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Multiply revised TKAs have worse outcomes compared to index revision TKAs

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Aims

Revision total knee arthroplasty (rTKA) is a technically challenging and costly procedure. It is well-documented that primary TKA (pTKA) have better survivorship than rTKA; however, we were unable to identify any studies explicitly investigating previous rTKA as a risk factor for failure following rTKA. The purpose of this study is to compare the outcomes following rTKA between patients undergoing index rTKA and those who had been previously revised.

Methods

This retrospective, observational study reviewed patients who underwent unilateral, aseptic rTKA at an academic orthopaedic speciality hospital between June 2011 and April 2020 with > one-year of follow-up. Patients were dichotomized based on whether this was their first revision procedure or not. Patient demographics, surgical factors, postoperative outcomes, and re-revision rates were compared between the groups.

Results

A total of 663 cases were identified (486 index rTKAs and 177 multiply revised TKAs). There were no differences in demographics, rTKA type, or indication for revision. Multiply revised patients had significantly longer rTKA operative times ($p < 0.001$), and were more likely to be discharged to an acute rehabilitation centre (6.2% vs 4.5%) or skilled nursing facility (29.9% vs 17.5%; $p = 0.003$). Patients who had been multiply revised were also significantly more likely to have subsequent reoperation (18.1% vs 9.5%; $p = 0.004$) and re-revision (27.1% vs 18.1%; $p = 0.013$). The number of previous revisions did not correlate with the number of subsequent reoperations ($r = 0.038$; $p = 0.670$) or re-revisions ($r = –0.102$; $p = 0.251$).

Conclusion

Multiply revised TKA had worse outcomes, with higher rates of facility discharge, longer operative times, and greater reoperation and re-revision rates compared to index rTKA.

Cite this article: *Bone Jt Open* 2023;4-5:393–398.

Keywords: total knee arthroplasty, revision knee arthroplasty, risk factors, outcomes, re-revision

Introduction

Revision total knee arthroplasty (rTKA) is a technically challenging and costly procedure. As Bozic et al[1] demonstrated in their 2010 report examining rTKA from the National Inpatient Sample (NIS) database, the average hospital stay for all rTKA procedures was 5.1 days, with an average total bill of $49,360.[1] These charges varied by rTKA type, with all component revisions having the highest bills at $56,087, while patellar component revision procedures had the lowest charges at $26,047. In Bhandari et al's[2] 2012 article, they outlined that over 55,000 revision surgeries were performed in 2010 in the USA.[3] Assuming a cost of $49,000 per case, in 2010, the annual economic burden of rTKA was $2.7 billion for hospital charges alone.[2] In 2018, 67,370 patients had the Clinical Classification Software Refined (CCSR) code INJ035 (Complication of internal orthopaedic device or implant, initial encounter),

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doi: 10.1302/2633-1462.45.BJO-2023-0025.R1

Bone Jt Open 2023;4-5:393–398.

bringing the annual economic burden of rTKA to $3.3 billion for hospital charges alone, assuming that the cost per rTKA has not changed.[4] Considering the projections put forth by article,[5] there will be 268,200 rTKAs performed in the year 2030.[5] Ignoring inflation and changes in cost, this will place a burden of $13.1 billion on the USA healthcare system from rTKA hospital charges alone. This value is likely an underestimate, as costs associated with rTKA have been increasing, primarily due to greater preoperative workup and more expensive modern implants.[6,7]

Given the cost of the rising rTKA burden, it is essential to understand risk factors that may affect a patient's odds of requiring one or more revision surgeries following TKA. Reports in the literature have shown that patient factors, including young age,[8] obesity,[9] male sex,[10] and African American race,[10] are independent risk factors for rTKA.[11,12] It is well documented that primary TKA (pTKA) have better survivorship than rTKA. In the series published by Bae et al,[13] the ten-year survival rates following rTKA was 86.1%, which is much less than the ten-year survival rates of 96% and 94% following pTKA reported in the Swedish and Australian registries, respectively.[14,15] Given these findings, it is intuitive to extrapolate that patients who have previously had rTKA are at greater risk for subsequent re-revision than their non-revised counterparts. However, we were unable to identify any studies explicitly investigating previous rTKA as a risk factor for failure following rTKA. Therefore, the purpose of this study is to investigate patients undergoing their first revision TKA (index; irTKA) and patients undergoing a revision TKA after their first revision TKA (multiply revised; mrTKA). Postoperative outcomes, including hospital length of stay, discharge disposition, 90-day emergency department visits and readmissions, reoperations, and re-revisions will be compared between mrTKA and irTKA patients. We hypothesize that patients undergoing re-revision surgery (mrTKA) are at greater risk for short-term poor outcomes as compared to patients undergoing index rTKA (irTKA).

Methods

After receiving approval from our institutional review board (IRB), the rTKA database at our large, urban, academic institution (NYU Langone Health, New York, USA) was retrospectively queried for all patients who underwent index, aseptic, unilateral rTKA between June 2011 and April 2020. Any patients who underwent bilateral revision, revision for periprosthetic infection, or conversion arthroplasty from unicompartmental knee arthroplasty or previous fracture fixation were excluded from the study. Only patients with at least one year of documented follow-up (office visit notes or radiological imaging, whichever was most recent) were included.

Demographic information (age, sex, race, BMI, American Society of Anesthesiology (ASA) score, and smoking status), admission data (implants revised, indication for revision, date of surgery, length of stay (LOS), and surgical history (date of pTKA and index rTKA) were collected from our electronic medical record warehouse, Epic (USA).

Implants revised included femoral component, polyethylene liner, tibial baseplate, and patellar button. Full rTKA required revision of the femoral component, polyethylene liner, and tibial baseplate. Femoral rTKA required revision of the femoral component without revision of the tibial baseplate. Tibial rTKA required revision of the tibial baseplate without revision of the femoral component. Polyethylene liner exchanges required revision of the polyethylene liner without revision of the femoral component or tibial baseplate. Patellar rTKA required revision of the patellar component without revision of the femoral, or tibial components.

Hospital LOS was determined as the whole number of days between admission and discharge. Surgical time was calculated as the time between incision start and incision close. Discharge disposition categories included discharge to home with either self-care or home health services, discharge to an acute rehabilitation facility, discharge to a skilled nursing facility, and "other" discharge, which were discharges to places that did not fall into any of these categories. Emergency department (ED) and readmissions within 90 days, all reoperations, and all re-revisions were dichotomized to, "yes" or "no".

A reoperation was defined as any procedure requiring return to the operating room following rTKA that was related to the ipsilateral knee and did not require a change in implants. A re-revision was defined as any procedure requiring return to the operating room following the rTKA that was related to the ipsilateral knee and did require a change in implants. Patients were dichotomized into irTKA and mrTKA based on whether the index rTKA surgery was their first rTKA following primary TKA or if they had one or more previous rTKA prior to the index rTKA.

Statistical analysis. Categorical variables were analyzed using a chi-square analysis or Fisher's exact test as appropriate. Continuous variables were analyzed using an independent-samples *t*-test. SPSS Statistics version 25 (IBM, USA) was used for the statistical analyses. The level for statistical significance was set at $p < 0.05$.

Results

Patient selection. Our institution's rTKA database was reviewed for rTKA cases performed between June 2011 and April 2020. During this timeframe, 1,671 rTKA were identified;;663 cases met the inclusion criteria, with 486 irTKA and 177 mrTKA. Overall, 527 rTKAs (31.5%) were excluded for revision for septic reasons. Six rTKAs (0.36%) were excluded for simultaneous bilateral revisions. A total of 69 rTKAs (4.1%) were excluded for conversion arthroplasty

Table I. Demographic information.

Variable	Multiply revised (n = 177)	Index (n = 486)	p-value
Mean age, yrs (SD)	62.19 (10.04)	63.59 (9.02)	0.086*
Sex, n (%)			
Male	65 (36.7)	147 (30.2)	0.132†
Female	112 (63.3)	339 (69.8)	
Race, n (%)			
White	102 (58.0)	251 (52.0)	
Black	46 (26.1)	135 (28.0)	0.134‡
Asian	6 (3.4)	8 (1.7)	
Other	22 (12.5)	89 (18.4)	
Mean BMI, kg/m² (SD)	34.11 (6.80)	33.07 (6.75)	0.091*
ASA score, n (%)			
1	4 (2.4)	6 (1.3)	
2	86 (51.8)	237 (52.9)	0.807‡
3	72 (43.4)	196 (43.8)	
4	4 (2.4)	9 (2.0)	
Smoking status, n (%)			
Never	94 (53.1)	272 (56.1)	0.725‡
Former	71 (40.1)	178 (36.7)	
Current	12 (6.8)	35 (7.2)	
Laterality, n (%)			
Right	97 (54.8)	269 (55.3)	0.930†
Left	80 (45.2)	217 (44.7)	

*Independent-samples *t*-test.
†Fisher's exact test.
‡Chi-squared test.
ASA, American Society of Anesthesiologists; SD, standard deviation.

Table II. Surgical information for all revisions.

Variable	Multiply revised (n = 177)	Index (n = 486)	p-value
Type of revision, n (%)			
Full	85 (48.0)	268 (55.1)	
Femoral	21 (11.9)	34 (7.0)	0.248*
Tibial	19 (10.7)	54 (11.1)	
Liner	40 (22.6)	103 (21.2)	
Patellar	12 (6.8)	27 (5.6)	
Reason for revision, n (%)			
Arthrofibrosis/ stiffness/ankylosis	27 (15.3)	80 (16.5)	
Aseptic loosening	61 (34.5)	183 (37.7)	
Component malpositioning	4 (2.3)	16 (3.3)	
Extensor mechanism/patellar clunk	10 (5.6)	16 (3.3)	
Periprosthetic fracture	5 (2.8)	16 (3.3)	0.161*
Implant failure	6 (3.4)	16 (3.3)	
Instability/ dislocation	55 (31.1)	129 (26.5)	
Liner wear	4 (2.3)	19 (3.9)	
Metallosis	3 (1.7)	0 (0.0)	
Nickel metal allergy	1 (0.6)	1 (0.2)	
Osteoarthritis	1 (0.6)	8 (1.6)	
Osteolysis	0 (0.0)	2 (0.4	
Mean surgical time, mins (SD)	133.42 (63.50)	113.54 (49.23)	< 0.001†

*Chi-squared test.
†Independent-samples *t*-test.
SD, standard deviation.

from bicompartmental, or unicompartmental knee arthroplasty. Overall, eight rTKAs (0.48%) were excluded for patella component removal only, with the patella left unresurfaced, and 389 rTKAs (23.8%) were excluded for inadequate follow-up.

Patient demographics. There were no significant differences between the two cohorts with respect to age, sex, race, BMI, ASA score, and smoking status (Table I).

Procedural information. There were no differences in rTKA type or indication for rTKA between the two groups (Table II). mrTKA procedures had significantly longer operative times by approximately 20 minutes (mrTKA 133.42 minutes (standard deviati0n (SD) 63.50 vs irTKA 113.54 minutes (SD 49.23); p < 0.001, independent-samples *t*-test). When looking specifically at full rTKA, mrTKA had longer operative times by nearly 27 minutes (mrTKA 164.40 minutes (SD 49.26) vs irTKA 137.56 minutes (SD 43.28); p < 0.001, independent-samples *t*-test).

Short-term outcomes. There were no differences between the two cohorts with respect to hospital length of stay, all-cause 90-day emergency department visits, all-cause 90-day hospital readmissions, and number of re-revisions. mrTKA patients were significantly more likely to be discharged to an acute rehabilitation centre (6.2% vs 4.5%) or skilled nursing facility (29.9% vs 17.5%; p = 0.003, chi-squared test). Similar trends were seen when examining the full rTKA sub-analysis: mrTKA patients were significantly more likely to be discharged to a skilled nursing facility (37.6% vs 19.4%) or acute rehabilitation facility (7.1% vs 5.6%; p = 0.005, chi-squared test).

Patients who had undergone mrTKA were also significantly more likely to have subsequent reoperation (18.1% vs 9.5%; p = 0.004, Fisher's exact test) and re-revision (27.1% vs 18.1%; p = 0.013, Fisher's exact test; Table III). Revision number did not significantly correlate with the number of subsequent reoperations (r = 0.038; p = 0.670, Pearson correlation) or re-revisions (r = –0.102; p = 0.251, Pearson correlation).

A subanalysis of the full rTKA group can be found in Tables IV–V.

Discussion

Given the dramatic projected increase in rTKA incidence by 2030,[5] it is imperative to understand the risk factors that both predict a patient's likelihood of undergoing rTKA and their outcomes following rTKA. Having a previous revision is an easily identifiable risk factor that intuitively portends future issues, notably due to the need for repeat skin incision and arthrotomy. This can predispose re-revisions to increased infection risk and soft-tissue attenuation, as well as significant bone loss

Table III. Outcome information for all revisions.

Variable	Multiply revised (n = 177)	Index (n = 486)	p-value
Mean length of stay, days (SD)	7.31 (18.61)	7.48 (18.76)	0.915*
Discharge disposition, n (%)			
Home	112 (63.3)	376 (77.4)	0.003†
Acute rehabilitation facility	11 (6.2)	22 (4.5)	
Skilled nursing facility	53 (29.9)	85 (17.5)	
Other	1 (0.6)	3 (0.6)	
All cause 90 day ED visit, n (%)	10 (5.6)	20 (4.1)	0.402‡
All cause 90 day readmission, n (%)	26 (14.7)	49 (10.1)	0.126‡
Reoperation, n (%)	32 (18.1)	46 (9.5)	0.004‡
Re-revision, n (%)	48 (27.1)	88 (18.1)	0.013‡
Mean no. of re-revisions (SD)	0.38 (0.78)	0.27 (0.67)	0.077*
Mortality, n (%)	1 (0.6)	2 (0.4)	1.000‡

*Independent-samples *t*-test.
†Chi-squared test.
‡Fisher's exact test.
ED, emergency department; SD, standard deviation.

Table IV. Surgical information for full revisions.

Variable	Multiply revised (n = 85)	Index (n = 268)	p-value
Reason for revision, n (%)			
Arthrofibrosis/stiffness/ankylosis	15 (17.6)	44 (16.4)	0.497*
Aseptic loosening	32 (37.6)	107 (39.9)	
Component malpositioning	2 (2.4)	12 (4.5)	
Extensor mechanism/patellar clunk	2 (2.4)	7 (2.6)	
Periprosthetic fracture	4 (4.7)	9 (3.4)	
Implant failure	2 (2.4)	7 (2.6)	
Instability/dislocation	23 (27.1)	67 (25.0)	
Liner wear	2 (2.4)	8 (3.0)	
Metallosis	2 (2.4)	0 (0.0)	
Nickel metal allergy	1 (1.2)	1 (0.4)	
Osteoarthritis	0 (0.0)	4 (1.5)	
Osteolysis	0 (0.0)	2 (0.7)	
Mean surgical time, mins (SD)	164.40 (49.26)	137.56 (43.28)	< 0.001†

*Chi-squared test.
†Independent-samples *t*-test.
SD, standard deviation.

Table V. Outcome information for full revisions.

Variable	Multiply revised (n = 85)	Index (n = 268)	p-value
Mean length of stay, days (SD)	10.12 (24.75)	9.09 (20.53)	0.702*
Discharge disposition, n (%)			
Home	47 (55.3)	200 (74.6)	0.005†
Acute rehabilitation facility	6 (7.1)	15 (5.6)	
Skilled nursing facility	32 (37.6)	52 (19.4)	
Other	0 (0.0)	1 (0.4)	
All cause 90 day ED visit, n (%)	8 (9.4)	13 (4.9)	0.184‡
All cause 90-day readmission, n (%)	14 (16.5)	33 (12.3)	0.360‡
Reoperation, n (%)	10 (11.8)	33 (12.3)	1.000‡
Re-revision, n (%)	13 (15.3)	45 (16.8)	0.867‡
Mean no. of re-revisions (SD)	0.26 (0.67)	0.20 (0.53)	0.470*

*Independent-samples *t*-test.
†Chi-squared test.
‡Fisher's exact test.
ED, emergency department; SD, standard deviation.

and periprosthetic fracture due to repeated component removal.[16-18] Previous registry studies have demonstrated that multiply revised patients undergo re-revision at a higher rate than index revision patients, and each subsequent revision survives for approximately half of the time as the preceding revision.[19] Our study seeks to build on this finding by looking specifically at a large tertiary referral hospital with an orthopedic-speciality hospital.

In the present study, mrTKA had significantly worse outcomes, with higher rates of facility discharge, longer operative times, and greater reoperation and re-revision rates, compared to irTKA. Although the comparison between index and multiply revised rTKA have not been explicitly studied in the literature, our findings align with reports that have demonstrated that rTKA have worse outcomes than pTKA. As Roman et al[20] detailed, complications following rTKA varied between 5% and 50%, depending on the literature, including persistent stiffness, neurovascular impairment, extensor mechanism damage, wound healing issues, thrombosis, infection, instability, and periprosthetic fractures.[21,22]

Patients who underwent mrTKA had higher rates of discharge to a facility as compared to patients who underwent irTKA. The reason for this difference is likely multifactorial. Given the higher rates of stiffness and instability following rTKA, as well as greater restrictions on ambulatory and weightbearing status, mrTKA patients likely have slower recoveries than their irTKA counterparts. These factors likely all contribute to worse postoperative function and mobilization, necessitating a stay in a postoperative facility to ensure a safe discharge appropriate for their level of function.[16,17,23,24]

The longer operative times for mrTKA can also be explained by case complexity. Knees that have been multiply revised likely have a higher degree of skin, soft tissue, and bone loss compared to knees that have never been revised. This requires more complicated reconstructions to achieve construct stability, including the use of augments, stems, metaphyseal cones, and sleeves.[18,25] Similarly, the repetitive skin, soft tissue, and joint capsule disruptions necessitate a meticulous wound closure at the end of the case. These types of closures may require intraoperative plastic surgery consultation, which may also have contributed to the longer surgical times for the mrTKA group. Similar findings are reported when

comparing primary and revision TKA, emphasizing that additional revisions likely portends worse outcomes.[26]

Finally, mrTKA patients underwent reoperation and re-revision at two-times and 1.5-times the rate of irTKA patients, respectively. These results are consistent with reports in the literature comparing pTKA to rTKA. Ong et al[27] examined 72,913 pTKA and 1,599 rTKA from the 5% Medicare claims dataset and found patients with rTKA were five- to six-times more likely to undergo re-revision (adjusted relative risk, 5.71). They postulated that the reason behind this finding was multifactorial, including rTKA being a more technically demanding procedure, the additional loss of bone stock, the longer operative times, or a consequence of the original diseased joint.[27–29] Our study findings parallel these to a lesser degree, which we believe is likely because all of our patients had at least one prior rTKA surgery (irTKA with prior pTKA, mrTKA with prior pTKA, and subsequent one or more rTKA). Similarly, Deere et al[19] showed that about 20% of rTKA in the UK/Wales' National Joint Registry were revised again within 13 years, 21% of second rTKA were revised again within five years, and 21% of third rTKA were revised again within three years. This study mirrors our findings that multiply revised patients undergo re-revision at a higher rate than index revision patients, and each subsequent revision survives, before undergoing another revision, for approximately half of the time as the preceding revision.

Limitations. Given this study's retrospective observational design, there are several inherent limitations, including the possibility for collection error and selection bias. However, the groups were well-matched with respect to demographic data points, type of rTKA, and indication for rTKA, which can help mitigate some bias introduced by the retrospective design. Second, given that this study was conducted at one large, academic, urban tertiary referral centre that performs a high volume of rTKA, these results may not necessarily be generalizable to smaller community centres in other areas of the country. Third, this study has a relatively limited sample size. Larger studies are necessary to confirm these findings across different patient populations and institutions. Fourth, data on clinical and patient-reported outcomes were inconsistently recorded in the medical chart and therefore we were unable to compare these data points between irTKA and mrTKA. Fifth, our centre is a large tertiary referral centre in an academic setting in a large metropolitan area. Although not all the patients in this study had their primary TKA performed at our institution, many of the cases that we perform are on patients with complicated primary TKA, predisposing them to requiring revision surgery. This factor likely contribute to the younger average age of patients in our study. This may limit the generalizability of our study to other populations in small cities and rural areas. Finally, we had to exclude many cases due to inadequate follow-up, which may contribute to selection bias. Additionally, our minimum follow-up was one year, which likely will not capture all complications encountered by this high-risk group.

In conclusion, mrTKA patients had significantly longer operative times, greater rates of facility discharge, and higher rates of reoperation and re-revision as compared to patients undergoing irTKA. Understanding the effect of previous rTKA on future rTKA is important for intraoperative and postoperative planning, and surgeons should be aware of these differences when counselling their patients prior to rTKA. Minimizing the complications and re-revisions associated with mrTKA will help reduce the burden of rTKA on the healthcare system and improve patient quality of life after rTKA.

Take home message

- Multiply-revised total knee arthroplasty (mrTKA) patients had longer operative times, lower home discharge rates, and higher reoperation and re-revision rates compared to patients undergoing index revision TKA.
- Understanding these differences is important for intraoperative and postoperative planning.
- Minimizing complications and re-revisions associated with mrTKA will help reduce the burden of revision TKA (rTKA) on the healthcare system and improve patient quality of life after rTKA.

References

1. **Bozic KJ**, **Kurtz SM**, **Lau E**, **et al**. The epidemiology of revision total knee arthroplasty in the United States. *Clin Orthop Relat Res*. 2010;468(1):45–51.
2. **Bhandari M**, **Smith J**, **Miller LE**, **Block JE**. Clinical and economic burden of revision knee arthroplasty. *Clin Med Insights Arthritis Musculoskelet Disord*. 2012;5:89–94.
3. Agency for Healthcare Research and Quality. 2010. https://www.ahrq.gov/data/hcup/index.html (date last accessed 11 May 2023).
4. Agency for Healthcare Research and Quality. HCUPnet: HCUPnet Healthcare Cost and Utilization Project. 2018. https://datatools.ahrq.gov/hcupnet-dua (date last accessed 11 May 2023).
5. **Kurtz S**, **Ong K**, **Lau E**, **Mowat F**, **Halpern M**. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am*. 2007;89(4):780–785.
6. **Oduwole KO**, **Molony DC**, **Walls RJ**, **Bashir SP**, **Mulhall KJ**. Increasing financial burden of revision total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(7):945–948.
7. **Okafor C**, **Hodgkinson B**, **Nghiem S**, **Vertullo C**, **Byrnes J**. Cost of septic and aseptic revision total knee arthroplasty: a systematic review. *BMC Musculoskelet Disord*. 2021;22(1):706.
8. **Wainwright C**, **Theis JC**, **Garneti N**, **Melloh M**. Age at hip or knee joint replacement surgery predicts likelihood of revision surgery. *J Bone Joint Surg Br*. 2011;93(10):1411–1415.
9. **Kerkhoffs G**, **Servien E**, **Dunn W**, **Dahm D**, **Bramer JAM**, **Haverkamp D**. The influence of obesity on the complication rate and outcome of total knee arthroplasty: a meta-analysis and systematic literature review. *J Bone Joint Surg Am*. 2012;94(20):1839–1844.
10. **Blum MA**, **Singh JA**, **Lee G-C**, **Richardson D**, **Chen W**, **Ibrahim SA**. Patient race and surgical outcomes after total knee arthroplasty: an analysis of a large regional database. *Arthritis Care Res (Hoboken)*. 2013;65(3):414–420.
11. **Hamilton DF**, **Howie CR**, **Burnett R**, **Simpson AHRW**, **Patton JT**. Dealing with the predicted increase in demand for revision total knee arthroplasty: challenges, risks and opportunities. *Bone Joint J*. 2015;97-B(6):723–728.
12. **Jasper LL**, **Jones CA**, **Mollins J**, **Pohar SL**, **Beaupre LA**. Risk factors for revision of total knee arthroplasty: a scoping review. *BMC Musculoskelet Disord*. 2016;17:182.
13. **Bae DK**, **Song SJ**, **Heo DB**, **Lee SH**, **Song WJ**. Long-term survival rate of implants and modes of failure after revision total knee arthroplasty by a single surgeon. *J Arthroplasty*. 2013;28(7):1130–1134.

14. **Parkinson B**, **Armit D**, **McEwen P**, **Lorimer M**, **Harris IA**. Is Climate Associated With Revision for Prosthetic Joint Infection After Primary TKA? *Clin Orthop Relat Res*. 2018;476(6):1200–1204.
15. The Swedish knee Arthroplasty Register annual report. 2010. https://www.myknee.se/pdf/114_SKAR2010_Eng1.0.pdf (date last accessed 11 May 2023).
16. **Liang H**, **Bae JK**, **Park CH**, **Kim KI**, **Bae DK**, **Song SJ**. Comparison of mode of failure between primary and revision total knee arthroplasties. *Orthop Traumatol Surg Res*. 2018;104(2):171–176.
17. **Mortazavi SMJ**, **Molligan J**, **Austin MS**, **Purtill JJ**, **Hozack WJ**, **Parvizi J**. Failure following revision total knee arthroplasty: infection is the major cause. *Int Orthop*. 2011;35(8):1157–1164.
18. **Fleaca SR**, **Mohor CI**, **Dura H**, **et al**. Effect of patella resurfacing on functional outcome and revision rate in primary total knee arthroplasty (Review). *Exp Ther Med*. 2022;23(1):104.
19. **Deere K**, **Whitehouse MR**, **Kunutsor SK**, **et al**. How long do revised and multiply revised knee replacements last? An analysis of the National Joint Registry. *Lancet Rheumatol*. 2021;3(6):e438–e446.
20. **Roman MD**, **Russu O**, **Mohor C**, **et al**. Outcomes in revision total knee arthroplasty (Review). *Exp Ther Med*. 2022;23(1):29.
21. **Rosso F**, **Cottino U**, **Dettoni F**, **Bruzzone M**, **Bonasia DE**, **Rossi R**. Revision total knee arthroplasty (TKA): mid-term outcomes and bone loss/quality evaluation and treatment. *J Orthop Surg Res*. 2019;14(1):280.
22. **Evangelopoulos DS**, **Ahmad SS**, **Krismer AM**, **et al**. Periprosthetic Infection: Major Cause of Early Failure of Primary and Revision Total Knee Arthroplasty. *J Knee Surg*. 2019;32(10):941–946.
23. **Kennedy DM**, **Hanna SE**, **Stratford PW**, **Wessel J**, **Gollish JD**. Preoperative function and gender predict pattern of functional recovery after hip and knee arthroplasty. *J Arthroplasty*. 2006;21(4):559–566.
24. **Ditton E**, **Johnson S**, **Hodyl N**, **et al**. Improving Patient Outcomes Following Total Knee Arthroplasty: Identifying Rehabilitation Pathways Based on Modifiable Psychological Risk and Resilience Factors. *Front Psychol*. 2020;11:1061.
25. **Radnay CS**, **Scuderi GR**. Management of bone loss: augments, cones, offset stems. *Clin Orthop Relat Res*. 2006;446:83–92.
26. **Stirling P**, **Middleton SD**, **Brenkel IJ**, **Walmsley PJ**. Revision total knee arthroplasty versus primary total knee arthroplasty: a matched cohort study. *Bone Jt Open*. 2020;1(3):29–34.
27. **Ong KL**, **Lau E**, **Suggs J**, **Kurtz SM**, **Manley MT**. Risk of subsequent revision after primary and revision total joint arthroplasty. *Clin Orthop Relat Res*. 2010;468(11):3070–3076.
28. **Bozic KJ**, **Katz P**, **Cisternas M**, **Ono L**, **Ries MD**, **Showstack J**. Hospital resource utilization for primary and revision total hip arthroplasty. *J Bone Joint Surg Am*. 2005;87(3):570–576.
29. **Peersman G**, **Laskin R**, **Davis J**, **Peterson M**. Infection in total knee replacement: a retrospective review of 6489 total knee replacements. *Clin Orthop Relat Res*. 2001;2001(392):15–23.

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Funding statement:
- The author(s) received no financial or material support for the research, authorship, and/or publication of this article.

ICMJE COI statement:
- R. Schwarzkopf reports grants or contracts from AAOS, OREF, AAHKS, the Knee Society, and the Hip Society; royalties or licenses from Smith & Nephew; consulting fees from Smith & Nephew, Zimmer, and Intellijoint; and stock or stock options from PSI and Intelijoint, all of which are unrelated to this work. S. E. Marwin declares consulting fees and payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing, or educational events from Intellijoint and Zimmer, which are unrelated. M. Meftah reports patents (planned, issued, or pending) and stock or stock options from Caira Surgical; and a leadership or fiduciary role for ISTA, both of which are also unrelated.

Data sharing:
- The datasets generated and analyzed in the current study are not publicly available due to data protection regulations. Access to data is limited to the researchers who have obtained permission for data processing. Further inquiries can be made to the corresponding author.

Ethical review statement:
- IRB #i17-01223_CR4

Open access funding:
- The authors report that the open access funding for this manuscript was self-funded.