Malposition is main cause of failure of Oxford mobile-bearing medial unicompartmental knee arthroplasty

A retrospective study with minimum five-year follow-up

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Aims

Unicompartmental knee arthroplasty (UKA) is the preferred treatment for anterior medial knee osteoarthritis (OA) owing to the rapid postoperative recovery. However, the risk factors for UKA failure remain controversial.

Methods

The clinical data of Oxford mobile-bearing UKAs performed between 2011 and 2017 with a minimum follow-up of five years were retrospectively analyzed. Demographic, surgical, and follow-up data were collected. The Cox proportional hazards model was used to identify the risk factors that contribute to UKA failure. Kaplan-Meier survival was used to compare the effect of the prosthesis position on UKA survival.

Results

A total of 407 patients who underwent UKA were included in the study. The mean age of patients was 61.8 years, and the mean follow-up period of the patients was 91.7 months. The mean Knee Society Score (KSS) preoperatively and at the last follow-up were 64.2 and 89.7, respectively ($p = 0.001$). Overall, 28 patients (6.9%) with UKA underwent revision due to prosthesis loosening (16 patients), dislocation (eight patients), and persistent pain (four patients). Cox proportional hazards model analysis identified malposition of the prostheses as a high-risk factor for UKA failure ($p = 0.007$). Kaplan-Meier analysis revealed that the five-year survival rate of the group with malposition was 85.1%, which was significantly lower than that of the group with normal position (96.2%; $p < 0.001$).

Conclusion

UKA constitutes an effective method for treating anteromedial knee OA, with an excellent five-year survival rate. Aseptic loosening caused by prosthesis malposition was identified as the main cause of UKA failure. Surgeons should pay close attention to prevent the potential occurrence of this problem.

Take home message

- The accurate implantation of prostheses is crucial in unicompartmental knee arthroplasty.
- Although the early impact of malposition on joint function may not be significant, it is very important for long-term survival.

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Introduction

Although the overall proportion of unicompartmental knee arthroplasty (UKA) surgeries is relatively low, it has become a preferred surgical option for knee salvage in recent years and constitutes an effective treatment for anterior medial osteoarthritis (OA).[1,2] UKA has not been a widely used surgical option for a long time owing to concerns regarding its long-term clinical efficacy, limitations in implant design, and for other unknown reasons.[3] However, with continuous improvements in prostheses and the application of standardized techniques, the clinical outcomes of UKA have improved substantially in the past two decades.[4] Studies have reported that the long-term clinical efficacy and survival rate of UKA are comparable to those of total knee arthroplasty (TKA),[5,6] which has led to a significant increase in the application of UKA in joint surgery.

Common complications of UKA, and the main reasons for failure, include aseptic loosening, periprosthetic infection, joint instability, and periprosthetic fractures.[7] Earlier, the medium- and long-term efficacies of UKA were not as good as that of TKA, and these were mainly attributable to the inappropriate selection of surgical indications. In other words, UKA was performed on unsuitable patients, and the technical factors of the surgeon were often overlooked. Compared to TKA, UKA represents a more challenging surgical procedure that requires exceptional surgical techniques,[8] indication assessments, preoperative evaluations, and extensive clinical experience.[9] A minor surgical mistake or lack of experience can lead to a series of complications that can affect the clinical outcomes and survival rate of the prosthesis.

The risk factors that lead to UKA failure and affect the survival rate of prostheses remain controversial. Some studies suggest that application of UKA in relatively young and active patients increases the risk of failure,[10] whereas others indicate the opposite.[11,12] A series of studies based on dynamic image monitoring found that early postoperative displacement of prostheses is common in UKA, and leads to the eventual loosening and failure of the prostheses. However, there are clear differences among the different studies.[13] In recent years, some studies have found that robotic-assisted UKA can improve the positioning of the prostheses, thereby improving their clinical efficacy and reducing revision rates.[14-16] To the best of our knowledge, there are no current reports on the impact of UKA prosthesis position deviation on the survival rate. Therefore, in this study we sought to retrospectively evaluate the clinical data of 407 patients who underwent UKA in a single joint arthroplasty centre with long-term follow-up (five to 11 years), and to analyze the clinical efficacy of the procedure and the risk factors for UKA failure. Furthermore, we sought to investigate the impact of the prosthesis position on the UKA survival rate.

Table I. Baseline characteristics.

Variable	Cases, n (%)
Age, yrs	
< 55	93 (22.9)
55 to 65	163 (40.0)
> 65	151 (37.1)
Sex	
Male	148 (38.7)
Female	234 (61.3)
Side	
Left	185 (45.5)
Right	222 (54.5)
Job	
Manual labour	118 (30.9)
Non-manual labour	264 (69.1)
Aetiology	
Osteoarthritis	371 (91.2)
Necrosis	36 (8.8)
Comorbidities	
Yes	97 (23.8)
No	310 (76.2)
KSS	
Preporerative	64.2
Last follow-up	89.7*
Hospital stay, days	
≤ 7	316 (77.6)
7	91 (22
Complications	**28 (6.9)**
Infection	0 (0.0)
Loosening	16 (57.1)
Dislocation	8 (28.6)
Unexplained pain	4 (14.3)

*$p < 0.05$.
KSS, Knee Society Score.

Methods

Case data and research design

All patients who underwent UKA in the joint surgery centre at our hospital (Shanghai General Hospital, Shanghai, China) between January 2011 and December 2017 were enrolled in the study, and their clinical data were retrospectively evaluated for a mean follow-up period of 91.7 months (standard deviation (SD) 27.15). After excluding 37 patients with incomplete follow-up data and those lost to follow-up, the study included 382 patients (148 males and 234 females) with 407 UKA procedures between them. In all, 25 of these patients underwent a staged bilateral arthroplasty. The mean age of the patients was 61.8 years (49 to 74). All data were sourced from the medical records, outpatient follow-up data system, and questionnaire surveys. The follow-up concluded in December 2022 to ensure that all the patients were followed up for at least five years.

This study was approved (No. 2023180) by the ethics committee of the Clinical Research Centre of the hospital and obtained informed consent from patients. The data collected included demographic information, nature of work, aetiology of UKA, comorbidities (severe cardio-cerebral pulmonary

Table II. Analysis of the relationship between poor prosthesis position and revision rate based on postoperative imaging at six months.

Variable	Total cases, n	Revision cases, n	Revision rate, %	Pearson chi-squared calculation	p-value
Malposition	114	17	14.9*	15.949	< 0.001
Normal position	293	11	3.8		
Malposition of tibial prosthesis	93	13	14.0	0.347	0.556
Incomplete coverage or protrusion	34	N/A	N/A	N/A	N/A
Varus/valgus > 5°	53	N/A	N/A	N/A	N/A
Posterior inclination > 7° or < 0°	6	N/A	N/A	N/A	N/A
Malposition of femoral prosthesis	21	4	19.0	N/A	N/A
Varus/valgus > 10°	4	N/A	N/A	N/A	N/A
Flexion > 15°/ extension > 0°	17	N/A	N/A	N/A	N/A

*p < 0.05.

Variables in the Equation[b]

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
gender	-.079	.615	.017	1	.897	.924	.277	3.080
age <55y	1.318	.791	2.776	1	.096	3.735	.793	17.601
age 55-65y	.538	.570	.890	1	.345	1.713	.560	5.239
age >65y			.	0[a]	.			
side	.502	.392	1.641	1	.200	1.653	.766	3.565
heavy labor	-.466	.499	.871	1	.351	.628	.236	1.669
etiology	1.017	1.031	.974	1	.324	2.765	.367	20.857
sever comorbidity	-.722	.558	1.669	1	.196	.486	.163	1.452
KSS before surgery	-.021	.034	.383	1	.536	.979	.915	1.047
KSS after surgery	.010	.045	.048	1	.827	1.010	.925	1.102
length of stay	-.145	.156	.866	1	.352	.865	.638	1.174
malposition of the prosthesis	1.608	.591	7.394	1	.007	4.994	1.567	15.917
malposition of tibial prosthesis	-.058	.581	.010	1	.920	.943	.302	2.946
malposition of femoral prosthesis			.	0[a]	.			

a. Degree of freedom reduced because of constant or linearly dependent covariates

b. Constant or Linearly Dependent Covariates age >65y = 1 - age <55y - age 55-65y ; malposition of femoral prosthesis = malposition of the prosthesis - malposition of tibial prosthesis ;

Fig. 1
Cox proportional hazards model analysis found that only malposition of the prosthesis is a high-risk factor of unicompartmental knee arthroplasty failure (p = 0.007).

disease, and severe osteoporosis with a bone mineral density T-score <- 2.5), surgery- and hospitalization-related information, imaging data, Knee Society Score (KSS),[17] complications, and other follow-up data. Although obesity and osteoporosis are not absolute contraindications for UKA, there were no cases in this group with a BMI > 30 kg/m^2, nor were there any patients with severe osteoporosis (T-score < −2.5). Two experienced joint surgeons (JM, LZ) performed the 407 UKAs. All UKAs were performed using Oxford partial knee prosthetic implants (Zimmer Biomet, USA) and the femoral condyle composed of a single-column prosthesis fixed with bone cement and designed with a mobile platform. Clinical data were collected and organized by an independent researcher (HQ, YX). The imaging data were independently analyzed by a senior surgeon from another centre. According to the follow-up schedule, the first stage of the follow-up was performed at one, three, six, and 12 months post-surgery, at which time imaging was performed and the joint function was evaluated for complications. The second stage of the follow-up was conducted annually thereafter, with revision surgery or

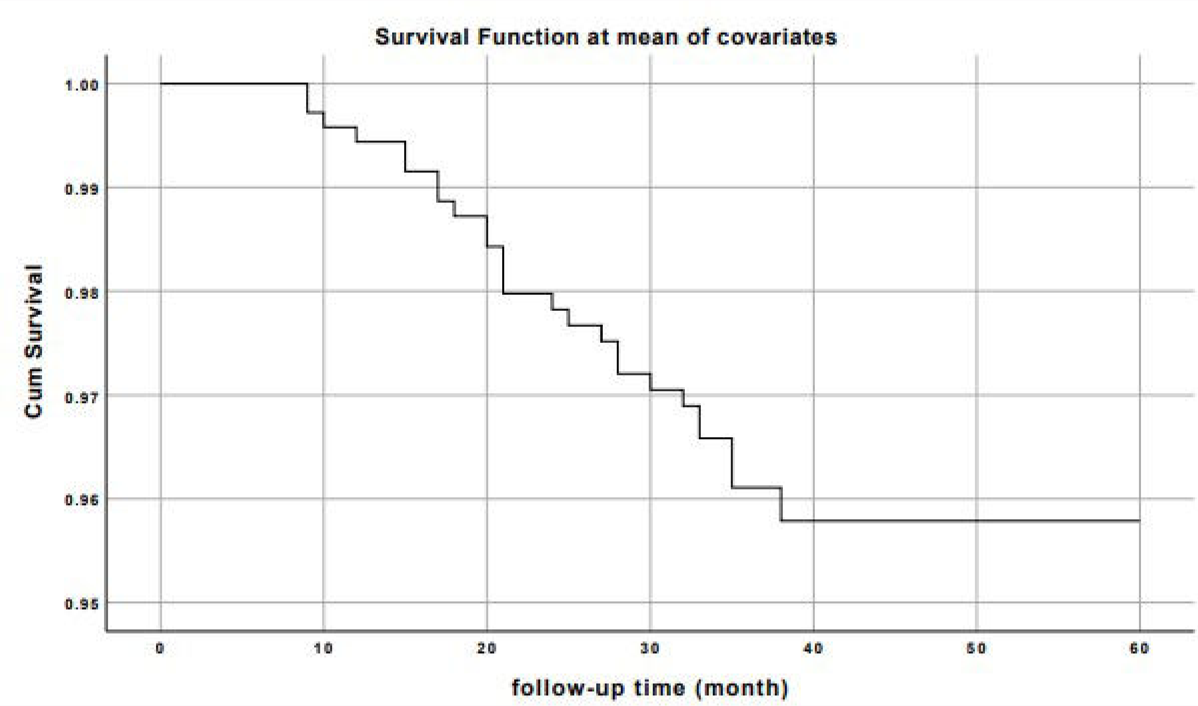

Fig. 2
Cumulative survival analysis function shows excellent five-year survival rate.

death from any cause constituting the follow-up endpoint. In cases where major complications led to revision surgery, detailed records of the cause of failure and the time interval from surgery to revision were maintained.

Postoperative radiological imaging data were obtained for each patient at six-month follow-up, and the position of the tibial and femoral prostheses were measured and analyzed. Based on standard anteroposterior and lateral radiographs, postoperative UKA prosthetic malposition was identified based on the following criteria: incomplete coverage or protrusion (> 2 mm) of the tibial prosthesis on the anteroposterior radiograph, > 5° varus or valgus of the tibial prosthesis, and > 10° varus or valgus of the femoral prosthesis; on the lateral film, posterior inclination of the tibial prosthesis > 7° or < 0°, flexion of the femoral prosthesis > 15°, or extension > 0°. Based on these criteria, all the UKA cases were divided into two groups: with normal prosthesis position and with prosthesis malposition.

Statistical analysis

Descriptive analysis was used to obtain basic information pertaining to demographics, case, and complications. Quantitative KSS data collected before and after the surgery were statistically analyzed using paired *t*-test. Imaging data were used to study the effect of differences in prosthetic position on UKA revision rates using Pearson's chi-squared test. The Cox proportional hazards model was used to analyze the effect of various patient and surgical factors on UKA revision, and the Kaplan-Meier survival curve was used to analyze the effect of the position of the UKA prostheses on the survival rate of UKA. Statistical analysis were performed using SPSS v. 26.0 (IBM, USA), and statistical significance was set at $p < 0.05$.

Sample size estimation

To determine whether the position of the implant affects the survival rate of UKA, we used ten-year UKA survival data reported in the existing literature for sample size estimation. According to Ekhtiari et al,[18] the revision rate of UKA after ten years is approximately 16.5%, whereas a recent study by Kyriakidis et al[12] reported it as being 3.5%. Based on the differences in the revision rates between the two reports, the calculated risk ratio (RR) was 4.71 (bilateral $\alpha = 0.05$, $\beta = 0.10$, and the number of cases in the two groups is 1:1). Using Power Analysis & Sample Size (PASS) v. 15.0,[19] the sample size required for our study was estimated to be 107 patients in each group (totalling 214 patients). The total sample size and number of participants in each group in our study met these requirements.

Results

This study included 407 patients who underwent UKA between January 2011 and December 2017. The longest and shortest follow-up periods were eleven and five years, respectively, with a mean follow-up period of 91.7 months (SD 27.15). In our study, females and patients aged over 55 years accounted for 61.3% and 77.1% of patients, respectively (40.0% aged between 55 and 65 years, and 37.1% aged over 65 years). The proportion of manual workers was relatively low (30.9%). Most patients who underwent UKA had anterior medial OA of the knee joint (91.2%), and most of them were in good physical health (76.2%). The clinical efficacy of these 407 UKAs was excellent, with the average KSS increasing from 64.2 points before surgery to 89.7 points after surgery ($p = 0.001$). Only 28 patients presented with serious postoperative complications and underwent TKA, contributing to a total revision rate of 6.9%. In revision cases, the mean

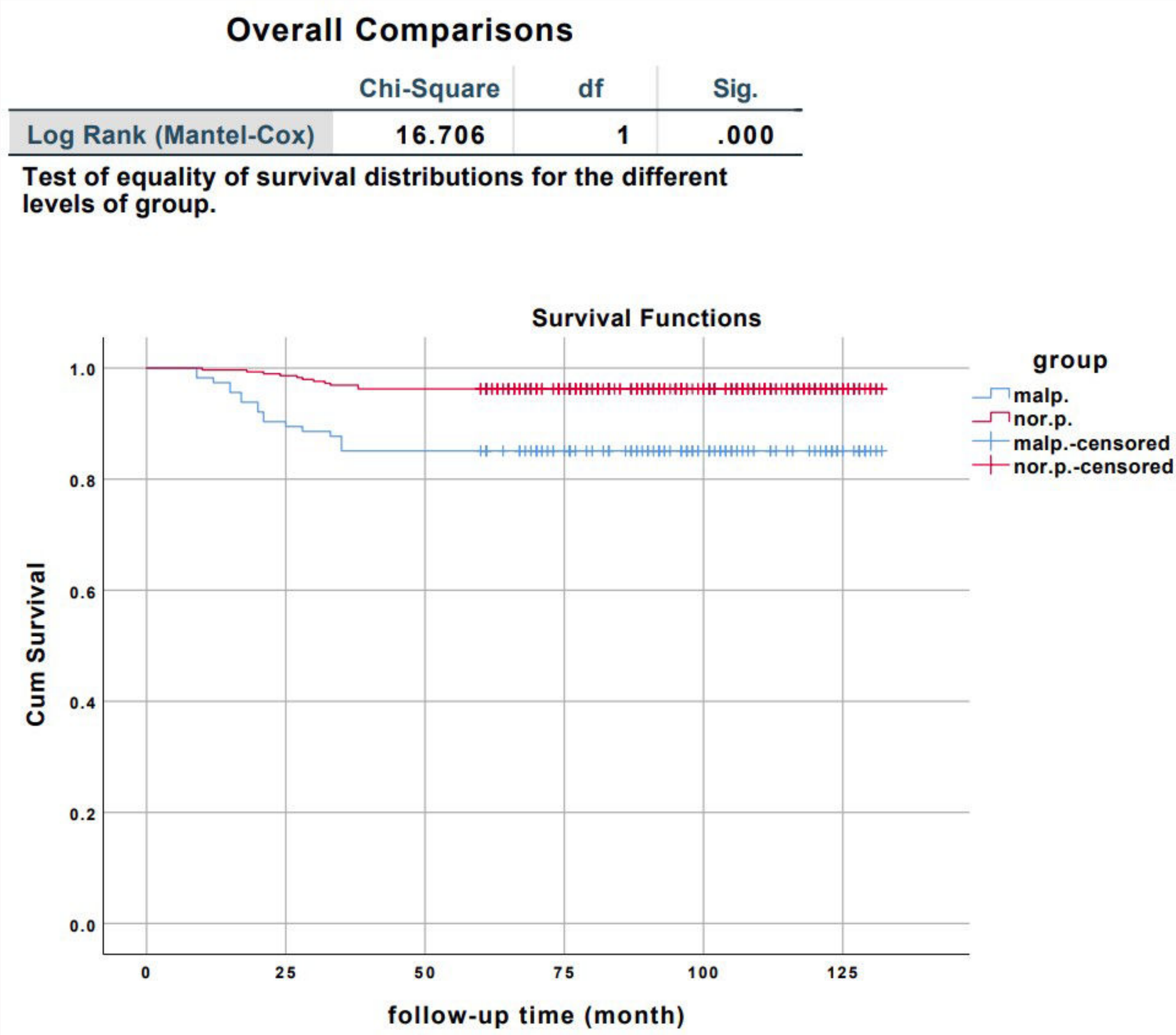

Fig. 3
Kaplan-Meier survival shows different survival rate between malposition group and normal position group ($p < 0.05$).

time from surgery to revision was 18.3 months (9 to 35). The highest proportion of revision cases was aseptic loosening of the prosthesis (57.1%), and none of the patients had severe osteoporosis prior to surgery. Among the eight cases of revision owing to dislocation, only three were the consequence of minor trauma. None of the patients required revision surgery for infection (Table I).

Analysis of the anteroposterior and lateral images of the postoperative knee joint at six-month follow-up revealed that, based on the aforementioned prosthesis position standards, 114 of 407 UKAs (28.0%) showed poor prosthesis position. Among them, 93 patients (22.9%) showed tibial implant malposition and 21 (5.1%) showed femoral implant malposition. In all, 12 cases of aseptic loosening and three cases of dislocation showed different types of tibial prosthesis malpositions. Two cases of dislocation and one case of unexplained pain showed femoral prosthesis malpositioning. The revision rate in the group with poor prosthesis position was significantly higher than that in the group with normal prosthesis position ($p < 0.001$, Pearson's chi-squared test), whereas there was no significant difference in the revision rate between poor tibial and femoral prosthesis positions (14.0% vs 19.0%) (Table II).

Using the Cox proportional hazards model (Figures 1 and 2), we analyzed the impact of various potential factors on the survival rate of UKA prostheses and found that sex, age, left and right sides, physical labour, aetiology of UKA, and underlying comorbidities, KSS before and after surgery, and length of hospital stay did not pose a significant risk to the survival rate of UKA. Malpositioning of the prosthesis was identified as a high-risk factor for UKA failure ($p = 0.007$, Cox proportional hazards model), and the most significant impact period was within the first three years following surgery.

Kaplan-Meier analysis revealed that the overall five-year survival rate of patients who underwent UKA was 93.1%. The mean survival time of the group with normal prosthesis position was significantly higher than that of the group with poor prosthesis position (128.1 months (SD 1.2

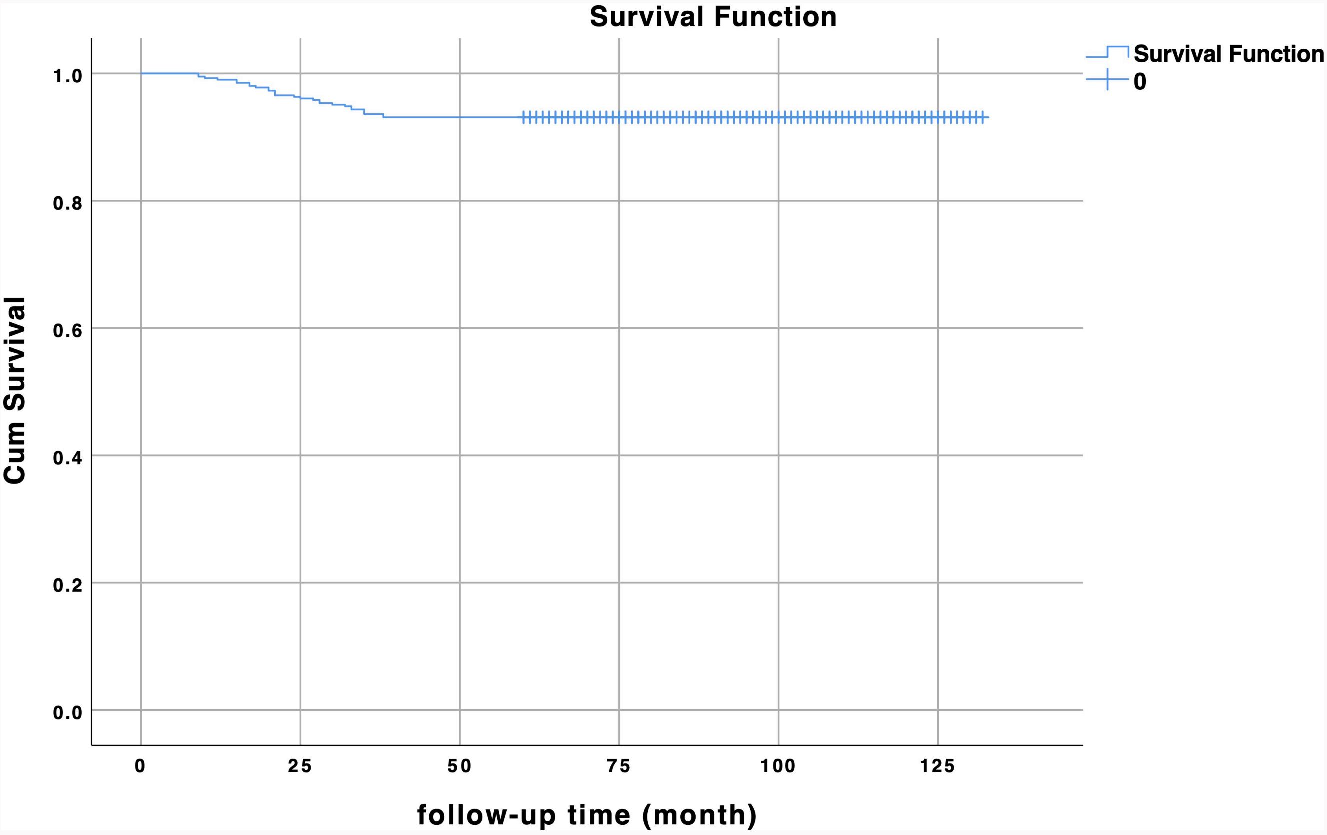

Fig. 4
Overall five-year survival rate of 407 cases.

vs 115.5 months (SD 3.7); p < 0.001, Kaplan-Meier survival analysis). In addition, the five-year survival rate of the group with a normal prosthesis position was also significantly higher than that of the group with poor prosthesis position (96.2% vs 85.1%; p < 0.001) (Figures 3 and 4).

Discussion

UKA has been a surgical treatment option for OA for nearly 50 years.[1] With continuous improvements in prosthetic design and surgical techniques, UKA has become the preferred procedure for treating anterior medial knee OA. Although high tibial osteotomy (HTO) also holds a place in the treatment of knee OA with non-TKA, clinical reports suggest that UKA has better clinical efficacy and lower incidence of complications compared with HTO.[20,21] The results of this study also revealed that the KSS improved significantly following UKA from an average preoperative score of 64.2 points to 89.7 points postoperatively. According to previous clinical follow-up studies, the ten-year UKA survival rate was between 80.6% and 84.0%.[22,23] Exciting new data suggest that improvements in prosthetic design, surgical tools, and techniques have markedly improved the effectiveness of UKA. Price et al[24] reported that only 29 of 682 patients with UKA underwent revision surgery in 20 years of follow-up, with a survival rate of 91%. Yoshida et al[25] reported that only 25 of 1,279 patients with UKA underwent revision in ten years of follow-up, with a ten-year survival rate of 95%. Recent large-scale clinical follow-up studies and systematic reviews suggest that the ten-year survival rate following UKA exceeds 85%, with a maximum of 96.5%.[18,26,27] In our study of 407 UKAs with a mean follow-up of 91.7 months (SD 27.15), only 28 patients underwent revision surgery. Major complication rate was found to be 6.9%, and the prosthesis survival rate was consistent with that reported in the literature. Therefore, UKA should be considered a reliable surgical option for treating medial compartment knee OA.

The most common causes of failure and revision following TKA are infection, mechanical instability, periprosthetic fractures, and aseptic loosening, with infection reported as the primary acute cause of TKA failure.[28] However, the factors contributing to UKA failure appear to be different. In the 407 cases analyzed in this study, no revision was attributable to periprosthetic joint infection and 57.1% of the revisions were a consequence of aseptic loosening. Several studies have reported similar findings. In their population-based cohort study of 4,385 UKA cases with minimum ten-year follow-up, Ekhtiariet al[18] reported that revisions owing to mechanical loosening accounted for 83.4% of all revisions. Tay et al[10] also found that aseptic loosening of prosthesis was the primary cause of revision among all patients, and was significantly higher in relatively young patients, accompanied by pain and bearing displacement.[10] Furthermore, some studies have speculated that the poor positioning of UKA prostheses may cause changes in the load-bearing force of the knee joint, thereby affecting the survival rate of the prostheses. However, if the cost is not a consideration, robotic-assisted UKA may improve the precision and accuracy of prosthesis positioning. Matassi et al[16] reported that robotic-assisted UKA can help doctors with low hand counts improve the accuracy of the prosthetic position and reduce deviation rates.[16] Gaudiani et al[15] and Zhang et al[14] also found that robotic-assisted medial UKA helped to improve the accuracy of prosthetic positioning and recovery of joint function. However, these studies did not investigate the degree to which prosthesis position deviation affected the UKA survival rate. In the current study, and using Cox proportional hazards model analysis, we identified poor prosthesis positioning as the main risk factor for UKA failure and found that majority of UKA failures were caused by aseptic loosening. In addition, the 407 UKA cases were divided into two groups based on imaging measurements. Statistical analysis revealed that the revision rate in the group with poor prosthesis position was significantly higher than that in the group with normal prosthesis position (14.9% vs 3.8%; $p < 0.05$, Pearson's chi-squared test). The postoperative five-year survival rate in the group with malposition was also significantly lower than that in the group with normal position (85.1%vs. 96.2%). In summary, the results of this study showed that aseptic loosening caused by poor prosthesis positioning was the main reason for UKA failure.

In the past, discussions on the effectiveness of UKA in achieving good long-term clinical results have focused on reasonable assessment of the indications. Although this is an important component to achieve good surgical outcome following UKA,[29,30] some joint surgeons often overlook the importance of poor prosthesis installation owing to iatrogenic factors. Given the increase in number of UKAs being performed, surgeons who have performed few UKA procedures are more likely to experience poor installation of prosthetic positions, which may affect the long-term survival rate. Surgeons need to pay close attention to the positioning of the prosthesis during surgery, or alternately use robotic-, navigation-, and other assisted devices to improve the accuracy of prosthesis positioning. Clinical data of the 407 cases evaluated in this study revealed that although the two surgeons who performed the UKA surgeries had over 20 years of TKA and ten years of UKA experience between them, with approximately 114 patients (28%) presenting with poor prosthetic positioning; of these patients, 17 (14.9%) underwent revision surgery. These data suggest that UKA should not be treated as a scaled-down version of TKA, and is a technically challenging procedure that should be performed by highly experienced surgeons to achieve optimal clinical outcomes.[8] Using the New Zealand Joint Registry database to investigate UKA usage on UKA revision rates, Klasan et al[8] concluded that surgeons with higher UKA usage had lower UKA revision rates, and that TKA surgical experience did not reduce the UKA revision rate. In addition, all 28 UKA revisions occurred within three years of surgery in the present study; therefore, early follow-up following UKA is crucial.

Due to the design principles of different prostheses, anatomical differences in individual knee joints may lead to differences in the position of the prosthesis. We need to fully consider this when determining the position accuracy of the prosthesis after surgery; the Oxford mobile-bearing prosthesis used in this study is designed based on the principle that the tibial plateau prosthesis is perpendicular to the alignment of the lower limb, while the femoral prosthesis is perpendicular to the tibial prosthesis on the coronal plane. Therefore, this design requires a relatively unified standard for imaging measurement of prosthetic components in different individuals, without being affected by anatomical variations.

This study has some limitations. First, this was a retrospective study, and its results may have been influenced and interfered with by several factors, such as the patient's preoperative lower-limb alignment, surgeon preferences, and regional differences, which may have contributed to the differences with the other reports. Second, the sample size of this study was relatively small and the mean follow-up time was short, making it difficult to identify all the risk factors for UKA failure, as the effects of certain factors may take longer to manifest. Third, there was no discussion on the impact of different degrees of malposition on outcomes, as varying degrees of malposition are also completely different. Finally, the mean number of UKAs performed annually by the surgeons in this study was approximately 30, and the lower specific procedure experience may have contributed to the high incidence of prosthetic malposition, which may have influenced the results of this study.

Overall, this study shows that the position of the prosthesis is very important for UKA, and robotic-assisted UKA can effectively help improve position accuracy not only in the preoperative planning stage, but also in the intraoperative stage. Comparative studies between "classic" positioning versus robotic assistance could later on be of major interest to objectify the benefit provided by the robot.

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W. Sang: designed the study and wrote the original draft.
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Y. Xu: collected and organized the data.
Y. Pan: did the investigation and supervision.
J. Ma: were the project administration. Libo zhu reviewed and edited the manuscript.
L. Zhu: were the project administration. Libo zhu reviewed and edited the manuscript.

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Data sharing

All data generated or analyzed during this study are included in the published article and/or in the supplementary material.

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