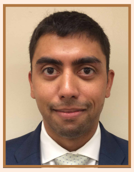
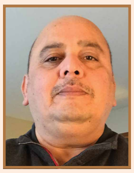
5 Points on
Outcomes and Aseptic Survivorship of Revision Total Knee Arthroplasty

Jeffrey J. Cherian, DO, Anil Bhave, PT, Steven F. Harwin, MD, and Michael A. Mont, MD

Over the past 3 decades, total knee arthroplasty (TKA) has been considered a safe and effective treatment for end-stage knee arthritis.[1] However, as the population, the incidence of obesity, and life expectancy continue to increase, the number of TKAs will rise as well.[2,3] It is expected that over the next 16 years, the number of TKAs performed annually will exceed 3 million in the United States alone.[4] This projection represents an over 600% increase from 2005 figures.[5] Given the demographic shift expected over the next 2 decades, patients are anticipated to undergo these procedures at younger ages compared with previous generations, such that those age 65 years or younger will account for more than 55% of primary TKAs.[6] More important, given this exponential growth in primary TKAs, there will be a concordant rise in revision procedures. It is expected that, the annual number has roughly doubled from that recorded for 2005.[4]

Compared with primary TKAs, however, revision TKAs have had less promising results, with survivorship as low as 60% over shorter periods.[7,8] In addition, recent studies have found an even higher degree of dissatisfaction and functional limitations among revision TKA patients than among primary TKA patients, 15% to 30% of whom are unhappy with their procedures.[9-11] These shortcomings of revision TKAs are thought to result from several factors, including poor bone quality, insufficient bone stock, ligamentous instability, soft-tissue incompetence, infection, malalignment, problems with extensor mechanisms, and substantial pain of uncertain etiology.

Despite there being several complex factors that can lead to worse outcomes with revision TKAs, surgeons are expected to produce results equivalent to those of primary TKAs. It is therefore imperative to delineate the objective and subjective outcomes of revision techniques to identify areas in need of improvement. In this article, we provide a concise overview of revision TKA outcomes in order to stimulate manufacturers, surgeons, and hospitals to improve on implant designs, surgical techniques, and care guidelines for revision TKA. We review the evidence on 5 points: aseptic survivorship, functional outcomes, patient satisfaction, quality of life (QOL), and economic impact. In addition, we compare available outcome data for revision and primary TKAs.

Dr. Cherian is an Orthopedic Research Fellow, and Mr. Bhave is Lead Physical Therapist, Center for Joint Preservation and Replacement, Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore, Baltimore, Maryland. Dr. Harwin is Orthopaedic Surgeon, Department of Orthopaedic Surgery, Mount Sinai Beth Israel Medical Center, New York, New York. Dr. Mont is Director, Center for Joint Preservation and Replacement, Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore, Baltimore, Maryland.

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Address correspondence to: Michael A. Mont, MD, Center for Joint Preservation and Replacement, Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore, 2401 W Belvedere Ave, Baltimore, MD 21215 (tel, 410-601-8500; fax, 410-601-8501; email, mmont@lifebridgehealth.org, rhondamont@aol.com).

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1 Aseptic survivorship

Fehring and colleagues[12] in 2001 and Sharkey and colleagues[13] in 2002 evaluated mechanisms of failure for revision TKA and reported many failures resulted from infection or were associated with the implant, and occurred within 2 years after the primary procedure. More recently, Dy and colleagues[14] found the most common reason for revision was aseptic loosening, followed by infection. The present review focuses on aseptic femoral and tibial revision.

The failure rate for revision TKA is substantially higher than for primary TKA with the same type of prosthesis because of the complexity of the revision procedure, the increasing constraint of the implant design, and the higher degree of bone loss. (**Appendix 1** lists risk factors for revision surgery. **Appendix 2** is a complete list of survivorship outcomes of revision TKA. Both are available online at www.amjorthopedics.com.)

Sheng and colleagues[15] in 2006 and Koskinen and colleagues[16] in 2008 analyzed Finnish Arthroplasty Register data to determine failure rates for revision and primary TKA. Sheng and colleagues[15] examined survivorship of 2637 revision TKAs (performed between 1990 and 2002) for all-cause endpoints after first revision procedure. Survivorship rates were 89% (5 years) and 79% (10 years), while Koskinen and colleagues[16] noted all-cause survival rates of 80% at 15 years. More recently, in 2013, the New Zealand Orthopaedic Association[17] analyzed New Zealand Joint Registry data for revision and re-revision rates (rates of revision per 100 component years) for 64,556 primary TKAs performed between 1999 and 2012. During the period studied, 1684 revisions were performed, reflecting a 2.6% revision rate, a 0.50% rate of revision per 100 component years, and a 13-year Kaplan-Meier survivorship of 94.5%. The most common reasons for revision were pain, deep infection, and tibial component loosening (**Table 1**).

Posterior stabilized implants

Laskin and Ohnsorge[18] retrospectively reviewed the cases of 58 patients who underwent unilateral revision TKA (with a posterior stabilized implant), of which 42% were for coronal instability and 44% for a loose tibial component. At minimum 4-year follow-up, 52 of the 58 patients had anteroposterior instability of less than 5 mm. In addition, 5 years after surgery, aseptic survivorship was 96%. Meijer and colleagues[19] conducted a retrospective comparative study of 69 revision TKAs (65 patients) in which 9 knees received a primary implant and 60 received a revision implant with stems and augmentation (60 = 37 posterior stabilized, 20 constrained, 3 rotating hinge). Survival rates for the primary implants were 100% (1 year), 73% (2 years), and 44% (5 years), and survival rates for

Table 1. **Studies of Survivorship From National Joint Registries**

Study	Year	TKA Type	Registry	Knees, N	Aseptic Survivorship, y	% Survival
Sheng et al[15]	2006	Revision	Finland	2637	5	89
					10	79
Koskinen et al[16]	2008	Primary	Finland	48,607	10	90
					15	80
Registry report[17]	2013	Revision	New Zealand	1684	13	79
		Primary		64,556		95
Registry report[71]	2014	Revision	Australia	1358	1	4.8[a]
					3	12.4[a]
					5	16.6[a]
					10	18.9[a]
					12	22.8[a]
Registry report[72]	2013	Primary	Australia	342,574	1	1[a]
					3	2.8[a]
					5	3.8[a]
					10	5.5[a]
					12	6.5[a]

Abbreviation: TKA, total knee arthroplasty.
[a]Revision rate.

Table 2. **Studies of Aseptic Survivorship of Posterior Stabilized Prostheses in Revision Total Knee Arthroplasty**

Study	Year	Implant Type	Knees, N	Aseptic Survivorship, y	% Survival
Meijer et al[19]	2013	PS	69	1	96
				2	89
				5	85
Lee et al[48]	2012	PS	42	8	83.1
		RH	79		93
Greene et al[56]	2013	PS	119	5	100
Laskin & Ohnsorge[18]	2005	PS	58	5	100
Dalury & Adams[57]	2012	PS	26	6	100
Whaley et al[58]	2003	PS	38	10	95.7
Mabry et al[53]	2007	PS	37	10	91.8

Abbreviations: PS, posterior stabilized; RH, rotating hinge.

the revision implants were significantly better: 95% (1 year), 92% (2 years), and 92% (5 years) (hazard ratio, 5.87; $P = .008$). The authors therefore indicated that it was unclear whether using a primary implant should still be an option in revision TKA and, if it is used, whether it should be limited to less complex situations in which bone loss and ligament damage are minimal (**Table 2**).

Constrained and semiconstrained implants

In a study of 234 knees (209 patients) with soft-tissue deficiency, Wilke and colleagues[20] evaluated the long-term survivorship of revision TKA with use of a semiconstrained modular fixed-bearing implant system. Overall Kaplan-Meier survival rates were 91% (5 years) and 81% (10 years) at a mean follow-up of 9 years. When aseptic revision was evaluated, however, the survival rates increased to 95% (5 years) and 90% (10 years). The authors noted that male sex was the only variable that significantly increased the risk for re-revision (hazard ratio, 2.07; $P = .02$), which they attributed to potentially higher activity levels. In 2006 and 2011, Lachiewicz and Soileau[21,22] evaluated the survival of first- and second-generation constrained condylar prostheses in primary TKA cases with severe valgus deformities, incompetent collateral ligaments, or severe flexion contractures. Of the 54 knees (44 patients) with first-generation prostheses, 42 (34 patients) had a mean follow-up of 9 years (range, 5-16 years). Ten-year survival with failure, defined as component revision for loosening, was 96%. The 27 TKAs using second-generation prostheses had a mean follow-up of about 5 years (range, 2-12 years). At final follow-up, there were no revisions for loosening or patellar problems, but 6 knees (22%) required lateral retinacular release of the patella (**Table 3**).

Rotating hinge implants

Neumann and colleagues[23] evaluated the clinical and radiographic outcomes of 24 rotating hinge prostheses used for aseptic loosening with substantial bone loss and collateral ligament instability. At a mean follow-up of 56 months (range, 3-5 years), there was no evidence of loosening of any implants, and nonprogressive radiolucent lines were found in only 2 tibial components. Kowalczewski and colleagues[24] evaluated the clinical and radiologic outcomes of 12 primary TKAs using a rotating hinge knee prosthesis at a minimum follow-up of 10 years. By most recent follow-up, no implants had been revised for loosening, and only 3 had nonprogressive radiolucent lines (**Table 4**).

Endoprostheses (modular segmental implants)

In a systematic review of 9 studies, Korim and colleagues[25] evaluated 241 endoprostheses used for limb salvage under

Table 3. **Studies of Aseptic Survivorship of Condylar Constrained Prostheses in Revision Total Knee Arthroplasty**

Study	Year	Implant Type	Knees, N	Aseptic Survivorship, y	% Survival
Hartford et al[29]	1998	CCK	17 (primary)	5	100
			16 (revisions)	5	87.5
Bae et al[49]	2013	CCK	224	10	94.6
Friedman et al[59]	1990	CCK	137	5	97.1
Wilke et al[20]	2014	CCK	234	5	95
				10	90
Sheng et al[50]	2005	CCK	16	5	100
Barrack et al[60]	2000	RH	14	5	100
		CCK	87	5	100
Christensen et al[61]	2002	CCK	11	3	90.9
Garcia et al[62]	2010	CCK	45	5	74
Patil et al[63]	2010	CCK	45	3	100
Luque et al[64]	2014	CCK	125	2	92.7
				5	87.8
				8	87.8
Sheng et al[15]	2006	CCK	71	6	95.7
Hwang et al[31]	2010	PS	8	2	100
		CCK	25		100
		RH	13		73
Lachiewicz & Soileau[21,22]	2006	First-generation CCK	54	10	96
	2011	Second-generation CCK	27	5	100

Abbreviations: CCK, condylar constrained knee; PS, posterior stabilized; RH, rotating hinge.

nononcologic conditions. Mean follow-up was about 3 years (range, 1-5 years). The devices were used to treat various conditions, including periprosthetic fracture, bone loss with aseptic loosening, and ligament insufficiency. The overall reoperation rate was 17% (41/241 cases). Mechanical failures were less frequent (6%-19%) (**Table 5**).

2 Functional outcomes

The goal in both primary and revision TKA is to restore the function and mobility of the knee and to alleviate pain. Whereas primary TKAs are realistically predictable and reproducible in their outcomes, revision TKAs are vastly more complicated, which can result in worse postoperative outcomes and function. In addition, revision TKAs may require extensive surgical exposure, which causes more tissue and muscle damage, prolonging rehabilitation. (**Appendix 3** is a complete list of studies of functional outcomes of revision TKA, which is available online at www.amjorthopedics.com.)

This discrepancy in functional outcomes between primary and revision TKA begins as early as the postoperative inpatient rehabilitation period. Using the functional independence measurement (FIM), which estimates performance of activities of daily living, mobility, and cognition, Vincent and colleagues[26] evaluated the functional improvement produced by revision versus primary TKA during inpatient rehabilitation. They compared 424 consecutive primary TKAs with 138 revision TKAs. For both groups, FIM scores increased significantly ($P = .015$) between admission and discharge. On discharge, however, FIM scores were significantly ($P = .01$) higher for

Table 4. Studies of Aseptic Survivorship of Rotating Hinge Prostheses in Revision Total Knee Arthroplasty

Study	Year	Implant Type	Knees, N	Aseptic Survivorship, y	% Survival
Gudnason et al[54]	2011	RH	42	10	89.2
Baier et al[28]	2013	RH	78	5	94
Bistolfi et al[65]	2012	RH	31	5	78.6
Bottner et al[66]	2006	RH PS CCK	2 1 30	5	94
Jensen et al[67]	2014	RH CCK	16 14	4	96.3
Howard et al[68]	2011	CCK RH PS	11 10 3	3	100
Lee et al[48]	2013	PS RH	42 79	8	83.1 93
Hwang et al[31]	2010	PS CCK RH	8 25 13	2	100 100 73
Yang et al[69]	2012	RH	40	10	87
Neumann et al[23]	2012	RH	24	4.5	100
Kowalczewski et al[24]	2014	RH	12	10	100

Abbreviations: CCK, condylar constrained knee; PS, posterior stabilized; RH, rotating hinge.

Table 5. Studies of Aseptic Survivorship of Tumor Prostheses in Revision Total Knee Arthroplasty[a]

Study	Year	Knees, N	Aseptic Survivorship, y	% Survival
Korim et al[25]	2013	241	3.3	83
Hofmann et al[55]	2005	89	10	98.9
Peters et al[70]	2009	184	10	99.5
Haas et al[52]	1995	76	8	98.7

[a]All implants were modular segmental.

the primary group than the revision group (29 and 27 points, respectively). Furthermore, in the evaluation of mechanisms of failure, patients who had revision TKA for mechanical or pain-related problems did markedly better than those who had revision TKA for infection.

Compared with primary knee implants, revision implants require increasing constraint. We assume increasing constraint affects knee biomechanics, leading to worsening functional outcomes. In a study of 60 revision TKAs (57 patients) using posterior stabilized, condylar constrained, or rotating hinge prostheses, Vasso and colleagues[27] examined functional outcomes at a median follow-up of 9 years (range, 4-12 years). At most recent follow-up, mean International Knee Society (IKS) Knee and Function scores were 81 (range, 48-97) and 79 (range, 56-92), mean Hospital for Special Surgery (HSS) score was 84 (range, 62-98), and mean range of motion (ROM) was 121° (range, 98°-132°) ($P < .001$). Although there were no significant differences in IKS and HSS scores between prosthesis types, ROM was significantly ($P < .01$) wider in the posterior stabilized group than in the condylar constrained and rotating hinge groups (127° vs 112° and 108°), suggesting increasing constraint resulted in decreased ROM. Several studies have found increasing constraint might lead to reduced function.[28-30]

However, Hwang and colleagues[31] evaluated functional outcomes in 36 revision TKAs and noted that the cemented posterior stabilized (n = 8), condylar constrained (n = 25), and rotating hinge (n = 13) prostheses used did not differ in their mean Knee Society scores (78, 81, and 83, respectively).

There remains a marked disparity in patient limitations seen after revision versus primary TKA. Given the positive results being obtained with newer implants, studies might suggest recent generations of prostheses have allowed designs to be comparable. As design development continues, we may come closer to achieving outcomes comparable to those of primary TKA.

3 Patient satisfaction

Several recent reports have shown that 10% to 25% of patients who underwent primary TKA were dissatisfied with their surgery[30,32]; other studies have found patient satisfaction often correlating to function and pain.[33-35] Given the worse outcomes for revision TKA (outlined in the preceding section), the substantial pain accompanying a second, more complex procedure, and the extensive rehabilitation expected, we suspect patients who undergo revision TKA are even less satisfied with their surgery than their primary counterparts are. (See **Appendix 4** for a complete list of studies of patient satisfaction after revision TKA, which is available online at www.amjorthopedics.com.)

Barrack and colleagues[32] evaluated a consecutive series of 238 patients followed up for at least 1 year after revision TKA. Patients were asked to rate their degree of satisfaction with both their primary procedure and the revision and to indicate their expectations regarding their revision prosthesis. Mean satisfaction score was 7.4 (maximum = 10), with 13% of patients dissatisfied, 18% somewhat satisfied, and 69% satisfied. Seventy-four percent of patients expected their revision prosthesis to last longer than the primary prosthesis.

Greidanus and colleagues[36] evaluated patient satisfaction in 60 revision TKA cases and 199 primary TKA cases at 2-year follow-up. The primary TKA group had significantly ($P < .01$) higher satisfaction scores in a comparison with the revision TKA group: Global (86 vs 73), Pain Relief (88 vs 70), Function (83 vs 67), and Recreation (77 vs 62). These findings support the satisfaction rates reported by Dahm and colleagues[33,34]: 91% for primary TKA patients and 77% for revision TKA patients.

4 Quality of life

Procedure complexity leads to reduced survivorship, function, and mobility, longer rehabilitation, and decreased QOL for revision TKA patients relative to primary TKA patients.[37] (See **Appendix 5** for a complete list of studies of QOL outcomes of revision TKA, which is available online at www.amjorthopedics.com.)

Greidanus and colleagues[36] evaluated joint-specific QOL (using the 12-item Oxford Knee Score; OKS) and generic QOL (using the 12-Item Short Form Health Survey; SF-12) in 60 revision TKA cases and 199 primary TKA cases at a mean follow-up of 2 years. (The OKS survey is used to evaluate patient perspectives on TKA outcomes,[38] and the multipurpose SF-12 questionnaire is used to assess mental and physical function and general health-related QOL.[39]) Compared with the revision TKA group, the primary TKA group had significantly higher OKS after surgery (78 vs 68; $P = .01$) as well as significantly higher SF-12 scores: Global (84 vs 72; $P = .01$), Mental (54 vs 50; $P = .03$), and Physical (43 vs 37; $P = .01$). Similarly, Ghomrawi and colleagues[40] evaluated patterns of improvement in 308 patients (318 knees) who had revision TKA. At 24-month follow-up, mean SF-36 Physical and Mental scores were 35 and 52, respectively.

Deehan and colleagues[41] used the Nottingham Health Profile (NHP) to compare 94 patients' health-related QOL scores before revision TKA with their scores 3 months, 1 year, and 5 years after revision. NHP Pain subscale scores were significantly lower 3 and 12 months after surgery than before surgery, but this difference was no longer seen at the 5-year follow-up. There was no significant improvement in scores on the other 5 NHP subscales (Sleep, Energy, Emotion, Mobility, Social Isolation) at any time points.

As shown in the literature, patients' QOL outcomes improve after revision TKA, but these gains are not at the level of patients who undergo primary TKA.[36,41] Given that revision surgery is more extensive, and that perhaps revision patients have poorer muscle function, they usually do not return to the level they attained after their index procedure.

5 Economic impact

Consistent with the outcomes already described, the economic impact of revision TKAs is excess expenditures and costs to patients and health care institutions.[42] The sources of this impact are higher implant costs, extra operative trays and times, longer hospital stays, more rehabilitation, and increased medication use.[43] Revision TKA costs range from $49,000 to more than $100,000—a tremendous increase over primary TKA costs ($25,000-$30,000).[43-45] Furthermore, the annual economic burden associated with revision TKA, now $2.7 billion, is expected to exceed $13 billion by 2030.[46] In the United States, about $23.2 billion will be spent on 926,527 primary TKAs in 2015; significantly, the costs associated with revising just 10% of these cases account for almost 50% of the total cost of the primary procedures.[46]

In a retrospective cost-identification multicenter cohort study, Bozic and colleagues[47] found that both-component and single-component revisions, compared with primary procedures, were associated with significantly increased operative time (~265 and 221 minutes vs 200 minutes), use of allograft bone (23% and 14% vs 1%), length of stay (5.4 and 5.7 days vs 5.0 days), and percentage of patients discharged to extended-care facilities (26% and 26% vs 25%) ($P < .0001$). Hospital costs for both- and single-component revisions were 138% and 114% higher than costs for primary procedures ($P < .0001$). More recently, Kallala and colleagues[44] analyzed UK National Health Service data and compared the costs of revision for infection with revision for other causes (pain, instability, aseptic loosening, fracture). Mean length of stay associated with revision for infection (21.5 days) was more than double that associated with revision for aseptic loosening (9.5 days; $P < .0001$), and mean cost of revision for septic causes (£30,011) was more than 3 times that of revision for other causes (£9655; $P < .0001$). The authors concluded that the higher costs of revision knee surgery have a considerable economic impact, especially in infection cases.

With more extensive procedures, long-stem or more constrained prostheses are often needed to obtain adequate fixation and stability. The resulting increased, substantial economic burden is felt by patients and the health care system. Given that health care reimbursements are declining, hospitals that perform revision TKAs can sustain marked financial losses. Some centers are asking whether it is cost-effective to continue to perform these types of procedures. We must find new ways to provide revision procedures using less costly implants and tools so that centers will continue to make these procedures available to patients.

Conclusion

Given the exponential growth in primary TKAs, there will be a concordant increase in revision TKAs in the decades to come. This review provides a concise overview of revision TKA outcomes. Given the low level of evidence regarding revision TKAs, we need further higher quality studies of their prostheses and outcomes. Specifically, we need systematic reviews and meta-analyses to provide higher quality evidence regarding outcomes of using individual prosthetic designs.

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Appendix 1. **Risk Factors**

Study	Year	Risk Factors
Dy et al[1]	2014	Younger age Male sex Black race Lower hospital volume
Singh & Lewallen[2]	2014	**For limits to activities of daily living** Dislocation Fracture nonunion
Singh et al[3]	2010	**For functional limits** Body mass index higher than 40 Female sex Age over 80 years
Namba et al[4]	2013	Diabetes Bilateral procedures High-flexion implants LCS (Low Contact Stress) mobile bearing knee system Younger age Black race

Appendix 2. **Literature on All-Cause Survivorship Outcomes of Revision Total Knee Arthroplasty**

Study	Year	TKA Type	Knees, N	Mean (Range) Follow-Up, mo	Survivorship, y	% Survival
Sanguineti et al[5]	2014	Primary	25	42.2 (20-128)	5	96
		Revision	20	42.2 (20-128)	5	95
Tibrewal et al[6]	2014	Revision	50	126 (24-288)	10	98
Gudnason et al[7]	2011	Revision	42	106 (72-216)	10	65.1
Hartford et al[8]	1998	Primary	17	60 (24-120)	5	100
		Revision	16		5	81.3
Baier et al[9]	2013	Revision	78	81 (60-108)	5	74
Bachmann et al[10]	2014	Revision	159	132 (12-228)	10	97.7
Hofmann et al[11]	2005	Revision	89	99 (24-197)	10	89
Greene et al[12]	2013	Revision	119	62 (46-80)	5	97.5
Bae et al[13]	2013	Revision	224	97 (24-229)	5	97.2
					8	91.6
					10	86.1
Laskin & Ohnsorge[14]	2005	Revision	58	48 (49-98)	5	96.6
Peters et al[15]	2009	Revision	184	49 (24-132)	10	91.8
Friedman et al[16]	1990	Revision	137	62 (24-140)	5	94.2
Wilke et al[17]	2014	Revision	234	108 (2-213)	5	91
					10	81
Bistolfi et al[18]	2012	Revision	31	60 (32-100)	5	70.1
Haas et al[19]	1995	Revision	67	42 (24-108)	8	83
Barrack et al[20]	2000	Revision	103	51 (24-72)	5	100
Dalury & Adams[21]	2012	Revision	26	NR (72-132)	6	100
Mabry et al[22]	2007	Revision	73	122 (33-187)	10	91.8
Whaley et al[23]	2003	Revision	38	121 (NR)	10	96.7
Bottner et al[24]	2006	Revision	33	38 (24-109)	5	90.9
Sheng et al[25]	2006	Revision	71	71 (36-125)	5	95
					8	94
Hwang et al[26]	2010	Revision	36	30 (24-100)	3	86.1
Garcia et al[27]	2010	Revision	45	NR (24-108)	5	76.8
Rajgopal et al[28]	2013	Revision, septic	65	72 (31-118)	3	93
		Revision, aseptic	77	75 (30-119)	3	90
		Revision, septic	65	72 (31-118)	5	88
		Revision, aseptic	77	75 (30-119)	5	88
		Revision, septic	65	72 (31-118)	8	80
		Revision, aseptic	77	75 (30-119)	8	77

Abbreviations: NR, not reported; TKA, total knee arthroplasty.

Appendix 3. **Literature on Functional Outcomes of Revision Total Knee Arthroplasty**

						Value		
Study	**Year**	**TKA Type**	**Knees, N**	**Mean (Range) Follow-Up, mo**	**Metric Used**	**Preoperative**	**Postoperative**	***P***
Sanguineti et al[5]	2014	Primary	25	42.2 (20-128)	KSS	NR	86.8	.27
		Revision	20		Functional	NR	77.6	
		Primary	25		KSS	NR	95.9	.18
		Revision	20		Clinical	NR	92	
Gudnason et al[7]	2011	Revision	42	106 (72-216)	HSS	NR	67	NR
					KSS Functional	NR	29	NR
					KSS Clinical	NR	85	NR
Hartford et al[8]	1998	Primary	17	60 (24-120)	KSS	29	61	NR
		Revision	16		Functional	19	58	
		Primary	17		KSS	39	88	NR
		Revision	16		Clinical	37	83	
Baier et al[9]	2013	Revision	78	81 (60-108)	KSS Functional	NR	61.1	NR
					KSS Clinical	56.9	71.3	NR
					WOMAC	65	34	NR
Hofmann et al[11]	2005	Revision	89	99 (24-197)	KSS Combined	120	188	.04
Greene et al[12]	2013	Revision	119	62 (46-80)	KSS Function	58	79	<.05
Haidukewych et al[29]	2005	Revision	16	42 (24-72)	KSS Function	45	58	NR
					KSS Clinical	28	65	NR
Laskin & Ohnsorge[14]	2005	Revision	58	NR (49-98)	KSS Function	NR	56	NR
					KSS Clinical	NR	86	NR
Peters et al[15]	2009	Revision	184	49 (24-132)	KSS Function	63	82	<.05
					KSS Clinical	72	85	<.05
Ghomrawi et al[30]	2009	Revision	221	24 minimum (NR)	WOMAC Pain	10.1	6.14	.01
					WOMAC Stiffness	4.26	3.12	.01
					WOMAC Function	34.78	23.84	.01
					LEAS	7.53	8.67	.01
Greidanus et al[31]	2011	Primary	199	24 minimum (NR)	WOMAC	50.5	80.2	.01
		Revision	60			43.3	69.1	
		Primary	199		OKS	44	78.3	.01
		Revision	60			34.9	68.4	
					KSS Clinical	37.7	48.9	<.01
					OKS	38.4	28.8	<.001
Bistolfi et al[18]	2012	Revision	31	60 (32-100)	HSS	65.5	88.4	.00006
Haas et al[19]	1995	Revision	76	42 (24-108)	HSS	43	76	NR

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Appendix 3. **Literature on Functional Outcomes of Revision Total Knee Arthroplasty (continued)**

Richards et al[32]	2011	Revision with graft	24	48 (24-98)	WOMAC	NR	79	.004
		Revision without graft	48	38 (24-63)		NR	62	
		Revision with graft	24	48 (24-98)	OKS	NR	80	.001
		Revision without graft	48	38 (24-63)		NR	63	
		Revision with graft	24	48 (24-98)	UCLA Activity	NR	4.9	.052
		Revision without graft	48	38 (24-63)		NR	4	
Dalury & Adams[21]	2012	Revision	26	NR (72-132)	KSS Function	50	93	NR
					KSS Pain	30	45	NR
Mabry et al[22]	2007	Revision	73	122 (33-187)	KSS Function	46	46	NR
					KSS Clinical	58	85	NR
Whaley et al[23]	2003	Revision	38	121 (NR)	KSS Function	48.1	56.9	NR
					KSS Clinical	16.5	51	NR
Dahm et al[33]	2008	Primary	1630	69 (24-120)	UCLA Activity	NR	7.1	NR
Christensen et al[34]	2002	Revision	11	38 (24-53)	KSS Clinical	31.1	75.5	<.001
					KSS Function	8.6	62.3	<.001
Bottner et al[24]	2006	Revision	33	38 (24-109)	KSS Clinical	42	83	NR
					KSS Function	48	76	NR
Jensen et al[35]	2014	Revision	30	47 (3-84)	KSS Clinical	42	77	<.0005
					KSS Function	19	63	<.0005
Meek et al[36]	2004	Revision, septic	55	24 minimum (NR)	OKS	NR	67.3	.007
		Revision, aseptic	47			NR	55.3	
		Revision, septic	55		WOMAC Function	NR	68.9	.003
		Revision, aseptic	47			NR	55.8	
		Revision, septic	55		WOMAC Pain	NR	77.1	.007
		Revision, aseptic	47			NR	64.8	
		Revision, septic	55		WOMAC Stiffness	NR	70.2	.005
		Revision, aseptic	47			NR	56.3	
Dahm et al[37]	2007	Revision	335	67 (36-108)	UCLA Activity	NR	6.7	NR
					KSS Function	NR	62	NR

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Appendix 3. **Literature on Functional Outcomes of Revision Total Knee Arthroplasty (continued)**

Sheng et al[25]	2006	Revision	71	36 (3-81)	KSS Clinical	44	84	<.0001
					KSS Function	30	44	<.0001
Hwang et al[26]	2010	Revision	36	30 (24-100)	KSS Clinical	28	83	<.001
					KSS Function	42	82	<.001
Wang et al[38]	2004	Revision, septic	15	49 (19-81)	KSS Clinical	51.8	77.1	.002
		Revision, aseptic	33	53 (30-77)		58.7	86.5	
		Revision, septic	15	49 (19-81)	KSS Function	36.4	71.7	.189
		Revision, aseptic	33	53 (30-77)		33	68.6	
								.081
		Revision, septic	15	49 (19-81)	KSS Pain	21.3	43.7	
		Revision, aseptic	33	53 (30-77)		26.5	44.2	
Howard et al[39]	2011	Revision	24	33 (24-50)	KSS Clinical	55	81	NR
Garcia et al[27]	2010	Revision, septic	18	NR (24-108)	KSS Clinical	44	75	NR
		Revision, aseptic	27			37	75	NR
		Revision, septic	18		KSS Function	18	52	NR
		Revision, aseptic	27			37	54	NR
Rajgopal et al[28]	2013	Revision, septic	65	72 (31-118)	KSS Clinical	51	69	.72
		Revision, aseptic	77	75 (30-119)		52	70	
		Revision, septic	65	72 (31-118)	KSS Function	46	65	.72
		Revision, aseptic	77	75 (30-119)		43	64	

Abbreviations: HHS, Hospital for Special Surgery; KSS, Knee Society Score; LEAS, Lower-Extremity Activity Scale; NR, not reported; OKS, 12-item Oxford Knee Score; TKA, total knee arthroplasty; UCLA, University of California Los Angeles; VAS, visual analog scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

Appendix 4. **Literature on Patient Satisfaction After Revision Total Knee Arthroplasty**

Study	Year	TKA Type	Knees, N	Mean (Range) Follow-Up, mo	Satisfaction Rate, %
Barrack et al[40]	2007	Revision	238	12 minimum (NR)	69
Haidukewych et al[29]	2005	Revision	16	42 (24-72)	66
Richards et al[32]	2011	Revision with graft	24	48 (24-98)	93
		Revision without graft	48	38 (24-63)	71
Dahm et al[33]	2008	Primary	1630	69 (24-120)	91
Dahm et al[37]	2007	Revision	335	67 (36-108)	77

Abbreviations: NR, not reported; TKA, total knee arthroplasty.

Appendix 5. **Literature on Quality-of-Life Assessment After Revision Total Knee Arthroplasty**

Study	Year	TKA Type	Knees, N	Mean (Range) Follow-Up, mo	Metric Used	Value		P
						Preoperative	Postoperative	
Ghomrawi et al[30]	2009	Revision	221	24 minimum (NR)	SF-36 Physical	28.37	34.76	.01
					SF-36 Mental	48.94	51.97	.02
Greidanus et al[31]	2011	Primary	199	24 minimum (NR)	SF-36 Physical	31.6	42.6	.01
		Revision	60			29.8	37	
		Primary	199		SF-36 Mental	49.1	53.8	.03
		Revision	60			44	50.4	
Kasmire et al[41]	2014	Revision	175	24 minimum (NR)	SF-36 Physical	40.7	55.5	<.001
					SF-36 Mental	60.3	70.2	<.001
Richards et al[32]	2011	Revision with graft	24	48 (24-98)	SF-12 Physical	NR	40	.027
		Revision without graft	48	38 (24-63)		NR	33	
		Revision with graft	24	48 (24-98)	SF-12 Mental	NR	52	.337
		Revision without graft	48	38 (24-63)		NR	48	
Azzam et al[42]	2011	Revision	68	39 (24-96))	SF-36 Physical	40	53	.0001
					SF-36 Mental	59	67	.002
Meek et al[36]	2004	Revision, septic	55	24 minimum (NR)	SF-12 Physical	NR	41.2	.054
		Revision, aseptic	47			NR	35.6	
		Revision, septic	55		SF-12 Mental	NR	53.7	.105
		Revision, aseptic	47			NR	49.1	

Abbreviations: NR, not reported; SF-12, 12-Item Short Form Health Survey; SF-36, 36-Item Short Form Health Survey; TKA, total knee arthroplasty.

Appendices References

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