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REVIEW ARTICLE

Lateral unicompartmental knee replacement: a systematic review of reasons for failure

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Abstract
Purpose Currently, individual studies lack the power to successively illustrate different failure modes; therefore, we undertook a systematic review to examine lateral unicompartmental knee replacement (lat UKR) failure modes. Furthermore, we compared early with midterm and late failures and fixed-bearing with mobile-bearing implants.
Methods A search using the databases of PubMed, EMBASE, Cochrane, and annual registries was performed to search for failed lat UKRs. Studies were included when they reported more than four failures, described failure modes and were minimum level IV studies. Data was analysed based on overall failure modes, fixed- vs. mobile bearing and early (<5 years) vs. midterm (5–10 years) vs. late failures (>10 years).
Results Fourteen cohort studies and two registry-based studies were included. A total of 336 overall failures, 87 time-dependent failures, and 175 implant-specific failures were identified. The main overall causes of failure were osteoarthritis (OA) progression (30%) and aseptic loosening (22%). These were followed by less common causes such as instability (7%), unexplained pain (5%), infection (5%), polyethylene wear (5%), and bearing dislocation (5%). Bearing dislocation was the most common early failure (29%) and also the most common failure among mobile-bearing implants (27%). In midterm and late failures, OA progression had the highest rates (59% and 78% respectively) and was also the most common type of failure in fixed-bearing implants (44%).
Conclusions Progression of OA and aseptic loosening are the major overall failure modes in lat UKR. Bearing dislocation was the main failure mode in early years and in mobile-bearing implants, whereas OA progression caused most failures in late years and in fixed-bearing implants.

Level of evidence: Systematic Review of minimum level IV studies.

Keywords Arthroplasty · Knee · Unicompartmental · Lateral

Introduction

Unicompartmental knee replacement (UKR) has been proven to be a promising alternative to total knee replacement (TKR) in patients who suffer from isolated unicompartmental knee osteoarthritis (OA) [1–3]. The advantages of UKR include sparing of the healthy contralateral compartment, minimizing blood loss and preserving the fat pad, cartilage, and bone stock [4]. Clinically, a better range of motion [5], faster recovery [6, 7], reduced degree of pain [8], and superior functional outcomes [9] have been reported.

The majority of studies focus on describing the outcomes following medial UKR (med UKR) due to the increased incidence of isolated anteromedial OA [10]. Only less than 1% of the total number of knee replacements and only 5–10% of all UKRs performed are attributed to the lateral compartment [11–13].

The initial published articles describing the lateral UKR (lat UKR) were limited. These mainly included case series that involved a small cohort of patients, further comprised by mixed data including med UKR [14–16]. Following these studies, there is a dispute regarding the survivorship and

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function between the lateral and med UKRs. This is mainly because some series established inferior survivorship [17] and function [18] for the lat UKR. However, others reported that lat UKR are functionally superior to the medial ones [19–21].

The most common events that influence the survival of med UKR are aseptic loosening, progression of OA, bearing dislocation, wear, and unexplained pain [5, 22–24]. In contrast, only a paucity of studies described the outcome and the causes of failure in lat UKR [4, 25–35]. Nevertheless, the scarce evidence in literature has shown acceptable results for short and mid-term survivorship of lat UKR with remaining concerns on the long-term outcome together with difficulties about identifying the main reasons of failure [27].

It is fundamental to systematically examine and evaluate the etiology and the mechanism of lat UKR failure to improve the understanding and the revision strategy of a failed lat UKR. The aim of this systematic review is to identify the overall failure modes in lat UKR and to analyze the differences regarding failure modes between different implant types and failure modes at early, midterm, and late stages after surgery.

Methods

Search strategy and criteria

A computer-based search was conducted for studies reporting lat UKR and failure or revision of the prosthesis. Databases including PubMed, EMBASE, and CENTRAL (Cochrane Central Register of Controlled Trials) were used as search engines. The search process of the current systematic review included a combination of the following terms: "unicondylar", "unicompartmental", "arthroplasty", "replacement", "revision", "failure", "reoperation", "UKA", "UKR", "UCA", and "UCR". The title and abstract from each study within the results list was reviewed independently by three authors (LE, OA, and TP). Any disagreement was resolved by discussion with the senior author. Full text papers of relevant studies were subsequently obtained and reviewed against the eligibility criteria. Then, full texts of the eligible studies were further evaluated and references were checked for more suitable studies reporting the reasons for lat UKR failure. Annual registries and registry-based studies were also added according to our pre-set eligibility criteria.

Our inclusion criteria included: (1) human studies in English language between April 1990 and April 2015; (2) minimum level IV case series studies using Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence; [36, 37] (3) lat UKR; (4) a minimum of four or more failures in a study; and (5) failure modes were reported. Our exclusion criteria included: (1) studies reporting both on the medial and lateral compartments, without describing failure modes separately; (2) single specific modes of failure reported (e.g., infection); (3) using the same patient pool in multiple studies; and (4) patients with simultaneous knee pathology (e.g., torn anterior cruciate ligament).

Data collection

Data collection was performed for failure modes, differences between failures in fixed- and mobile-bearing implants and time-dependent failure modes. For the included cohort studies where the implant type was not mentioned or described, the authors were contacted by email and the required information about the implant was obtained and included [38].

Some studies reported the individual time to failure for either all of the patients [4, 27, 29, 35, 38, 39] or only for some of them [32, 38, 40], whereas other studies reported the average time to failure [25, 26, 28, 34]. For analysis of time-dependent failure modes, we decided to further classify the failures as early (<5 years), mid-term (5–10 years), or late (>10 years).

Results

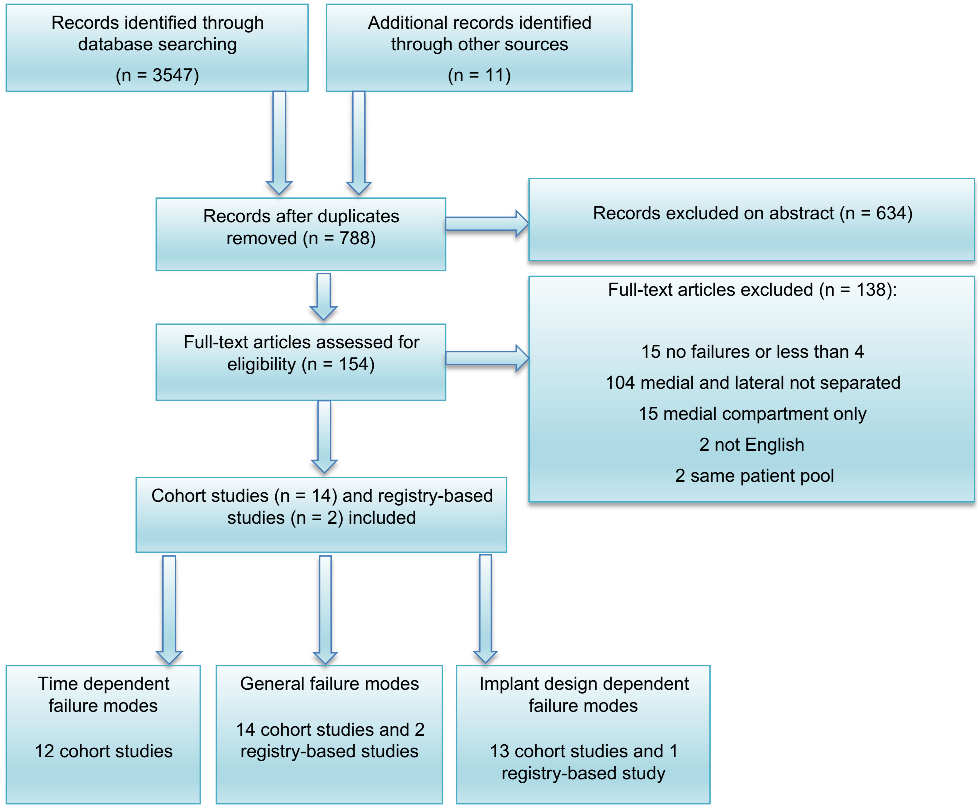
Search results

Using combinations of the selected search keywords, a total of 3547 studies were initially identified. After removing duplicates and reviewing the titles and abstracts, 154 studies were selected for further full text processing. During this step, 14 cohort studies [4, 25–30, 32–35, 38–40] and two registry-based studies [13, 24]were found to report the overall modes of failure specifically for lat UKR and therefore have been included for the systematic review. Twelve cohort studies reported the time-dependent failure mode and were subsequently used to classify the failures as being early, mid-term or late [4, 25–29, 32, 34, 35, 38–40]. Five cohort studies used mobile-bearing implants [29, 30, 33, 35, 39] and eight cohort studies used fixed-bearing implants [4, 25, 26, 28, 32, 34, 38, 40]. Only one registry-based study described the failure modes separately for fixed- and mobile-bearing implants [13] (Fig. 1).

Quality of included studies

Among the studies that were included, eight level II prospective cohort studies [4, 26, 28, 29, 33, 35, 38, 39], four level III retrospective studies [30, 32, 34, 40], and two level IV retrospective case series were identified [25, 27]. The absolute number of identified lat UKRs in all except one study [27] was 4573 (1185 in cohort studies and 3388 in registry-based studies) with 320 failures and a failure rate of 7% (excluding the study by Citak et al. [27]). The follow-up period ranged from 0.5 to 23 years with an average of 5.7 years. One cohort

Fig. 1 Flow diagram of the search results



study could not specify the type of implant because the primary UKRs were performed at other institutions [27].

Overall failure modes

Using the selected studies, 336 lat UKR failures were identified. From this cohort, 211 were reported in the registry-based studies and 125 in the cohort studies. The main causes of failure were OA progression (30%) and aseptic loosening (22%). These were followed by less common causes such as instability (7%), unexplained pain (5%), infection (5%), polyethylene (PE) wear (5%), and bearing dislocation (5%). The full data is summarized in Table 1.

Fixed- vs. mobile-bearing failure modes

A total of 81 and 97 fixed-bearing and mobile-bearing implant failures respectively along with their mode of failure were reported in 13 cohort studies and one registry-based study. Progression of OA (44%) was the most common mode of failure for fixed-bearing implants while bearing dislocation (27%) was the main mode of failure for mobile-bearing implants. Aseptic loosening was more frequently observed in mobile-bearing implants (20% vs. 10%). Failure due to unexplained pain and infection occurred at a similar rate between fixed- and mobile-bearing implants (9% vs. 11% and 6% vs. 11% respectively). Details are depicted in Table 2.

Early vs. midterm vs. late failure modes

Twelve cohort studies reported the time to failure for 87 lat UKR. Forty-five (52%), 24 (28%), and 18 (21%) were classified as early (<5 years), mid-term (between 5 and 10 years), and late failures (>10 years) respectively. Early failures most commonly occurred due to bearing dislocations (29%) and OA progression (22%). Progression of OA was the main cause of failure for both mid-term and late failures (59% and 78% respectively). Details are depicted in Table 3.

Discussion

The main finding of the current study is that the two most common overall failure modes for lat UKRs are OA progression and aseptic loosening. These results are similar to a systematic review reporting on failure modes in med UKR [5].

Analyzing the present outcomes in regard to the failure time reveals a difference. Bearing dislocation is the primary reason for early failure in lat UKR and is trailed by OA progression in the medial compartment and aseptic loosening. In med UKR [5, 41], aseptic loosening is the most common cause of early failure followed by bearing dislocation. The main cause of failure in the midterm and long-term follow-up of med UKR is progression of arthritis, which was also observed in the included studies reporting on time dependent

Table 1 Modes of failure in lateral unicompartmental knee replacement

	N[ʄ]	OA prog	Bearing disloc	Asep loos	Pain	Infection	Fracture	Instability	Wear	Tibial subsid	Other[†]	Implant
Cohort studies												
Citak et al. 2015 [27]	16	9		3				1	2		1	Unknown
Ashraf et al. 2002 [26]	15	9		2			4					Fixed
Liebs 2013 [30]	14	2		6			2				4	Mobile
Weston-Simons et al. 2014 [35]	12	3	4		3	2						Mobile
Gunther et al. 1996 [29]	11		6	1		3	1					Mobile
Romagnoli et al. 2013 [38]	11	5						3			3	Fixed
Pandit et al. 2010 [33]	10	3	4			1					2	Mobile
Lustig et al. 2014 [32]	7	6		1								Fixed
Walton et al. 2006 [34]	7	6		1								Fixed
Argenson et al. 2008 [25]	5	4					1					Fixed
Demange et al. 2015 [28]	5	2				2					1	Fixed
Harilainen et al. 1993 [40]	4						1		2	1		Fixed
Smith et al. 2014 [4]	4	1								1	2	Fixed
Streit et al. 2012 [39]	4		3			1						Mobile
Registry studies												
Lewold et al. 1998 [24]	140	48		43			4	10	8	3	24	Not specified
Baker et al. 2012 [13]	71	3		17	15	7	2	11	5		11	Both Fixed and Mobile
Total Lateral UKR	336	101	17	74	18	16	15	25	17	5	48	
Total (%)	100	30	5	22	5	5	4	7	5	2	14	

OA prog: progression of osteoarthritis; Bearing disloc: bearing dislocation; Asep loos: aseptic loosening; Tibial subsid: tibial subsidence; UKR: unicompartmental knee replacement

[†] Other causes include patellofemoral problems, arthrofibrosis, malalignment, stiffness, and unknown causes

[ʄ] N is the number of failed lateral UKR

Table 2 Failure modes in fixed- and mobile-bearing implants reflected as absolute and relative numbers (in %)

Implant design	Fixed-bearing	Mobile-bearing
Number of UKR failures	81	97
OA progression	36(44)	8 (8)
Bearing dislocation (%)	0	26 (27)
Aseptic loosening (%)	8(10)	19 (20)
Pain (%)	7 (9)	11 (11)
Infection (%)	5 (6)	11 (11)
Fracture (%)	8 (10)	3 (3)
Instability (%)	5 (6)	0
Polyethylene wear (%)	2 (2)	0
Tibial subsidence (%)	2 (2)	0
Other (%)[†]	8 (10)	19 (20)

[†] Other causes include patellofemoral problems, arthrofibrosis, malalignment, stiffness, and unknown causes

Table 3 Modes of failure during early-, mid-, and late-term reflected as absolute and relative numbers (in %)

Time UKR to revision	Early failures <5 years	Mid-term failures 5–10 years	Late failures >10 years
Number of UKR failures	45	24	18
OA progression	10 (22)	14 (59)	14 (78)
Bearing dislocation (%)	13 (29)	0	0
Aseptic loosening (%)	5 (11)	2 (8)	2 (11)
Pain (%)	3 (7)	0	0
Infection (%)	6 (13)	1 (4)	0
Fracture (%)	1 (2)	5 (21)	0
Instability (%)	2 (5)	2 (8)	0
Polyethylene wear (%)	1 (2)	0	2 (11)
Tibial subsidence (%)	1 (2)	0	0
Other (%)[†]	3 (7)	0	0

[†] Other causes include patellofemoral problems, arthrofibrosis, malalignment, stiffness, and unknown causes

failures in lat UKR. Polyethylene wear was the cause of failure in a minor percentage in the late phase, contributing only to 11% of the cases. Despite the fact that wear of PE was reported heavily in the literature as a major cause of failure of UKR [42–44], this could not be applied to the current practice. This is mainly because these reports were based on older clinical case series using older PE generations that were of lower quality and reduced mechanical properties. Accordingly, the current low PE wear incidence is because of the improvement in PE design, manufacturing, processing, sterilization, and storage that has developed significantly over the last few years. It has been shown that newly designed implants had reduced wear [45] with a lower failure rate [46] than the original implants.

Another thought provoking observation in the current analysis, is that it is crucial to further interpret the failure modes based on the implant type used. The mechanism of failure is different between fixed- and mobile-bearing implants. The results of our review demonstrate that bearing dislocation represents the main mode of failure with mobile-bearing implants, whereas OA progression is higher when using fixed-bearing implants.

The use of poorly designed or implanted mobile-bearing implants with the unique anatomy and different biomechanical properties of the lateral compartment have contributed to increased failure rates. These factors include convex lateral tibial condyle, loose lateral collateral ligament in flexed position, and a greater mean possible distraction (7 mm vs. 2 mm in the medial compartment). All these variables make mobile bearing implants more prone to failure [47, 48]. The use of domed Oxford mobile-bearing implants, characterized by a convex tibial component augmented with biconcave bearings, has significantly reduced the incidence of bearing dislocations as compared to previously designed Oxford implants with a flat tibial component [33]. Nonetheless, although at a lower rate, dislocations still frequently occur as observed in the present analysis. Biomechanically, the medial pivot of the knee during flexion [48] might also contribute to extrusion of the mobile bearing. The pathomechanics of bearing dislocation follow a similar pattern by undergoing medial subluxation into the intercondylar notch with a remaining part in the lateral compartment. Therefore, further technique modifications, starting from the simplest offered solution of placing a screw in the intercondylar notch, should improve the outcome of domed lat UKR [35, 39, 49].

Loading of different compartments differs dependent on static or dynamic loading and dependent on the knee deformity [50]. Those presenting with genu valgus have excessive load on the lateral compartment, mainly during the stance phase, however in the swing phase, the chief load moves to the medial compartment. On the other hand, in genu varus knees, the load is mainly on the medial compartment during both stance and swing phases of gait. In a biomechanical analysis [51], it had been advised to correct the alignment axis while performing lat UKR to a slightly more valgus angle between 5° to 7°, to aim at preventing the progression of the arthritic changes in the medial compartment. Van der List et al. [52] demonstrated that the under-correction of 3° to 7° is correlated with superior functional results. Another argument for under-correction might be the fact that the load during the dynamic phase in a valgus knee shifts to the medial compartment. This might explain why in mid- and long-term lat UKR, aseptic loosening is less common but progression of OA is increased.

Notwithstanding, we could not find a reasonable explanation why mobile-bearing implants seem to have higher aseptic loosening rates. In a review on the reasons for failure in med UKR, van der List et al. [5] found that higher aseptic loosening rates in the mobile-bearing group represented 35% versus 28% in the fixed-bearing group. It is reported that, this outcome is more likely affected by the presence of the cement rather than the type of implant [53]. Insufficient cement-fixation can lead to aseptic loosening, which is the most common failure mode in cemented UKR [5]. The cemented implants remain widely used and give favorable results as seen in a recent review on survivorship in UKR [54]. The interest in cementless fixation on the other hand, has also increased with the introduction of new updates such as bioactive materials and coated implants, which facilitate bone ingrowth and yield to better fixation and osteointegration [55].

There are several limitations in this study. As for most of the systematic reviews, this is a pooled investigation of case series and retrospective studies of low level of evidence. Hence, there are the risk of bias and other cofounding variables. Another limitation is the limited available evidence with limited number of studies describing the late failure of lat UKR, especially for follow-up of more than ten years. Also, we have included studies reporting a minimum of four revisions. This is essentially due to the fact that most of these long-term follow-up cohort and register-based studies reported medial and lateral failures in the results as one group. It is known that it can be challenging to include cohort and registry-based studies as they might report failures differently. Despite our strict choice of studies based on their methods of presenting the failure modes, there were variances between those studies. Furthermore, it was not possible to control the exact criteria why different studies classified failures as pain or aseptic loosening. Future studies with higher quality are necessary to assess any confounding factors.

In conclusion, OA progression and aseptic loosening were identified as the major overall failure modes. Bearing dislocation was the main failure mode in early years and in mobile-bearing implants, whereas OA progression caused most failures in late years and in fixed-bearing implants. However, better-designed well-conducted research with longer follow-up is still needed to assess factors behind the survival of lat UKR.

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Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest to declare.

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