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Clinical, functional, and radiographic outcomes of primary total knee arthroplasty using a rotating hinge implant – a retrospective cohort study

Nemanja Slavković[1,2], Boris Vukomanović[1,2], Dejan Aleksandrić[1,2], Želimir Jovanović[1,3], Petar Katalinić Jovanović[1], Lazar Mičeta[1,2], Nikola Žarković[1,2]

[1]Banjica Institute for Orthopedics, Belgrade, Serbia;
[2]University of Belgrade, Faculty of Medicine, Belgrade, Serbia;
[3]University of Banja Luka, Faculty of Medicine, Banja Luka, Bosnia and Herzegovina

SUMMARY

Introduction/Objective The aim was to evaluate the clinical, functional, and radiographic outcomes, as well as implant survivorship, of primary total knee arthroplasty using a rotating hinge knee prosthesis in complex primary knees.

Methods This single-center, retrospective observational cohort study included 32 patients (32 knees) operated between December 1, 2023, and December 31, 2025. Primary outcomes were cumulative implant survivorship (Kaplan–Meier analysis with revision for any cause as the endpoint) and complication rates. Secondary outcomes included functional scores using the Oxford Knee Score (OKS), range of motion, coronal alignment correction via the mechanical femorotibial angle, and radiographic stability.

Results The median follow-up was 20.3 months. Surgical indications included primary (43.8%) and secondary osteoarthritis (21.9%), post-traumatic arthritis (21.9%), neuropathic arthropathy (9.4%), and proximal tibial nonunion (3.1%). Preoperative ligamentous instability was present in 87.5% of knees. Cumulative 20-month implant survivorship was 87.5% (all four revisions occurred within five months postoperatively due to early periprosthetic joint infection and wound complications; 0% aseptic loosening). The overall complication rate was 34.4%. Postoperatively, the mean OKS significantly increased from 13.25 ± 5.62 to 41.09 ± 3.74 (ΔOKS = +27.84, $p < 0.001$), median range of motion increased from 70° to 115° ($p < 0.001$), and absolute coronal deformity (deviation from neutral biomechanical axis) decreased from 23.9° to 2.36° ($p < 0.001$).

Conclusion Primary total knee arthroplasty with a rotating hinge knee implant provides excellent functional recovery, robust early mechanical stability, and predictable deformity correction in complex primary cases, though strict infection control and soft-tissue handling remain essential.

Keywords: total knee arthroplasty; rotating hinge knee; primary arthroplasty; survival analysis; functional outcome

INTRODUCTION

Total knee arthroplasty (TKA) represents one of the most successful and frequently performed surgical procedures in modern orthopedic surgery. The primary objective of this intervention is pain reduction, correction of deformity, restoration of joint function, and improvement in quality of life for patients with end-stage degenerative joint disease. The most common indication for TKA is advanced primary osteoarthritis, but the procedure is also increasingly utilized in inflammatory arthropathies, post-traumatic arthritis, avascular necrosis, and other conditions leading to joint destruction. Advances in implant design, refinements in surgical technique, optimized perioperative care, and standardized rehabilitation protocols have significantly contributed to the reliability and durability of TKA. In modern literature, TKA is universally recognized as a procedure that yields substantial functional recovery in the vast majority of cases [1, 2, 3].

Alongside objective clinical and radiographic parameters, patient-reported outcome measures have emerged as essential indicators of therapeutic success and functional recovery following primary TKA [1–4]. Validated joint-specific instruments, such as the Oxford Knee Score (OKS), provide direct insight into postoperative pain relief, joint function, and the restoration of daily activities from the patient's perspective [1, 2, 3]. Nevertheless, the magnitude of functional improvement varies depending on preoperative deformity severity, baseline pain intensity, functional status, medical comorbidities, and postoperative complications [1–5]. Suboptimal outcomes are most frequently linked to persistent pain, stiffness, joint instability, or complications requiring secondary surgical intervention [1, 2, 5]. Consequently, meticulous preoperative evaluation, realistic patient counseling, and individualized surgical planning are paramount when managing complex knee pathology [3, 5].

The success of primary TKA relies not only on implant selection but also on precise

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Correspondence to:
Nikola ŽARKOVIĆ
Generala Ljubomira Milića 10
11000 Belgrade
Serbia
nikola0605081998@gmail.com

mechanical axis alignment, soft-tissue balancing, and joint stability throughout the full arc of motion [6, 7, 8]. In standard primary cases, unconstrained implants (such as posterior-stabilized or cruciate-retaining designs) are routinely employed to approximate physiological kinematics. However, a distinct subset of patients presents with complex primary pathology [6, 7, 8]. This challenging cohort includes patients with severe fixed *varus* or *valgus* deformities, gross collateral ligament insufficiency, massive bone loss, post-traumatic structural alterations, neuromuscular disorders, ankylosis, or joint hyperlaxity [6, 7, 8]. In these scenarios, standard unconstrained implants fail to provide adequate primary stability and predictable outcomes [6, 7, 8]. Collateral ligament incompetence cannot be addressed solely by soft-tissue releases, forcing the surgeon to select an implant constraint level that matches the anatomical and functional severity of the defect to compensate for irreversibly compromised soft-tissue envelope [6, 7, 8]. Inadequate constraint predisposes to catastrophic postoperative instability, whereas excessive constraint transfers increased mechanical stresses to the bone-implant or bone-cement interfaces [8, 9, 10]. Therefore, implant selection represents a critical determinant of surgical success in complex primary TKA [6–10].

Rotating hinge knee (RHK) prostheses were specifically developed to provide mechanical stability when native joint stabilizers are severely compromised [6–10]. Unlike early fixed-hinge mechanisms, modern RHK systems incorporate a mobile-bearing rotational axis that allows controlled axial rotation alongside flexion and extension [8, 9, 10]. The rotational mechanism is designed to reduce torsional stress transmission to the fixation interfaces compared with fixed-hinge designs [8, 9, 10]. In primary TKA, the application of an RHK implant is non-routine and strictly reserved for well-defined, complex clinical indications [6–10]. Most common indications comprise gross ligamentous instability, severe uncorrectable coronal deformities, massive flexion-extension gap mismatch, severe bone loss, and conditions where stability cannot be achieved with less constrained implants [6–10]. In such patients, an RHK construct facilitates safe structural reconstruction, adequate immediate stability, and early functional mobilization [6–10]. This is particularly advantageous in elderly or frail patients with poor soft-tissue quality, in whom postoperative instability would carry devastating clinical consequences [6, 7, 8]. However, because RHK implants represent the highest degree of constraint, their use requires strict adherence to surgical indications [8, 9, 10]. Potential disadvantages – such as increased stress transfer, risk of periprosthetic joint infection (PJI), aseptic loosening, and technically demanding future revisions – must be carefully weighed [8, 9, 10].

Recent literature demonstrates that when utilized in appropriately selected primary cases, modern RHK implants achieve favorable mid-term survivorship and remarkable clinical improvement [6, 7, 9, 10]. However, most available evidence stems from heterogeneous cohorts that combine revision and primary procedures, leaving a distinct knowledge gap regarding the performance and specific early failure modes of RHK implants exclusively in non-revision, complex primary settings [6, 7, 9, 10]. These outcomes are particularly encouraging given that using standard implants in these complex cases would carry a high risk of immediate failure or persistent instability [6, 7, 9, 10]. Functional outcomes in this cohort should be interpreted relative to severe baseline deformity and ligamentous loss rather than benchmarked against uncomplicated primary TKA [6, 7, 8]. Thus, RHK prostheses represent a valuable option in complex reconstructive knee surgery, yet further dedicated single-center evaluations in strictly primary cohorts are needed to better define their early complication profile and functional trajectory [6–10]. Evaluating institutional experience with RHK implants in primary TKA is of great practical value to further clarify surgical indications, expected clinical outcomes, and potential failure modes in challenging patient populations [6–10]. The aim of this study was to evaluate short-term implant survivorship, complications, functional outcomes, range of motion (ROM), coronal alignment, and radiographic stability following primary TKA with an RHK implant in patients with complex primary knee pathology.

METHODS

Study design and source data

This retrospective, single-center, observational cohort study evaluated the clinical, functional, and radiographic outcomes of patients who underwent primary TKA using an RHK prosthesis between December 1, 2023, and December 31, 2025. Final clinical and radiographic follow-up data collection was concluded on July 1, 2026, ensuring that all included patients – including the most recently operated cases – had at least six months of potential follow-up time to evaluate early outcomes and survivorship. All patients were tracked continuously from the index surgery, and those experiencing early adverse events or revisions remained within longitudinal institutional follow-up. Data were extracted retrospectively from the institutional electronic health information system, incorporating inpatient medical records, operative protocols, anesthesia records, discharge summaries, and outpatient follow-up notes.

Patient selection criteria

Inclusion criteria were: 1) patients aged > 18 years at index surgery; 2) primary TKA utilizing an RHK prosthesis; 3) surgical indication defined as severe end-stage knee joint degeneration accompanied by gross coronal plane deformity, massive bone defects, and/or severe collateral ligament instability; 4) minimum clinical and radiographic follow-up of six months.

Exclusion criteria were: 1) revision TKA; 2) resection arthroplasty for oncological indications (tumor megaprostheses); 3) active local or systemic infection at index surgery; 4) incomplete medical records lacking primary outcome parameters.

Study variables and clinical evaluation

Collected variables were categorized into three chronological phases: preoperative, intraoperative, and postoperative parameters. Preoperative variables included demographic characteristics, American Society of Anesthesiologists (ASA) physical status classification, and Charlson comorbidity index. Clinical characterization incorporated primary surgical indication, history of prior ipsilateral non-arthroplasty knee surgeries, and type of joint instability (isolated coronal/mediolateral, isolated sagittal/anteroposterior, or global/multiligamentous). Preoperative functional status was evaluated using the OKS, and ROM was measured using a standard goniometer. Full-length weight-bearing standing radiographs were analyzed to measure the preoperative mechanical femorotibial angle (mFTA), with positive values denoting *valgus* deformity and negative values denoting *varus* deformity.

Intraoperative variables recorded included type of anesthesia, application of modular metal augments or autologous bone grafts, stem fixation technique (cementless, cemented, or hybrid), and polyethylene liner thickness (mm). Postoperative variables comprised final follow-up OKS, maximum ROM following rehabilitation, postoperative mFTA, and detailed serial radiographic evaluation.

Surgical technique and perioperative protocol

Surgeries were performed under general or spinal anesthesia after adequate medical optimization. All procedures were carried out by a dedicated team of 10 fellowship-trained orthopedic specialists with extensive expertise in knee arthroplasty. Following standard positioning, an anterior midline skin incision was performed, followed by a medial parapatellar arthrotomy. Upon joint exposure, the preoperative decision for an RHK implant (Rotating Hinge Knee, RHK®, Zimmer Biomet, Warsaw, IN, USA) was confirmed intraoperatively.

Distal femoral and proximal tibial resections were executed using dedicated intramedullary and extramedullary alignment guides, adhering to planned resection angles and depths. Bony defects were reconstructed using modular metal augments or autologous bone grafting according to surgeon preference. Following medullary canal preparation and trial component placement, joint kinematics, gap balance, and hinge stability were verified through a full arc of motion. Final components were implanted using bone cement, obligatorily over resected articular surfaces, and optionally along medullary canal extensions depending on stem fixation protocol. Pulsatile lavage irrigation was performed, and the wound closed in anatomical layers.

Prophylactic first-generation cephalosporins were administered until the first postoperative day. Venous thromboembolism prophylaxis with low-molecular-weight heparin was maintained for five weeks postoperatively. Structured physical therapy commenced on the first postoperative day and was finalized at inpatient rehabilitation centers after hospital discharge.

Radiographic evaluation

Serial anteroposterior and lateral knee radiographs obtained at final follow-up were evaluated by two independent orthopedic surgeons not involved in index operations. Radiographic assessment aimed to detect radiolucent lines > 2 mm according to modern Knee Society zones, component migration, osteolysis, or aseptic loosening. Mechanical alignment correction was determined by comparing preoperative and postoperative mFTA values.

Study outcomes

Primary outcomes were implanting survivorship – defined as time (in months) from index surgery to revision surgery for any cause (involving exchange or removal of any component, including the liner) – and complication rates, categorized as intraoperative, early postoperative (< 90 days), or late postoperative (≥ 90 days).

Secondary outcomes included functional score improvement (mean absolute change in OKS, ΔOKS), gain in ROM, mechanical axis correction (absolute change in mFTA), and incidence of radiographic instability or loosening.

Statistical analysis

Statistical analysis was performed using SPSS version 27.0 (IBM Corp., Armonk, NY, USA). Continuous variables were evaluated for normality using the Shapiro–Wilk test. Normally distributed continuous variables are presented as mean ± standard deviation (m ± SD); non-normally distributed continuous variables are presented as median with interquartile range (IQR). Categorical variables are reported as frequencies and percentages (n, %).

Preoperative and postoperative continuous metrics (OKS, ROM, mFTA) were compared using the paired t-test for parametric data or Wilcoxon signed-rank test for non-parametric data. Time-to-event data were analyzed using the Kaplan–Meier survival analysis method, calculating cumulative survivorship with 95% confidence intervals (CI), setting revision for any cause as the primary endpoint. To identify independent risk factors for revision, variables demonstrating a univariate statistical trend ($p < 0.10$) were entered into a Cox proportional hazards regression model, calculating hazard ratios with 95% CIs. A two-tailed $p < 0.05$ was considered statistically significant.

RESULTS

Demographics and preoperative patient profile

Out of 3921 primary total knee arthroplasties performed at our institution between December 1, 2023, and December 31, 2025, a total of 32 patients underwent primary TKA utilizing an RHK prosthesis. The mean age of the cohort was 67.34 ± 10 years (range: 42–82 years), with a marked

female predominance (25 females *vs*. 7 males; 78.1% *vs*. 21.9%). The median postoperative follow-up was 20.33 months (IQR: 9–24.75 months).

Primary surgical indications comprised primary osteoarthritis (n = 14; 43.8%), secondary osteoarthritis (n = 7; 21.9%), post-traumatic arthritis (n = 7; 21.9%), neuropathic arthropathy (n = 3; 9.4%), and nonunion of the proximal tibia (n = 1; 3.1%). Preoperative ligamentous instability was confirmed in 28 patients (87.5%), most commonly presenting as coronal/mediolateral instability (n = 18; 56.3%) or global multiligamentous instability (n = 9; 28.1%), whereas isolated sagittal instability was noted in a single case (3.1%). Regarding comorbidity indices, the majority of patients belonged to ASA physical status Class II (n = 15; 46.9%) or Class III (n = 14; 43.8%), with a median Charlson comorbidity index of three (IQR: 2–5). Complete demographic and baseline data are detailed in Table 1.

Table 1. Demographic and preoperative patient baseline profile (n = 32)

Variable name	Value/distribution (n = 32)
Age at index surgery (years), mean ± SD (range)	67.34 ± 10 (42–82)
Follow-up duration (months), median (IQR)	20.33 (9–24.75)
Charlson comorbidity index, median (IQR)	3 (2–5)
Prior non-arthroplasty knee surgeries, median (IQR)	0 (0–0) (range: 0–7)
Gender, n (%) • Male (1) • Female (2)	 7 (21.9%) 25 (78.1%)
Surgical side, n (%) • Right (1) • Left (2)	 13 (40.6%) 19 (59.4%)
American Society of Anesthesiologists classification status, n (%) • Class I • Class II • Class III	 3 (9.4%) 15 (46.9%) 14 (43.8%)
Primary surgical indication, n (%) • Primary osteoarthritis (1) • Secondary osteoarthritis (2) • Post-traumatic osteoarthritis (3) • Neuropathic osteoarthritis (4) • Proximal tibial nonunion (5)	 14 (43.8%) 7 (21.9%) 7 (21.9%) 3 (9.4%) 1 (3.1%)
Preoperative knee instability profile, n (%) • No instability (0) • Coronal / mediolateral (1) • Sagittal / anteroposterior (2) • Global / multiligamentous (3)	 4 (12.5%) 18 (56.3%) 1 (3.1%) 9 (28.1%)

Surgical and intraoperative parameters

Spinal anesthesia was administered in 26 patients (81.2%), and a tourniquet was utilized in 22 operations (68.8%). Bone defect reconstruction was required in nine cases (28.1%): modular femoral augments were used in three patients, tibial augments in three patients, and autologous bone grafting for tibial defects in three patients. Bony defect reconstruction was performed using modular metal augments or autologous bone grafting based on defect geometry, intraoperative surgeon judgment, and implant augment availability; specifically, bone grafting was chosen in three tibial defect cases due to augment non-availability in two instances and superior anatomical conformity of the graft to the defect shape in the third.

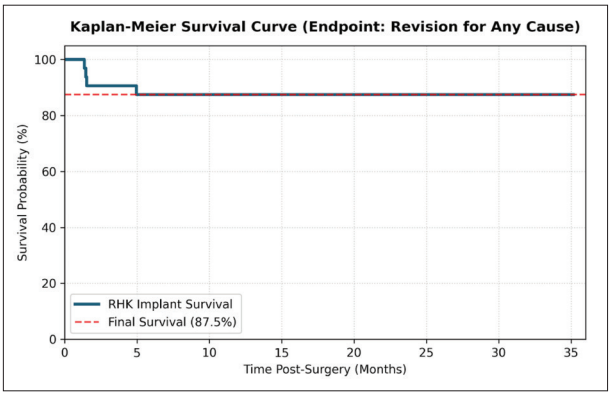


Figure 1. Kaplan–Meier survival curve for rotating hinge knee (RHK) in primary total knee arthroplasty, in months

Cementless stem fixation was predominantly utilized (n = 27; 84.4%). Cemented fixation of both femoral and tibial stems was performed in four cases (12.5%), whereas hybrid fixation (cementless femoral / cemented tibial stem) was used in one patient (3.1%). The most frequently implanted polyethylene liner thickness was 12 mm (n = 25; 78.1%), with an overall liner thickness range between 12 mm and 20 mm.

Implant survivorship (primary outcome)

The primary endpoint was defined as cumulative RHK construct survivorship free from revision surgery for any cause (exchange or removal of any component, including the polyethylene insert). Cumulative 20-month implant survivorship was 87.5% (Figure 1).

All revisions (n = 4) occurred early – within the first five months postoperatively; no late mechanical failures requiring revision were observed during follow-up. Two patients with early PJI underwent "DAIR" protocol (debridement, antibiotics, and implant retention) with polyethylene liner exchange. In one patient who had undergone primary TKA combined with open reduction and double-plate internal fixation for a pre-existing proximal tibial fracture, "DAIR" protocol was performed along with partial hardware removal due to superficial wound dehiscence. In one case of early PJI accompanied by femoral component instability, a two-stage revision was successfully executed, with complete implant removal and temporary placement of an antibiotic-impregnated cement spacer in the first stage.

Complication profile and radiographic status

The overall postoperative complication rate was 34.4% (n = 11). Intraoperative complications occurred in two patients: partial avulsion of the patellar tendon insertion (repaired intraoperatively using bioabsorbable suture anchors) and an iatrogenic femoral shaft fracture (identified on immediate postoperative radiographs and managed

Table 2. Chronological distribution of postoperative complications and treatment strategies

Time window	Observed complication type (n)	Re-operation / treatment strategy
Intraoperative (n = 2)	• Periprosthetic femur fracture (n = 1) • Partial patellar tendon avulsion (n = 1)	• Identified postoperatively; treated nonoperatively with cast immobilization • Repaired intraoperatively with anchors; no secondary revision
Early postoperative (< 90 days) (n = 8)	• Early periprosthetic joint infection (n = 6) • Periprosthetic femur fracture (n = 1) • Peroneal nerve palsy (n = 1)	• **Revision required (n = 4)**: three cases treated via debridement, antibiotics, and implant retention with liner exchange; one case treated via two-stage revision with spacer; two cases successfully treated with IV antibiotics alone • Managed nonoperatively • Complete functional recovery at six months with physical therapy
Late postoperative (≥ 90 days) (n = 1)	• Lateral patellar subluxation (n = 1)	• Managed nonoperatively
Radiographic failures	• Aseptic loosening, osteolysis, or component migration (n = 0)	• **Zero events (0%)** observed across the entire cohort during follow-up

Table 3. Preoperative *vs.* postoperative clinical, functional, and alignment parameters

Outcome parameter	Preoperative status	Postoperative status	Absolute change (δ)	p
Oxford knee score mean ± SD	13.25 ± 5.62	41.09 ± 3.74	**+27.84 ± 7.38**	**< 0.001**
Range of motion median (IQR)	70° (65°–80°)	115° (110°–120°)	**+45°**	**< 0.001**
Mechanical femorotibial angle mean ± SD	13.48° ± 26.36°	6.8° ± 2.86°	Variable	**< 0.001**

conservatively with cast immobilization and restricted weight-bearing).

Early postoperative complications (< 90 days) developed in eight cases, dominated by early PJI (n = 6). Among these, four cases required surgical revision (as detailed above), whereas two cases were successfully eradicated using targeted intravenous antibiotic therapy alone. Early complications also included one post-traumatic distal femoral periprosthetic fracture (managed nonoperatively) and one transient peroneal nerve palsy that achieved complete recovery after six months of physical therapy. Late complications (≥ 90 days) occurred in a single patient as lateral patellar subluxation, which was managed conservatively.

Serial radiographic analysis at final follow-up revealed no progressive radiolucent lines (> 2 mm according to Knee Society criteria), nor any signs of aseptic loosening, osteolysis, or component migration in any case. A chronological summary of complications and surgical management strategies is presented in Table 2.

Functional outcomes and alignment correction

Following operative treatment and complete physical rehabilitation, highly significant statistical improvements were recorded across all functional metrics. The mean OKS rose significantly from a preoperative baseline of 13.25 ± 5.62 to a postoperative mean of 41.09 ± 3.74, representing an absolute functional gain of ΔOKS = +27.84 ± 7.38 points ($p < 0.001$). ROM likewise demonstrated a statistically significant increase, with the median arc expanding from 70° preoperatively to 115° postoperatively ($p < 0.001$).

The RHK system demonstrated exceptional capability in correcting severe coronal alignment deformities. The raw preoperative mean mFTA was 13.48° ± 26.36°, which was corrected to a mean postoperative anatomical alignment of 6.8° ± 2.86° *valgus*. To account for mathematical cancellation of opposing deformities (*varus vs. valgus*), paired t-testing was performed on the absolute deviation from target neutral alignment (6° *valgus*). Absolute coronal plane deformity improved significantly from a preoperative mean of 23.9° to a postoperative mean of 2.36° ($t = 9.42$, $p < 0.001$). Preoperative and postoperative functional scores, ROM, and alignment values are summarized in Table 3.

DISCUSSION

RHK prostheses represent the highest level of implant constraint in knee arthroplasty, where construct stability depends entirely on the mechanical hinge linkage rather than on native joint stabilizers such as collateral or cruciate ligaments. Historically, RHK designs were reserved strictly for complex revision TKAs characterized by massive bone defects and uncorrectable instability. First-generation hinged prostheses suffered from unacceptably high mechanical failure rates, driven by intense stress transmission to the bone-implant-cement interface, which resulted in early aseptic loosening [11]. Second-generation designs introduced a rotating axis that accommodated axial rotation on the tibial plateau, significantly attenuating torsional shear stresses on the host bone. Third-generation systems further incorporated modular stem options, anatomical patellofemoral trochlear kinematics, highly conformal polyethylene inserts, and modular metal augments for joint line restoration and bone defect reconstruction [12].

These design refinements have broadened the clinical application of RHK implants to encompass complex primary TKAs. Neuhaus and Maier [7] recently confirmed that while RHK constructs were historically limited to salvage procedures, contemporary design iterations provide safe and predictable primary joint reconstruction when native collateral ligaments are non-functional. Our cohort achieved favorable 20-month cumulative RHK survivorship of 87.5% in complex primary knees. Furthermore, patients demonstrated a dramatic functional improvement,

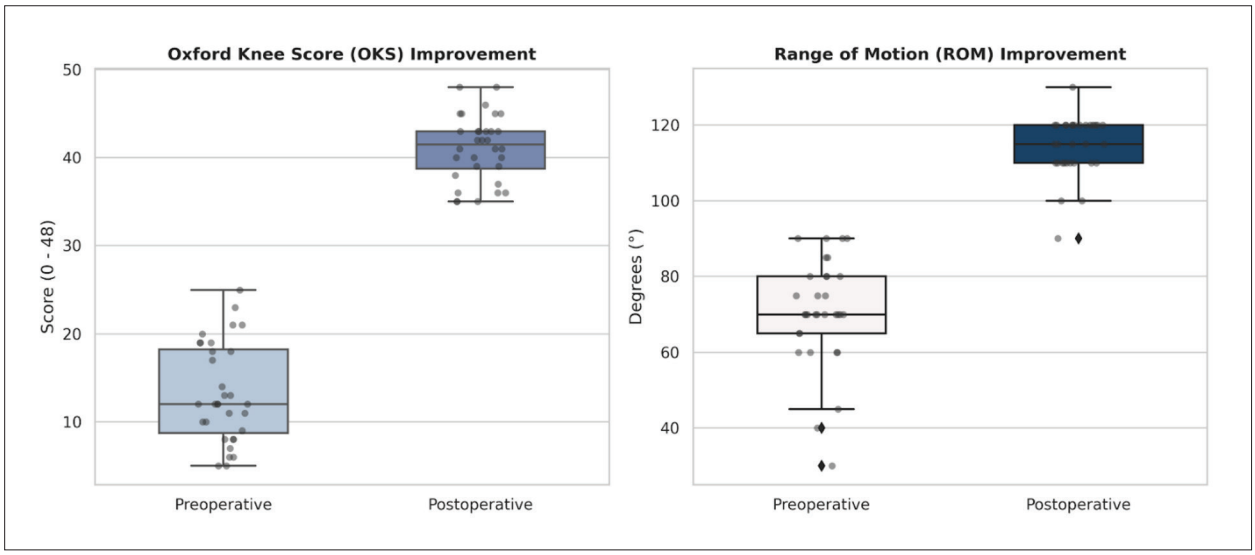


Figure 2. Functional Oxford knee score (OKS) and range of motion (ROM) improvement after rotating hinge knee primary total knee arthroplasty

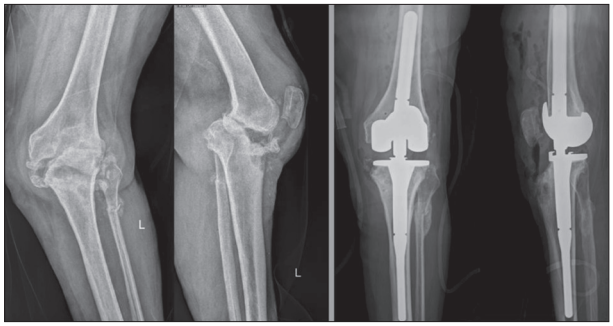


Figure 3. Preoperative X-ray of 67-year-old female patient with severe posttraumatic osteoarthritis, *valgus* deformity and antero-posterior instability (left); postoperative X-ray after primary total knee arthroplasty with rotating hinge knee (right)

evidenced by a mean ΔOKS gain of +27.84 points and complete elimination of preoperative joint laxity. These findings closely mirror the landmark findings by Puri et al. [6] from the Hospital for Special Surgery, who reported a 95% five-year reoperation-free survivorship and 100% survivorship free from aseptic loosening in 54 complex primary RHK cases. These collective findings underscore that RHK prostheses are no longer limited to revision salvage, but represent a crucial primary option when native joint stabilizers are irreversibly lost [6, 7].

Reported mid- and long-term survivorship rates for RHK implants in primary settings vary considerably across the literature depending on follow-up duration and the specific definition of endpoints (all-cause revision *vs*. re-operation) [9, 13–16]. In a comprehensive meta-analysis of 6554 primary knees, Abdel Khalik et al. [9] demonstrated a five-year revision-free survival rate of 93.8% and a 10-year survival rate of 91.5%, establishing robust global benchmarks for primary RHK implants. Similarly, von Hintze et al. [14] documented a 10-year survivorship of 91.6% in a dedicated primary cohort of 106 knees, while Schaible et al. [13] reported a 100% implant survival rate at a mean follow-up of 32 months. Conversely, some older series reported guarded outcomes, with five-year survival dropping as low as 52% [15]. In the longest single-center series (13.5 years mean follow-up), Kendoff et al. [16] demonstrated that younger age (< 60 years) and preoperative *valgus* deformity significantly increased revision risk (13.5-year survival of 96% in severe *varus vs*. 64% in *valgus* knees). In this context, our observed revision-free survivorship of 87.5% reflects an early- to mid-term observation window (median follow-up of 20.3 months); although direct comparison with five- and 10-year register benchmarks is limited by this time horizon discrepancy, our early trajectory is encouraging, and longer longitudinal follow-up is warranted to confirm whether these results remain comparable over the long term.

A paramount finding in our study is the complete absence of aseptic component loosening, osteolysis, or component migration (0%) throughout the follow-up window. While this is partially attributable to the short follow-up duration, it highlights the mechanical efficacy of modern RHK mechanisms combined with long stem extensions in dissipating torsional shear loads at the bone-implant interface [6]. Cottino et al. [17] corroborated this mechanical durability, demonstrating an exceptionally low 10-year cumulative revision rate for aseptic loosening of just 4.5% across 408 RHK knees. Furthermore, Moussa et al. [18] confirmed that intramedullary stem extensions in constrained primary TKA significantly enhance construct rigidity and eliminate early mechanical failure compared to non-stemmed constrained designs. Our experience aligns with Kowalczewski et al. [19], who achieved 100% 10-year survival free from mechanical loosening using hybrid press-fit long stems, and Spranz et al. [8], who proved in a dedicated cohort that adding metaphyseal modular interfaces to RHK stems does not compromise primary fixation stability ($p = 0.072$).

Etiological and chronological analysis of our failures ($n = 4$ revisions) demonstrates that implant loss was driven exclusively by early PJI and soft-tissue healing problems rather than mechanical loosening or material fatigue (all

revisions occurred within five months postoperatively). Severe preoperative deformities, prolonged operative times, and compromised host health (high ASA physical status and comorbidity indices) render this patient population highly vulnerable to infectious complications [11, 20]. In their meta-analysis, Abdel Khalik et al. [9] showed an overall rate of complications requiring revision of 7.4%, with the most common causes being infection (2.6%), aseptic loosening (1.2%), and periprosthetic fracture (1.1%). PJI as the dominant early failure mode is further corroborated by Bruce et al. [12], who evaluated 53 RHK implants at a mean 7.6-year follow-up and confirmed that soft-tissue complications and PJI represent the primary causes of early secondary intervention, as well as Rouquette et al. [20], who emphasized that septic risks are substantially heightened in patients with prior non-arthroplasty surgeries and compromised soft-tissue envelopes. Furthermore, given the extreme deformities and extensive posterior capsular releases frequently required in complex primary RHK TKA, meticulous intraoperative dissection is mandatory to avoid catastrophic neurovascular complications, such as iatrogenic popliteal artery injury [21].

Functional recovery in our cohort was remarkable, characterized by a dramatic increase in mean OKS (from 13.25 ± 5.62 preoperatively to 41.09 ± 3.74 postoperatively) and expansion of median ROM to 115°. This high functional ceiling is facilitated by the primary TKA setting, where periarticular soft tissues are well preserved, unlike in revision TKA [11, 20, 22]. In a prospective matched-pair analysis comparing primary RHK directly against standard primary TKA, Schaible et al. [13] demonstrated that primary RHK achieved statistically superior postoperative ROM (mean 126°) compared to matched standard TKA (117°, $p = 0.012$), alongside complete elimination of mediolateral laxity (which was present in 26% of standard primary TKAs). Our mean postoperative ROM of 115° matches the findings of Hecker et al. [11], while our postoperative OKS score of 41.09 aligns with contemporary patient-reported outcome expectations highlighted in recent meta-analyses by Park et al. [5] and matched-pair satisfaction studies by Vogel et al. [2].

The geometric restoration of limb alignment (reducing absolute coronal deviation from 23.9° preoperatively to 2.36° postoperatively) highlights the biomechanical superiority of the RHK construct. Hecker et al. [11] emphasized that severe uncorrectable coronal deformities constitute a primary indication for RHK implantation. Our radiographic results align with Kendoff et al. [16], confirming that primary RHK provides exceptional alignment correction in severe *varus* deformities (96% long-term survival), while emphasizing that younger *valgus* patients require rigorous surgical precision and vigilant monitoring. Furthermore, as demonstrated by DeFrance et al. [3] and Singh et al. [1], restoring joint stability and overall mechanical alignment in complex primary knees directly correlates with achieving modern patient satisfaction rates above 85–90%.

Long-term surveillance remains essential given the systemic frailty of this cohort. In their 15-year landmark study, Yang et al. [23] noted that despite an 87% implant survival rate, 100% of primary RHK patients eventually required ambulatory gait aids (canes or walkers), with a cumulative late PJI rate of 14%. This indicates that reduced patient mobility in long-term follow-up is frequently driven by systemic, neurological, or medical comorbidity progression rather than mechanical TKA failure, which must be clearly communicated during preoperative patient counseling [6, 23, 24].

This study has several limitations. First, its retrospective single-center design carries inherent risk of selection bias. Second, follow-up duration (median 20.3 months) is optimal for detecting early soft-tissue and infectious failures, but insufficient for evaluating long-term polyethylene wear or late aseptic loosening [11, 17].

CONCLUSION

Primary TKA using a contemporary RHK prosthesis is a highly effective, reliable, and biomechanically sound procedure for patients presenting with severe coronal plane deformities, gross ligamentous instability, and major bone defects. The procedure yields dramatic, statistically significant functional recovery, substantial pain relief, and accurate mechanical axis restoration. With an 87.5% cumulative implant survivorship at median 20.3 months and a 0% rate of early mechanical loosening or component migration, modern RHK designs demonstrate excellent early structural durability. However, because early failures are driven exclusively by PJI and wound healing complications, long-term success relies on strict preoperative patient selection, meticulous soft-tissue handling, and aggressive infection prevention measures.

Ethical approval and consent to participate: The subjects' written consent was obtained, according to the Declaration of Helsinki. The study has been approved by the Institutional Ethics Committee (approval number I-226/24) and conducted in accordance with legal standards and STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for observational studies.

Conflict of interest: None declared.

REFERENCES

1. Singh M, Harary J, Schilling PL, Moschetti WE. Patient satisfaction is nearly 90% after total knee arthroplasty; we are better than we were. J Arthroplasty. 2025;40(6):1521–5.e1. [DOI: 10.1016/j.arth.2024.11.038] [PMID: 39581239]
2. Vogel N, Kaelin R, Rychen T, Wendelspiess S, Müller-Gerbl M, Arnold MP. Satisfaction after total knee arthroplasty: a prospective matched-pair analysis of patients with customised individually made and off-the-shelf implants. Knee Surg Sports Traumatol Arthrosc. 2023;31(12):5873–84. [DOI: 10.1007/s00167-023-07643-1] [PMID: 37982843]
3. DeFrance MJ, Scuderi GR. Are 20% of patients actually dissatisfied following total knee arthroplasty? A systematic review of the literature. J Arthroplasty. 2023;38(3):594–9. [DOI: 10.1016/j.arth.2022.10.011] [PMID: 36252743]
4. Blagojević Z, Gluščević B, Đorđević B. Total knee arthroplasty in patients with rheumatoid arthritis – midterm results. Vojnosanit Pregl. 2017;74(6):543–9. [DOI: 10.2298/VSP150901154G]
5. Park J, Chang MJ, Kim TW, D'Lima DD, Kim H, Han HS. Serial changes in patient-reported outcome measures and satisfaction rate during long-term follow-up after total knee arthroplasty: a systematic review and meta-analysis. Knee Surg Relat Res. 2024;36(1):43. [DOI: 10.1186/s43019-024-00241-6] [PMID: 39633483]
6. Puri S, Bornes TD, Neitzke CC, Jones AD, Hamilton AA, Premkumar A, et al. Survivorship and functional outcomes after complex primary total knee arthroplasty with contemporary rotating-hinge implants. HSS J. 2024;22(1):50–6. [DOI: 10.1177/15563316241276869] [PMID: 39564407]
7. Neuhaus HJ, Maier K. Rotating hinge prosthesis for primary and revision knee arthroplasty: comparison and indications. Biomed Res Int. 2022;2022:9930675. [DOI: 10.1155/2022/9930675] [PMID: 35136828]
8. Spranz DM, Koch KA, Reiner T, Hetto P, Gotterbarm T, Merle C. Mid-term results of complex primary total knee arthroplasty using a rotating-hinge implant. Knee. 2022;34:34–41. [DOI: 10.1016/j.knee.2021.10.001] [PMID: 34875496]
9. Abdel Khalik H, Cruickshank M, Nadeem SM, Ade-Conde AM, Chalmers BP. Rotating hinge implants for primary total knee arthroplasty: a systematic review and meta-analysis of 6,554 knees. J Arthroplasty. 2026;41(7):2198–211.e4. [DOI: 10.1016/j.arth.2025.10.057] [PMID: 41161503]
10. Barrack RL. Evolution of the rotating hinge for complex total knee arthroplasty. Clin Orthop Relat Res. 2001;392:292–9. [DOI: 10.1097/00003086-200111000-00038] [PMID: 11716398]
11. Hecker A, Pütz HJA, Wangler S, Eberlein SC, Klenke FM. Indications, clinical outcome and survival of rotating hinge total knee arthroplasty in a retrospective study of 63 primary and revision cases. Eur J Orthop Surg Traumatol. 2023;33(5):1885–94. [DOI: 10.1007/s00590-022-03349-1] [PMID: 35989369]
12. Bruce D, Awad F, Jonas S, Agarwal S. Longer term follow-up of outcomes following implantation of a modular rotating hinge knee prosthesis: 53 implants at mean 7.6 year follow up. Knee. 2024;47:35–42. [DOI: 10.1016/j.knee.2023.12.011] [PMID: 38181461]
13. Schaible SF, Eberlein SC, Schaefer R, Klenke FM, Hecker A. Clinical outcomes of standard primary vs. primary rotating hinge total knee arthroplasty: a retrospective matched-pair analysis. J Orthop Surg Res. 2025;20(1):575. [DOI: 10.1186/s13018-025-05961-3] [PMID: 40481600]
14. von Hintze J, Niemeläinen M, Sintonen H, Nieminen J, Eskelinen A. Good mid-term outcome of the rotating hinge knee in primary total knee arthroplasty: results of a single center cohort of 106 knees with a median follow-up of 6.3 years. Knee. 2021;28:273–81. [DOI: 10.1016/j.knee.2020.12.016] [PMID: 33453516]
15. Smith TH, Gad BV, Klika AK, Styron JF, Joyce TA, Barsoum WK. Comparison of mechanical and nonmechanical failure rates associated with rotating hinged total knee arthroplasty in nontumor patients. J Arthroplasty. 2013;28(1):62–7.e1. [DOI: 10.1016/j.arth.2012.05.008] [PMID: 23217527]
16. Kendoff D, Haasper C, Gehrke T, Klauser W, Sandiford N. Management of Gonarthrosis with a Rotating Hinge Prosthesis: Minimum 10-Year Follow-up. Clin Orthop Surg. 2020;12(4):464–9. [DOI: 10.4055/cios19153] [PMID: 33274023]
17. Cottino U, Abdel MP, Perry KI, Mara KC, Lewallen DG, Hanssen AD. Long-Term Results After Total Knee Arthroplasty with Contemporary Rotating-Hinge Prostheses. J Bone Joint Surg Am. 2017;99(4):324–30. [DOI: 10.2106/JBJS.16.00307] [PMID: 28196034]
18. Moussa ME, Lee YY, Patel AR, Westrich GH. Clinical Outcomes Following the Use of Constrained Condylar Knees in Primary Total Knee Arthroplasty. J Arthroplasty. 2017;32(6):1869–73. [DOI: 10.1016/j.arth.2017.01.001] [PMID: 28189441]
19. Kowalczewski J, Marczak D, Synder M, Sibiński M. Primary Rotating-Hinge Total Knee Arthroplasty: Good Outcomes at Mid-Term Follow-Up. J Arthroplasty. 2014;29(6):1202–6. [DOI: 10.1016/j.arth.2013.12.013] [PMID: 24418767]
20. Rouquette L, Batailler C, Muller B, Neyret P, Servien E, Lustig S. Early complications and causes of revision after rotating-hinge TKA. Arch Orthop Trauma Surg. 2020;140(1):109–19. [DOI: 10.1007/s00402-019-03290-9] [PMID: 31664574]
21. Boljanović J, Glišić M, Ilijevski N, Bećirović M, Stojanović S, Pavković I, et al. Anatomical variations of the popliteal artery as a risk factor for its laceration during total knee arthroplasty: Controversies with illustrative case report. Vojnosanitetski pregled. 2025;82(4):250–6. [DOI: 10.2298/VSP241005021B]
22. Manojlović S, Dodik R, Manojlović M, Jovičić Ž, Dragičević-Cvjetković D. Total knee arthroplasty in patients with a proximal tibial stress fracture associated with bilateral severe knee osteoarthritis. Srp Arh Celok Lek. 2024;152(1–2):39–43. [DOI: 10.2298/SARH221022115M]
23. Yang JH, Yoon JR, Oh CH, Kim TS. Primary total knee arthroplasty using rotating-hinge prosthesis in severely affected knees. Knee Surg Sports Traumatol Arthrosc. 2012;20(3):517–23. [DOI: 10.1007/s00167-011-1590-1] [PMID: 21773833]
24. Jeremić D, Jovanović Ž, Krivokapić B, Vasović D, Zekić B, Žarković N. The use of rotating hinge knee prosthesis in revision total knee arthroplasty. Serbian Journal of the Medical Chamber. 2025;6(2):232–41. [DOI: 10.5937/smclk6-57724]

Клинички, функционални и радиографски исходи примарне тоталне артропластике колена уз примену импланта са ротационом шарком – ретроспективна кохортна студија

Немања Славковић[1,2], Борис Вукомановић[1,2], Дејан Александрић[1,2], Желимир Јовановић[1,3], Петар Каталинић Јовановић[1], Лазар Мичета[1,2], Никола Жарковић[1,2]

[1]Институт за ортопедију „Бањица", Београд, Србија;
[2]Универзитет у Београду, Медицински факултет, Београд, Србија;
[3]Универзитет у Бањој Луци, Медицински факултет, Бања Лука, Босна и Херцеговина

САЖЕТАК

Увод/Циљ Циљ рада био је процена клиничких, функционалних и радиографских исхода, као и преживљавања имплантата након примарне тоталне артропластике колена уз примену протезе са ротационом шарком код комплексних примарних случајева.

Методе Ова ретроспективна, једноцентрична опсервациона кохортна студија обухватила је 32 болесника (32 колена) оперисана у периоду од 1. децембра 2023. до 31. децембра 2025. године. Примарни исходи били су кумулативна стопа преживљавања имплантата (Каплан–Мајерова анализа са ревизијом из било ког разлога као крајњом тачком) и стопа компликација. Секундарни исходи обухватали су функционални статус процењен помоћу Оксфордског упитника за процену функције колена (*OKS*), обим покрета, корекцију механичког феморотибијалног угла и радиографску стабилност.

Резултати Медијана периода праћења износила је 20,3 месеца. Индикације за уградњу биле су примарни (43,8%) и секундарни остеоартритис (21,9%), посттрауматски артритис (21,9%), неуропатска артропатија (9,4%) и псеудоартроза проксималне тибије (3,1%). Преоперативна лигаментарна нестабилност верификована је код 87,5% болесника. Кумулативна 20-месечна стопа преживљавања имплантата износила је 87,5% (све четири ревизије извршене су у првих пет месеци након операције услед ране перипротетске инфекције и компликација ране; стопа асептичног разлабављења износила је 0%). Укупна стопа компликација износила је 34,4%. Постоперативно, средња вредност *OKS* порасла је са 13,25 ± 5,62 на 41,09 ± 3,74 (Δ*OKS* = +27,84, $p < 0,001$), медијана обима покрета са 70° на 115° ($p < 0,001$), а апсолутни коронални деформитет (одступање од неутралне биомеханичке осовине) смањио се са 23,9° на 2,36° ($p < 0,001$).

Закључак Примарна тотална артропластика колена уз примену протезе са ротационом шарком обезбеђује одличан функционални опоравак, високу рану механичку стабилност и поуздану корекцију деформитета код комплексних примарних стања, при чему су ригорозна контрола инфекције и пажљиво поступање са меким ткивима од кључног значаја.

Кључне речи: тотална артропластика колена; протеза са ротационом шарком; примарна артропластика; анализа преживљавања; функционални исход