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Total and unicondylar knee arthroplasty are equivalent treatment options in end-stage spontaneous osteonecrosis of the knee, and the size of the lesion has no influence on the results

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Abstract

Purpose The purpose of the present study was to compare total (TKA) and unicondylar (UKA) knee arthroplasty for spontaneous osteonecrosis of the knee (SONK), and to investigate potential correlations to radiographic parameters.

Methods All consecutive patients with a magnetic resonance imaging (MRI) proven SONK treated with either TKA or UKA between 2002 and 2018 were analysed. The primary outcomes were postoperative complications and failure rates. Functional assessment included Knee Society Score (KSS), WOMAC Score, and range of motion. A novel three-dimensional measurement method was established to determine the size of the osteonecrotic lesion. All outcome parameters were correlated to the size of the necrotic lesion using Spearman's rank correlation.

Results The two treatment groups (34 TKAs, 37 UKAs) did not differ regarding age, body mass index, and ratio of the volume of the necrotic lesion to the volume of the femoral condyle (n.s.). At a mean follow-up of 6.6 years, patients with UKA had better functional outcomes compared to patients with a TKA (WOMAC Score 1.0 vs. 1.6, $p = 0.04$; KSS pain 86 vs. 83, n.s), with a similar complication rate. No correlation was found between necrotic lesion size and failure rate (n.s.).

Conclusion UKA is a valuable treatment option for SONK leading to good functional results and a low failure rate. In case of a surgeon's concern regarding implant anchorage, TKA represents an equivalent solution. The MR-tomographic size of the osteonecrotic lesions seems to have no influence on the results.

Level of evidence III.

Keywords Unicompartmental knee arthroplasty · Total knee arthroplasty · Osteonecrosis · Spontaneous osteonecrosis of the knee · Lesion size

Introduction

Spontaneous osteonecrosis of the knee (SONK) mainly involves one compartment of the knee. For these cases, unicompartmental knee arthroplasty (UKA) represents an interesting solution, allowing selective replacement of the focal necrosis in the medial or lateral compartment [21]. In general, UKA proved to have several advantages over total knee arthroplasty (TKA), such as preserved knee kinematics [23], reduced mortality and a lower complication rate [17]. However, regarding implant longevity, disturbed implant anchorage because of residual necrotic bone stock or sparing osseous resection might portray potential disadvantages of UKA in SONK [11, 19]. Nevertheless, UKA was reported to be an effective treatment of focal osteonecrosis and femoral component fixation did not appear to be a major concern in recent mid to long-term follow-up studies [4, 10–12, 22]. However, only two studies compared the outcome of UKA and TKA for osteonecrosis of the knee [20, 24]. Both studies were limited to a small sample size and inclusion of out-dated prosthetic implant designs [20, 24]. Moreover, one of these studies is a systematic review, comparing cohort studies that performed either UKA or TKA in case of both secondary and spontaneous osteonecrosis of the knee [20].

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The purpose of the present study was to investigate a larger cohort of patients who underwent UKA or TKA for symptomatic SONK, and to determine which surgical treatment modality is superior regarding functional outcome and implant failure rate. The size of the osteonecrotic lesion and its relationship to the clinical outcome after UKA has previously only been evaluated based on conventional radiographs [11, 18]. Therefore, a novel three-dimensional measurement method was developed, applicable to both X-ray and MRI. Correlations between the lesion size and the primary outcome parameters were conducted. The hypothesis was that UKA is an effective treatment method for end-stage focal osteonecrosis of the knee independent of the necrotic lesion size with functional outcomes and failure rates comparable to TKA.

Methods

In this two-center study (Balgrist University Hospital, University of Zurich, Zurich, Switzerland, and Department of Orthopaedics and Traumatology, Bürgerspital Solothurn, Solothurn, Switzerland), all patients who had undergone contemporary knee arthroplasty for primary end-stage SONK (Ficat > 3) between January 2002 and January 2018 were retrospectively included. Only patients with a preoperative MRI and a minimal follow-up of 2 years were included. A minimum follow-up of 2 years was chosen because aseptic loosening of the implant due to residual necrotic bone stock is most likely encountered within this time span [4, 11]. The study was approved by the local ethics committee (Zurich Cantonal Ethics Commission, 2019–02114).

Of the 76 eligible patients, 4 patients missed all postoperative follow-up visits, and another patient died without having completed the minimum 2-year follow-up. Thus, 71 patients (25 men and 46 women) were included in the study, of which 34 patients underwent TKA and 37 patients UKA (34 medial, 3 lateral). The lesion was limited to the condyle of the distal femur in all cases. The two treatment groups did not show any significant differences in the mean body mass index (BMI) and age at surgery (Table 1) (all n.s.).

The prosthetic designs used for TKA included BalanSys (Mathys AG, Bettlach, Switzerland), GMK MyKnee (Medacta, Castel San Pietro, Switzerland), and NexGen LPS-Flex (Zimmer Biomet, Warsaw, USA). All prostheses were Posterior

Table 1 Comparison of the two groups

	Unicompartmental knee arthroplasty, $n = 37$				Total knee arthroplasty, $n = 34$					
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	p value	
Demographics										
Age (years)	67.5	7.9	54	86	66.4	10.3	45	83	0.6	
BMI (kg/m^2)	27.4	5	20.8	44	29.5	5.4	20.5	44.7	0.1	
Follow-up (months)	83.1	43.2	25	170	72.1	36.8	24	161	0.4	
Clinics										
KSS pain$_{postoperative}$	86	18	44	100	83.3	16	40	100	0.1	
KSS function$_{postoperative}$	83	23.8	25	100	79.7	24.6	20	100	0.6	
WOMAC score$_{postoperative}$	1	1.4	0	4.5	1.6	1.5	0	5.6	0.04*	
ROM$_{preoperative}$ (°)	121	12.4	90	150	117	13.5	90	140	0.2	
ROM$_{postoperative}$ (°)	125	10.4	100	150	121	11.7	90	140	0.2	
Radiographics										
Aglietti classification	4.1	1.1	1	5	4.1	1	1	5	1.0	
ICRS contralateral	2	1.2	0	4	2.4	1.4	0	4	0.2	
ICRS patellofemoral	3	1.1	0	4	3.1	1.4	0	4	0.3	
Volume necrotic lesion (cm^3)	3	3.5	0.4	20.8	2.9	2.1	0.3	7.7	0.8	
Volume femoral condyle (cm^3)	48.1	16.2	24.4	88	52.8	16.2	28.3	84	0.2	
Relative lesion size (%)	5.8	4.6	1.1	26.6	5.3	3.3	1.2	12.4	0.8	
Surrounding bone edema	1.8	0.4	0	2	1.8	0.4	1	2	0.6	
Complications	n	%			n	%				Relative risk
Failure rate	3	8.1	–	–	1	2.9	–	–	0.3	2.75
Aseptic loosening of femoral component	1	2.7			0	0			0.5	2.76
Total complication rate	4	10.8	–	–	2	5.8	–	–	0.4	1.83

BMI body mass index, *ICRS* International Cartilage Repair Society grading system, *KSS* Knee Society Score, *ROM* range of motion, *SD* standard deviation

*Statistically significant

Stabilized (PS) and nonhinged. No tibial or femoral stems were used. For UKA, Allegretto (Zimmer Biomet), ZUK (Zimmer Biomet), and MyKnee Uni (Medacta) were used. Implantation of the prosthesis was performed with patient-specific instrumentation in 24 cases (12 TKA and 12 UKA), and with conventional condylar referencing in the remaining cases. All implants were cemented. As regular osteotomy in UKA cannot eliminate large osteonecrotic lesions, large defects were filled with cement after curettage of necrotic bone. All implantations were performed or supervised by high-volume surgeons with more than 100 TKA and at least 50 UKA per year. The choice of TKA or UKA was based on the surgeon's prior training, individual preference, and clinical experience. All implanted UKAs met the standard applicability criteria [2, 6] including a stable knee joint, minimal lateral patellar facet disease, a flexion contracture of less than 15°, and a manageable limb alignment and bone loss.

All patients were kept as in-patients, received physiotherapy-assisted mobilization on the first postoperative day, and were discharged after safe self-mobilization, pain control, and dry wounds were established.

Clinical assessment

Clinical outcomes were evaluated with the Knee Society Score (KSS) for pain and function [26], and the Western Ontario and McMaster Universities Osteoarthritis Index [25] (WOMAC), which were completed by all patients during the routine follow-ups 3 months, 1 and 2 years postoperatively. For the final follow-up evaluation, all patients were interviewed by phone and invited to the outpatient clinic for a clinical examination between November 2019 and February 2020. Seven of the 71 patients refused to attend the examination but completed all questionnaires and stated no change in knee range of motion and joint stability compared to the previously performed follow-up.

Medical records were retrospectively reviewed. For this study, significant complications were considered: superficial or deep infection, according to the criteria of the Musculoskeletal Infection Society, wound dehiscence or postoperative hematoma, which required additional intervention. Failure was defined as conversion from UKA to TKA because of aseptic loosening, additional UKA of the initially unaffected compartment due to disease progression, or revision of TKA because of aseptic loosening or instability.

Radiographic assessment

A novel and reproducible method to measure the size of the osteonecrotic lesion in relation to the femoral condyle was introduced: the maximal width, length and depth of the lesion in millimetres among T1-weighted MRI slices were measured (Fig. 1a–b). The volume of the necrotic bone was calculated by multiplying values of width, length and depth. It was then expressed as a percentage of the volume of the femoral condyle by following formula:

$$\frac{\text{volume necrosis (cm}^3\text{)}}{\text{volume femoral condyle (cm}^3\text{)}/2} * 100 = (\%)$$

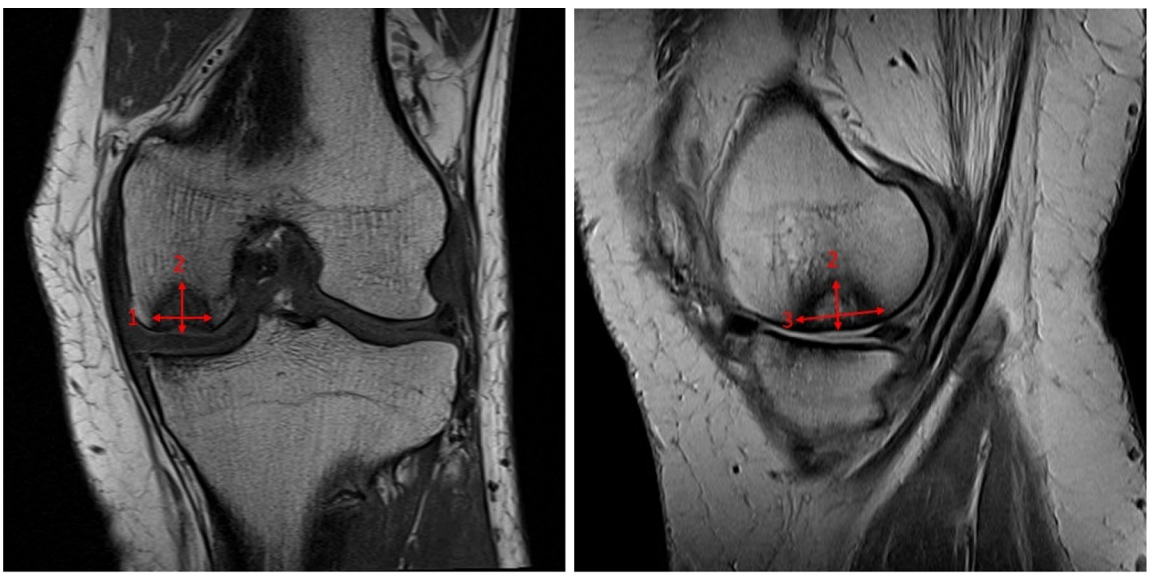

Fig. 1 The volume of the necrotic bone was calculated by multiplying the width (1), depth (2), and length (3) of the lesion, measured on MRI coronal (**a**) and sagittal (**b**) T1-weighted images

The volume of the femoral condyle was calculated with the cylinder formula (radius^2*π*width), and then devided by two. In the sagittal plane, the radius was measured in a standardized manner at the upper edge of the posterior condyle by placing a circle that best fit along the curvature (Fig. 2a, b). The width of the femoral condyle on MRI was measured on the coronal image that showed the popliteus tendon most prominently at his femoral insertion (Fig. 2b). The measurements were performed by a radiologist trained in musculoskeletal imaging (BF) and a senior orthopaedic resident (AF). The intraobserver and interobserver ICCs for the measurement of the necrotic lesion volume were 0.94 (95% confidence interval (CI) 0.81–0.98) and 0.90 (95% CI 0.70–0.97), respectively. The intraobserver and interobserver ICCs for the femoral condyle volume were 0.95 (95% CI 0.60–0.99) and 0.90 (95% CI 0.40–0.98), respectively.

Furthermore, correlations between the calculated relative lesion size and the clinical outcomes were evaluated. The similar measurement method was performed on conventional radiographs (Fig. 3a, b) to evaluate its applicability in case of an unavailable MRI.

The stage of the osteonecrotic lesion was determined based on the preoperative radiograph according to Aglietti et al. [1]. Dimension of surrounding bone edema was defined on MRI as follows: grade 0: no edema; grade 1: mild edema < 50% of affected femoral condyle; grade 2: moderate/severe edema > 50% of affected femoral condyle (Fig. 4). Possible confounding factors that might impair UKA survival were assessed: degenerative changes in contralateral and anterior compartments applying the International Cartilage Repair Society (ICRS) system [3], and correct component positioning (for tibial component: ± 5° varus/valgus, < 5° change of native tibial slope, implant congruency) [6, 7, 9].

Statistical analysis

Rater reliability of the novel MRI measurement method was analyzed with intraclass correlation coefficients (ICCs) and a two-way mixed-effect model assuming a single measurement and absolute agreement. The size of the lesion and its relation to the femoral condyle was compared to the method based on conventional X-rays (Fig. 3) using a method-comparison test. Normal distribution of the data was tested with Kolmogorov–Smirnov test. Accordingly, parametric (independent samples *t* test) or non-parametric (Mann–Whitney *U* test) *t* tests were applied to compare the clinical outcomes between the groups. The relative risk was calculated to identify whether UKA patients have an increased risk of developing postoperative complications like aseptic loosening of the femoral component. Spearman's rank correlation was calculated to analyze the association between the clinical outcome measured with the KSS and the radiological findings (cartilage defects in the contralateral compartment or the patellofemoral joint, necrosis volume, ratio of lesion size to femoral condyle size, and surrounding bone edema). Kruskal–Wallis test was performed to detect a correlation between implant failure and the absolute or relative size of the necrotic lesion. The significance level was set at 0.05. Statistical analyses were computed using MedCalc 19.2 (MedCalc Software Ltd, Ostend, Belgium).

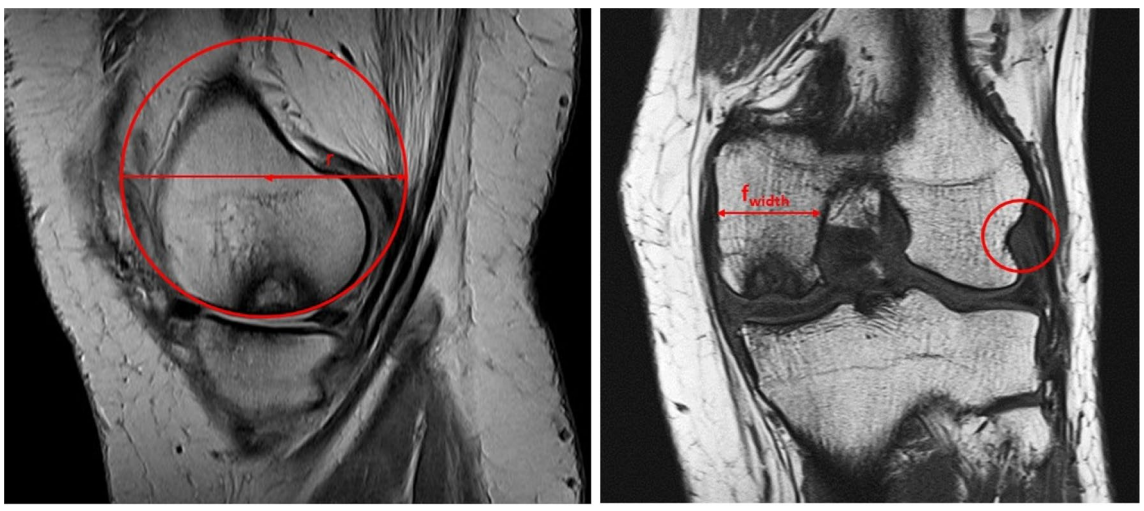

Fig. 2 The volume of the femoral condyle was calculated with the cylinder formula (r^2*π * f_{width}), divided by two. **a** A circle was placed that best fit the femoral curvature on the sagittal plane. The center was positioned at the highest point of the posterior medial condyle to determine the radius (*r*) in a standardized manner. **b** The width of the femoral condyle (f_{width}) is determined on the coronal image that showed the popliteus tendon most prominently at its femoral insertion (circle)

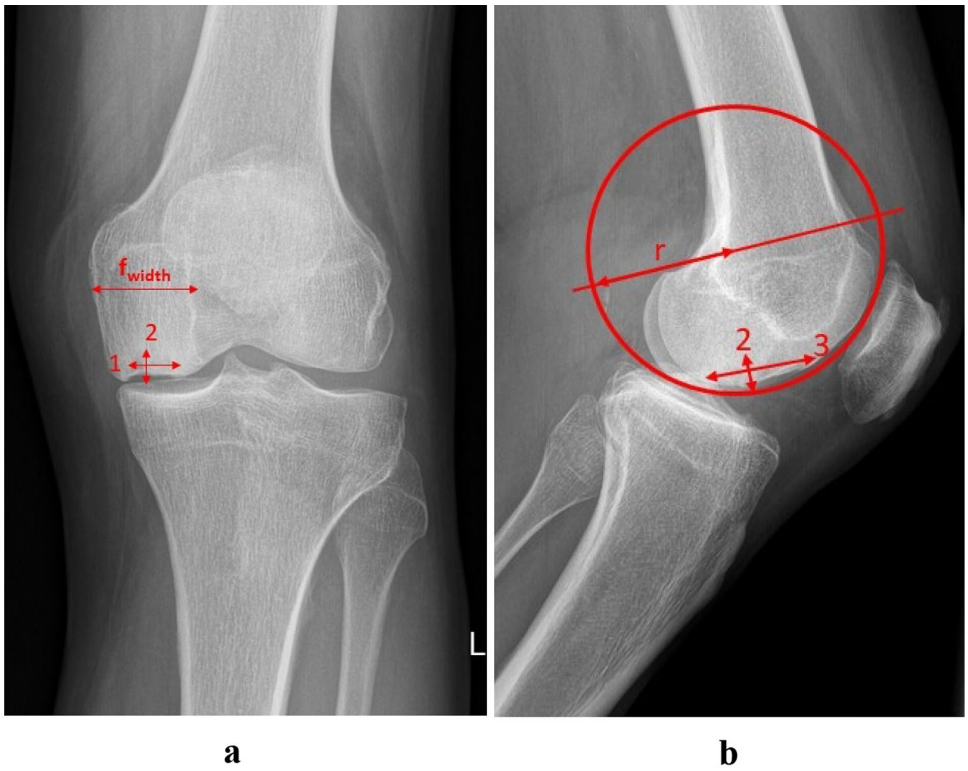

Fig. 3 Measurement method as described in Figs. 1, 2, but on conventional radiographs. **a** The lesion volume was calculated (width (1)*depth (2)*length (3)) and then expressed as the **b** percentage of the volume of the femoral condyle (r^2*π *f_{width}), divided by two

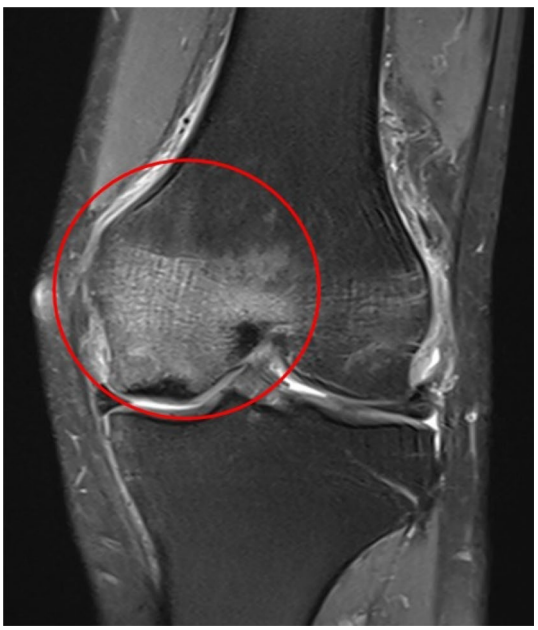

Fig. 4 The dimension of the surrounding bone edema was assessed on coronal MR images. As shown, a surrounding edema containing > 50% of the femoral condyle was graded as moderate/severe (grade 2)

Results

Patients treated with UKA had a higher KSS-pain and KSS-function; however, the differences were not statistically significant (n.s.). The WOMAC score was significantly higher after UKA compared to TKA ($p = 0.04$) (Table 1).

Complication and failure rate

In the TKA group, after a mean follow-up of 6.0 ± 3.1 years, only one TKA (2.9%) was revised to a hinged prosthesis because of persistent flexion instability, 8 months postoperatively.

After a mean follow-up of 6.9 ± 3.6 years, three (8.1%) UKA failures occurred: One patient (2.7%) presented with aseptic loosening of the femoral component, 2 years after UKA implantation. Relative lesion size was 9.6%. The second patient had symptomatic aseptic loosening of the tibial component (relative lesion size: 4%), 9.0 years after the implantation. The third patient sustained a trauma-induced periprosthetic collapse of the tibial plateau 2 months postoperatively. All three failures were medial UKAs, which were subsequently revised to TKAs.

One patient in each group developed a deep infection. Both infections were successfully treated with revision surgery (soft tissue debridement, joint lavage, polyethylene inlay exchange) and initial empiric intravenous antibiotic

therapy followed by targeted oral antibiotic therapy. No other complications occurred.

Based on the complications rate UKA showed a higher relative risk (RR) of 1.83 compared to TKA (Table 1).

Radiographic outcomes

The two treatment groups showed no significant difference in all conducted radiographic parameters (Table 1) (n.s.). The evaluation of implant positioning based on anteroposterior and lateral X-rays showed correct impantation within the generally accepted limits.

Measurement of the relative lesion volume

The mean relative osteonecrotic lesion volume was 5.7% (range 1.0–24.1%) based on conventional X-rays, and 5.8% (range 1.1–26.6%) based on MRI. The method-comparison test showed a bias of − 0.21 (95% CI − 0.67–0.26), ± 1.3 (95% limits of agreement; 95% CI − 2.7–2.3), and percentage error of 12.9% for MRI compared to conventional radiographs, indicating acceptable agreement of the measurement methods.

Correlation of clinical outcome and radiographic parameters

Relative lesion size showed no correlation to implant failure or functional outcome in both groups (Tables 2, 3). No correlation was shown between the functional outcome or implant failure in both groups and the size of the surrounding bone edema and the ICRS stage of the patellofemoral and the contralateral compartment (Table 2).

Discussion

The most important findings of this study are that UKA represents a valuable option for SONK and achieves good functional results and a low failure rate comparable to unicondylar osteoarthritis and comparable to TKA. Furthermore, no correlation could be detected between the relative necrotic lesion size or size of surrounding bone edema and the failure rate.

Despite encouraging results in the literature, it is still uncertain whether UKA is as reliable as TKA for the treatment of focal osteonecrosis [13, 20, 24]. Only few studies exist, which specifically compared both treatment modalities. A systematic review evaluated the results of studies reporting on the outcome of either UKA or TKA for osteonecrosis of the knee, and also found a lower overall revision rate after TKA [20]. However, all of the included studies were flawed by inclusion of both primary and secondary osteonecrosis and inappropriate patient selection for UKA [20]. So far, only one study directly compared the results of UKA to TKA for SONK [24]. In this study, Radke et al. [24] retrospectively evaluated 23 UKAs and 16 TKAs after a mean follow-up of 5 years. They found worse clinical long-term outcomes and a higher revision rate in patients undergoing UKA, which they attributed mostly to secondary osteoarthritic changes in the contralateral compartment. However, their results are limited to the small case series

Table 2 Correlation of clinical outcome and radiographic parameters

			Cartilage anterior (ICRS)	Cartilage contralateral (ICRS)	Necrosis Volume	Relative lesion size	Surrounding bone edema
Total Knee Arthroplasty ($n=34$)	KSS	Correlation coefficient	0.2	− 0.1	− 0.3	− 0.3	0.1
		p value	0.4	0.5	0.1	0.1	0.5
Unicompartmental Knee Arthroplasty ($n=37$)	KSS	Correlation coefficient	− 0.2	− 0.2	0.1	0.2	0.2
		p value	0.3	0.3	0.5	0.2	0.4

KSS = Knee Society Score; ICRS = International Cartilage Repair Society grading system

Table 3 Correlation of clinical outcome and radiographic parameters 2

			KSS pain	KSS function	Failure rate
Total Knee Arthroplasty ($n=34$)	Relative lesion size	Correlation coefficient	− 0.3	− 0.3	0.2
		p value	0.1	0.1	0.2
Unicompartmental Knee Arthroplasty ($n=37$)	Relative lesion size	Correlation coefficient	0.2	0.3	0.1
		p value	0.2	0.1	0.1

KSS Knee Society Score

and lack of contemporary implant designs, with all UKAs implanted before 1988. Moreover, two recent meta-analysis demonstrated that in properly selected patients, UKA is a reliable treatment option for patients with SONK, and that UKA has similar survival rates and clinical outcomes in SONK and medial osteoarthritis [13, 27].

In the present study, the results of a larger cohort of 71 patients suffering from focal SONK treated with either TKA or UKA were compared. After a mean follow-up of 6.6 years, UKA showed slightly superior functional outcomes. The overall complication rate was higher (RR 1.83) when compared to TKA but did not reach significance ($p = 0.4$). This mirrors the results of a recent study comparing TKA to UKA in case of unicondylar osteoarthritis, where the UKA group had higher functional scores but a non-significant lower long-term survivorship (91.8% vs. 94.6%; $p = 0.66$) [8]. Moreover, concerning functional outcome and patient's satisfaction, the results are consistent with recent published literature [5, 14, 15, 28].

It is of further interest, if the reported higher complication rate is due to impaired component fixation. Major concerns were expressed regarding UKA implant anchorage to the femoral condyle because of residual necrotic bone stock [11, 27]. The longest series to date disproved this assumption with a UKA survivorship of 92% at 15 years [21]. In this study, most revisions were indicated for arthritic progression as opposed to component loosening. Nevertheless, only few studies evaluated the correlation between the osteonecrotic lesion size and the clinical outcome after UKA, with no study investigating the influence of the surrounding bone edema. So far, the size of the osteonecrotic lesion was calculated according to the method of Lotke et al. [18]. This technique is based on standard anteroposterior weight-bearing radiographs, with the lesion width and depth expressed as percentages of the width and depth of the medial femoral condyle. To consider the three-dimensional anatomical aspect, a more accurate measurement method on MRI was introduced, which can also reliably be extrapolated to conventional radiographs. With this technique, no significant correlation between failures and osteonecrotic lesion size could be found, independent on the type of implant used. Only one UKA (2.7%) underwent revision because of aseptic loosening of the femoral component in this cohort. This patient had a relative lesion size of 9.6% (mean overall 5.6%; range 1.1–26.6%). Similarly, Greco et al. [11] reported 64 UKAs for SONK and found also only one aseptic loosening of a femoral component (0.6%), as did Bruni et al. [4] (0.8%; one of 84). Other long-term studies reported no cases of aseptic femoral loosening [10, 12]. Moreover, in the meta-analysis of Yoon et al. [27], the risk of revision due to aseptic loosening was not significantly different for UKA indicated for SONK or medial osteoarthritis.

One of the main limitations of this study is the retrospective study design with lacking randomisation to the two treatment groups and possible selections bias due to the individual therapy decisions according to the surgeon's preference. However, the standardized clinical and radiological follow-up protocol with continuous documentation by both institutions allowed for a thorough analysis and comparison of both treatment groups, which were similar in demographic and radiographic data. Especially, comparable values of necrotic area size give some objectivity. Moreover, various prosthesis designs were used in this study, resulting in a more heterogenous cohort. However, a recent randomized-controlled trial found no difference in terms of alignment and clinical results in patients operated with patient-specific or conventional instrumentation [16]. Another limiting factor is the small sample size. Although being underpowered, the present study is, due to the relative rarity of the pathology, the largest published series of patients treated with arthroplasty for focal osteonecrosis, including a mean follow-up of more than 6 years.

Despite the mentioned limitations, this study is of great clinical value as it showed that UKA is a reliable treatment modality for SONK, leading to equally high functional results and low failure rates compared to TKA. Moreover, there is no need for a change of treatment strategy because of the size of the necrotic lesion nor the surrounding bone edema.

Conclusion

UKA is a valuable treatment option for SONK leading to good functional results and a low failure rate comparable to the outcome of UKA in unicondylar osteoarthritis. In case of a surgeon's concern regarding implant anchorage, TKA represents an equivalent solution. However, the MR-tomographic size of the osteonecrotic lesion seems to have no influence on the results.

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Compliance with ethical standatds

Conflict of interest No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

Ethical approval Ethical approval for this study was obtained from Zurich Cantonal Ethics Comission: KEK 2019–02114.

Informed consent Written informed consent was obtained from all subject before the study.

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