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Clinical Outcomes Following Revision Total Knee Arthroplasty: Minimum 2-Year Follow-up

Jonathan Quinn, MBBS, Peter Jones, PhD, Ray Randle, MBBS*

*Faculty of Health Sciences and Medicine, Bond University, Robina,
Gold Coast Centre for Bone and Joint Surgery, Gold Coast, Australia

Background: The longer-term outcomes of revision total knee arthroplasty are not well described in the current literature. Managing patient expectations of revision total knee arthroplasty can be challenging for orthopedic surgeons due to a paucity of data to guide decision-making. We present outcomes of revision total knee arthroplasty performed by a single surgeon over a 12-year period from 2004 through 2015.

Methods: A retrospective review of hospital and private medical records demonstrated 202 revision total knee arthroplasties performed by the senior author in 178 patients from 2004 through 2015. Of these, 153 patients were available for assessment. Patients were contacted and invited to participate in a structured telephone interview to assess Oxford Knee Score (OKS) and patient satisfaction. All patients received the PFC (Depuy) prosthesis at a single institution and were followed up for minimum 2 years postoperatively at the time of review. Retrospective chart review was used to obtain other data for analysis including patient demographics, preoperative and postoperative range of motion (ROM), and intraoperative details.

Results: This cohort demonstrated a 93.5% survival rate and an 85% satisfaction rate at a mean of 6.5 years postoperatively. Mean ROM improved from 100° (range, 5°–145°) to 112° (range, 35°–135°) ($p < 0.001$). The mean OKS was 39.25 (range, 14–48). The factors associated with improved postoperative outcomes included male sex, fewer previous revision total knee arthroplasty procedures, increased preoperative ROM, and receiving a less constrained implant.

Conclusions: This study provides a comprehensive description of outcomes following revision total knee arthroplasty in a large patient cohort with a long follow-up. Although revision total knee arthroplasty is a challenging and complex aspect of arthroplasty surgery, high patient satisfaction and good functional outcomes can be achieved for the majority of patients.

Keywords: *Knee, Total knee arthroplasty, Revision total knee arthroplasty*

The long-term outcomes following revision total knee arthroplasty (RTKA) and factors that contribute to these outcomes remain an area of important research in orthopaedics. While the outcomes following primary total knee arthroplasty (TKA) have been well documented, the long-term outcomes of RTKA are less robustly supported by

the literature. Although RTKA has been shown to result in considerable improvement in outcomes in comparison to the pre-RTKA condition,¹⁾ the factors affecting outcomes following RTKA are poorly understood.²⁾ It remains widely accepted that RTKA is a challenging surgical procedure^{3,4)} and that postoperative outcomes are poorer than those for primary TKA.³⁻⁶⁾

The reasons for increased difficulty of surgery and poorer outcomes have been attributed to difficult surgical exposure, stiffness, adhesion of tissues, instability due to ligamentous laxity, and poor bone stock.⁴⁾ The revision procedure imparts an additional burden of disability onto patients, and accordingly most revision patients will never experience an outcome as favorable as their pri-

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Correspondence to: Jonathan Quinn, MBBS

Faculty of Health Sciences and Medicine, Bond University, PO Box 809, Burleigh Heads, Queensland 4220, Australia

Tel: +61-4-247-6484, Fax: +61-7-5598-0294

E-mail: jonathan.quinn@student.bond.edu.au

mary procedure.⁵⁾

The paucity of information available to guide the patient and the surgeon in decision-making and postoperative expectations for RTKA is a current challenge for orthopedic surgeons. We investigated and reported the mid- to long-term outcomes in patients undergoing RTKA performed by a single surgeon (RR) using a single prosthesis design (PFC; Depuy Synthes, Warsaw, IN, USA) at a single institution. We also identified factors that may contribute to intraoperative management decisions and postoperative outcomes.

METHODS

Ethical approval was obtained from the Institutional Health Research Ethics Committee (No. BUHREC 0000015604). Patients were identified through operative and clinical records. Patients were contacted by telephone for consent and completion of a structured assessment questionnaire, including the Oxford Knee Score (OKS) and satisfaction assessment (patient-rated numerical score, 0–10 with Mahomed Satisfaction Scale). A chart review of hospital and orthopedic documentation was then conducted to extract other key data, selected prior to study commencement based on clinical relevance.

Inclusion criteria were as follows: RTKA (replacement of all major components) performed by the senior author (RR) from 2004 through 2015 using the PFC prosthesis (Depuy Synthes) at John Flynn Private Hospital and a minimum follow-up of 2 years since RTKA. Patients were excluded from functional and satisfaction outcome assessment if they had received a subsequent re-revision by a different surgeon, but were included in assessment for RTKA failure/survivorship. Failure was defined as undergoing re-revision TKA.

IBM SPSS ver. 26 (IBM Corp., Armonk, NY, USA) was used for statistical analysis, utilizing Mann-Whitney test, Wilcoxon signed rank test, Kruskal-Wallis test, Spearman correlation coefficient, and chi-square tests. Binary regression, multinomial regression, and Spearman's correlation coefficient testing were used to assess the impact of preoperative range of motion (ROM) on intraoperative variables.

A total of 202 RTKAs were performed in 178 patients during the study period and met inclusion criteria. Of these, 27 patients (29 RTKAs) were deceased at the time of review, 14 patients (16 RTKAs) were unable to be contacted, and 4 patients (4 RTKAs) declined to participate. Therefore, 153 RTKAs (133 patients) were assessed by telephone using OKS and satisfaction scores and in-

cluded in the analysis. Patient characteristics are summarized in Table 1.

All patients who underwent RTKA for infection received a two-stage revision with a minimum of 6 weeks between initial debridement and removal of implants and the second-stage revision. Implant constraint required was determined intraoperatively, with cruciate-retaining (CR) used in 43 patients, posterior-stabilized (PS) used in 73 patients, TC3 used in 29 patients, and a hinged implant used in 8 patients. Preoperative, intraoperative, and postoperative data were collected and analyzed.

Further to the reporting of postoperative clinical outcomes following RTKA, the primary objective of statistical analysis was the identification of significant factors (preoperatively and intraoperatively) on postoperative outcomes. We considered the most important postoperative outcome variables to be OKS, ROM at 1 year, and failure of RTKA. Clinical assessment was performed postoperatively until a minimum of 1 year after RTKA. ROM was assessed

Table 1. Patient Characteristics

Characteristic	Value
Male sex, % (n)	57 (71)
Time since RTKA (yr)	6.5 ± 3.1 (2–13)
Age at time of review (yr)	74.8 ± 8.8 (49–98)
Age at time or RTKA (yr)	68.3 ± 9.1 (45–90)
Age at time of primary TKA (yr)	60.1 ± 8.9 (32–86)
Weight at time of surgery (kg)	84.4 ± 16.2 (50–130)
BMI at time of surgery (kg/m ²)	29.9 ± 4.9 (19–46)
ASA score	2.4 (1–4)
Diabetic status	19 (2 type 1, 17 type 2)
Smoking status	Current, 5%; past, 32%; never, 63%
Reason for primary TKA	OA, 150; RA, 1; juvenile arthritis, 1; trauma, 1
Number of prior revisions	26 Patients had prior RTKA (range, 1–4)
Reason for RTKA	Loosening, 51; infection, 34; instability, 14; UKA/PFJ progression of disease, 13; pain, 11; stiffness, 5; other, 25

Values are presented as mean ± standard deviation (range), mean (range), or number unless otherwise indicated.

RTKA: revision total knee arthroplasty, TKA: total knee arthroplasty, BMI: body mass index, ASA: American Society of Anesthesiologists, OA: osteoarthritis, RA: rheumatoid arthritis, UKA: unicompartmental knee arthroplasty, PFJ: patellofemoral joint.

postoperatively by the senior author, using a goniometer. Radiographic evaluation was conducted postoperatively according to the senior author's routine care.

RESULTS

Operative details are summarized in Table 2. Statistical analysis results are presented in Table 3. Postoperative functional outcomes demonstrated a mean OKS of 39.25 (range, 14–48). Mean ROM increased from 100° (range, 5°–145°) preoperatively to 112° (range, 35°–135°) at 1 year postoperatively ($p < 0.001$). Statistically significant factors on postoperative OKS included male sex ($p = 0.02$), fewer previous RTKA operations ($p = 0.001$), higher preoperative ROM ($p \leq 0.001$), and implant type (highest OKS in CR group and lowest OKS in hinge group, $p \leq 0.001$). Reason for revision approached, but did not achieve statistical significance ($p = 0.058$), with the stiffness group having the highest OKS and instability group having the lowest OKS. Other factors that were not related to postoperative OKS include age ($p = 0.228$), weight ($p = 0.081$), body mass index (BMI; $p = 0.314$), polyethylene thickness ($p = 0.415$), and surgical time ($p = 0.720$). Reason for revision demonstrated a statistically significant difference between groups for 1-year ROM ($p = 0.007$). ROM was lowest for the stiffness group and greatest for the instability group.

Number of previous RTKA operations demonstrated a statistically significant influence on 1-year postoperative ROM ($p = 0.032$). Increased number of revisions resulted in a lower ROM. Implant type, polyethylene thickness, and

surgical time did not demonstrate a statistically significant difference in ROM at 1 year postoperatively ($p = 0.097$, $p = 0.386$, and $p = 0.543$, respectively). Preoperative and 1-year postoperative ROM demonstrated a statistically significant correlation ($p \leq 0.001$).

Preoperative ROM did not demonstrate a significant impact on the intraoperative implant used or surgical time. A moderate relationship was found between the number of previous RTKAs and implant type ($\Phi = 0.388$, $p = 0.027$), with increased constraint implant used as the number of previous RTKAs increased. Postoperative blood transfusion was required in 15% of RTKAs. Duration of hospital stay was a mean of 7.6 days (range, 3–42 days). Two patients required readmission within 30 days of discharge. Nineteen patients had a postoperative complication within 90 days of surgery: 9 patients with stiffness requiring manipulation under anesthesia, 6 superficial surgical site infections (1 requiring intravenous antibiotics), 1 postoperative pain, 1 wound dehiscence after a fall, 1 hemarthrosis, and 1 pulmonary embolism.

Approximately 85% of patients were satisfied with their RTKA and stated that they would undergo an RTKA again. Survival rate of 93.5% was demonstrated within the patients who were able to be contacted by telephone. Ten RTKAs in 9 patients demonstrated failure of TKA and required re-revision. Eight RTKAs (7 patients) were re-revised by the senior author, and 2 were re-revised by a different surgeon. Hospital and orthopedic charts for all patients were reviewed, with no evidence of failure/re-revision in any patients unable to be contacted by telephone.

Infection was the most common cause of RTKA failure, occurring in 2 of 2 failures within 1 year, 4 of 6 failures within 5 years, and 6 of 10 failures in total. Other causes for re-revision were periprosthetic fracture, impingement, loosening, and pain. Mean time from RTKA to re-revision was 4.5 years (range, 0.6–10 years). Cases of re-revision for infection had a mean of 3.6 years (range, 0.6–8.2 years) between RTKA and re-revision. Aseptic causes of re-revision had a mean time of 5.7 years between RTKA and re-revision (range, 2.3–10 years). Within this cohort, 101 patients were available for 5-year or longer follow-up after RTKA. The failure rate at 5 years after RTKA in our cohort was 6% (6/101). The re-revisions by the senior author are now a mean of 4.9 years (range 1–9 years) since re-revision, with a mean OKS of 35.2 (range, 27–47). Five of the 7 patients are satisfied with their RTKA.

Table 2. Operative Details

Variable	Value
Implant type	CR, 43; PS, 73; TC3, 29; hinge, 8
Polyethylene thickness (mm)	10.7 ± 2.8 (8–22.5)
Cemented prosthesis	153
Antibiotics in cement	153
Stemmed implant	125 (99 femur and tibia, 4 femur alone, 22 tibia alone)
Bone augments used	67 (27 femur and tibia, 23 femur alone, 17 tibia alone)
Artificial augments used	84 (52 femoral posterior condyle, 67 distal femur, 15 femoral sleeve, 4 medial tibial plateau, 15 tibial sleeve)
Surgical time (min)	147 ± 36 (60–315)

Values are presented as number or mean ± standard deviation (range). CR: cruciate retaining, PS: posterior stabilized.

DISCUSSION

This study gives a comprehensive descriptive review of

Table 3. Statistical Results

Independent variable	Dependent variable	Test	Statistical significance	p-value
Sex	OKS	Mann-Whitney	Male, 40.5 ± 6.7; female, 37.7 ± 7.9	0.020*
Age (yr)	OKS	Spearman Rho	$R = -0.101$	0.228
Weight (kg)	OKS	Spearman Rho	$R = 0.150$	0.081
BMI (kg/m ²)	OKS	Spearman Rho	$R = -0.087$	0.314
Reason for revision	OKS	Kruskal-Wallis	Infection, 39.2 ± 6.6; loosening, 39.2 ± 7.7; stiffness, 43.2 ± 7.1; pain, 37.2 ± 8.5; instability, 34.0 ± 10.3; other, 39.6 ± 8.1; UKA/PFJ progression, 39.0 ± 8.9	0.058
Previous RTKAs	OKS	Spearman Rho	$R = -0.271$	0.001*
Preoperative ROM	OKS	Spearman Rho	$R = 0.388$	< 0.001*
Implant type	OKS	Kruskal-Wallis	CR, 42.7 ± 3.9; PS, 37.9 ± 7.0; TC3, 40.1 ± 7.6; hinge, 28.7 ± 12.1	< 0.001*
Polyethylene thickness (mm)	OKS	Spearman Rho	$R = -0.068$	0.415
Surgical time (min)	OKS	Spearman Rho	$R = 0.031$	0.720
Sex	1-Year ROM (°)	Mann-Whitney	Male, 112 ± 19.2; women, 108 ± 17.2	0.300
Age (yr)	1-Year ROM (°)	Spearman Rho	$R = -0.01$	0.905
Weight (kg)	1-Year ROM (°)	Spearman Rho	$R = 0.141$	0.094
BMI (kg/m ²)	1-Year ROM (°)	Spearman Rho	$R = 0.011$	0.893
Reason for revision	1-Year ROM (°)	Kruskal-Wallis	Infection, 107.2 ± 18.7; loosening, 113.8 ± 15.6; stiffness, 92.5 ± 10.2; pain, 103.7 ± 8.9; instability, 116 ± 12.2; other, 110.7 ± 15.1; UKA/PFJ progression, 113 ± 6.7	0.007*
Previous RTKAs	1-Year ROM (°)	Spearman Rho	$R = -0.174$	0.032*
Implant type	1-Year ROM (°)	Kruskal-Wallis	CR, 115 ± 11.9; PS, 109 ± 18.2; TC3, 114 ± 12.2; hinge, 100 ± 16.9	0.097
Polyethylene thickness (mm)	1-Year ROM (°)	Spearman Rho	$R = 0.071$	0.386
Surgical time (min)	1-Year ROM (°)	Spearman Rho	$R = -0.052$	0.543

OKS: Oxford Knee Score, BMI: body mass index, UKA: unicompartmental knee arthroplasty, PFJ: patellofemoral joint, RTKA: revision total knee arthroplasty, ROM: range of motion, CR: cruciate retaining, PS: posterior stabilized.

*Statistically significant difference between groups (two-tailed), $p < 0.05$.

outcomes following RTKA in a large patient cohort with a long follow-up. These patient outcomes following RTKA performed by a single surgeon using a single prosthesis at a single institution are one of the largest and most comprehensive data in the published literature. The preoperative, intraoperative, and postoperative characteristics can be used to guide understanding of the factors influencing patient outcomes after RTKA.

All patients in this cohort received the Depuy PFC prosthesis in RTKA performed by an experienced arthroplasty surgeon at a single center. Antibiotic-impregnated cement was used in all cases. All patients had preoperative

and intraoperative assessment for infection. For all cases, adjuncts such as increased constraint prostheses, augments, and bone allograft were available to enable the final result of a balanced, stable, well-fixed prosthesis.

This cohort of patients was similar to Australian national averages and international publications regarding reason for revision.⁷⁻¹¹ Postoperative outcomes in this cohort demonstrated a high survival rate (93.5% at a mean of 6.5 years) and satisfaction rate (85% satisfied). The postoperative complication rate was low and unexpected readmission within 90 days occurred in only 2 patients. The revision rate within this patient cohort is comparable

to the national revision rate for primary TKA.¹²⁾ National RTKA survival rates are significantly lower, with re-revision rates of 16% at 5 years and 23.8% at 10 years after RTKA, excluding patients who had initial RTKA for infection.¹³⁾ Current international literature estimates the overall complication rate for RTKA to be up to 26.3%, with 12.9% of RTKA requiring re-revision.¹⁾

Mean OKS at time of telephone follow-up was 39.25, demonstrating a successful functional outcome. The New Zealand Orthopaedic Association arthroplasty registry includes OKS after TKA and RTKA, with the mean OKS after RTKA of 32.85, and a mean OKS after primary TKA of 40.43 at 5 years and 39.87 at 10 years.¹⁴⁾ The results of this cohort contribute significantly to the growing body of knowledge surrounding outcomes following RTKA.

Rajgopal et al.¹⁵⁾ described no significant difference in outcome measures between RTKAs for septic and aseptic causes of failure in a retrospective review of 142 patient charts with a mean follow-up of 73 months. They concluded that septic failure does not preclude good outcomes of RTKA. In contrast, Barrack et al.¹⁶⁾ reported outcomes following 125 RTKAs with a mean follow-up of 36 months, showing that patients who underwent RTKA for infection had poorer postoperative functional and clinical outcomes. Despite these differences, satisfaction was similar between groups. van Kempen et al.¹⁷⁾ described the 2-year outcomes of 150 RTKA patients, with best functional results in the aseptic loosening group and poorest results in the stiffness group. We also identified reason for revision as having statistically significant influence on postoperative ROM and approaching statistical significance for postoperative OKS.

Mortazavi et al.¹⁸⁾ investigated failure of RTKA in 499 RTKAs with a mean follow-up of 64.8 months: 18.3% of RTKAs failed and required further surgery, with infection being the major cause (44.1%), and the majority of failures were found to occur within 2 years of RTKA. Similarly, Bae et al.¹⁹⁾ published on 224 RTKAs performed by a single surgeon using a single prosthesis over a period of 19 years with a mean follow-up of 8.1 years. They demonstrated a 5-year survival rate of 97.2% and 10-year survival rate of 86.1%.

We believe that there are a number of factors that have contributed to the high-quality outcomes for patients within our cohort. Firstly, all operations were performed by an experienced arthroplasty surgeon, familiar with the prosthesis and intraoperative technique. Secondly, the prosthesis used has demonstrated high-quality long-term outcomes with low revision rates over 15 years.⁷⁾ Thirdly, these patients underwent a well-structured postoperative

physiotherapy and rehabilitation program within a private healthcare setting.

There are a number of considerations that the senior author adopts in the approach to RTKA surgery. Firstly, preoperative diagnosis and intraoperative assessment for infection are critical; conversion to two-stage revision is required if evidence of infection is present. Secondly, appropriate preoperative planning and the availability of implant combinations and other surgical adjuncts such as bone graft and artificial augments are needed to avoid compromise intraoperatively. Thirdly, implant fixation and long-term joint stability should be anticipated at the completion of the operation. We believe that it is appropriate to accept increased level of constraint rather than instability. Postoperatively, rehabilitation is performed as per primary TKA, with consideration of weight bearing status variability based on grafts used. Finally, given the complexity of the surgical procedure involved in RTKA, consideration should be made to refer complex cases to high-volume RTKA subspecialist surgeons and an experienced surgical team. We believe that centralization likely improves patient outcomes in both short and long term.

Unfortunately, there is little opportunity preoperatively to address modifiable patient factors and thereby improve postoperative outcomes. The results of this study demonstrated no statistically significant difference in modifiable factors (weight and BMI) and postoperative outcomes (OKS and ROM). Instead, this research provides an insight into the likely postoperative outcomes given the patient's preoperative variables, such as preoperative ROM and the number of previous RTKA operations. This research also helps inform clinicians and therefore guide patients in their expectations of postoperative outcomes.

This study has a number of limitations, including selection bias, retrospective review of ROM assessment, and utilization of telephone interview techniques. Selection bias is present due to all patients receiving care by an experienced arthroplasty surgeon and by a surgical and perioperative team with minimal variation of members and established practices and the use of a prosthesis that has demonstrated good results and low revision rates over long-term follow-up.⁷⁾ This combination of factors is likely to contribute to successful outcomes and therefore these findings cannot be applied to all patients and surgical settings.

Patient ROM measurements were retrieved from orthopedic follow-up records, which were retrospectively reviewed. Although ROM was reliably measured with a goniometer by the senior author at set time points, we cannot guarantee that patient ROM remains unchanged

during the period from 1 year postoperatively to the time of telephone assessment. Current ROM may give a better insight into this outcome's effect on patient satisfaction; however, we consider the change in ROM after 1 year postoperatively to be minimal in most patients.^{2,20)}

The duration of follow-up (minimum, 2 years; mean, 6.5 years) represents mid-term outcomes; however, survival and satisfaction may not be maintained from this time point forward. Future follow-up is required to assess the change in outcomes over time within this cohort. Performing further clinical and radiographic assessment was considered at the time of study design; however, it was not practical given the geographic dispersion of this patient cohort. Patients' OKS and satisfaction were assessed by telephone, which may demonstrate slightly different results from written assessment.

This cohort of RTKA patients demonstrated successful outcomes at a mean of 6.5 years, with improvement in ROM, high patient satisfaction, a low complication rate, and high survivorship. Patients with a lower preoperative ROM or an increased number of previous RTKA procedures were more likely to require implants providing greater constraint. As in primary TKA, preoperative

ROM correlated with postoperative ROM. While RTKA is a challenging and complex aspect of arthroplasty surgery, high patient satisfaction and good functional outcomes can be achieved in the majority of patients. This should provide encouragement to patients and clinicians alike that successful outcomes are achievable following RTKA.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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ORCID

Jonathan Quinn <https://orcid.org/0000-0003-0374-2205>
 Peter Jones <https://orcid.org/0000-0003-2932-6971>
 Ray Randle <https://orcid.org/0000-0003-3524-9001>

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