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Review article

Why Do Medial Unicompartmental Knee Arthroplasties Fail Today?

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ABSTRACT

Background: Failure rates are higher in medial unicompartmental knee arthroplasty (UKA) than total knee arthroplasty. To improve these failure rates, it is important to understand why medial UKA fail. Because individual studies lack power to show failure modes, a systematic review was performed to assess medial UKA failure modes. Furthermore, we compared cohort studies with registry-based studies, early with midterm and late failures and fixed-bearing with mobile-bearing implants.
Methods: Databases of PubMed, EMBASE, and Cochrane and annual registries were searched for medial UKA failures. Studies were included when they reported >25 failures or when they reported early (<5 years), midterm (5-10 years), or late failures (>10 years).
Results: Thirty-seven cohort studies (4 level II studies and 33 level III studies) and 2 registry-based studies were included. A total of 3967 overall failures, 388 time-dependent failures, and 1305 implant design failures were identified.
Aseptic loosening (36%) and osteoarthritis (OA) progression (20%) were the most common failure modes. Aseptic loosening (26%) was most common early failure mode, whereas OA progression was more commonly seen in midterm and late failures (38% and 40%, respectively). Polyethylene wear (12%) and instability (12%) were more common in fixed-bearing implants, whereas pain (14%) and bearing dislocation (11%) were more common in mobile-bearing implants.
Conclusion: This level III systematic review identified aseptic loosening and OA progression as the major failure modes. Aseptic loosening was the main failure mode in early years and mobile-bearing implants, whereas OA progression caused most failures in late years and fixed-bearing implants.

Over the last two decades, there is a growing interest in use of medial unicompartmental knee arthroplasty (UKA) in patients with isolated unicompartmental osteoarthritis (OA) of the medial compartment. In the United States, an annual increase of 32.5% was reported by Riddle et al [1], and this increase has been reported by others as well [2,3]. A possible explanation for this increase can be found by several reported advantages of the UKA in contrast to the total knee arthroplasty (TKA) in the setting of medial OA. These include better range of motion, subjective preference and less pain [4], faster recovery [5,6], better proprioception, and better functional outcomes [7,8].

Analyzing various reports by studies reporting survivorship with >500 medial UKAs, 10-year survivorship percentages of 93%-98% have been reported with good-to-excellent subjective scores [9-14]. However, these satisfying results are not supported by recent global national registries with 10-year survivorship percentages between 81% and 88% [15-17]. Evaluating these registries in detail, we note that the causes of UKA failure are not described in detail or that medial and lateral UKA are presented together.

To optimize clinical outcomes and lower the revision rates, it is crucial to clearly identify the reason of medial UKA failure by reviewing the modes of failure with a standardized method in cohort studies and annual registries. Furthermore, we aimed to assess differences in failure modes between early, midterm, and late stages of the arthroplasty and differences in failure modes between fixed-bearing and mobile-bearing implant designs.

Patients and Methods

Search Strategy and Criteria

An electronic search was performed for studies regarding UKA and failure of prosthesis or revision. In the databases of PubMed, EMBASE, and CENTRAL, the search was performed (Cochrane

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Central Register of Clinical Trials) with the search terms “knee, arthroplasty, replacement,” “unicompartmental,” “unicondylar,” “partial,” “UKA,” “UKR,” “UCA,” “UCR,” “PKA,” “PKR,” “PCA,” “prosthesis failure,” “reoperation,” “survivorship,” and “treatment failure” in an algorithm. In the first step, all these studies were scanned for the title and abstract of the study by two authors independently (JL and HZ). In the second step, both authors reviewed the full text of these selected studies and were evaluated for the inclusion criteria and exclusion criteria. The references were evaluated for missed studies, and annual registries reporting failure modes were added. Any disagreement between the authors was discussed, and in all issues, an agreement was reached.

The inclusion criteria were studies including (1) English articles in humans between January 2000 and March 2015, (2) minimum level III retrospective cohort studies using adjusted Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence [18,19], (3) medial UKA, (4) 10 or more failures in a study, and (5) that reported failure modes. The exclusion criteria were studies including (1) only a specific group of failure (eg, aseptic failures only), (2) previous surgery in same knee (high tibial osteotomy and lateral UKA), (3) acute concurrent knee diagnoses (acute anterior cruciate ligament rupture and acute meniscal tear), (4) reporting medial and lateral UKA together, and (5) multiple studies with the same patient database.

Data Collection

For data collection of general failure modes and differences between fixed- and mobile-bearing implants, studies with a minimum number of 25 failures were included. Annual registries were reviewed and used if modes of failure were reported and medial and lateral were reported separately. The number of failures was noted in a datasheet in Microsoft Excel 2011 (Microsoft Corp., Redmond, WA) and if only percentages were presented and the total number of failures, the number of failures was calculated. Final failure modes were presented in percentage form.

For the analysis of modes of failure in either early, midterm, or late stage, the search criteria were extended for studies that reported time to failure with a minimum of 10 failures. This was chosen because only six studies reported time to failure with 25 or more failures [14,20-24]. Some studies reported time to failure in a specific group (<5 years, 5-10 years, or >10 years) [25-28], whereas other studies reported the time to failure for all individual failures [14,20-24,29-36]. Therefore, the patients were classified as early (<5 year), midterm (5-10 year), or late (>10 year) failure, and their failure modes were assessed.

Statistical Analysis

For this systematic review, statistical analysis was performed with IBM SPSS Statistics 22 (SPSS Inc., Armonk, NY). We performed a chi-square test for two analyses to assess a difference between the cohort studies and registry-based studies, between the early, midterm, and late failures with the null hypothesis that the groups were equal and between fixed- and mobile-bearing implant designs. A difference was considered significant when $P < .05$, and all tests were two-sided.

Results

Search Result

A total of 1294 studies were found through the initial search. Thirty-seven cohort studies and two registry-based studies were found eligible for this systematic review after removing duplicates and reviewing the studies for title, abstract, full text, references, and annual registries (Fig. 1). Twenty-five of 37 cohort studies [14,20-24,37-55] and two registry-based studies [56,57] could be used for the overall failure modes, whereas 18 of these 37 cohort studies could be used for the early, midterm, and late failures [14,20-36]. Eight of 37 cohort studies used fixed-bearing implants [23,28,31,32,37,38,42,43] and 24 studies used mobile-bearing implants [14,21,24-27,29,30,33-36,40,41,44-52,55], whereas five studies [20,22,39,53,54] and two registry-based studies [56,57] had various implants.

Quality of Included Studies

Four studies were level II prospective cohort studies [14,37,45,52], whereas 33 studies were level III retrospective cohort studies [20-36,38-44,46-51,53-55]. None of the studies were randomized clinical trials or double–blind, and none of the studies were

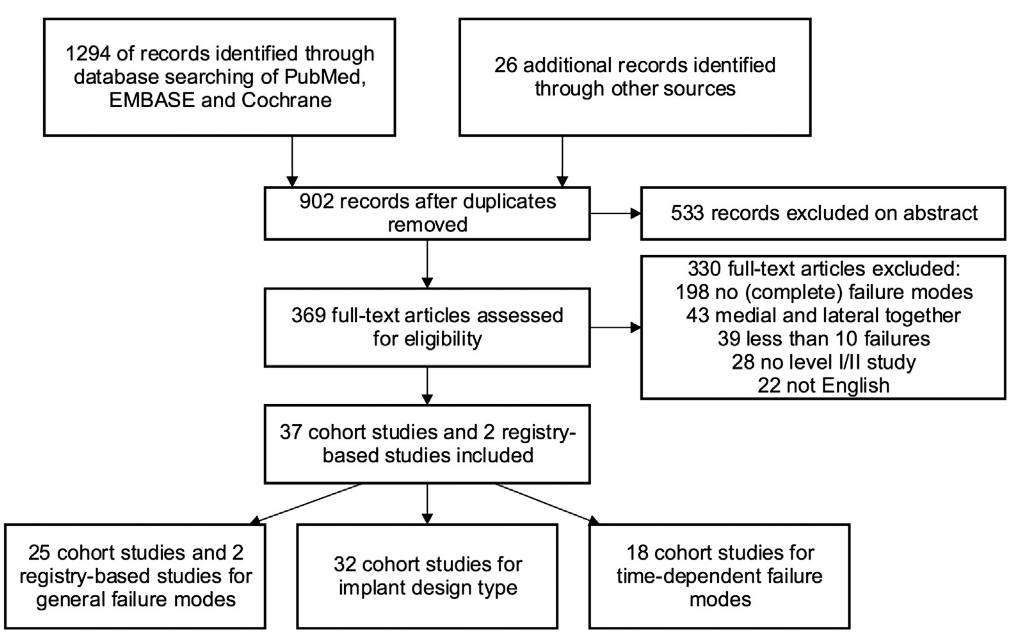

Fig. 1. Flow diagram of the systematic search.

level I or level IV studies. The mean follow-up of the included studies was 5.0 years (range, 0.1-39.9 years). Heterogeneity existed in length of follow-up and implant design, whereas not all studies stated the method for reporting failure modes.

Overall Failure Modes

In the cohort studies, 1641 failed medial UKAs, and in the registry-based studies, 2326 failed medial UKAs were found, which resulted in a total of 3967 failed medial UKAs. Most common modes of failure were aseptic loosening (36%) and progression of OA (20%). Other less common causes of failure were unexplained pain (11%), instability (6%), infection (5%), and polyethylene wear (4%). Cohort studies and registry-based studies reported different modes of failure in progression of OA (29% and 13%, respectively; $P < .01$), pain (7% and 14%, respectively; $P < .01$), polyethylene wear (6% and 3%, respectively; $P < .01$), bearing dislocation (4% and 2%, respectively; $P < .01$), and malalignment (1% and 4%, respectively; $P < .01$; Table 1).

Early vs Midterm vs Late Failure Modes

Eighteen cohort studies were identified that reported the time to failure in 388 medial UKA failures. Early failures (ie, <5 years) were most commonly caused by aseptic loosening (25%), progression of OA (20%), bearing dislocation (17%), pain (8%), infection (7%), and tibial subsidence (7%). In midterm (5-10 years) and late failures (>10 years), progression of OA (38% and 40%, respectively) was the most common mode of failure, whereas common causes of failure in the late phase were aseptic loosening (29%) and polyethylene wear (10%; Table 2).

Differences between the early, midterm, and late failure were found in progression of OA (20%, 38%, and 40%, respectively; $P < .001$), bearing dislocation (17%, 8%, and 2%, respectively; $P = .001$), and pain (8%, 0%, and 5%, respectively; $P = .032$). Progression of OA was significantly more common in midterm compared with early phase (38% vs 20%, $P < .001$) and in the late phase compared with early phase (40% vs 17%; $P < .001$). Polyethylene wear was more common in the late failures compared with the early failures (10% vs 1%; $P < .001$), whereas pain was more common in the early failures compared with the midterm (8% and 0%; $P = .01$; Table 2).

Fixed- vs Mobile-Bearing Failure Modes

Thirty-two cohort studies reported the implant design and a total of 597 fixed-bearing failures and 708 mobile-bearing failures were identified. Failure modes that were more common in fixed-bearing implants compared with mobile-bearing implants were instability (12% vs 1%; $P < .001$) and polyethylene wear (12% vs 0%; $P < .001$). More common failure modes in mobile-bearing implants compared with fixed-bearing implants were unexplained pain (14% vs 2%; $P < .001$) and bearing dislocation (11% vs 0%; $P < .001$). Failure modes in fixed-bearing and mobile-bearing designs are displayed in Table 3.

Discussion

The first finding of this study is that there are two important modes of failure in medial UKA: aseptic loosening and progression of OA. In the early failures, aseptic loosening was the most common failure mode, whereas progression of OA was most common in

Table 1
Modes of Failure in Medial Unicompartmental Knee Arthroplasty.

	N	Asep loos	OA prog	Pain	Instability	Infection	Wear	Bearing disloc	Malalign	Fracture	Tibial subsid	Other[a]	Implant
Citak 2014 [40]	471	120	186	8	72	7	66					12	Fixed
Sierra 2013 [52]	175	96	59			5				5		10	Various
Kalra 2011 [42]	92	45	10	10		5		14		8			Mobile
Wynn-Jones 2012 [53]	87	39	10	10		5		14		9			Mobile
Murray 2013 [47]	63	18	8	18		7		8		2		2	Mobile
Rancourt 2012 [49]	63	13	39	6		1		2				2	Mobile
Kristensen 2013 [43]	51	11	16	10	0	4		4	2	2		2	Mobile
Berend 2009 [37]	50	22	10			5	5				8		Various
Fehring 2010 [19]	43	21	4	10	2		1		1	2		2	Various
Kuipers 2010 [44]	45	12	9	13	1	2		4	1	3			Mobile
Hamilton 2014 [41]	43	19	11	2		3					2	6	Fixed
Bergeson 2013 [38]	40	15	2	12		1		2			7	1	Mobile
Saldanha 2007 [50]	39	14	13	4		3		4				1	Mobile
Lim 2014 [46]	38	17	5	4	3	2				2		5	Mobile
Burnett 2014 [39]	38	18	18	1				1					Mobile
Bohm 2000 [17]	35	17	4			2	6			1		5	Various
Price 2011 [21]	34	9	10	3		5		6				1	Mobile
Saragaglia 2009 [51]	33	22	4			1	2	2				2	Various
Dervin 2011 [18]	32	5	16	3				3				5	Mobile
Liebs 2013 [45]	32	16	7							2		7	Mobile
Aleto 2008 [36]	32	6	6				1				15	4	Fixed
Pandit 2011 [48]	29	1	9	6		5		6				2	Mobile
Hamilton 2010 [20]	26	10	3	1		3					4	5	Fixed
Yoshida 2013 [22]	25	12	1					10		2			Mobile
Ackroyd 2002 [35]	25	12	9	1			3						Fixed
Cohort studies	1641	590	469	122	78	66	84	80	4	38	36	74	
Sweden [54]	1331	400	60	327	116	73	25	35	74	29		192	Various
England/Wales [55]	995	449	251		27	42	51	15	21	21	32	86	Various
Registry-based studies	2326	849	311	327	143	115	76	50	95	50	32	278	
Cohort vs registry		0.72	<0.01	<0.01	0.06	0.17	<0.01	<0.01	<0.01	0.73	0.06	<0.01	
Total medial UKA	3967	1439	780	449	221	181	160	130	99	88	68	352	
Total (%)	100	36.3	19.7	11.3	5.6	4.6	4.0	3.3	2.5	2.2	1.7	8.9	

N indicates number of failed medial UKA.
Asep loos, aseptic loosening; OA prog, progression of osteoarthritis; Tibial subsid, tibial subsidence; Malalign, malalignment; Bearing disloc, bearing dislocation; UKA, unicompartmental knee arthroplasty.
[a] Other causes include patellar problems, arthrofibrosis, stiffness, other, and unknown causes.

Table 2
Modes of Failure in Early, Midterm, and Late Failure in Percentages (%).

Time UKA to Revision	Early Failures, <5 Years	Midterm Failures, 5-10 Years	Late Failures, >10 Years	Chi-square Test (P)
Number of UKA failures	267	79	42	
Aseptic loosening (%)	25	29	29	.515
Progression of OA (%)	20[a,b]	38[a]	40[b]	<.001
Pain (%)	8[a]	0[a]	5	.032
Instability (%)	3	0	0	.124
Infection (%)	7[a]	0[a]	5	.039
Polyethylene wear (%)	1[a,b]	6[a]	10[b]	.002
Bearing dislocation (%)	17[a,b]	8[a]	2[b]	.001
Malalignment (%)	1	1	0	.753
Fracture (%)	4	0	0	.098
Tibial subsidence (%)	7	10	5	.493
Other (%)[c]	7	8	5	.838

Chi-square test was performed with null hypothesis that groups were equal.
OA, osteoarthritis; UKA, unicompartmental knee arthroplasty.
[a] Indicates a significant difference ($P < .05$) between early and midterm failures.
[b] Indicates a significant difference ($P < .05$) between early and late failures.
[c] Other causes include implant failure, patella problems, arthrofibrosis, stiffness, other, and unknown causes.

midterm and late failures. Finally, we found several differences in failure mode between fixed-bearing and mobile-bearing implants although the most common failure modes were aseptic loosening and OA progression.

Over the course of the last few years, some studies introduced other important modes like malalignment [58], tibial subsidence [38], bearing dislocation [55], or instability [42]. In this systematic review, with a large number of failed UKA prostheses, we could not find a significant role in the modes of failure for these causes. Altered mechanical forces in the medial and lateral compartment can explain the major roles of aseptic loosening and progression of OA in failure of medial UKA. Chatellard et al proved that medial UKA changes the joint space between the medial and lateral side in 61.8% of cases. In 48.1% of the cases, the joint space of the prosthetic (medial) side was lower than the lateral side, and a difference of >2 mm was associated with aseptic loosening. A joint space that was lower in the lateral side than the medial side (13.7% of cases) was associated with progression of lateral OA and tibial wear [59]. Because medial UKA can alter the alignment of the knee and alters the forces on the articular surface [60,61], the viability of articular cartilage is influenced, and this can cause further degenerative changes and pain on the lateral side [62]. The effect of altered alignment and associated changes to mechanical forces seems to play a causative role in aseptic loosening at the medial side and progression of OA at the lateral side. These factors can partially explain why these modes of failure dominate failure modes in medial UKA.

Table 3
Failure Modes in Fixed-Bearing and Mobile-Bearing Implants in Percentages (%).

Implant Design	Fixed Bearing	Mobile Bearing	Chi-square Test (P)
Number of UKA failures	597	708	
Aseptic loosening (%)	28	35	.010
Progression of OA (%)	36	24	<.001
Pain (%)	2	14	<.001
Instability (%)	12	1	<.001
Infection (%)	2	6	.001
Polyethylene wear (%)	12	0	<.001
Bearing dislocation (%)	0	11	<.001
Malalignment (%)	0	0	.110
Fracture (%)	0	4	<.001
Tibial subsidence (%)	4	1	.001
Other[a] (%)	5	4	.611

Chi square test was performed with null hypothesis that groups were equal.
OA, osteoarthritis; UKA, unicompartmental knee arthroplasty.
[a] Other causes include implant failure, patella problems, arthrofibrosis, stiffness, other, and unknown causes.

Despite our strict selection of studies regarding their methods of reporting the modes of failure, there were some differences between cohort studies and registry-based studies. It can be difficult to use both annual registries and cohort studies because of different methods of reporting modes of failure [17]. An example is the registry of Norway that did not report progression of OA in 711 UKA revisions [63] although this study was excluded for not reporting separately the medial and lateral UKA failures. Only two registry-based studies reported medial and lateral UKA revisions separately, and in spite of the large number of failed knees and same method of reporting failures as cohort studies, there were some differences compared with cohort studies. In the registry of England and Wales, the incidence of progression of OA was lower than that in cohort studies (5% vs 29%) and the pain was higher (24% vs 7%) [57]. Recently, Baker et al found that the incidence of unexplained pain is higher in UKA than that in TKA and suggested that this can be explained by the fact that an easier UKA revision lowers the threshold for revision for unexplained pain [64]. We, however, think that the different study designs between cohort studies and registry-based studies can play a role in these differences of OA and unexplained pain. Because the other modes of failure are at the same level in cohort studies and registry-based studies, an explanation could be that a part of the patients with unexplained pain belong to the (early) progression of OA. Park et al recently assessed the role of magnetic resonance imaging (MRI) in patients with unexplained pain after UKA [65]. The authors found in 28 cases with unexplained pain that OA progression in the other compartments was not seen at radiographs but was in all cases seen with MRI of which 82% even had grade 3 of 4 OA. The authors suggested that MRI should be used as a supplemental diagnostic imaging modality for patients with unexplained pain. Their findings suggest that in a part of cases, unexplained pain could be caused by OA progression and is therefore underreported in this review.

Two other systematic reviews are published about the revision of UKA. The first was performed by Siddiqui et al and presented the revision rates of UKA to TKA and secondarily presented the modes of failure of UKA. However, the failure modes were beyond their scope and they did not specify or summarize the results and did not draw a conclusion about these causes [66]. The second was performed by Kim et al about the causes of failure of the Oxford design medial UKA and found meniscal bearing as the most common cause of failure (32%) [67]. This high percentage was not found in our study, and this difference can be explained by their focus on Oxford mobile bearing UKA as opposed to our studies that encompassed all types of medial UKA designs. However, this high percentage was not found when only reviewing mobile-bearing implants. There are many differences in failure modes between fixed bearing and mobile bearing as is shown in this study, and this has been shown in several systematic reviews and meta-analyses. Cheng et al [68] performed a systematic review and described differences in failure modes between 41 mobile-bearing knees and 52 fixed-bearing knees. Smith et al performed a level I meta-analysis between fixed- and mobile-bearing implants and could not find a difference in failure mode in four studies. In our study, differences in failure modes between fixed-bearing and mobile-bearing implants were found, although these studies were no level I randomized clinical trials as were used in the study of Smith et al (Table 3).

To our knowledge, no previous studies reported the modes of failure in different (early, midterm, and late) stages. Aseptic loosening was the most important mode of failure in the first five years after the surgery followed by progression of OA and bearing dislocation. Peersman et al [69] found comparable results of early failure (mean time to revision of 1.8 years) with aseptic loosening as the most important mode of failure and bearing dislocation being the second most important mode of failure in the mobile-bearing prosthesis. Progression of OA was the main cause of failure in the midterm and long-term follow-up of UKA. Aseptic loosening was similar in the three different stages after UKA, but progression of OA increased as the time to initial surgery increases. Polyethylene wear plays only a minor role in the late stage causes of failure (up to 10%), whereas wear was discussed broadly in the literature as one of the major causes of failure of the UKA [70-72]. However, these reports were mainly older studies, and the low polyethylene wear incidence can be attributable to the many improvements in polyethylene design and processing over the years. It is known that the improved implants had less wear [73] and a lower failure rate [74] than the original implants and 36 of the 39 studies in this systematic review are published in 2005 or later.

A limitation of our study is the number of patients in the midterm and late group. This is because of the low number of studies that describe the late failure of UKA, especially after more than 10 years. This is mainly because of the fact that most of these long-term follow-up cohort and register-based studies described medial and lateral failures in the results as one group [16,17,75,76]. Another limitation of this systematic review is the study type of the selected studies. Nearly all studies were level III studies, and it is therefore difficult to control confounding factors and causes a higher risk for selection bias [77]. Furthermore, we were not able to control for the exact criteria why different studies classified failures as pain or aseptic loosening. The aim of this study was to assess the most common failure modes in medial UKA. Despite the lack of control for confounding factors with the retrospective studies, it is to the author's opinion that the overview of failure modes is useful for the surgeon. Future studies with higher quality are necessary to assess any confounding factors.

In conclusion, to our knowledge, this is the first systematic review that reports failure modes in medial UKA with a large number of failures. Aseptic loosening and OA progression are the most common causes of failure in medial UKA. Aseptic loosening is the most common failure in early failures and mobile-bearing implants, whereas OA progression is the most common failure in later failures and fixed-bearing implants. Future studies should strive to improve the quality of reporting failure modes.

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