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Early to Mid-Term Clinical and Functional Outcomes of a Modern Modular Revision Knee System

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Abstract

Background/Objectives: As demand for primary total knee arthroplasty (TKA) continues to rise, the incidence of revision TKA (rTKA) is expected to increase. This study reports early to mid-term clinical and functional outcomes of a modern modular rTKA implant system. **Methods**: This was a retrospective review of all patients who underwent rTKA at a single academic tertiary care center between 2020 and 2022 utilizing both tibial and femoral components from a modern rTKA system. A total of 31 patients with a median follow-up of 3.9 years (range, 4.2 months to 5.7 years) were included. Sixteen patients underwent rTKA for aseptic loosening (52%), nine for instability (29%), four for infection (13%), and two for arthrofibrosis (6%). **Results**: Fully hybrid fixation was most common (52%). Metaphyseal cones were implanted in 84% of cases and augments in 74%. One 90-day readmission occurred for cellulitis. Four patients underwent re-revision, including one for aseptic loosening, two for infection, and one liner exchange for patellar clunk syndrome. Two additional patients (6.5%) had failure diagnosed without subsequent surgery—one with radiographic aseptic loosening and one with chronic periprosthetic joint infection. Both patients declined further operative management. Mean Knee Injury and Osteoarthritis Outcome Score, Joint Replacement (KOOS, JR) change was 3.7 ± 12.7 points at six weeks ($n = 12$), 17.8 ± 27.5 points at three months ($n = 11$), 11.8 ± 16.4 points at one year ($n = 6$), and 11.5 ± 19.0 points at two years ($n = 9$). **Conclusions**: We observed favorable early to mid-term clinical outcomes in this cohort of complex revision TKA procedures performed with a modern, modular rTKA implant system. As a descriptive series without a comparator group, these findings do not establish that the implant system itself accounts for the observed outcomes. Further investigation with larger cohorts and longer follow-up will be necessary to determine long-term durability.

Keywords: total knee arthroplasty; revision knee arthroplasty; cone; augment; KOOS; JR

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1. Introduction

Total knee arthroplasty (TKA) is a common and highly successful orthopedic procedure [1]. Demand for TKA is expected to continue rising, particularly given the aging population, with over 3 million TKA procedures projected in 2040 alone [2,3]. Despite generally favorable patient outcomes, revision TKA (rTKA) incidence is expected to more than double by 2040 due to increases in primary TKA volume [4,5]. As rTKA is associated with a higher incidence of complications, increased cost, and shortened implant survival, it is crucial to minimize re-revision after implant failure [6–10].

Aseptic mechanical failure is the primary indication for about 80% of rTKAs, with aseptic loosening as the most common sub-indication, accounting for 10–30% of all revision procedures [9,11,12]. Mechanical failure, particularly aseptic loosening, results from incomplete fixation of the implant during primary TKA, periprosthetic osteolysis, and instability of the knee joint due to the rTKA prosthesis [9,10]. Importantly, the incidence of aseptic loosening and other mechanical complications can be minimized with appropriate implant selection and fixation. Morgan-Jones et al. emphasized the importance of "zonal" fixation in rTKA, specifically highlighting the need to ensure that at least two zones from the epiphysis, metaphysis, or diaphysis achieve adequate fixation [9,10,13]. In the context of rTKA, poor bone quality and bony defects are more likely, necessitating well-sized components with cones and augments to adapt to the patient's existing joint anatomy [14,15]. Therefore, versatile implant systems are necessary to optimize joint stability and longevity in rTKA.

A modern rTKA system was introduced to the US market in late 2019 after FDA approval. The system is highly versatile with varied stem lengths and designs, along with proprietary porous tantalum-based cones to manage bony defects. Clinical outcomes of this system have recently been reported in a multicenter prospective cohort of 185 patients undergoing revision or complex primary TKA, which demonstrated 97.2% implant survivorship at two years [16]. That cohort was predominantly aseptic (89.7%) and included complex primary procedures, and follow-up was limited to two years. The present series therefore examines a distinct population—consecutive revision procedures only, including septic indications, performed at a single center with longer available follow-up—and reports patient-reported outcomes alongside survivorship. Therefore, this study aims to provide a descriptive evaluation of early to mid-term outcomes of a modern rTKA system with contextual comparison to published outcomes of other revision knee systems.

2. Materials and Methods

Following Institutional Review Board approval, a retrospective review was conducted of all patients ≥ 18 years of age who underwent rTKA between September 2020 and December 2022 at a single academic tertiary care center using both tibial and femoral components from the Persona® Personalized Revision Knee System (Zimmer Biomet, Warsaw, IN, USA). Revisions were performed by 10 arthroplasty surgeons at this institution. The final study cohort consisted of 31 patients undergoing 31 rTKAs, with a median follow-up of 3.9 years (range, 4.2 months to 5.7 years). Twenty-eight patients had at least one year of follow-up, 26 patients had at least two years, 23 had at least three, 13 had at least four, and two patients had over five years of follow-up.

Data were collected through a comprehensive chart review of our institution's electronic medical record database (Epic Caboodle, Version 15; Verona, WI, USA). Baseline patient characteristics included age, body mass index (BMI), sex, race, smoking status, diabetes, American Society of Anesthesiologists (ASA) class, and Charlson Comorbidity Index (CCI). Type of index surgery, time interval between index surgery and revision, and any prior surgeries on the knee excluding index arthroplasty were collected. Perioperative characteristics including surgeon identity, revision indication, laterality, anesthesia type, tourniquet use and duration, bone loss, operative time, hospital length of stay, and discharge disposition were recorded. Revision indication was defined as "infection" if the patient met 2018 International Consensus Meeting criteria for periprosthetic joint infection (PJI) [17]. Bone loss severity was assessed according to the Anderson Orthopaedic Research Institute (AORI) classification by a single clinical fellow assessor for both femoral and tibial defects based on operative reports and radiographic review of preoperative radiographs. Implant characteristics such as fixation pattern, metaphyseal cone use, and distal femoral, posterior femoral, or tibial augment use were documented. Fixation strategy (cemented, hybrid, or

fully cemented) and the use of metaphyseal cones and augments were determined intraoperatively based on trial reduction findings at the discretion of the operating surgeon. Constraint level was similarly determined intraoperatively via gap-balancing and stability testing. Septic revisions were managed according to a two-stage protocol consisting of component explantation with antibiotic spacer placement, systemic antibiotics, and reimplantation contingent upon normalized inflammatory markers, aspiration cell count, and negative intraoperative frozen section/cell count. Postoperative complications included orthopedic-related 90-day readmissions and any re-revisions performed until the latest follow-up. Re-revision was defined as any subsequent procedure in which a component was exchanged, added, or removed, including isolated polyethylene liner exchange. Readmissions managed without operative intervention and procedures in which no components were exchanged were recorded as complications but were not recorded as re-revisions. Radiographic or clinical failure that did not proceed to reoperation was likewise recorded descriptively and was not classified as a re-revision. Functional outcomes were assessed using the Knee Injury and Osteoarthritis Outcome Score, Joint Replacement (KOOS, JR). Scores were collected preoperatively and assigned to postoperative intervals using prespecified windows: 6 weeks (1–42 days), 3 months (43–180 days), 1 year (181–540 days), and 2 years (541–913 days). Where more than one assessment fell within a window, the assessment closest to the nominal time point was used. Change scores were calculated only for patients with both a preoperative score and a score within the corresponding window.

Categorical variables were presented as counts and percentages. Continuous variables were presented as means and standard deviations or medians and ranges. X^2 and Fisher's exact tests were used to analyze categorical data. Kaplan–Meier survivorship analysis was performed for three endpoints: all-cause re-revision, re-revision for aseptic loosening, and re-revision for infection. All endpoints counted only procedures that were actually performed. No inferential statistical testing (e.g., paired comparisons) was performed on KOOS, JR data given the small and incomplete sample at each time point due to lack of available data; these results are presented descriptively only, and change scores are calculated only for patients with preoperative scores available. The 95% confidence intervals are reported for paired mean change scores. Kaplan–Meier analysis was performed using the lifelines (version 0.30.3), matplotlib (version 3.11.0), and pandas (version 2.3.3), packages in Python (version 3.14.6; Python Software Foundation, Wilmington, DE, USA).

The last event-free observation was defined as the date of last clinical contact. Patients were censored at the earliest of last clinical contact, death, or the data cutoff. Patients who died without reaching an endpoint were censored at the date of death, and patients lost to follow-up were censored at their last recorded clinical contact. Patients undergoing re-revision for a competing indication were censored at that date for the remaining endpoints, as the original construct was no longer in situ. Reoperations not meeting the definition of a given endpoint did not censor observation for that endpoint. Survivorship estimates are reported at annual postoperative time points with 95% confidence intervals, and numbers at risk are reported beneath each survival curve.

3. Results

3.1. Baseline Characteristics

The study cohort had a median age of 64 years (range, 46 to 84 years) with 32% of patients ($n = 10$) under the age of 60. The median BMI was 34 kg/m^2 (range, 18 to 48 kg/m^2). The majority of patients were women ($n = 20$, 65%) and self-identified as White ($n = 19$, 61%). Most patients had never smoked ($n = 15$, 48%) or were former smokers ($n = 14$, 45%). Five patients had diabetes (16%). Most patients had an ASA class of III ($n = 17$, 55%) or II ($n = 13$, 42%), with a cohort-wide mean CCI of 1.3 ± 2.0. The overall median time

elapsed between primary TKA and index rTKA was 7.5 years. Time elapsed is also shown stratified by indication for revision (Table 1).

Table 1. Baseline characteristics.

Parameter	*n* = 31
Age (years), median [range]	64 [46–84]
BMI (kg/m^2), median [range]	34 [18–48]
Men, *n* (%)	11 (35)
Race, *n* (%)	
White	19 (61)
Black	9 (29)
Other	3 (10)
Smoking Status, *n* (%)	
Current	2 (6)
Former	14 (45)
Never	15 (48)
Diabetes, *n* (%)	5 (16)
ASA Class, *n* (%)	
II	13 (42)
III	17 (55)
IV	1 (3)
CCI, mean [SD]	1.3 [2.0]
Follow-up (years), median [range]	3.9 [0.3–5.7]
Primary TKA to index rTKA (years), median [range]	7.5 [1.3–18.3]
Arthrofibrosis	4.3 [2.0–6.6]
Aseptic loosening	7.7 [2.6–18.3]
Infection	5.2 [3.0–7.5]
Instability	8.3 [1.3–17.3]

BMI, body mass index; kg, kilogram; m, meter; *n*, number of; %, percent; American Society of Anesthesiologists; CCI, Charlson Comorbidity Index; SD, standard deviation.

All patients in the cohort underwent TKA as the index procedure; none were conversions from unicompartmental knee arthroplasty. Eleven patients underwent knee surgery on the same knee during the interval between primary TKA and index rTKA, which is detailed below in Table 2 by indication and type of surgery. Among the cohort of 31 patients, the average number of knee surgeries between primary TKA and index rTKA was 0.5. Six patients were diagnosed with PJI during the interval period. Three patients had arthroscopies on the knee for meniscal tears prior to primary TKA.

Table 2. Patients with interim knee operations excluding primary TKA and index rTKA.

Patient	Indication	Intervention
1	Infection	1. 1st stage of 2-stage exchange
2	Instability	1. Liner exchange without I&D 2. Liner exchange without I&D
3	Arthrofibrosis	1. Lysis of adhesions
4	Infection	1. DAIR
5	Infection	1. DAIR 2. Excisional debridement
6	Infection	1. 1st stage of 2-stage exchange

Table 2. *Cont.*

Patient	Indication	Intervention
7	Infection	1. 1st stage of 2-stage exchange
8	Aseptic loosening, infection	1. Revision of tibial and patellar components 2. DAIR with liner exchange 3. 1st stage of 2-stage exchange 4. 2nd stage of 2-stage exchange
9	Instability	1. Liner exchange without I&D
10	Aseptic loosening	1. Revision of tibial and femoral components
11	Instability	1. Soft-tissue release

I&D, irrigation and debridement; DAIR, debridement, antibiotics, implant retention.

3.2. Perioperative Characteristics

Procedures on right-sided knees were more common ($n = 17$, 55%). Spinal anesthesia was used in 77% of cases ($n = 24$), and tourniquets were used in 71% ($n = 22$), with a mean tourniquet time of 96 ± 32 minutes. Mean operative time was 211 ± 42 minutes. Most patients were discharged home ($n = 27$, 87%), following a mean hospital length of stay of 65 ± 42 hours (Table 3).

Table 3. Perioperative characteristics.

Parameter	*n* = 31
Right Knee, *n* (%)	17 (55)
Anesthesia Type, *n* (%) Spinal General	 24 (77) 7 (23)
Tourniquet, *n* (%) Time (minutes), mean [SD]	22 (71) 96 [32]
Operative Time (minutes), mean [SD]	211 [42]
Length of Stay (hours), mean [SD]	65 [42]
Discharge Disposition, *n* (%) Home Skilled Nursing Facility	 27 (87) 4 (13)

n, number of; %, percent; SD, standard deviation.

Just over half of patients were revised due to aseptic loosening ($n = 16$, 52%), followed by instability ($n = 9$, 29%), infection ($n = 4$, 13%), and arthrofibrosis ($n = 2$, 6%). Bone loss severity based on the Anderson Orthopaedic Research Institute (AORI) classification demonstrated femoral defects classified as Type 1 in 15 cases (48%), Type 2A in five cases (16%), Type 2B in nine cases (29%), and Type 3 in two cases (6%). Tibial bone loss showed a similar distribution, with Type 1 defects in 17 cases (55%), Type 2A in three cases (10%), Type 2B in nine cases (29%), and Type 3 in two cases (6%). (Table 4). Younger patients (<60) were more likely to have AORI 2A tibial defects ($p = 0.027$), while older patients (≥60) more commonly had AORI 2B tibial defects ($p = 0.030$). No patient was aged exactly 60 years. Given the small sample and the number of comparisons performed, these age-related associations should be regarded as exploratory and hypothesis-generating.

Table 4. Revision indications and bone loss classification by age.

Parameter	Overall (n = 31)	Age < 60 (n = 10)	Age ≥ 60 (n = 21)	p-Value
Revision Indication, n (%)				
Aseptic loosening	16 (52)	4 (40)	12 (57)	0.458
Instability	9 (29)	4 (40)	5 (24)	0.417
Infection	4 (13)	1 (10)	3 (14)	0.999
Arthrofibrosis	2 (6)	1 (10)	1 (5)	0.999
AORI Bone-loss Classification: Femur				
1	15 (48)	5 (50)	10 (48)	0.901
2A	5 (16)	3 (30)	2 (10)	0.296
2B	9 (29)	1 (10)	8 (38)	0.206
3	2 (6)	1 (10)	1 (5)	0.999
AORI Bone-loss Classification: Tibia				
1	17 (55)	7 (70)	10 (48)	0.280
2A	3 (10)	3 (30)	0 (0)	0.027
2B	9 (29)	0 (0)	9 (43)	0.030
3	2 (6)	0 (0)	2 (10)	0.999

n, number of; %, percent; SD, standard deviation; AORI, Anderson Orthopaedic Research Institute.

3.3. Implant Characteristics

The most common fixation pattern utilized was fully hybrid (n = 16, 52%), followed by cemented femoral and hybrid tibial fixation (n = 7, 23%), fully cemented (n = 5, 16%), and hybrid femoral and cemented tibial fixation (n = 3, 10%). Metaphyseal cones were used in 26 cases (84%), including 17 tibial-only cases (55%) and nine cases involving both the femur and tibia (29%). Augments were used in 74% of cases (n = 23). Distal femoral augments were most common (n = 20, 65%), most often placed both medially and laterally (n = 16, 52%), while four cases involved lateral-only augments (13%). Posterior femoral augments were used in 13 cases (42%), including five medial-only (16%), three lateral-only (10%), and five medial and lateral cases (16%). Tibial augments were utilized in nine cases (29%), all of which were placed both medially and laterally (Table 5).

Table 5. Implant characteristics.

Parameter	n = 31
Fixation Pattern, n (%)	
Fully Hybrid	16 (52)
Fully Cemented	5 (16)
Hybrid Femur & Cemented Tibia	3 (10)
Cemented Femur & Hybrid Tibia	7 (23)
Metaphyseal Cone, n (%)	26 (84)
Tibial only	17 (55)
Femoral & Tibial	9 (29)
Augment, n (%)	23 (74)
Distal Femoral Augment, n (%)	20 (65)
Lateral only	4 (13)
Medial & Lateral	16 (52)
Posterior Femoral Augment, n (%)	13 (42)
Medial only	5 (16)
Lateral only	3 (10)
Medial & Lateral	5 (16)
Tibial Augment, n (%)	9 (29)
Medial & Lateral	9 (29)

n, number of; %, percent.

3.4. Postoperative Complications

Within 90 days of surgery, one patient was admitted for cellulitis and was discharged with antibiotics without operative intervention. Four patients underwent re-revision before their latest follow-up (12.9%). One patient required re-revision for aseptic loosening of both femoral and tibial components two years after index rTKA. Another patient had aseptic loosening of the tibial component confirmed on radiographs five years after index rTKA; this patient chose to defer additional revision surgery. Both patients with loosening were originally indicated for index rTKA due to aseptic loosening of the primary implant. Figure 1 demonstrates radiographic examples of well-fixed rTKAs with loosening at several years of postoperative follow-up.

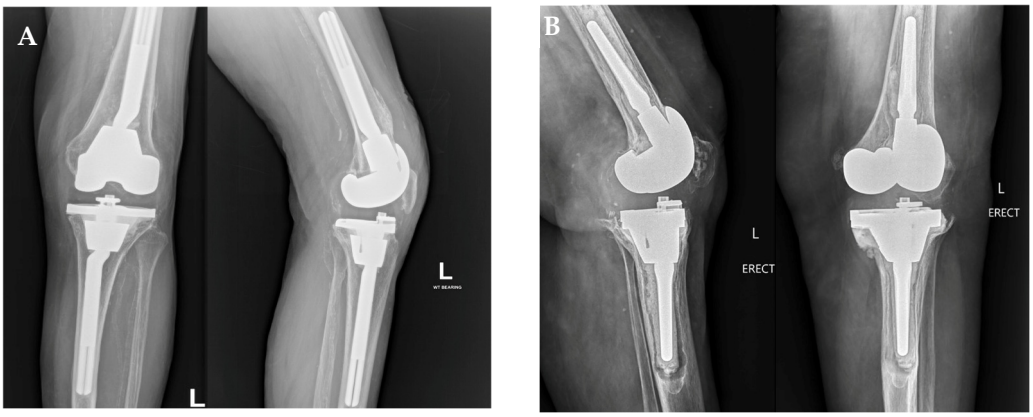

Figure 1. Radiographs of well-fixed and loose rTKAs. (**A**) AP and lateral knee X-rays demonstrating well-fixed revision components at 2-year follow-up. (**B**) AP and lateral knee X-rays demonstrating loosening of the tibial components at 5-year follow-up.

A third patient underwent re-revision with liner exchange due to patellar clunk syndrome, ten months after their index rTKA for aseptic loosening; the femoral and tibial components were retained. Among patients requiring re-revision for infection, one patient underwent a two-stage re-revision procedure for infection three years after the index rTKA for aseptic loosening, with femoral and tibial components from the same modern rTKA system implanted. Another patient underwent DAIR with liner exchange for infection seven months after their index rTKA for infection, with the femoral and tibial components retained. At the time of index rTKA, this patient's intraoperative frozen section was negative for acute inflammation. However, preoperative synovial fluid analysis was unavailable due to no fluid in the knee. This patient passed away three years after re-revision due to complications immediately following a cardiac procedure (Table 6).

In addition to the patient with radiographic tibial loosening described above, one patient was diagnosed with chronic prosthetic joint infection 1.1 years after index rTKA and elected not to undergo surgical treatment. Neither of these two nonoperatively managed failures was classified as a re-revision or contributed an event to the survivorship analyses. The latter patient subsequently underwent component revision for aseptic loosening at 2.2 years, which was classified as an all-cause and aseptic-loosening re-revision event (Table 6).

Kaplan–Meier survivorship analysis was performed for all-cause re-revision, re-revision for aseptic loosening, and re-revision for infection. Median time to event was not reached for any endpoint due to the low number of observed events. Survival free of all-cause re-revision was 93.1% (95% CI: 75.1–98.2%) at one and two years, 89.2% (95% CI: 70.1–96.4%) at three years, and 84.8% (95% CI: 64.0–94.1%) at four years, with 26, 24, 20, and 11 patients at risk, respectively. Survival free of re-revision for aseptic loosening was 100% at two years and 96.2% (95% CI: 75.7–99.4%) at three and four years, with 26, 22, and

11 patients at risk. Survival free of re-revision for infection was 96.6% (95% CI: 77.9–99.5%) through three years and 92.2% (95% CI: 71.8–98.0%) at four years, with 27, 25, 22, and 12 patients at risk at one through four years. Only one patient remained at risk beyond five years; estimates beyond four years are therefore imprecise and are not reported (Figure 2).

Table 6. Postoperative complications.

Pt	Index Indication	Time (yr)	Complication	Procedure Performed	Components	Endpoint
1	Aseptic loosening	0.1	Cellulitis	None—antibiotics only	—	None
2	Infection	0.6	PJI	DAIR with liner exchange	Liner exchanged; femoral and tibial components retained	AC, I
3	Aseptic loosening	0.8	Patellar clunk	Liner exchange with lysis of adhesions	Liner exchanged; femoral and tibial components retained	AC
4	Aseptic loosening	1.1	Chronic PJI	None—patient declined surgery	—	None
4	Aseptic loosening	2.2	Aseptic loosening	Revision of femoral and tibial components with tibial bone graft	Femoral and tibial components exchanged	AC, AL
5	Aseptic loosening	3.1	Recurrent PJI	First-stage explant with antibiotic spacer; reimplantation at 3.3 yr	Femoral and tibial components explanted	AC, I
6	Aseptic loosening	4.8	Radiographic tibial loosening	None—patient declined surgery	—	None

n, number of. Patient 4 appears twice. AC, all-cause re-revision; AL, re-revision for aseptic loosening; I, re-revision for infection. Endpoint "None" denotes complications and failures not meeting a re-revision endpoint.

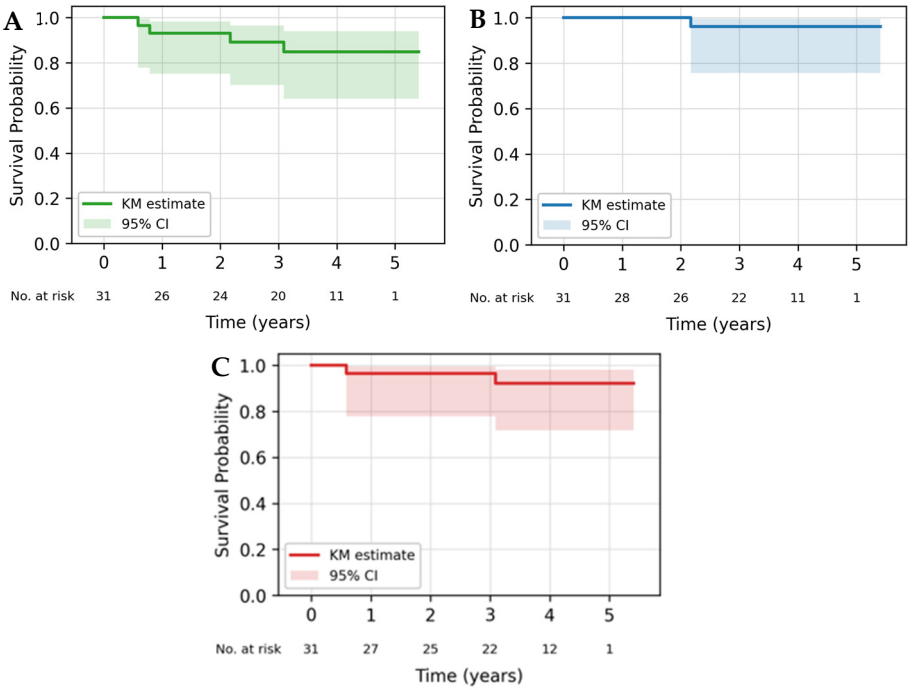

Figure 2. Kaplan–Meier implant survivorship analysis. Kaplan–Meier survivorship curves plotted with 95% confidence intervals for all-cause re-revisions (**A**), re-revisions for aseptic loosening (**B**), and re-revisions for infection (**C**).

3.5. Functional Outcomes

Preoperative KOOS, JR scores were available for 18 patients (58%). Mean KOOS, JR change from preoperative to postoperative scores was 3.7 ± 12.7 points at six weeks (n = 12; 95% CI −4.4 to 11.8), 17.8 ± 27.5 points at three months (n = 11; 95% CI −0.7 to 36.3), 11.8 ± 16.4 points at one year (n = 6; 95% CI −5.4 to 29.0), and 11.5 ± 19.0 points at two years (n = 9; 95% CI −3.1 to 26.1) (Table 7). Postoperative scores within the two-year window (541–913 days) were available for 12 patients, of whom nine had a paired preoperative score. Confidence intervals for all paired change scores included zero, and these results should be interpreted as descriptive only.

Table 7. Knee Injury and Osteoarthritis Outcome Score, Joint Replacement (KOOS, JR).

Parameter	Mean [SD], *n*	95% CI
Preoperative	44.8 [16.1], 18	
At 6 weeks	51.9 [10.6], 12	
At 3 months	59.3 [12.3], 12	
At 1 year	51.8 [14.8], 9	
At 2 years	59.0 [14.6], 12	
Δ 6 weeks	3.7 [12.7], 12	−4.4 to 11.8
Δ 3 months	17.8 [27.5], 11	−0.7 to 36.3
Δ 1 year	11.8 [16.4], 6	−5.4 to 29.0
Δ 2 years	11.5 [19.0], 9	−3.1 to 26.1

SD, standard deviation; *n*, number of participants.

4. Discussion

The findings of this study highlight the early survivorship and encouraging clinical outcomes of a modern, modular revision system. In this cohort of revision TKA procedures, we observed few complications and reoperations despite the complexity of the patient population. Only one patient (3.2%) required hospital readmission within 90 days, and four patients (12.9%) underwent re-revision procedures, two of which involved exchange of fixed femoral and tibial components (6.5%). Two patients (6.5%) had radiographic evidence of prosthesis loosening at maximum follow-up, with one of these patients choosing to undergo an additional revision operation. These findings describe the early to mid-term course of this cohort. In the absence of a comparator group, they cannot establish the safety of the implant system or attribute the observed fixation to it.

A retrospective study investigating the Legion® Revision Total Knee Arthroplasty System (Smith & Nephew, Memphis, TN, USA) found 100% aseptic survivorship at one year, with 92.3% overall survivorship at five years [18]. Similarly, an investigation of the Triathlon® TS Revision Knee System (Stryker Orthopedics, Mahwah, NJ, USA) reported a 96% aseptic survivorship at a mean follow-up of four years, with the first component revision occurring approximately four years postoperatively [19]. A separate study found a 12% reoperation incidence at a median follow-up of 7.2 years, with approximately half of those revisions occurring due to aseptic complications [20]. A recent review paper of rTKA outcomes similarly reported overall survivorship of 90% at five years postoperatively [21]. Overall, early clinical outcomes observed with this modern revision knee system appear consistent with those reported for other contemporary revision knee implants, although direct comparisons to other knee implants remain limited due to differences in cohort size, follow-up, bone-loss severity, and definitions of failure.

A multicenter prospective cohort of 185 patients undergoing revision or complex primary TKA with this system reported implant survivorship of 97.2% (95% CI 93.5–98.8) at two years, and 97.0% (95% CI 93.0–98.7) among revision cases [16]. In the present series, survivorship free of all-cause re-revision was 93.1% (95% CI 75.1–98.2) at two years. These estimates are not directly comparable. The earlier cohort was predominantly aseptic (89.7%) and included complex primary procedures, whereas the present series comprised revision procedures only, 13% of which were performed for infection, and required both femoral and tibial components from the system. Endpoint definitions, follow-up duration, and cohort size also differ, and the confidence interval around the present estimate is wide. The principal additional contribution of this series is longer available follow-up, with a median of 3.9 years and a maximum of 5.7 years, in a consecutively identified single-center revision population.

A notable finding in our study is the frequent need for structural reconstruction to address bone loss, as evidenced by the high utilization of metaphyseal cones and augments. Metaphyseal cones were used in 84% of combined femoral and tibial revisions ($n = 26$), most commonly in the tibia, and augments were used in 74% of cases ($n = 23$). Distal femoral augments were the most frequently used, although posterior femoral and tibial augments were also commonly required to restore joint alignment and stability. Utilization of metaphyseal cones and augments is determined by surgeon preference after intraoperative examination of the bony defects. Nevertheless, the frequent use of these reconstructive options may reflect the degree of bone loss encountered in this patient population and suggests that surgeons may prefer the optionality of a versatile modular revision system while trialing intraoperatively. The severity of bone defects in this cohort is further reflected in the distribution of AORI bone loss classifications, with a substantial proportion of patients demonstrating Type 2B or Type 3 defects in both the femur and tibia. In this context, the ability to utilize metaphyseal cones and modular augments may be particularly valuable when addressing substantial bone loss.

The reconstructive approach used in this cohort aligns with the concept of zonal fixation described by Morgan-Jones et al., in which durable revision TKA constructs are thought to require stable fixation in at least two of three anatomic zones—epiphyseal (joint surface), metaphyseal, and diaphyseal [13]. Metaphyseal cones provide the multi-zonal fixation that this framework calls for in combination with modular stems engaging the diaphysis.

Technical execution of cone implantation is likely a key determinant of long-term stability. During progressive broaching, the goal is immediate axial and rotational stability of the final broach, indicating a high likelihood of bony on-growth and biologic fixation. Equally important is unitization of the construct: the femoral or tibial component must be cemented into the cone so that the cone, stem, and articulating component behave as a single mechanical unit. Failure of any of these steps can compromise construct stability regardless of the implant system used. In cases of severely compromised bone quality or bone loss that exceeds what a cone-based reconstruction can reasonably address, alternative strategies (structural allograft, sleeves, hinged or megaprosthetic constructs) should be considered rather than forcing a cone-based solution.

The radiograph in Figure 1, Panel B, with aseptic loosening 5 years after rTKA, demonstrates cortical thinning and endosteal scalloping along the lateral margin of the proximal tibial diaphysis. Focal endosteal resorption of this pattern has been attributed to stem-related micromotion and to particulate osteolysis from an incompletely sealed stem-bone interface, either of which may reflect inadequate zone 3 (diaphyseal) fixation. Undersizing of the stem relative to the diaphyseal canal and incomplete unitization with the tibial baseplate are possible contributing mechanisms, but these cannot be confirmed from the available radiographic findings. No standardized serial radiographic assessment was performed, and

the relative contributions of implant design, component sizing, fixation technique, bone quality, and patient-related factors cannot be determined from this case series.

While other studies of revision TKA systems often do not report cone or augment use in detail, prior literature has reported use of tibial metaphyseal cones in only 10% of revision TKA procedures [22]. The low frequency of mechanical complications in our cohort is encouraging given the complexity of these cases. Whether the versatility of this implant system—including modular stems, metaphyseal cones, and multiple augment configurations—contributes to management of bone defects or to fixation in revision TKA cannot be assessed in this study, which includes no comparator group. This observation is hypothesis-generating only.

Limited conclusions regarding patient-reported outcomes can be drawn due to the lack of comprehensive follow-up for many patients. Mean KOOS, JR scores were numerically higher than preoperative values at each postoperative interval; however, confidence intervals for all paired change scores included zero, and preoperative scores were unavailable for 42% of the cohort. These data are insufficient to establish the magnitude or durability of functional recovery in this population.

This study has several limitations. The retrospective design introduces potential selection bias, and the cohort represents a relatively small sample treated at a single tertiary academic center, which may limit generalizability. The cohort was also clinically heterogeneous, combining aseptic loosening, instability, infection, and arthrofibrosis indications with substantially different underlying failure mechanisms and prognoses; septic and aseptic outcomes should not be conflated, and this heterogeneity should be considered when interpreting the reported outcomes. Age-related heterogeneity (range, 46–84 years) may similarly confound interpretation of favorable outcomes. No standardized radiographic assessment of fixation (e.g., serial evaluation for radiolucent lines, migration, subsidence, osteolysis, or cone integration) was performed; absence of re-revision does not equal absence of radiographic loosening. AORI classification was performed by a single assessor without formal inter-rater reliability testing. Finally, this study lacks a comparator group, precluding attribution of the observed outcomes specifically to the implant system rather than to patient selection, surgical technique, or surgeon experience. In addition, follow-up duration remains limited, a notable constraint given that mechanical complications following revision TKA often do not occur until several years after surgery, further reflected in the width of the Kaplan–Meier confidence intervals, which widen substantially beyond four years as the number of patients at risk declines. Survivorship estimates at later time points should therefore be interpreted with caution. Finally, preoperative KOOS, JR scores were available for only 18 of 31 patients, and paired change scores could be calculated for no more than 12 patients at any interval. Missing observations reflected absent preoperative documentation, assessments not captured at telehealth encounters, death, and loss to follow-up. Patients with available scores may not be representative of the full cohort.

5. Conclusions

This case series describes favorable early to mid-term outcomes following revision total knee arthroplasty using this modern, modular revision knee system. In a complex revision population frequently requiring metaphyseal cones and modular augments, few complications and few cases of aseptic mechanical failure were observed at early to mid-term follow-up. These observations describe the course of this cohort and do not establish that the implant system accounts for the outcomes observed. Further investigation with larger cohorts and longer follow-up is needed to determine long-term implant survivorship and patient outcomes.

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Informed Consent Statement: Patient consent was waived due to the retrospective nature of the study.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

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Abbreviations

The following abbreviations are used in this manuscript:

TKA	Total knee arthroplasty
rTKA	Revision total knee arthroplasty
BMI	Body mass index
ASA	American Society of Anesthesiologists
CCI	Charlson Comorbidity Index
AORI	Anderson Orthopaedic Research Institute
KOOS, JR	Knee Injury and Osteoarthritis Outcome Score, Joint Replacement
DAIR	Debridement, antibiotics, and implant retention

References

1. Bourne, R.B.; Chesworth, B.M.; Davis, A.M.; Mahomed, N.N.; Charron, K.D.J. Patient satisfaction after total knee arthroplasty: Who is satisfied and who is not? *Clin. Orthop. Relat. Res.* **2010**, *468*, 57–63. [CrossRef] [PubMed] [PubMed Central]
2. Singh, J.A.; Yu, S.; Chen, L.; Cleveland, J.D. Rates of Total Joint Replacement in the United States: Future Projections to 2020-2040 Using the National Inpatient Sample. *J. Rheumatol.* **2019**, *46*, 1134–1140. [CrossRef] [PubMed]
3. Shichman, I.; Roof, M.; Askew, N.; Nherera, L.; Rozell, J.C.; Seyler, T.M.; Schwarzkopf, R. Projections and Epidemiology of Primary Hip and Knee Arthroplasty in Medicare Patients to 2040-2060. *JBJS Open Access.* **2023**, *8*, e22.00112. [CrossRef] [PubMed] [PubMed Central]
4. Schwartz, A.M.; Farley, K.X.; Guild, G.N.; Bradbury, T.L. Projections and Epidemiology of Revision Hip and Knee Arthroplasty in the United States to 2030. *J. Arthroplast.* **2020**, *35*, S79–S85. [CrossRef] [PubMed] [PubMed Central]
5. Shichman, I.; Askew, N.; Habibi, A.; Nherera, L.; Macaulay, W.; Seyler, T.; Schwarzkopf, R. Projections and Epidemiology of Revision Hip and Knee Arthroplasty in the United States to 2040–2060. *Arthroplast Today* **2023**, *21*, 101152. [CrossRef] [PubMed] [PubMed Central]
6. Nham, F.H.; Patel, I.; Zalikha, L.; El-Othmani, M.M. Epidemiology of primary and revision total knee arthroplasty: Analysis of demographics, comorbidities and outcomes from the national inpatient sample. *Arthroplasty* **2023**, *5*, 18. [CrossRef] [PubMed] [PubMed Central]

7. Ashkenazi, I.; Christensen, T.; Ward, S.A.; Bosco, J.A.; Lajam, C.M.; Slover, J.; Schwarzkopf, R. Trends in Revenue and Cost for Revision Total Knee Arthroplasty. *J. Arthroplast.* **2023**, *38*, S97–S102. [CrossRef] [PubMed]
8. Deere, K.; Whitehouse, M.R.; Kunutsor, S.K.; Sayers, A.; Mason, J.; Blom, A.W. How long do revised and multiply revised hip replacements last? A retrospective observational study of the National Joint Registry. *Lancet Rheumatol.* **2022**, *4*, e468–e479. [CrossRef] [PubMed] [PubMed Central]
9. Jones, M.D.; Buckle, C.L. How does aseptic loosening occur and how can we prevent it? *Orthop. Trauma* **2020**, *34*, 146–152. [CrossRef]
10. Bahraminasab, M.; Sahari, B.B.; Edwards, K.L.; Farahmand, F.; Arumugam, M.; Hong, T.S. Aseptic loosening of femoral components—A review of current and future trends in materials used. *Mater. Des.* **2012**, *42*, 459–470. [CrossRef]
11. Jones, C.M.; Acuna, A.J.; Forlenza, E.M.; Serino, J.; Della Valle, C.J. Trends and Epidemiology in Revision Total Knee Arthroplasty: A Large Database Study. *J. Arthroplast.* **2025**, *40*, S308–S314.e1. [CrossRef] [PubMed]
12. Dubin, J.A.; Bains, S.S.; Paulson, A.E.; Monarrez, R.; Hameed, D.; Nace, J.; Mont, M.; Delanois, R.E. The Current Epidemiology of Revision Total Knee Arthroplasty in the United States from 2016 to 2022. *J. Arthroplast.* **2024**, *39*, 760–765. [CrossRef] [PubMed]
13. Morgan-Jones, R.; Oussedik, S.I.S.; Graichen, H.; Haddad, F.S. Zonal fixation in revision total knee arthroplasty. *Bone Jt. J.* **2015**, *97-B*, 147–149. [CrossRef] [PubMed]
14. Sculco, P.K.; Abdel, M.P.; Hanssen, A.D.; Lewallen, D.G. The management of bone loss in revision total knee arthroplasty: Rebuild, reinforce, and augment. *Bone Jt. J.* **2016**, *98-B*, 120–124. [CrossRef] [PubMed]
15. Sheth, N.P.; Bonadio, M.B.; Demange, M.K. Bone Loss in Revision Total Knee Arthroplasty: Evaluation and Management. *J. Am. Acad. Orthop. Surg.* **2017**, *25*, 348–357. [CrossRef] [PubMed]
16. Frisch, N.B.; Edwards, P.; Bloomfield, M.; Redfern, R.E.; Brown, N.; Dundon, J. Midterm clinical outcomes and survivorship of a next generation revision knee system in complex primary and revision total knee arthroplasty. *The Knee* **2026**, *60*, 104328. [CrossRef] [PubMed]
17. Parvizi, J.; Tan, T.L.; Goswami, K.; Higuera, C.; Della Valle, C.; Chen, A.F.; Shohat, N. The 2018 Definition of Periprosthetic Hip and Knee Infection: An Evidence-Based and Validated Criteria. *J. Arthroplast.* **2018**, *33*, 1309–1314.e2. [CrossRef] [PubMed]
18. Stockwell, K.D.; Malleck, S.; Gascoyne, T.C.; Turgeon, T.R. Clinical and radiographic outcomes of a hybrid fixation revision total knee arthroplasty system at short to mid-term follow-up. *Knee* **2019**, *26*, 240–249. [CrossRef] [PubMed]
19. Gwam, C.U.; Chughtai, M.; Khlopas, A.; Mohamed, N.; Elmallah, R.K.; Malkani, A.L.; Mont, M.A. Short-to-Midterm Outcomes of Revision Total Knee Arthroplasty Patients with a Total Stabilizer Knee System. *J. Arthroplast.* **2017**, *32*, 2480–2483. [CrossRef] [PubMed]
20. Stevens, J.M.; Clement, N.D.; MacDonald, D.; Hamilton, D.F.; Burnett, R. Survival and functional outcome of revision total knee arthroplasty with a total stabilizer knee system: Minimum 5 years of follow-up. *Eur. J. Orthop. Surg. Traumatol.* **2019**, *29*, 1511–1517. [CrossRef] [PubMed]
21. Roman, M.D.; Russu, O.; Mohor, C.; Necula, R.; Boicean, A.; Todor, A.; Mohor, C.; Fleaca, S.R. Outcomes in revision total knee arthroplasty (Review). *Exp. Ther. Med.* **2022**, *23*, 29. [CrossRef] [PubMed] [PubMed Central]
22. Hadley, M.L.; Harmer, J.R.; Wright, B.H.; Larson, D.R.; Abdel, M.P.; Berry, D.J.; Lewallen, D.G. Porous Tantalum Tibial Metaphyseal Cones in Revision Total Knee Arthroplasty: Excellent 10-Year Survivorship. *J. Arthroplast.* **2024**, *39*, S263–S269. [CrossRef] [PubMed]

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