30,31]. As a result, TKA procedures among ACLR patients are complicated by excessive scar tissue which may result in increased stiffness and obscured key landmarks, requiring additional releases and extensive debridement to achieve appropriate ligament balance and allow adequate surgical exposure. Additional releases, especially of the lateral soft tissue structures, may also be required in the correction of the valgus knee [32,33]. In this study, patients in the ACLR cohort more frequently presented with valgus knee deformity at time of TKA when compared to a matched cohort. Although the primary function of the ACL is restricting anterior translation of the tibia relative to the femur, it also plays an important role in stabilizing the knee against excessive valgus stress [33]. In ACLR patients, failed restoration of the kinematics of the native knee may contribute to the increased incidence of valgus deformity observed. Altered kinematics in combination with a dysregulated inflammatory response in the post-ACLR knee may also contribute to increased damage and osteophyte formation of the patella, necessitating resurfacing at the time of TKA [29,34,35]. Ultimately, these findings highlight the multifactorial nature of the challenges faced in TKA following ACLR, with scarring, altered knee kinematics, and valgus deformity all playing interconnected roles in influencing operative times and surgical complexity.

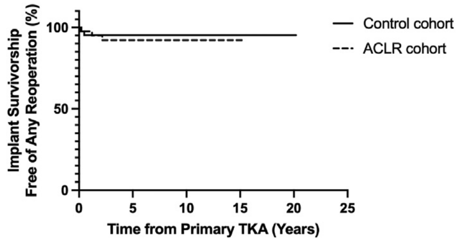

Figure 1. Kaplan-Meier curves depicting implant survivorship free of any reoperation in years from time of primary TKA for the ACLR and control cohorts. Implant survivorship at 10 years was 92% and 95% in the ACLR and control cohorts, respectively, and similar between groups ($P = .777$). ACLR, anterior cruciate ligament reconstruction; TKA, total knee arthroplasty.

Soft-tissue insufficiency and bony deficiency further complicate the operative management of ACLR patients undergoing TKA. Soft-tissue insufficiency may arise from non-anatomical graft placement, failed graft fixation, and concomitant meniscal injuries [31,36]. Stiffness may also contribute to soft-tissue instability, with reduced knee ROM impairing postoperative surrounding muscle tissue rehabilitation. In patients with soft tissue insufficiency, implants with higher levels of constraint are recommended [37]. Constrained implants, however, increase the load-bearing capacity in the joint, and may result in increased stress between the implant-cement interface or the cement-bone interface [38]. Thus, more stable fixations in the form of stemmed implants are often warranted in patients with prior ACLR undergoing TKA [39]. Stemmed implants are also indicated in patients with bony deficiency, another problem common to ALCR patients [40]. Bony deficiency may arise from graft tunnel creation, revascularization of the graft leading to resorption of the surrounding bone, osteolysis around graft materials, and hardware removal at the time of TKA [41]. These factors are reflected in the findings of this present study, where ACLR patients more frequently required stemmed components. Ultimately, there are several intraoperative challenges unique to ACLR patients undergoing TKA which contribute to prolonged operative times and must be considered preoperatively by surgeons.

Despite challenges faced by surgeons intraoperatively, the outcomes of patients with history of ACLR undergoing TKA, including clinical outcomes and revision rates, were found to be comparable to those of the control cohort in this study. These findings are generally consistent with the findings of prior studies, with the exception of a higher rate of PJI and reoperation reported among ACLR patients by Watters et al. [23]. The higher incidence of PJI and associated revision surgery among ACLR patients has been proposed to be a result of retained implants from prior surgery and should be considered by surgeons to ensure all efforts are made to reduce the risk of PJI [23,42,43]. Thorough preoperative planning to help reduce duration of surgery should also be considered as prolonged procedure lengths have been shown to be associated with a significantly increased risk of PJI [44,45].

The findings of this study must be considered in light of its limitations. First, the retrospective nature of the study renders it vulnerable to confounding factors that may have gone unrecognized and unaccounted for during statical analyses. Through matching, however, key demographic variables with potential to differentially impact outcomes between groups were balanced, with the exception of a higher proportion of ACLR patients than control patients presenting with valgus deformity. Second, despite the inclusion of patients from an extended study period, the sample size of this study was limited, and may have resulted in it being underpowered to identify statistically significant differences in certain outcomes between groups, such as difference in operative times by extent of hardware removal, incidence of postoperative surgical complications requiring revision, and so on. Finally, the mean time from ACLR to TKA was 28.7 years, with the earliest ACLR included in this study having been performed in 1968. With the emergence of minimally invasive techniques and a greater appreciation of the anatomy and function of the ACL, ACLR techniques have evolved greatly since the time at which much of the patients in this study underwent ACLR. The results of this study may thus not reflect outcomes of patients undergoing TKA with a more recent history of ACLR. Additionally, many patients included in this study underwent ACLR at external institutions, thus the details of the techniques used in their ACLR were not known or accounted for in this study, for example, open vs arthroscopic reconstruction. Regardless, ACLR procedures as they currently stand fail to perfectly restore the kinematics of the native knee and there continues to exist variability in ACLR techniques adopted at different institutions [46–48]. It can thus be expected that surgeons will continue to face challenges unique to this patient population undergoing TKA in the foreseeable future. Further investigations of outcomes in subsequent TKA associated with different ACLR techniques are required to elucidate differences between techniques.

Conclusions

TKA is an effective procedure for the management of end-stage OA in the context of a prior ACLR, with postoperative outcomes similar to those of patients with no known history of ACLR in this matched cohort study. However, the care team should be prepared for longer operative times and the utilization of more advanced techniques, including additional soft-tissue releases, patellar resurfacing, and stemmed implants, to achieve satisfactory soft tissue balance and implant stability postoperatively. Thorough preoperative planning is required to ensure surgeons are best prepared to manage patients with a history of ACLR undergoing TKA. These findings should be considered in light of the limited sample size and higher proportion of ACLR patients compared to control patients presenting with valgus deformity, warranting further investigation among a larger population for validation.

Conflicts of interest

J.R. Lex serves as an unpaid consultant for PrecisionOS Technologies, receives research support from Arthrex Inc., is an American Association of Hip and Knee Surgeons Young Arthroplasty Group member; D.J. Backstein receives royalties from Microport Orthopedics, presents paid presentations for Microport Orthopedics and Depuy Synthes Orthopedics, is a Microport Orthopedics and Depuy Synthes Orthopedics paid consultant, receives stock or stock options from Intellijoint Surgical and Augmented Joint Reality, is an American Knee Society Membership Committee member; J.I. Wolfstadt is a Depuy Synthes and Microport Orthopaedics paid consultant, is an American Association of Hip and Knee Surgeons board member, American Association of Hip and Knee Surgeons Young Arthroplasty Group chair, Canadian Arthroplasty Society Education Committee member, and Canadian Orthopaedic Association Nominating Committee member.

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CRediT authorship contribution statement

Bahar Entezari: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation. **Johnathan R. Lex:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Jonathan Peck:** Writing – review & editing, Methodology, Conceptualization. **Emmanuel N. Igbokwe:** Writing – review & editing, Methodology, Conceptualization. **Jeremy F. Kubik:** Writing – original draft, Methodology, Data curation, Conceptualization. **David J. Backstein:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Jesse I. Wolfstadt:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization.

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