Total knee arthroplasty after anterior cruciate ligament reconstruction: a narrative review

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Background and Objective: Knee replacement following anterior cruciate ligament (ACL) reconstruction can be demanding due to altered anatomy, soft tissue scars, bone loss, extensor mechanism complications, and knee instability. This narrative review summarizes the strategies and approaches to managing operative challenges in total knee arthroplasty (TKA) following ACL reconstruction.

Methods: Studies reporting outcomes of patients who underwent TKA after ACL reconstruction were retrieved and assessed to be included in this review that synthesizes the available evidence highlighting the pitfalls encountered during surgery, the intraoperative challenges posed by ligament balancing and exposure, and the leading role of modular and retained implants.

Key Content and Findings: TKA following ACL reconstruction has a high rate of intra-operative complications such as instability, bone loss, difficult exposure and demanding soft tissue balancing, representing a revision surgery rather than routine primary knee arthroplasty and a revision-oriented skill set and modular components are recommended to significantly optimize both surgical strategy and patient outcomes. With a rising incidence of ACL injuries and growing reconstructions, anticipating an increase in TKA procedures, this review aims to provide a call for rethinking clinical approaches to ensure effective and patient-centric care.

Conclusions: This narrative review seems to indicate that TKA after ACL reconstruction should be considered as revision surgery and modular components should be used. However, future prospective and high-quality studies are required to better clarify risk factors and give strong recommendations for this complex surgery.

Keywords: Knee replacement; ligament reconstruction; bone loss; augment; modularity

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Introduction

The advent of advanced surgical techniques and improved implant design have enhanced clinical outcomes and joint kinematics following knee arthroplasty. Anterior cruciate ligament (ACL) reconstruction has become a mainstay of orthopedic practice, with an increasing prevalence, particularly in younger, athletically active cohorts (1,2). On the other end of the spectrum, total knee arthroplasty (TKA) has emerged as the definitive intervention for end-stage knee osteoarthritis (OA), with projections estimating an exponential rise in the number of TKA procedures by 2050 (3). These converging trends hypothesize a complex clinical scenario: a growing number of patients who have had previous ACL reconstruction may eventually require TKA as they age or develop secondary OA (4).

While TKA is commonly performed as a primary procedure for knee OA with large numbers worldwide, TKA following ACL reconstruction can be challenging and cannot be understated. The distorted anatomy, bone tunnels, ligament instability, extensor mechanism disorders and the presence of fixation hardware from the prior ACL reconstruction introduce a set of unique challenges that can make these TKA procedures as complicated as revision surgeries (5-9). The anatomical alterations resulting from ACL reconstruction due to multiple scars, poor bone loss and chronic instability lead to difficult exposure that often require the use of techniques and implants normally reserved for revision TKA (6,10,11).

In light of these considerations, this paper shows how TKA following ACL reconstruction should be approached as revision surgery, incorporating principles and techniques that are often used in complex knee implants. Careful pre-operative planning and proper implant choice become imperative given the higher rates of operative complications, including infection and hardware-related issues, that have been reported in the literature (5,8,12,13). The need for accessory soft tissue procedures and request of revision components such as modular augments, stems, and constrained components cannot be overlooked in these complex scenarios (7,14). We present this article in accordance with the Narrative Review reporting checklist (available at https://aoj.amegroups.com/article/view/10.21037/aoj-23-62/rc).

Methods

This comprehensive review aims to summarize the multifaceted challenges involved in performing TKA after ACL reconstruction. This research synthesizes current scientific literature to provide a strategic framework for surgeons. The specific search summary is reported in *Table 1*.

This paper analyzes the technical demands, operative complications, and the necessity for a revision-oriented approach to optimize surgical outcomes. By providing this encompassing overview, we aim to equip orthopedic surgeons with the insights needed for the effective management of this increasingly common and intricate clinical scenario.

ACL reconstruction and knee OA

Recent epidemiological studies indicate significant trends in the prevalence of ACL injuries and subsequent reconstructions. According to research by Silvers-Granelli *et al.* (2), there are currently approximately 200,000 to 250,000 ACL injuries that occur annually in the United States (US), a rate that has doubled over the last two decades. Furthermore, Collins *et al.* (1) reported that approximately 22.6% of adults diagnosed with an ACL injury undergo ACL reconstruction within three years of diagnosis. Extrapolating from these data, if the doubling trend continues over the next 20 years, the US could witness between 400,000 and 500,000 ACL injuries annually. Consequently, if the rate of ACL reconstructions remains consistent at 22.6%, this would translate to an estimated 90,400 to 113,000 ACL reconstructions per year two decades from now. Given that 20% of these patients are likely to develop some form of OA post-reconstruction (4), this could potentially result in between 18,080 and 22,600 individuals facing this degenerative condition annually 20 years from now in the US. Furthermore, considering that 50% of persons with knee OA eventually undergo TKA (15), this could translate to around 9,040 to 11,300 TKA surgeries annually being attributed to this specific cohort 20 years from now.

TKA after ACL reconstruction

The frequency and occurrence of TKA have been on a consistent upward trajectory for the last two decades. Each year, more than 600,000 TKAs are conducted in the US, and projections suggest that this number could rise by an additional 140% by the year 2050 (3). There is a paucity of literature exploring the patterns and epidemiology of individuals who eventually require TKA following a

Table 1 Search summary

Items	Specification
Date of search	From 01 Sep 2023 to 24 Sep 2023
Databases and other sources searched	MEDLINE/PubMed, Scopus, Embase, CINAHL, Cochrane Central Register of Controlled Trials (CENTRAL), the Science Citation Index Expanded from Web of Science and ScienceDirect
Search terms used	The research was conducted using the following keywords: "ACL", "reconstruction", "knee", "osteoarthritis", "TKA", "graft", "BTB", "hamstring", "quadricep", and "allograft"
Timeframe	From 01 Jan 1990 to 25 Sep 2023
Inclusion and exclusion criteria	Inclusion criteria: English language level IV to I studies, reporting outcomes of TKA following ACL reconstruction
	Exclusion criteria: technical notes, *ex vivo*, biomechanical, pre-clinical studies
Selection process	First authors applied selection process

ACL, anterior cruciate ligament; TKA, total knee arthroplasty; BTB, bone-patellar tendon-bone.

prior ACL reconstruction. A population-based study with matched cohorts (10) showed that between 1993 and 2008, those who underwent ligament reconstruction in the knee, of which over 98% were post-ACL reconstructions, had a TKA rate of 0.68 per 1,000 person-years. This was in contrast to a rate of 0.10 per 1,000 person-years among a general population cohort without prior knee surgeries (10). Fifteen years post-ligament reconstruction, the cumulative incidence of TKA was notably higher, 1.4% compared to 0.2% in the control group (10). Studies have also delved into the demographic characteristics of patients who have had an ACL reconstruction and later require TKA. Watters *et al.* (5) reported an average age of 58 years for patients who underwent TKA after ACL reconstruction, with 55% being male, while a smaller study by Lizaur-Utrilla *et al.* (7) revealed an average age of 69.6 years, with 60% of the patients being male.

Operative complications

The surgical exposure and technical demands of TKA in ACL reconstructed knee remain unclear, with studies reporting conflicting findings. Watters *et al.* (5) reported operative times were significantly longer in ACL reconstructed knees due to the greater complexity of exposure and component placement. Magnussen *et al.* (6) also found more difficult exposure in ACL patients, with some requiring tibial tubercle osteotomy for exposure, although this did not affect outcomes. However, Hoxie *et al.* (13) found no increased difficulty due to prior ACL reconstruction cited in operative notes, and no difference in failure rate or clinical outcomes. However, the authors reported a 2.8% early revision rate for implant instability only in patients with a previous ACL reconstruction underlining the importance of proper soft tissue balancing in TKA following ACL reconstruction.

The discrepancy in findings may relate to surgical techniques and implants utilized for prior ACL reconstruction. For example, Salmon *et al.* (10) reported patellar tendon shortening and patella baja in some patients after bone-patella-bone autograft ACL reconstruction, which could impair exposure and patellar mobilization required for bony resection of TKA. However, Hoxie *et al.* (13) found no evidence of patella baja in patients with prior bone-patella-bone autografts.

Several studies reported difficulties obtaining adequate ligamentous balance during TKA with prior ACL reconstruction. Lizaur-Utrilla *et al.* (7) noted severe tibial internal rotation and translation in ACL reconstructed knees leading to impaired balance. The main challenge was varus deformity and medial retraction requiring progressive medial releases. Additional capsular releases were often required for appropriate balancing. Chong *et al.* (14) also reported challenges related to ligament balancing. The increased need for constrained inserts in some studies (5,16) also suggests issues with soft tissue stability.

Ligamentous laxity has been cited as a potential contributing factor to the exposure and balancing difficulties in TKA after ACL reconstruction (7). Attenuation of ACL grafts over time may lead to instability. Persistent laxity after initial ACL reconstruction may also predispose to further stress of secondary restraints leading to knee laxity.

Table 2 Schematic summary of treatment trend for fixation hardware, reported risk of infection, and measured operative time following TKA after ACL reconstruction

Criteria	Findings	Authors
Hardware		
Retained	No impact on outcomes if left in place	Hoxie *et al.*
Removed	Recommended to avoid complications	Chaudhry *et al.*, Chong *et al.*
Infection		
Increased risk	Elevated rates with retained hardware	Watters *et al.*
No difference	No significant difference in rates	Hoxie *et al.*, Lizaur-Utrilla *et al.*
Operative time		
Increased	Longer due to complex exposure and component placement	Watters *et al.*
No difference	No increased difficulty cited	Hoxie *et al.*

TKA, total knee arthroplasty; ACL, anterior cruciate ligament.

The resultant instability could impair exposure and make soft tissue balancing challenging.

In some cases, intraoperative difficulties related to surgical scarring may also be a factor (16).

Lizaur-Utrilla *et al.* (7) reported patellar tendon avulsion during exposure in one ACL reconstructed knee. James *et al.* (16) demonstrated how a prior ACL reconstruction may alter anatomy making prosthetic component placement more difficult.

The implications of retained hardware for ACL fixation are unclear. Hoxie *et al.* (13) did not find prior ACL hardware impacted outcomes if left in place when possible. However, other authors recommend removal to avoid complications (12,14). Rates of periprosthetic infection were elevated in some studies, leading to suggestions that retained hardware may increase infection risk (5). However, other studies found no significant difference in perioperative infection rates (7,13). Possible operative complications are summarized in *Table 2*.

In summary, exposure and ligamentous balancing during TKA may be more complex in the ACL reconstructed knee, potentially due to distortion of native anatomy from prior surgery, scarring, extensor mechanism retraction, hardware, and ligament laxity over time.

Pearls and pitfalls of TKA after ACL reconstruction

A TKA after ACL reconstruction often warrants a revision surgery approach given the altered anatomy and technical challenges encountered (5-7). Certain techniques common in revision TKA procedures are useful in addressing the specific issues that arise in ACL-reconstructed knees.

Extensive exposures like tibial tubercle osteotomies or quadriceps snips may be required for adequate visualization in the presence of scarring or patellar tendon abnormalities from prior ACL reconstruction (6,10). These approaches are commonly employed in revision settings where exposure can be difficult due to scar tissue. Modular components (stems, cones or augments) are frequently needed to address bony defects resulting from prior ligament graft harvests (7,17) (*Figures 1,2*). Uncontained defects often require augments in revision TKA cases. Constrained condylar implants can help achieve stability in cases with incompetent collaterals, ligament imbalance, or instability from ACL graft attenuation (16). Such designs are indicated in revision scenarios with compromised ligamentous stability.

Customized and offset stems (*Figure 2*) facilitate proper component alignment when anatomy is distorted (14).

Metaphyseal cones are helpful to increase prosthetic stability in case of massive metaphyseal bone loss following ACL tunnel enlargement and these specific devices are frequently used in case of complex TKA revisions (17,18). If retained hardware poses issues, specialized instrumentation from revision systems allows the removal of interfering implants (11,12,18,19). Broken or stripped screws can be challenging to extract and often require revision-type instrumentation.

When stiffness is present, more aggressive soft tissue releases and bearing dislocations can improve the range of motion (7). Manipulation under anesthesia with arthrolysis is commonly performed for stiffness after TKA revision (20).

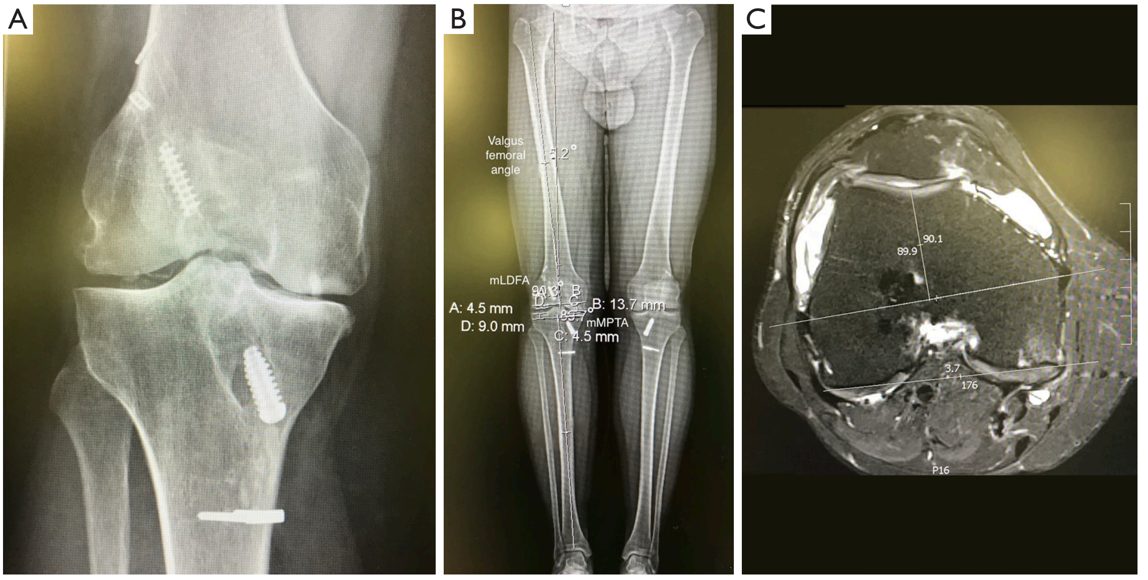

Figure 1 Pre-operative examination of a 54-year-old male patient with severe osteoarthritis after multiple ACL reconstructions. (A) Anteroposterior radiographical examination of the right knee. (B) Long-standing X-ray assessment that is used to carefully plan TKA, calculating prosthetic alignment and bony resections. Precisely, the following measurements are reported: the femoral valgus angle (5.2°) that is used to plan distal femoral resection, the mLDFA (90.3°) and the mMPTA (89.7°) that demonstrated a varus alignment; the letter A measured the lateral femoral condyle resection of 4.5 mm, B the medial femoral condyle resection of 13.7 mm, C the lateral tibial plateau resection of 4.5 mm, D the lateral tibial plateau resection of 9 mm. (C) MRI scan that is used to calculate rotational femoral alignment. ACL, anterior cruciate ligament; TKA, total knee arthroplasty; mLDFA, mechanical lateral distal femoral angle; mMPTA, mechanical medial proximal tibial angle; MRI, magnetic resonance imaging.

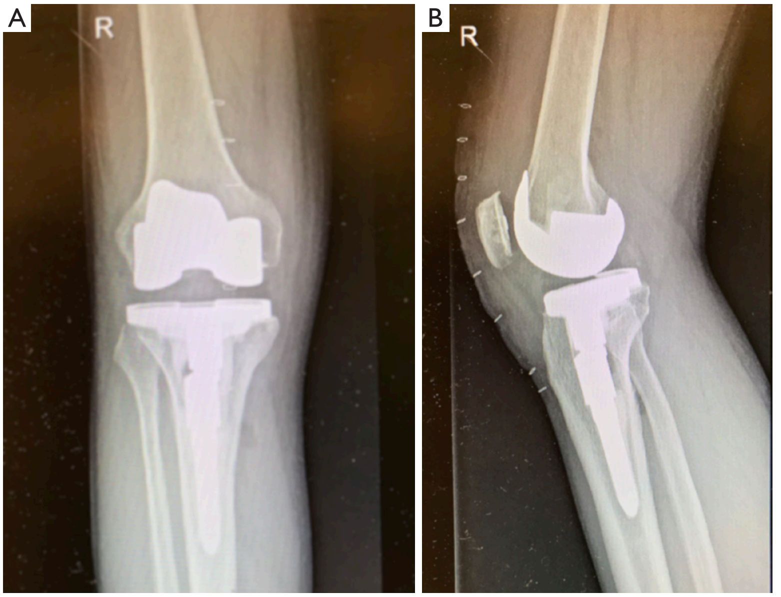

Figure 2 Example of cemented modular total knee replacement (tibial component with offset stem) in a right knee of a 65-year-old female patient suffering from knee osteoarthritis after ACL reconstruction. Hardware (metallic interference screws have been removed during surgery). (A) An anteroposterior view. (B) Lateral view. ACL, anterior cruciate ligament.

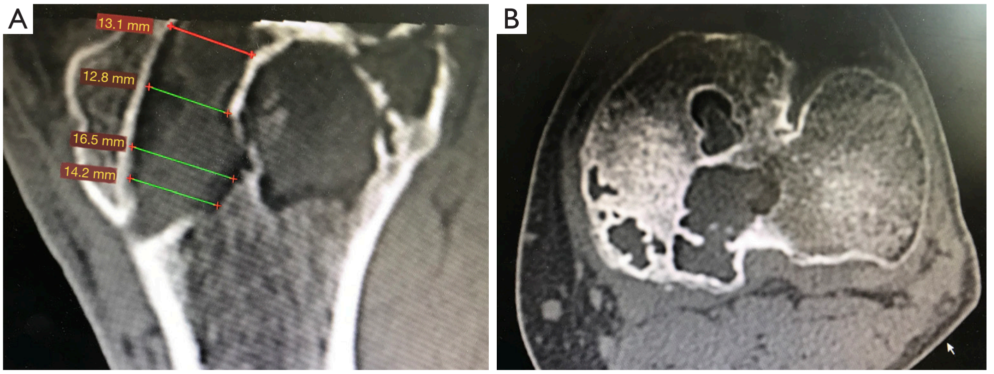

Figure 3 A CT scan of a 56-year-old male patient affected by severe knee osteoarthritis, knee instability and massive metaphyseal bone loss for tunnel enlargement 10 years after ACL reconstruction with a synthetic graft. (A) Coronal plane, (B) axial plane. CT, computed tomography; ACL, anterior cruciate ligament.

The technical challenges of ACL reconstructed knees relate to chronic ligamentous instability leading to progressive distortion of native knee anatomy over time (7). The attenuation of ACL graft and stretching of secondary restraints likely contribute to the collateral ligament imbalance, progressive varus deformity, and medial/lateral tibiofemoral mismatch often reported in these cases (7). Furthermore, the chronic instability may accelerate articular degeneration, necessitating more complex soft tissue balancing to properly manage TKA stability similar to rheumatic disease (10,21).

Accurate preoperative planning is critical when approaching TKA in ACL reconstructed knees (*Figure 1*) (14). Magnetic resonance imaging (MRI) or computed tomography (CT) are both helpful to assess the location of tunnels and graft harvest sites and to quantify the metaphyseal bone loss often underestimated with standard radiographs (*Figure 3*). Advanced imaging helps characterize bony defects requiring augments. Assessing ligamentous stability on exam helps guide implant constraints needed (14). Having a full complement of standard and complex components available is key to proper intraoperative decision-making (14).

Given the anticipated complexity, it is prudent to approach TKA in the ACL reconstructed knee using principles and techniques from the revision surgery playbook. Having specialized exposure instrumentation, modular augments, stems, constrained components and implants to address retained hardware available maximizes the surgeon's ability to overcome distorted anatomy (7,14). Meticulous surgical technique and soft tissue handling can help mitigate scarring-related complications like extensor mechanism disruption (5). Employing revised thinking and a revision surgery skillset can lead to better outcomes when performing TKA on these complex post-ACL reconstruction cases.

Discussion

With escalating rates of ACL injuries (2) and a projected exponential increase in TKA procedures (3), the orthopedic community stands on the cusp of a clinical scenario replete with nuanced challenges that defy conventional surgical protocols. In the ACL reconstructed knee, the native anatomy undergoes alterations that introduce significant complexities in TKA procedures, complexities which are often comparable to those faced in revision TKA cases (5,7). These complexities underscore the argument that approaching TKA in the context of prior ACL reconstruction warrants a shift in perspective, from viewing it as a primary procedure to considering it akin to a revision surgery. This perspective is fortified by the range of intraoperative challenges that surgeons frequently encounter, from ligamentous laxity to surgical scarring, which complicate the dynamics of ligamentous balancing and the surgical exposure required for component placement (7,16). Additional layers of complexity are introduced by the question of retained hardware. While some studies indicate that retaining the hardware does not impact outcomes (13), others counter-argue, recommending hardware removal to preempt potential complications such as elevated infection risks (12,14). In cases of elevated infection risk, the standard protocol leans towards a two-stage exchange strategy with an interim antibiotic spacer (18,19).

As the likelihood increases that orthopedic surgeons will encounter a growing number of patients requiring TKA after prior ACL reconstruction, the imperative grows stronger for the incorporation of a revisionist skill set into orthopedic training paradigms. Concurrently, there is an unequivocal need for further research. In particular, comparative studies that scrutinize the long-term outcomes of TKA post-ACL reconstruction against those of primary TKA could provide invaluable insights. Such studies would contribute to the development of evidence-based guidelines aimed at optimizing surgical strategies and, by extension, patient outcomes in these inherently intricate and increasingly frequent cases.

Strength and limitations

This research provides a narrative review with pearls and pitfalls that help surgeons who approach TKA in patients with previous ACL reconstruction. On the other hand, the literature on this topic is still limited and precludes a high level of evidence. Future prospective and high-quality studies are requested to better clarify risk factors and give strong recommendations for this complex surgery.

Conclusions

In conclusion, the evolving landscape of orthopedic surgery increasingly brings clinicians face-to-face with patients who require TKA after previous ACL reconstruction. The unique challenges and complexities of these cases clearly signal the need for an experienced approach. Given the altered anatomy and potential for ligamentous instability, these are not routine primary arthroplasties. Rather, they demand meticulous planning, specialized techniques, and modular components traditionally used in revision surgeries. As the orthopedic community braces for a surge in such complicated scenarios, a shift in surgical training and planning becomes imperative. This review serves as a clarion call for the integration of a revision-oriented skill set, underscoring the need for modular components to ensure optimal outcomes. With the patient's well-being as the ultimate goal, this approach offers a roadmap for navigating the intricate surgical landscape that lies ahead.

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