The Journal of Arthroplasty xxx (2017) 1–7

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Regional Femoral and Tibial Radiolucency in Cemented Unicompartmental Knee Arthroplasty and the Relationship to Functional Outcomes

Laura J. Kleeblad, MD [a,*], Jelle P. van der List, MD [a], Hendrik A. Zuiderbaan, MD, PhD [b], Andrew D. Pearle, MD [a]

[a] Department of Orthopaedic Surgery, Sports Medicine and Shoulder Service, Hospital for Special Surgery, Weill Medical College of Cornell University, New York, New York

[b] Department of Orthopaedic Surgery, Noordwest Hospital, Alkmaar, The Netherlands

ARTICLE INFO

Article history:
Received 14 March 2017
Received in revised form
8 June 2017
Accepted 12 June 2017
Available online xxx

Keywords:
unicompartmental knee arthroplasty
physiological radiolucency
WOMAC
hip-knee-ankle angle
radiolucent lines
cemented

ABSTRACT

Background: Femoral and tibial radiolucent lines (RLL) after unicompartmental knee arthroplasty (UKA) can be categorized in physiological and pathological radiolucencies. Although physiological tibial radiolucency is assessed extensively in literature, studies reporting femoral radiolucency are lacking. Therefore, a retrospective study was performed to assess physiological femoral RLL and its relationship to short-term functional outcomes.

Methods: A total of 352 patients were included who underwent robotic-assisted medial UKA surgery and received a fixed-bearing metal-backed cemented medial UKA. Radiographic follow-up consisted of standard anteroposterior and lateral radiographs. Functional outcomes, using the Western Ontario and McMaster Universities Arthritis Index questionnaire, of patients with RLL were compared with a matched cohort, based on gender, age, and body mass index.

Results: In this cohort, 101 patients (28.8%) had physiological regional radiolucency around the femoral (10.3%) and/or tibial (25.3%) components, of which 6.8% concerned both components. Tibial RLL were more frequently seen compared with femoral RLL ($P < .001$). Our data suggest that the time of onset of femoral radiolucency develops later (1.36 years) than tibial radiolucency (1.00 years, $P = .02$). No difference in short-term functional outcomes was found between the RLL group and the matched cohort group without radiolucency.

Conclusion: This study acknowledges that tibial and femoral physiological radiolucencies may develop after cemented medial UKA. Furthermore, this was the first study showing that physiological femoral RLL occur later than tibial RLL. Prospective studies with longer follow-up and larger numbers are necessary to compare radiolucency in different UKA designs and the relationship to outcomes.

Published by Elsevier Inc.

Unicompartmental knee arthroplasty (UKA) is a common treatment option for isolated medial knee osteoarthritis (OA), with good to excellent results at 5- and 10-year follow-up [1–4]. Recently, a large systematic review showed survivorship of 94% after 5 years and 92% after 10 years [3]. Concerning the modes of failure after UKA surgery, several studies and national registries have noted that aseptic loosening is one of the most frequent causes of revision [5–10].

Importantly, periprosthetic radiolucent lines (RLL) after UKA can be divided into pathologic and physiologic types of radiolucencies [11]. As Goodfellow et al [11–13] described, pathological RLL are >2 mm, poorly defined, and often related to aseptic loosening. On the contrary, physiological RLL are 1-2 mm and well-defined. The presence of these RLL is neither related to symptoms nor indicative or predictive of loosening according to current literature [11,12,14]. The etiology of radiolucency remains unknown; although, association between postoperative leg alignment and the emergence of

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to http://dx.doi.org/10.1016/j.arth.2017.06.022.

* Reprint requests: Laura J. Kleeblad, MD, Department of Orthopaedic Surgery, Sports Medicine and Shoulder Service, Hospital for Special Surgery, 535 East 70th St, New York, NY 10021.

http://dx.doi.org/10.1016/j.arth.2017.06.022
0883-5403/Published by Elsevier Inc.

RLL has been suggested by several authors [11,15,16]. Many studies have reported on the incidence of physiological tibial RLL, ranging from 62%-96%, which were clinically not related to inferior functional outcomes [13,14,17,18]. However, only a few older studies have assessed RLL around the femoral component, when different UKA designs were used [2,19]. There are no recent studies which assess the different aspects of physiological femoral radiolucency around cemented medial UKA, especially relative to the frequency of tibial radiolucency.

Therefore, this study assessed the incidence of physiological femoral and tibial radiolucency in cemented UKA. Aims of this article were to evaluate the incidence of RLL of the femoral component in relationship to the tibial component in different alignment ranges. Furthermore, the time of onset of radiolucency and its correlation with short-term patient-reported functional outcomes was assessed. We hypothesized that physiological femoral RLL are commonly seen regionally around the femoral component, but are not correlated with inferior functional outcomes after UKA.

Materials and Methods

Study Design and Patient Selection

Our study was carried out at Hospital for Special Surgery, with a prospective database that included over 900 UKAs, which were performed over the last 8 years by the senior author (A.D.P.). After institutional review board's approval (IRB 2013-056), an electronic registry search was performed for all patients who underwent medial UKA between April 2008 and December 2015. The surgical indications were medial compartment OA, no significant joint space narrowing in the lateral compartment, an intact anterior cruciate ligament, a correctable varus deformity, and a fixed flexion deformity of <10°. Surgical contraindications included the presence of Kellgren-Lawrence grade III or greater OA of the lateral compartment, patellofemoral-related pain symptoms, or inflammatory arthritis. Obesity was not a contraindication, as several studies have shown that increasing body mass index (BMI) is not associated with increasing failure or worse outcomes [20–24]. Inclusion criteria for this study were: (1) medial onlay UKA, (2) baseline radiographs at 2 weeks postoperatively, and (3) available functional outcomes. Patients with bicompartmental arthroplasty or different types of UKA than the study implant were excluded.

Implant and Surgical Technique

All patients received the identical cemented fixed-bearing Medial Onlay implant (RESTORIS MCK, Stryker, Mahwah, NJ). All surgeries were carried out by the senior author (A.D.P.), using a robotic-arm assisted surgical platform (MAKO System, Stryker, Mahwah, NJ) [25,26]. The surgical goal was to establish a relative undercorrection of the preoperative varus alignment to avoid osteoarthritic progression on the lateral compartment [27,28].

Radiologic Assessment

Radiographic evaluation was performed in Picture Archiving and Communication System (PACS, Sectra Imtec AB, Version 16, Linköping, Sweden). The anteroposterior (AP) and lateral radiographs were obtained 2 weeks postoperatively, repeated after 6 weeks and during follow-up visits after surgery. In addition, hip-knee-ankle (HKA) radiographs were taken at 6-week follow-up to assess the postoperative leg alignment. All radiographs were taken according to a standardized protocol, consisting of AP weight-bearing view, lateral view at 30° of flexion and HKA standing radiograph, for which the x-ray beam was aligned with the patella and foot and centered at the distal pole of the patella, aligning the image parallel to the tibial joint line in the frontal plane [29]. The radiographic assessment for this study was performed by a single assessor (L.J.K.), according to current and validated standards in the literature [14,18,30]. The radiographic assessment was conducted blinded to clinical scores. Similar to previous studies assessing radiolucency, the AP radiograph was used to assess tibial RLL, dividing the area underneath the tibial tray into 5 zones (Fig. 1A) [14,17,18,31]. Femoral RLL were assessed using lateral radiographs, because the component-bone interface is not visible on the AP view. Therefore, the flat area at the anterior and posterior femoral condyle was examined on the lateral view, as well as the area around the 2 pegs of the implant (Fig. 1B) [17,31]. Radiolucency is quantified by physiological and pathological RLL. Physiological RLL are well-defined, 1-2 mm thick, accompanied with a radiodense line, in contrast to pathological RLL that are >2 mm thick, poorly defined, and have no radiodense line [11].

The time of onset of RLL on the radiographs was scored by screening every radiograph from direct postoperative until the most recent one; however, this was depending on the regularity of the follow-up visits. The time of onset was related to patient-reported outcomes to compare the 2 groups (RLL vs non-RLL). Furthermore, the postoperative leg alignment (HKA angle) was measured on HKA radiographs of all patients.

Functional Outcomes

Patient-reported functional outcome scores were collected using the Western Ontario and McMaster Universities Arthritis Index (WOMAC). The WOMAC is a validated questionnaire in the setting of knee OA and quantifies the patient-reported outcome using 24 Likert-scale questions [32,33]. Questionnaires were collected during clinic visits or electronically by email, preoperatively and at 1-, 2-, and 5-year follow-up. Functional outcomes of patients with RLL were compared with a matched cohort without any RLL, based on gender, age, and BMI. All patients with WOMAC scores after the occurrence of RLL were matched with a patient without radiolucency, based on gender, age (within range of 3 years), and BMI (within range of 3 kilograms per square meter).

Statistical Analysis

Analyses were carried out using Excel 2010 (Microsoft Corp, Redmond, WA) and SPSS version 24 (SPSS Inc, Armonk, NY). The clinical details including gender, age, BMI, date of surgery, date of radiographic follow-up, and frequency of femoral and tibial RLL were assessed using descriptive statistics, consisting of mean, range values, and frequencies reported as percentages. Chi-square test was used to assess the differences between the incidence of femoral and tibial RLL. Furthermore, an analysis of variance was conducted to test for any differences in clinical characteristic features among the 3 patient groups (femoral RLL, tibial RLL, and both component RLL). Finally, continuous outcomes were used to compare functional outcomes in RLL group and non-RLL group. Paired t tests were performed to compare both groups based on their WOMAC scores. Statistical significance was set at $P < .05$.

Results

Between April 2008 and December 2015, 964 medial UKA were performed, 613 patients were excluded for this study. The reasons for exclusion were missing baseline radiographs or usage of

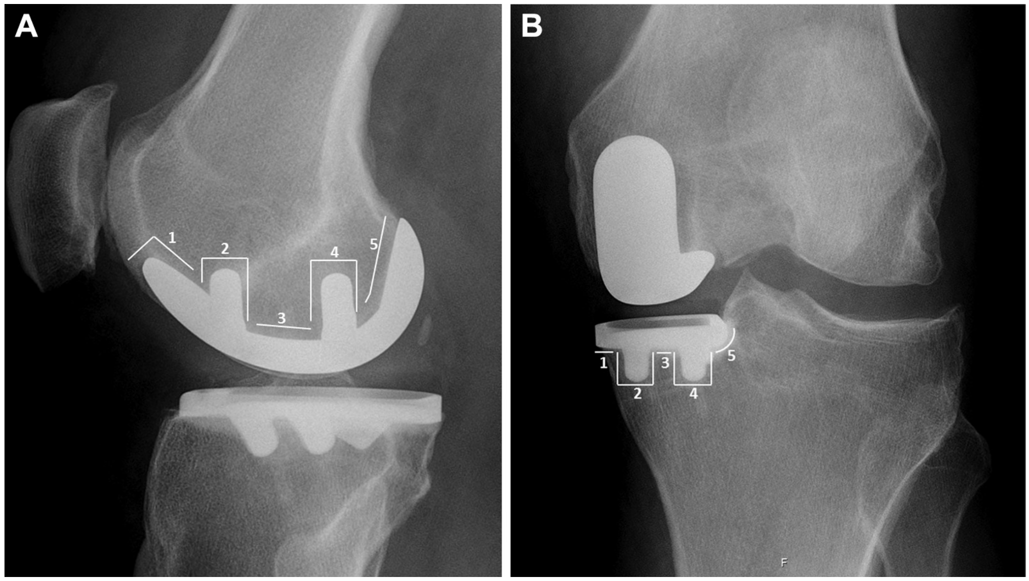

Fig. 1. Distribution of radiolucent lines (RLL) per zone. (A) Anteroposterior radiograph, which shows RLL around the tibial component and (B) lateral radiographs, which assesses RLL around the femoral component of unicompartmental knee arthroplasty (UKA).

different UKA design than MAKO Onlay. Three hundred fifty-one patients with minimum radiographic follow-up of 3 months were screened for radiolucency (Fig. 2). Radiographic assessment showed femoral and/or tibial physiological radiolucencies in 101 patients (28.8%), of which 57 (56%) were men and 44 (44%) were women. Mean age was 63.4 years (range 44.6-85.0 years), and mean BMI was 29.6 kg/m^2 (range 18.6-52.9 kg/m^2). At baseline (2 weeks postoperative), no femoral or tibial RLL were noted. The mean follow-up was 18 months (range 4-77 months).

In our cohort, the incidence of femoral and tibial physiological RLL was 10.2% and 25.3%, respectively, of which 6.8% concerned both components. Tibial RLL were more frequently seen compared with femoral RLL ($P < .001$) (Table 1). No significant characteristic differences among the patients with femoral RLL, tibial RLL, or both femoral and tibial RLL were present regarding male gender (45%, 58%, and 54%, respectively, $P = .715$), age (68.9, 62.7, and 63.1, respectively, $P = .114$), or BMI (28.8, 29.4, and 30.1, respectively, $P = .809$).

The HKA angles were measured on all 351 patients, mean HKA angle in RLL group was 2.89° varus and in the non-RLL group 2.47° varus. No significant difference was noted ($P = .115$). In Table 2,

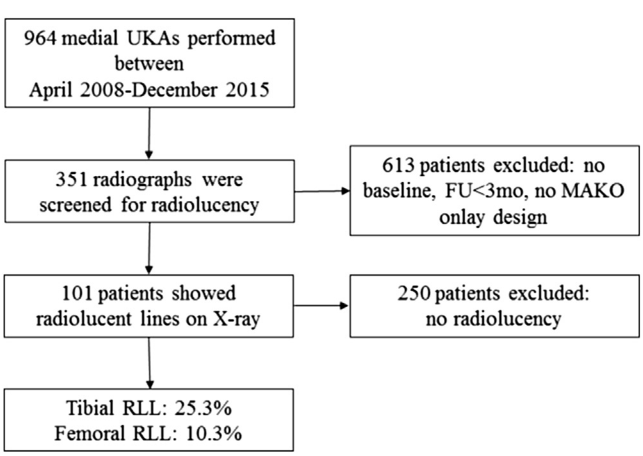

Fig. 2. Flow chart of the inclusion process. FU, follow-up; UKA, unicompartmental knee arthroplasty; RLL, radiolucent lines.

femoral and tibial RLL were subdivided into different alignment ranges. No relationship was noted between the incidence of RLL and the HKA angle postoperatively.

Distribution of radiolucency per zone according to the aforementioned classification (Fig. 1) revealed that femoral RLL were most common in zones 1 and 5, 37.0% and 52.2%, respectively. A similar trend was noted on the tibial side, of all tibial radiolucencies 59.6% was located in zone 1 and 73.0% in zone 5 (Table 3).

In our cohort, the mean time of occurrence of tibial RLL was 1.00 years (standard deviation 0.77) compared with 1.36 years (standard deviation 0.88) for the femoral component based on the available radiographic data. This significant difference ($P = .02$) in time of onset of radiolucency was showed in Figure 3, where the majority of tibial RLL developed within the first year after surgery.

Forty patients (38.8%) had reported WOMAC scores after the onset of RLL. Average age and BMI were comparable with the matched group (Table 4). Preoperatively and at 1-, 2- and 5-year follow-up, the total WOMAC scores of the RLL group were 55, 91, 81, and 92, respectively, whereas these were 53, 86, 89, and 87 for the non-RLL group, respectively. The difference between the two groups was not significant on all follow-up moments ($P > .188$).

At final review, one patient had been revised to a total knee arthroplasty; and in another patient, the femoral component was revised, both showing pathological RLL. The reason for revision to total knee arthroplasty was tibial subsidence and the femoral component was replaced because of component loosening. Three patients have had an arthroscopic procedure (ie, partial lateral meniscectomy, debridement patella, loose body), all showed physiological RLL.

Table 1
Incidence of Regional Tibial and Femoral Radiolucencies in Medial Unicompartmental Knee Arthroplasty.

	No Radiolucency	Radiolucency Detected	Incidence	Chi-Square
Tibial component (n = 351)	263	89	25.3%	$P < .001$
Femoral component (n = 351)	316	36	10.3%	

Table 2
Incidence of Regional Femoral and Tibial RLL in Different Alignment Groups Based on Hip-Knee-Ankle Angle.

Postoperative HKAA	Femoral RLL (n = 12)	Tibial RLL (n = 65)	Combined RLL (n = 24)	Non-RLL (n = 250)
<1° (n = 91)	4.4%	15.4%	5.5%	74.7%
1°-4° (n = 167)	1.8%	20.4%	7.2%	70.7%
>4° (n = 93)	5.4%	18.3%	7.5%	68.8%
Chi-square (*P* value)	.263	.615	.836	

HKAA, hip-knee-ankle angle; RLL, radiolucent lines.

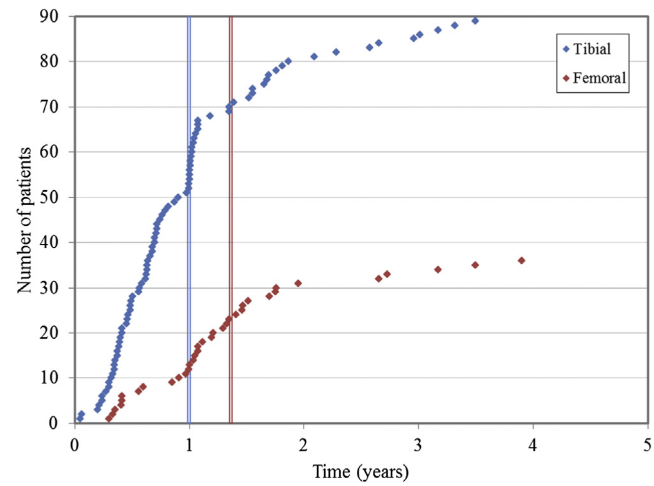

Fig. 3. Time of onset of all patients with femoral and tibial RLL is showed. The colored vertical lines represent the mean time of onset per component, blue line represents the tibial component (1.00 y), and the red line represents the femoral component (1.36 y).

Discussion

Data from this study confirmed that physiological RLL may develop under the tibial component of the cemented medial UKA. This study is one of the first assessing the presence of femoral RLL around the cemented medial UKA. Furthermore, our data suggest that the time of onset of femoral RLL is significantly later than tibial RLL. Both tibial and femoral radiolucencies were not correlated with inferior functional outcomes. These results should be interpreted with caution, because of the retrospective data collection and the technique of assessing radiolucency.

The first finding was the incidence of physiological radiolucency around cemented UKA, both femoral and tibial (10.2% and 25.3%, respectively). Comparing these results to the results found in literature, the incidence of tibial radiolucency was indeed lower than found by other studies (range 62%-96%) [13,14,19]. There are many factors which could have contributed to this discrepancy. Firstly, the UKA design is different as most studies assessed radiolucency around the Oxford UKA, whereas this study described RLL around the MAKO UKA [13,14]. The shape of both femoral and tibial components is different, as the MAKO UKA has 2 femoral pegs compared with the cemented Oxford design, which has one peg and is evaluated in most previous studies assessing radiolucency. The current cemented Oxford design UKA has 2 pegs as well. Furthermore, the surface of the tibial tray facing the bone is shaped differently. The Oxford tibial tray has from anterior to posterior a vertical stabilizer, whereas the MAKO UKA has 2 short pegs to stabilize the component. Secondly, each design was implanted using different surgical techniques, conventional techniques for Oxford UKA and robotic-assistance for MAKO UKA.

Concerning the postoperative leg alignment, our results showed mean HKA angle of 2.91° varus in the RLL group compared with 2.48° varus in the non-RLL group. Furthermore, no relationship was noted between the incidence of femoral or tibial RLL in the specific alignment ranges. Gulati et al [14] found no statistical relationship between the incidence of tibial RLL and the residual varus deformity, which corresponds with our results. According to several authors, an HKA angle of 1°-4° should be pursued to optimize subjective results, especially in the WOMAC domains of pain, function, and total scores compared with HKA angle ≤1° or ≥4° [16,34]. These findings correspond to the results of Vasso et al [16], which reported higher International Knee Society Scores among patients with a mild postoperative varus deformity (1°-7°) compared with neutral alignment. A number of hypotheses have been proposed to explain the etiology of radiolucency, of which postoperative leg alignment is one. However, in this cohort, it is questionable if the HKA angle plays a role, because both groups fit within the optimal range. To get more insight in the etiology of radiolucency, prospective studies are required to assess the theoretical hypotheses and possible attributable factors.

Although much is known about tibial RLL, limited number of studies have reported incidence of femoral radiolucencies. Possible explanations could be the lower incidence of femoral RLL or the follow-up is too short to show femoral RLL [35,36]. Berger et al [19] have described the occurrence of femoral radiolucency, and this study was performed more than 15 years ago. In their study, they found an incidence of femoral RLL 14%, which is slightly higher than our findings (10.2%). Furthermore, Kalra et al [17] performed a radiographic assessment of physiological and pathological femoral lucency in patients who required revision because of suspected loosening. A matched control group was created to be able to compare the both groups. Results showing a greater frequency of physiological lucency on the femoral side in the revision group; however, no significant difference was noted. A similar trend was noted for the pathological RLL.

It is important to emphasize that there is a difference between cemented and uncemented prostheses in the evaluation of radiolucency around UKA. A few more recent studies by the Oxford

Table 3
Distribution of Tibial and Femoral RLL Per Zone.

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Tibial RLL (n = 90), %	59.6	13.5	20.2	10.1	73.0
Femoral RLL (n = 36), %	44.4	22.2	0.0	33.3	63.9

RLL, radiolucent lines.

Table 4
Demographic Information and WOMAC Scores of With Means and Standard Deviation in the 2 Groups; RLL and the Matched Non-RLL.

	RLL Group (n = 40)	Non-RLL Group (n = 40)	*P* Value
Gender			
Male	18 (46%)	18 (46%)	
Female	22 (54%)	22 (54%)	
Age, y	64.2 (±8.9)	64.0 (±8.9)	.915
Body mass index, kg/m^2	28.7 (±5.6)	28.9 (±4.0)	.855
WOMAC scores			
Preoperatively	55 (±14)	53 (±16)	.718
1-y follow-up	91 (±8)	86 (±12)	.366
2-y follow-up	81 (±23)	89 (±12)	.188
5-y follow-up	91 (±8)	87 (±13)	.284

RLL, radiolucent lines; WOMAC, Western Ontario and McMaster Universities Arthritis Index.

group described the incidence of radiolucencies around uncemented UKA compared with cemented UKA [30,31,36]. Pandit et al [36] proposed that radiolucency occurred less frequently in the uncemented UKA, 6.3% vs 75% in cemented UKA. It has been argued the cemented UKAs show a higher incidence of radiolucencies, because of possible incomplete cementation (thermal), osteonecrosis, and formation of fibrous tissue [37,38]. These arguments relate to our second finding concerning the zone distribution of the radiolucencies and the possible causes, both tibial and femoral zones 1 and 5 were most commonly affected. Comparing our results with the current literature, a similar trend is noted in tibial RLL [13,14,17]. Zone 5 is considered to be a non–weight-bearing area and a site where the component does not fixate [14]. Therefore, Gulati et al [14] suggested that it could be considered as clinically irrelevant. Interestingly, femoral radiolucencies were often located in zones 1 and 5, which is anteriorly and posteriorly. More theories have been proposed in the literature. Riebel et al [39] performed a cadaver study to explain early failure of the femoral component in UKA. They found that the cause of failure could be high shear and tensile stresses developed at the bone-prosthesis interface. These stresses will cause failure of the cement column, allowing rocking of the implant at the apex of the bone-prosthesis interface as the implant cycles through physiologic flexion and extension [39]. Future radiostereometric analysis studies would be informative to confirm this theory. It has also been suggested that the underlying cause of the occurrence of radiolucency may be micromotion between the implant or cement surface, or both, and the bone. The associated mechanical stress is thought to promote the migration of synoviocytes into the space along the cement-bone and implant-bone interfaces. Therefore, creating a “synovium-like” or “fibrous” membrane and release osteoclast-stimulating cytokines that contribute to adjacent bone resorption [40,41]. However, Kendrick et al demonstrated that whether there is no, partial, or complete RLL beneath the tibial component, there is always some direct contact between cement and bone. In the case of direct contact, the cement interdigitation with the bone demonstrates that the interface is stable and not loose [38]. The strength of the bone-cement interface is dependent on cement penetration and interdigitation into cancellous bone. However, cement penetration into bone can lead to increased interface temperatures during polymerization of the cement [42]. For thermal necrosis to occur, temperatures need to exceed 44°C [43]. As was showed by Seeger et al [44], the highest temperature inside the cancellous measured was 25.7°C, and therefore it seems unlikely that thermal necrosis occurs during UKA cementation. Concluding, our results and the previous mentioned studies suggest that there is an obvious relation between UKA and radiolucency. However, a definite answer on the etiology question is still based on multiple explanations and hypotheses. Therefore, future studies are necessary to test the proposed theories and mechanisms.

Our third finding was the significant difference in the time of onset of tibial and femoral RLL (1.00 and 1.36 years, respectively) in this cohort. Comparing results with those in literature, physiological radiolucency tends to develop most often within the first 2 years after surgery [13,36,45]. However, no difference in onset of tibial and femoral RLL has been described earlier in literature. Although it is still unclear why RLL appear, the finding of a different time of onset of tibial and femoral RLL might be explained by different etiological mechanisms of both RLL. Berger et al [19] showed that there was a difference in location of partial radiolucencies in femoral and tibial RLL with most of the femoral RLL occurring at the cement-prosthesis interface and tibial RLL occurring at the cement-bone interface. Regarding the mechanisms, Riebel et al found in a cadaveric study that femoral RLL occur with a rocking phenomenon of the femoral component, whereas several studies have suggested that tibial RLL occur by compressive loading of the component, which is likely to generate fibrocartilage [13,38,39,46]. Although this has not been studied extensively, this might be a possible explanation for the difference in time of occurrence of RLL in both components. Future studies are necessary to confirm our finding and further assess this [39]. Current literature only states the time to revision for tibial and femoral loosening; however, failed to show the relationship to radiolucencies [6]. Epinette et al assessed 418 failed UKAs based on their modes of failure, and they found aseptic loosening to be the main reason for revision. Furthermore, they showed that tibial loosening developed significantly earlier than did femoral (54% vs 40% within 2 years, respectively) [6]. Therefore, it could be argued that there might be a difference in time of onset of radiolucencies as well. Our results confirm this theory; however, prospective studies with frequent follow-up are necessary to address this more carefully.

Our results show no correlation between femoral or tibial radiolucency and inferior functional outcomes when comparing the RLL group with the non-RLL group. Comparing both groups based on their WOMAC scores after the occurrence of RLL, a trend of even better results in the RLL group was noted. As discussed previously, Pandit et al proposed that tibial radiolucency was less frequently seen in the uncemented UKA at 1 year after surgery. Although the varied incidence of RLL, they failed to show any significant differences between clinical scores and fixation techniques. Therefore, it was suggested that both uncemented and cemented UKA were similarly effective at 1-year follow-up [36]. To our knowledge, this is the first study that assessed femoral RLL in relationship to functional outcomes after medial UKA surgery.

Several authors described the radiological results of the tibial component of the UKA, whereas the results of the femoral component were unknown [13,14,19,36]. It has been noted that different methods have been used to assess RLL around UKA, most studies used AP and lateral radiographs [30,31,47]. The Oxford group used fluoroscopically aligned radiographic technique to evaluate radiolucency to overcome the alignment issues of standard radiographs [13,14,19,36]. As discussed by Kalra et al, fluoroscopically guided radiographs are not routine practice in the United Kingdom. Instead, AP and lateral radiographs are routinely obtained clinically. The assessment of RLL of the tibial component, by means of accuracy and validity, have been emphasized in numerous studies [13,17,45]. The sensitivity and specificity of the tibial RLL for detecting radiolucency were 63.6% and 94.4%, respectively. The radiographic evaluation of the femoral component is a bit more challenging, with a sensitivity and a specificity of 63.6% and 72.7%, respectively [17].

This study has several limitations. Firstly, the large number of excluded patients because of lack of radiographic follow-up or usage of different UKA designs, could potentially lead to a selection bias. Furthermore, based on the aforementioned literature regarding the challenges faced by assessing RLL, the reliability of using plain radiographs might lead to an underestimation of the incidence [17,45]. For that reason, the Oxford group uses fluoroscopically guided radiographs to detect RLL. RLL around the tibial component may be missed because of that their characteristic features are concealed by a nonparallel x-ray beam [48]. Computed tomography or magnetic resonance imaging would improve the assessment of periprosthetic lucency and bone-component interface; however, both are more invasive and associated with higher costs [49,50]. Another limitation is that component alignment was not assessed, as this was not the goal of this study. Although several studies have shown that component alignment plays a role in pathological RLL, no correlation has been found between component position and the occurrence of physiological RLL [51–53].

Moreover, the correlation between component alignment and physiological radiolucency should be assessed on computed tomography, as this allows a more accurate evaluation of both the component position as periprosthetic lucency [54,55]. Finally, the number of patients with functional outcomes after the occurrence of radiolucency was 39% relative to all patients with RLL. To overcome this limitation, a matched cohort group was composed similar to the approach of Gulati et al [14]. Taking into account these limitations, a caution approach is needed when interpreting the results of this study.

Conclusion

This study acknowledges that femoral and tibial physiological radiolucency may develop after fixed-bearing cemented UKA. Furthermore, this study showed that femoral RLL occur later than tibial RLL. No correlations regarding functional outcomes were found in the presence of femoral or tibial RLL. Prospective studies with longer follow-up and higher compliance on functional outcomes are necessary to assess radiolucency in different UKA designs and correlate this with outcomes.

References

[1] Murray DW, Goodfellow JW, O'Connor JJ. The Oxford medial unicompartmental arthroplasty: a ten-year survival study. J Bone Joint Surg Br 1998;80:983–9.
[2] Price AJ, Waite JC, Svard U. Long-term clinical results of the medial Oxford unicompartmental knee arthroplasty. Clin Orthop Relat Res 2005:171–80.
[3] van der List JP, McDonald LS, Pearle AD. Systematic review of medial versus lateral survivorship in unicompartmental knee arthroplasty. Knee 2015;22:454–60.
[4] Berger RA, Meneghini RM, Jacobs JJ, Sheinkop MB, Della Valle CJ, Rosenberg AG, et al. Results of unicompartmental knee arthroplasty at a minimum of ten years of follow-up. J Bone Joint Surg Am 2005;87:999–1006.
[5] Furnes O, Espehaug B, Lie SA, Vollset SE, Engesaeter LB, Havelin LI. Failure mechanisms after unicompartmental and tricompartmental primary knee replacement with cement. J Bone Joint Surg Am 2007;89:519–25.
[6] Epinette J-A, Brunschweiler B, Mertl P, Mole D, Cazenave A. French Society for Hip and Knee. Unicompartmental knee arthroplasty modes of failure: wear is not the main reason for failure: a multicentre study of 418 failed knees. Orthop Traumatol Surg Res 2012;98:S124–30.
[7] American Joint Replacement Registry. American Joint Replacement Registry - Annual report 2014. 2014, http://www.ajrr.net/images/annual_reports/AJRR_2014_Annual_Report_final_11-11-15.pdf.
[8] Australian Orthopaedic Association National Joint Registry. Hip and knee arthroplasty annual report 2015. 2015, https://aoanjrr.sahmri.com/documents/10180/217745/Hip and Knee Arthroplasty.
[9] National Joint Registry for England, Wales and Northern Ireland. 12th Annual report 2015. 2015, http://www.njrreports.org.uk/Portals/0/PDFdownloads/NJR 12th Annual Report 2015.pdf.
[10] New Zealand Joint Registry. The New Zealand registry annual report. 2014, http://nzoa.org.nz/system/files/Web_DH7657_NZJR2014Report_v4_12Nov15.pdf.
[11] Goodfellow JW, Kershaw CJ, Benson MK, O'Connor JJ. The Oxford Knee for unicompartmental osteoarthritis. The first 103 cases. J Bone Joint Surg Br 1988;70:692–701.
[12] Goodfellow J, O'Connor J, Dodd C, Murray D. Unicompartmental arthroplasty with the Oxford knee. England: Oxford Univ. Press; 2006. p. 117–28.
[13] Tibrewal SB, Grant KA, Goodfellow JW. The radiolucent line beneath the tibial components of the Oxford meniscal knee. J Bone Joint Surg Br 1984;66:523–8.
[14] Gulati A, Chau R, Pandit HG, Gray H, Price AJ, Dodd CAF, et al. The incidence of physiological radiolucency following Oxford unicompartmental knee replacement and its relationship to outcome. J Bone Joint Surg Br 2009;91:896–902.
[15] Hernigou P, Deschamps G. Alignment influences wear in the knee after medial unicompartmental arthroplasty. Clin Orthop Relat Res 2004:161–5.
[16] Vasso M, Del Regno C, D'Amelio A, Viggiano D, Corona K, Schiavone Panni A. Minor varus alignment provides better results than neutral alignment in medial UKA. Knee 2015;22:117–21.
[17] Kalra S, Smith TO, Berko B, Walton NP. Assessment of radiolucent lines around the Oxford unicompartmental knee replacement: sensitivity and specificity for loosening. J Bone Joint Surg Br 2011;93:777–81.
[18] Liddle AD, Pandit H, O'Brien S, Doran E, Penny ID, Hooper GJ, et al. Cementless fixation in Oxford unicompartmental knee replacement: a multicentre study of 1000 knees. Bone Joint J 2013;95-B:181–7.
[19] Berger RA, Nedeff DD, Barden RM, Sheinkop MM, Jacobs JJ, Rosenberg AG, et al. Unicompartmental knee arthroplasty. Clinical experience at 6- to 10-year followup. Clin Orthop Relat Res 1999:50–60.
[20] Murray DW, Pandit H, Weston-Simons JS, Jenkins C, Gill HS, Lombardi AV, et al. Does body mass index affect the outcome of unicompartmental knee replacement? Knee 2013;20:461–5.
[21] Thompson SAJ, Liabaud B, Nellans KW, Geller JA. Factors associated with poor outcomes following unicompartmental knee arthroplasty: redefining the "classic" indications for surgery. J Arthroplasty 2013;28:1561–4.
[22] van der List JP, Chawla H, Zuiderbaan HA, Pearle AD. The role of preoperative patient characteristics on outcomes of unicompartmental knee arthroplasty: a meta-analysis critique. J Arthroplasty 2016;31:2617–27.
[23] Plate JF, Augart MA, Seyler TM, Bracey DN, Hoggard A, Akbar M, et al. Obesity has no effect on outcomes following unicompartmental knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2017;25:645–51.
[24] Cavaignac E, Lafontan V, Reina N, Pailhé R, Wargny M, Warmy M, et al. Obesity has no adverse effect on the outcome of unicompartmental knee replacement at a minimum follow-up of seven years. Bone Joint J 2013;95-B:1064–8.
[25] Pearle AD, O'Loughlin PF, Kendoff DO. Robot-assisted unicompartmental knee arthroplasty. J Arthroplasty 2010;25:230–7.
[26] Roche M, O'Loughlin PF, Kendoff D, Musahl V, Pearle AD. Robotic arm-assisted unicompartmental knee arthroplasty: preoperative planning and surgical technique. Am J Orthop (Belle Mead NJ) 2009;38:10–5.
[27] Pennington DW, Swienckowski JJ, Lutes WB, Drake GN. Lateral unicompartmental knee arthroplasty: survivorship and technical considerations at an average follow-up of 12.4 years. J Arthroplasty 2006;21:13–7.
[28] Ridgeway SR, McAuley JP, Ammeen DJ, Engh GA. The effect of alignment of the knee on the outcome of unicompartmental knee replacement. J Bone Joint Surg Br 2002;84:351–5.
[29] Thein R, Zuiderbaan HA, Khamaisy S, Nawabi DH, Poultsides LA, Pearle AD. Medial unicondylar knee arthroplasty improves patellofemoral congruence: a possible mechanistic explanation for poor association between patellofemoral degeneration and clinical outcome. J Arthroplasty 2015;30:1917–22.
[30] Hooper N, Snell D, Hooper G, Maxwell R, Frampton C. The five-year radiological results of the uncemented Oxford medial compartment knee arthroplasty. Bone Joint J 2015;97-B:1358–63.
[31] Hooper GJ, Maxwell AR, Wilkinson B, Mathew J, Woodfield TBF, Penny ID, et al. The early radiological results of the uncemented Oxford medial compartment knee replacement. J Bone Joint Surg Br 2012;94:334–8.
[32] Bellamy N, Campbell J, Stevens J, Pilch L, Stewart C, Mahmood Z. Validation study of a computerized version of the Western Ontario and McMaster Universities VA3.0 Osteoarthritis Index. J Rheumatol 1997;24:2413–5.
[33] Bellamy N, Campbell J, Hill J, Band P. A comparative study of telephone versus onsite completion of the WOMAC 3.0 osteoarthritis index. J Rheumatol 2002;29:783–6.
[34] Zuiderbaan HA, van der List JP, Chawla H, Khamaisy S, Thein R, Pearle AD. Predictors of subjective outcome after medial unicompartmental knee arthroplasty. J Arthroplasty 2016;31:1453–8.
[35] Hooper G, Lee AJ, Rothwell A, Frampton C. Current trends and projections in the utilisation rates of hip and knee replacement in New Zealand from 2001 to 2026. N Z Med J 2014;127:82–93.
[36] Pandit H, Jenkins C, Beard DJ, Gallagher J, Price AJ, Dodd CAF, et al. Cementless Oxford unicompartmental knee replacement shows reduced radiolucency at one year. J Bone Joint Surg Br 2009;91:185–9.
[37] Windsor RE, Scuderi GR, Moran MC, Insall JN. Mechanisms of failure of the femoral and tibial components in total knee arthroplasty. Clin Orthop Relat Res 1989;248:15–20.
[38] Kendrick BJL, James AR, Pandit H, Gill HS, Price AJ, Blunn GW, et al. Histology of the bone-cement interface in retrieved Oxford unicompartmental knee replacements. Knee 2012;19:918–22.
[39] Riebel GD, Werner FW, Ayers DC, Bromka J, Murray DG. Early failure of the femoral component in unicompartmental knee arthroplasty. J Arthroplasty 1995;10:615–21.
[40] Goldring SR, Schiller AL, Roelke M, Rourke CM, O'Neil DA, Harris WH. The synovial-like membrane at the bone-cement interface in loose total hip replacements and its proposed role in bone lysis. J Bone Joint Surg Am 1983;65:575–84.
[41] Fritz J, Lurie B, Potter HG. MR imaging of knee arthroplasty implants. RadioGraphics 2015;35:1483–501.
[42] Halawa M, Lee AJ, Ling RS, Vangala SS. The shear strength of trabecular bone from the femur, and some factors affecting the shear strength of the cement-bone interface. Arch Orthop Trauma Surg 1978;92:19–30.
[43] Eriksson RA, Albrektsson T. The effect of heat on bone regeneration: an experimental study in the rabbit using the bone growth chamber. J Oral Maxillofac Surg 1984;42:705–11.
[44] Seeger JB, Jaeger S, Bitsch RG, Mohr G, Rohner E, Clarius M. The effect of bone lavage on femoral cement penetration and interface temperature during Oxford unicompartmental knee arthroplasty with cement. J Bone Joint Surg Am 2013;95:48–53.

[45] Mukherjee K, Pandit H, Dodd CAF, Ostlere S, Murray DW. The Oxford unicompartmental knee arthroplasty: a radiological perspective. Clin Radiol 2008;63:1169–76.

[46] Gray HA, Zavatsky AB, Gill HS. The sclerotic line: why it appears under knee replacements (a study based on the Oxford Knee). Clin Biomech 2010;25:242–7.

[47] Monk AP, Keys GW, Murray DW. Loosening of the femoral component after unicompartmental knee replacement. J Bone Joint Surg Br 2009;91:405–7.

[48] Gulati A, Pandit H, Jenkins C, Chau R, Dodd CAF, Murray DW. The effect of leg alignment on the outcome of unicompartmental knee replacement. J Bone Joint Surg Br 2009;91:469–74.

[49] Solomon LB, Stamenkov RB, MacDonald AJ, Yaikwavong N, Neale SD, Moss MJ, et al. Imaging periprosthetic osteolysis around total knee arthroplasties using a human cadaver model. J Arthroplasty 2012;27:1069–74.

[50] Park CN, Zuiderbaan HA, Chang A, Khamaisy S, Pearle AD, Ranawat AS. Role of magnetic resonance imaging in the diagnosis of the painful unicompartmental knee arthroplasty. Knee 2015;22:341–6.

[51] Gulati A, Chau R, Simpson DJ, Dodd CAF, Gill HS, Murray DW. Influence of component alignment on outcome for unicompartmental knee replacement. Knee 2009;16:196–9.

[52] Barbadoro P, Ensini A, Leardini A, d'Amato M, Feliciangeli A, Timoncini A, et al. Tibial component alignment and risk of loosening in unicompartmental knee arthroplasty: a radiographic and radiostereometric study. Knee Surg Sports Traumatol Arthrosc 2014;22:3157–62.

[53] Chatellard R, Sauleau V, Colmar M, Robert H, Raynaud G, Brilhault J, et al. Medial unicompartmental knee arthroplasty: does tibial component position influence clinical outcomes and arthroplasty survival? Orthop Traumatol Surg Res 2013;99:S219–25.

[54] Bell SW, Anthony I, Jones B, MacLean A, Rowe P, Blyth M. Improved accuracy of component positioning with robotic-assisted unicompartmental knee arthroplasty: data from a prospective, randomized controlled study. J Bone Joint Surg Am 2016;98:627–35.

[55] Citak M, Suero EM, Citak M, Dunbar NJ, Branch SH, Conditt MA, et al. Unicompartmental knee arthroplasty: is robotic technology more accurate than conventional technique? Knee 2013;20:268–71.