The Knee 37 (2022) 188–195

Contents lists available at ScienceDirect

The Knee

journal homepage:

Effect of tibial component overhang on survivorship in medial mobile-bearing unicompartmental knee arthroplasty

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ARTICLE INFO

Article history:
Received 29 March 2022
Revised 28 May 2022
Accepted 28 June 2022

Keywords:
Unicompartmental knee arthroplasty
Unicondylar knee replacement
Tibial component overhang
Revision
Survival rate

ABSTRACT

Background: Some studies have shown that the position of the tibial component in Oxford unicompartmental knee arthroplasty with a mobile bearing will affect the clinical outcome of patients. Hence, our study aimed to investigate the relationship between the overhang distance of the tibial component and the survival of the implant.
Methods: A retrospective analysis of patients who underwent unicompartmental knee arthroplasty at the same institution from 2014 to 2018 was presented. The study was divided into three groups: minor underhang group (underhang between −3 and 0 mm); minor overhang group (overhang 0–3 mm); and major overhang group (overhang $\geq$ 3 mm). Demographic and clinical profile characteristics of each group were compared, and survival curves of each group were also compared using Kaplan–Meier and modeled using multivariate Cox regression.
Results: A total of 351 knees were included in this study with a minimum follow up of three years and a mean follow up of 4.8 ± 1.5 years. The revision rates in each group were 3.6% (minor underhang group), 2.7% (minor overhang group), and 20.9% (major overhang group) ($P < 0.001$). From the three groups' cumulative survival rates, the major overhang group was significantly lower than the other two groups (log rank $P < 0.001$). Multivariate Cox regression showed an association between the major overhang group and implant survival rate (hazard ratio = 7.515, 95% confidence interval = 2.500–22.593, $P < 0.001$)
Conclusion: The risk of revision will increase if the tibial component overhangs more than 3 mm medially. Moreover, the reasons for revision are generally bearing dislocation and aseptic loosening.

1. Introduction

As an efficient treatment for anteromedial knee osteoarthritis, unicompartmental knee arthroplasty (UKA) is characterized by minimal invasiveness, rapid recovery, reasonable functional and patient satisfaction, and good long-term follow up

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https://doi.org/10.1016/j.knee.2022.06.011
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outcomes [1–5]. Although UKA has many advantages, the literature [2,6–8] has shown that UKA has a higher revision rate than total knee arthroplasty (TKA). Common reasons for revision in UKA are knee pain, aseptic loosening of the component, progression of contralateral knee osteoarthritis, and bearing wear/dislocation [9,10]. However, fewer researchers have focused on the relationship between tibial component position and postoperative revision rates. Chau et al. [11] reviewed tibial component coverage in 160 cases after UKA and explained the effect of tibial component position on postoperative knee function. Gardena et al. [12] introduced the impact of unicondylar tibial component probing on medial collateral ligament tension using six cadaveric specimens.

Hence, our current knowledge of the relationship between the tibial component overhang and postoperative implant survival after UKA remains limited. This study aimed to examine the effect of tibial component position on postoperative revision rates by retrospectively analyzing patients who underwent UKA at our institution from January 2014 to December 2018. We hypothesized that excessive tibial component overhang was associated with a postoperative revision.

2. Methods

After obtaining ethics committee approval, cases undergoing unicondylar replacement at the Department of Joint Surgery, The Second Hospital of Dalian Medical University, from January 2014 to December 2018, were collected for this study. The Oxford criteria were used for surgical indications. Inclusion criteria included: anteromedial osteoarthritis, inversion deformity completely correctable, and no sclerosis of the lateral intercondylar compartment during valgus stress. Exclusion criteria included: cases with lateral unicondylar replacement, revision due to infection, traumatic knee osteoarthritis, rheumatoid arthritis, history of knee surgery, and personal history of trauma, tumor, skeletal or neuromuscular disorders that may affect clinical outcome were excluded. Obesity, advanced age, and patellofemoral arthritis did not take contraindications into consideration. In addition, if postoperative X-rays showed the rotation of the patient's knee in the coronal position (Fig. 1), i.e., the thickness of the vertical wall of the tibial component [11], to avoid measurement errors of the medial tibial component overhang, the patient's outpatient review X-ray records without rotation would be examined for accurate measurement.

All procedures were performed with the Oxford mobile-bearing UKA (Zimmer Biomet, Warsaw, IN, USA). The tibial and femoral components were fixed with acrylic resin bone cement (Zimmer Biomet, Warsaw, IN, USA). All procedures were performed by the same joint surgeon with experience in more than 100 UKAs using Oxford III instruments and according to standard protocols described in the literature [13,14]. All patients underwent functional exercises on the first postoperative day under medical supervision and were ambulatory on the second postoperative day. Front and lateral radiographs of the knee and full-length films of both lower extremities were taken in the standard position under the supervision of the imaging surgeon. Moreover, we used the same postoperative rehabilitation protocol for all patients.

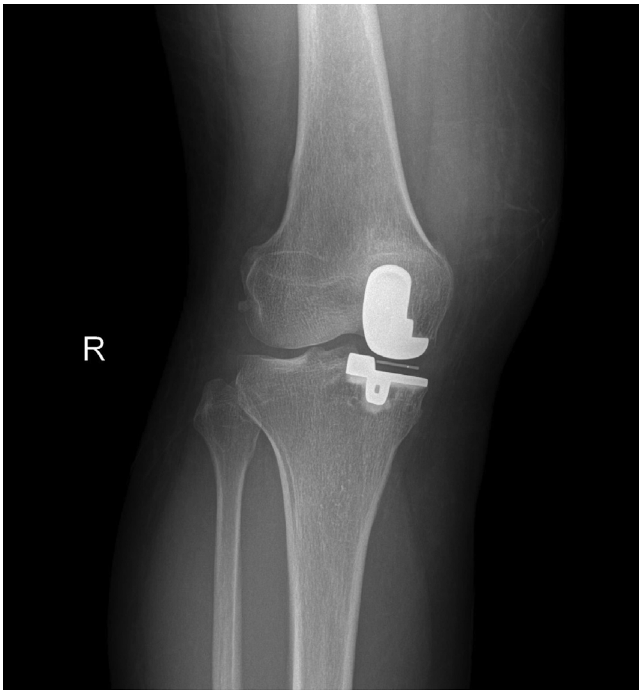

Fig. 1. Over-rotated knee X-ray. The thickness of the vertical wall indicates that the knee is rotated in the coronal position.

The data were obtained by two joint surgeons blinded to the purpose of this study using the Picture Archiving and Communication System (Zhonglian, Chongqing, China) on a computer to measure the distance of tibial component overhang (a) on a standard anteroposterior X-ray and then averaged (Fig. 2). If the difference in 'a' between the two surgeons' measurements was more than 1 mm at any one time during the process, the measurement was repeated. The overhang was expressed as a positive number, and the underhang was defined as a negative number. According to the overhang distance of the tibial component, the study was divided into three groups: the 'minor underhang group' was defined as -3 mm < a < 0 mm; the 'minor overhang group' was defined as 0 mm $\leq$ a < 3 mm; the 'major overhang group' was described as $\geq$ 3 mm.

This study focused on the Oxford Knee Score (OKS, 0–48), range of motion (ROM), and visual analog scale (VAS) pain score (0–10) at the last follow up to evaluate the clinical outcomes of each group. All patients were tracked by chart review and telephone follow up to see whether they received revision surgery at our hospital or another hospital in the years following surgery. Replacement bearings or TKA resulting from the following causes were considered revision: progressive arthritis, bearing dislocation, prosthesis loosening, periprosthetic fractures, and other aseptic causes. In addition, we recorded the patient's gender, age at the time of surgery, body mass index (BMI), surgical site, postoperative hip–knee–ankle (HKA), varus/valgus angle of the tibial and femoral component (positive numbers mean valgus), tibial slope, femoral flexion/extension (positive numbers means flexion), size of the tibial component, and bearing thickness. The demographic and clinical data of each group, except for gender (P < 0.001), were not statistically different (P > 0.05) (Table 1).

SPSS 26.0 software for windows was applied for statistical analysis. The mean ± standard deviation was used for normally distributed measures, and numbers (%) were used for categorical variables. The Kolmogorov–Smirnov test was used to check the normality of the data. Analysis of variance was used for measurement data; the chi-squared test or Fisher's exact test was used for categorical variables. Furthermore, the Bonferroni method was used for comparison among groups. Kaplan–Meier survival curves were used to compare postoperative prosthetic survival differences among groups and determine whether the equiproportional risk condition was met. Cox regression models were created by including multiple variables in Cox

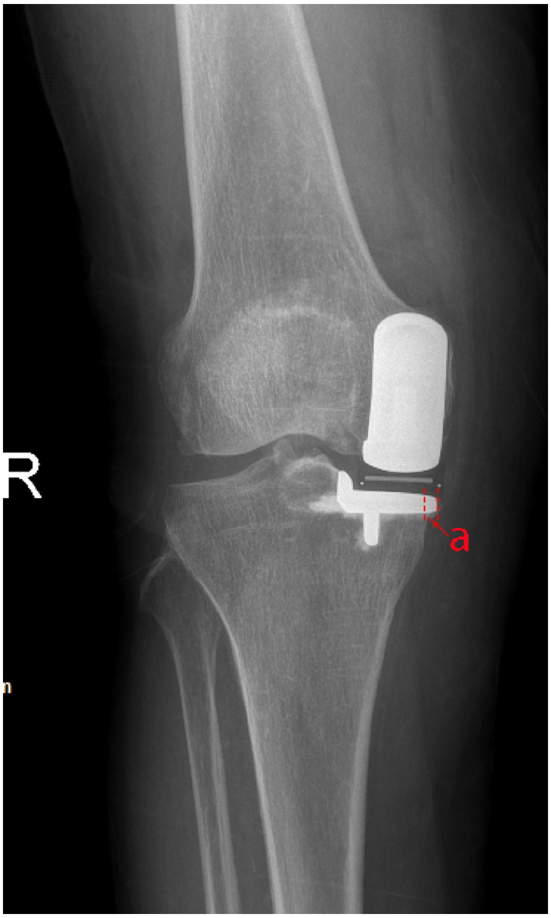

Fig. 2. Overhanging tibial component. The dashed line and arrow depict the distance of the tibial component over the medial tibial cortex of the tibial plateau.

Table 1
Demographic and clinical characteristics among the three groups.

Category		Group			*P*
		Minor underhang	Minor overhang	Major overhang	
Number	-	84	224	43	-
Age	–	67.1 ± 8.3	67.0 ± 7.5	67.5 ± 7.8	0.92
Sex	Males	31 (36.9)	40 (17.9)	4 (9.3)	**<0.001**
	Females	53 (53.1)	184 (82.1)	39 (90.7)	
BMI	–	67.1 ± 8.3	67.0 ± 7.5	67.5 ± 7.8	0.42
Surgical site	Left	37 (44.0)	129 (57.6)	24 (55.8)	0.10
	Right	47 (56.0)	95 (42.4)	19 (44.2)	
Thickness of bearing	Thick bearing (3–4 mm)	70 (83.3)	189 (84.4)	34 (81.1)	0.690
	Thin bearing (5–6 mm)	14 (16.7)	35 (15.6)	7 (18.9)	
Size of tibial component	AA	55 (24.6)	17 (20.2)	10 (23.3)	0.989
	A	93 (41.5)	34 (40.5)	16 (37.2)	
	B	41 (18.3)	18 (21.4)	9 (20.9)	
	C	30 (13.4)	12 (14.3)	7 (16.3)	
	D	5 (2.2)	3 (3.6)	1 (2.3)	

Continuous data are specified as mean ± standard deviation. Categorical variables are defined as number (percent). BMI, body mass index.

regression, with hazard ratio (HR) values and 95% confidence intervals (CIs) as measures of exposure factors. Differences were considered statistically significant at $P < 0.05$.

3. Results

We collected 355 knees, and after strict nadir criteria, excluding two infected knees and two lateral UKA. No cases were excluded due to excessive knee rotation on X-ray. A total of 351 knees with at least three years of follow up were eventually included in this study, with a mean follow up time of 4.8 ± 1.5 years (range 3.0–7.7), of which 75 were male and 276 were female. The mean age of undergoing surgery was 67.1 ± 7.7 years (range 44–84).

There were no statistical differences in preoperative OKS score, VAS pain score, ROM, postoperative HKA, varus/valgus angle of the tibial and femoral component, tibial slope, femoral flexion/extension, and bearing thickness among the three groups ($P > 0.05$). At the last follow up OKS, VAS, and ROM improved to varying degrees in all three groups compared with the preoperative period. However, at the last follow up OKS and VAS scores were worse in the major overhang group than in the remaining two groups (OKS: 36.88 ± 4.01 vs. 43.06 ± 2.13, 43.45 ± 2.13; VAS: 3.12 ± 1.37 vs. 1.15 ± 0.94, 1.32 ± 0.97) ($P < 0.001$). Moreover, both ΔOKS and ΔVAS were also lower in the very prominent group than in the remaining two groups (ΔOKS: 9.23 ± 4.91 vs. 14.33 ± 3.46, 15.26 ± 3.78; ΔVAS: 3.28 ± 1.40 vs. 5.45 ± 1.50, 5.46 ± 1.41) ($P < 0.001$), but there was no statistical difference between ROM and ΔROM at the last follow up ($P > 0.05$) (Table 2).

Several revision cases occurred in all three groups postoperatively, and the major overhang group had significantly more revision rates than the other two groups. Three cases appeared in 84 patients in the minor underhang group, with a revision

Table 2
Clinical outcomes and radiological values of the three groups.

Category	Group			*P*
	Minor underhang	Minor overhang	Major overhang	
Pre-OKS	28.73 ± 2.55 (4)	28.19 ± 3.00 (5)	27.65 ± 2.83 (4)	0.120
Last-OKS	43.06 ± 2.13 (3)	43.45 ± 2.13 (3)	36.88 ± 4.01 (7)	**<0.001**
ΔOKS	14.33 ± 3.46 (5)	15.26 ± 3.78 (6)	9.23 ± 4.91 (8)	**<0.001**
Pre-VAS pain score	6.61 ± 1.11 (2)	6.78 ± 1.07 (2)	6.40 ± 1.00 (1)	0.076
Last-VAS pain score	1.15 ± 0.94 (2)	1.32 ± 0.97 (1)	3.12 ± 1.37 (2)	**<0.001**
ΔVAS	5.45 ± 1.50 (2)	5.46 ± 1.41 (1.8)	3.28 ± 1.40 (2)	**<0.001**
Pre-ROM	119.92 ± 5.43 (3.8)	119.13 ± 6.06 (9)	121.19 ± 6.56 (5)	0.101
Last-ROM	124.45 ± 5.45 (6.8)	124.21 ± 6.16 (10)	125.81 ± 6.23 (7)	0.277
ΔROM	4.54 ± 3.61 (3)	5.08 ± 3.56 (4)	4.63 ± 3.21 (5)	0.427
HKA	2.43 ± 4.05 (5.6)	3.43 ± 4.04 (6.4)	3.53 ± 4.33 (6.4)	0.139
Tibial varus/valgus	1.46 ± 2.06 (3.2)	1.77 ± 1.97 (3.2)	1.06 ± 2.20 (3.0)	0.087
Tibial slope	6.52 ± 1.75 (3.0)	6.24 ± 1.70 (3.5)	6.87 ± 1.68 (3.1)	0.067
Femoral varus/valgus	1.67 ± 1.99 (3.5)	1.34 ± 1.70 (2.5)	1.01 ± 2.01 (2.5)	0.135
Femoral flexion/extension	5.93 ± 2.43 (3.2)	5.60 ± 2.27 (2.5)	4.92 ± 1.95 (2.9)	0.063

Categorical variables are specified as numbers (percent); continuous variables are specified as mean ± standard deviation (interquartile range).
HKA, hip–knee–ankle; Last, last follow up; OKS, Oxford Knee Score; Pre, preoperative; ROM, range of motion; VAS, visual analog scale.

Table 3
Distribution of reasons for revision among the three groups.

The reasons for revision	Overhang distance			Total	Fisher's exact test	
	Minor underhang	Minor overhang	Major overhang		χ^2	*P*
Unrevision	81 (96.4)	218 (97.3)	34 (79.1)	333	17.89	<0.001
Mobile-bearing dislocation	2 (2.4)	3(1.3)	5 (11.6)	10		
Aseptic loosening	1 (1.2)	3 (1.3)	4 (9.3)	8		

Categorical variables are specified as numbers (percent).

Table 4
Comparison of implant overhang distance among three revision reasons.

The reasons for revision	Overhang distance		ANOVA	
	Median (IQR)	Difference and 95% CI	*F*	*P*
Unrevision*	0 (2.08)	–	8.93	<0.001
Mobile-bearing dislocation	3.30 (2.93)	1.79 (0.44–3.14) †		
Aseptic loosening	3.19 (2.22)	1.79 (0.28–3.29) ‡		

ANOVA, analysis of variance; CI, confidence interval; IQR, interquartile range.
* Control group.
† Statistically significant difference compared with unrevision, *P* = 0.005.
‡ Statistically significant difference compared with unrevision, *P* = 0.014.

Table 5
Radiological value of implant position in revision reasons.

Category	Unrevision	Mobile-bearing dislocation	Aseptic loosening	*P*
Tibial varus/valgus	1.60 ± 2.02	0.98 ± 2.42	2.61 ± 1.79	0.234
Tibial slope	6.35 ± 1.72	7.57 ± 1.39	6.51 ± 1.65	0.084
Femoral varus/valgus	1.40 ± 1.80	0.93 ± 1.98	1.13 ± 2.49	0.674
Femoral flexion/extension	5.62 ± 2.29	4.34 ± 1.22	6.18 ± 2.72	0.170

Continuous variables are specified as mean ± standard deviation.

rate of 3.6%. Six cases appeared in 224 patients in the minor overhang group, with a revision rate of 2.7%. In addition, nine cases appeared in 43 patients in the major overhang group, with a revision rate of 20.9%. The difference in revision rate was statistically significant ($P < 0.001$). Among all reasons for revision, bearing dislocation was the most common, reaching 10 cases (55.6%), including two cases in the minor underhang group, three cases in the minor overhang group, and five patients in the major overhang group, followed by prosthesis loosening with eight patients (44.4%), including one case in the minor underhang group, three patients in the minor overhang group, and four cases in the major overhang group (Table 3). The

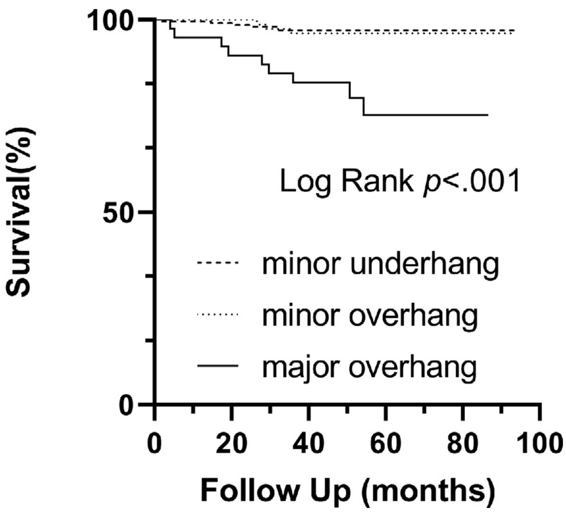

Fig. 3. Survival curves for Oxford medial unicompartmental knee arthroplasty with bearing replacement or revision total knee arthroplasty as the endpoint between minor underhang, minor overhang, and major overhang groups.

Table 6
Multivariate Cox analysis for the association between medial tibial overhang and revision.

Variable		*P*	HR	95% CI
BMI		0.247	1.077	0.950–1.220
Postoperative HKA		0.045	1.137	1.003–1.289
Tibial varus/valgus		0.277	1.158	0.889–1.507
Tibial slope		0.155	1.246	0.920–1.686
Femoral varus/valgus		0.459	0.904	0.692–1.181
Femoral flexion/extension		0.580	0.937	0.743–1.181
Size of tibial component	AA/A/B/C/D	0.481	0.836	0.508–1.375
Thickness of bearing	Thin bearing * (3–4 mm)	–	–	–
	Thick bearing (5–6 mm)	0.723	1.229	0.393–3.847
Tibial component overhang distance	Minor overhang *	–	–	–
	Minor underhang	0.644	1.396	0.339–5.747
	Major overhang	**<0.001**	7.515	2.500–22.593

BMI, body mass index; CI, confidence interval; HKA, hip–knee–ankle; HR, hazard ratio.
* Control group.

overhang distance was 0 (2.08) mm in unrevised patients, 3.30 (2.93) mm in bearing dislocation, and 3.19 (2.22) mm in aseptic loosening, with a statistically significant difference in overall overhang distance among the three clinical outcomes (mean difference = 1.79, 1.79; 95% CI = 0.44–3.14, 0.28–3.29; $F = 8.93$; $P < 0.001$). Furthermore, the overhang distance was significantly greater in patients who experienced bearing dislocation and aseptic loosening than in those who did not have revision ($P = 0.005$; $P = 0.014$) (Table 4). However, there were no statistical differences in other implant position radiological values (tibial varus/valgus, tibial slope, femoral varus/valgus and femoral flexion/extension) ($P > 0.05$) (Table 5). During the follow up time, the cumulative survival rates of the three groups were analyzed using Kaplan–Meier, and the differences were statistically significant at 91.5% (95% CI = 89.0–94.1) in the minor underhang group, 91.8% (95% CI = 90.2–93.3) in the minor overhang group, and 72.9% (95% CI = 64.8–80.9) in the major overhang group (log rank $P < 0.001$) (Fig. 3).

After adjusting for BMI, postoperative HKA angle, tibial varus/valgus, tibial slope, femoral varus/valgus and femoral flexion/extension, size of the tibial component, and bearing thickness, it was found that there was a statistically significant association between tibial plateau component overhang distance and postoperative revision rate in patients undergoing UKA. There was an association between the major overhang group and revision after UKA relative to the minor overhang group (HR = 7.515, 95% CI = 2.500–22.593, $P < 0.001$) (Table 6).

4. Discussion

First, the study found that in mobile-bearing UKA, the risk of postoperative revision is increased approximately seven-fold if the tibial component overhang is $\geq$ 3 mm beyond the medial cortex of the tibial plateau (HR = 7.515, 95% CI = 2.500–22.593), especially in those caused by bearing dislocation and prosthesis loosening. Second, tibial component overhang less than 3 mm or underhang within 3 mm do not increase postoperative revision rates.

In the present study, we verified that excessive protrusion of the tibial implant could irritate the medial soft tissue and affect the functional prognosis of the patient [11,15]. All patients received a 94.9% survival rate during the follow up time, which is similar to the five-year revision rates of 87.5–90.5% reported by Moore et al. and Ekhtiari et al. [10,16]. Nevertheless, the postoperative revision rate in the major overhang group was a striking 20.9%, with the reasons for revision being bearing dislocation and aseptic loosening, respectively. Furthermore, the length of overhang of the tibial component was significantly greater in patients who experienced both spacer dislocation and aseptic loosening than in those who did not have revision (Table 4). This might be related to poor positioning of the tibial component, which ultimately leads to poor bearing movement trajectory and abnormal force loading.

In UKA, bearing dislocation is one of the most common complications causing postoperative revision [17,18]. Common risk factors for bearing dislocation include poor bearing movement trajectory, flexion–extension gap imbalance, impingement of the bearing by residual bone or bone cement, and poor medial collateral ligament function [18]. Lee et al. [19] showed that the posterior tibial tilt angle might also be associated with shim dislocation. Previous studies [18,20,21] have introduced that the relative position of the femoral component to the tibial component is essential. When the distance between the two is too great, it increases the space of the gap, which will increase the possibility of rotation of the bearing in the gap, therefore decreasing the restriction of the femoral component to the bearing. However, when the tibial component is very close to the femoral component, the impact of the bearing occurs. In a retrospective analysis, Kamenaga et al. [20] found that if the tibial component was too far inboard, which is a risk that the bearing would impact the lateral wall of the tibial component during knee flexion, the result was dislocation. The operator's choice of a sizeable tibial component size was an important cause of overhang. However, a Standard Manual for UKA review shows that the surgical step of vertical tibial osteotomy also influences the final tibial component position. Therefore, another possible cause of overhang is that the overly medial vertical tibial osteotomy causes the tibial component to lean inwards, resulting in impingement of the patient's bearing during postoperative motion. Hence, we speculate that the oversized tibial component and an overly medial tibial vertical osteotomy would cause poor positioning of the femoral component relative to the tibial component, which would lead to dislocation of the mobile bearing. However, further studies are needed to verify the above conjecture.

Chau et al. [11] argued that the underhang of the tibial component would concentrate the force load on the cancellous bone, increasing the risk of subsidence and loosening. However, in this study, although the revision rate was greater in minor underhang than in minor overhang (3.6% vs. 2.7%), the difference was not statistically significant ($P = 0.644$). We think this may be related to the smaller sample size of the slightly indented group. The surgeon should still avoid retraction of the tibial component during surgery. It is relatively straightforward that the revision rate was much higher in major overhang (20.9%) than in the other two groups. Furthermore, five of 11 revisions in major overhang were caused by prosthesis loosening. These results show that the overhang of the tibial component may affect implant survival through some mechanism. We recommend that this may be because excessive tibial component overhang concentrates a large portion of the force load on the knee joint on the overhang component. Nevertheless, there is no bone beneath the overhang component to transmit this load.

In a retrospective study last year, Graham et al. [22] presented that tibial component overhang was not associated with long-term postoperative prognosis or survival, which is contrary to the findings of our study. Our interpretation is that, first, Graham et al. defined a tibial component overhang greater than 2 mm as an outlier (the outlier in our study was more than 3 mm), which may introduce an error. Also, the results of our study support that a tibial component overhang distance between 2 and 3 mm (minor overhang group) does not affect postoperative implant survival rate. We consider an overhang of 3 mm or less acceptable, and only cases with an overhang distance greater than 3 mm will ultimately affect clinical outcomes. Second, their abnormal group of only 14 patients is a small sample size. Third, the difference in implant type (fixed vs. mobile) may also account for the difference. We speculate that a movable meniscal bearing would transfer more load to the overhang tibial component than a fixed bearing.

There are many common reasons for postoperative revision of UKA, including pain, aseptic loosening of the implant, progression of contralateral knee osteoarthritis, dislocation or wear of the bearing, and sinking of the implant [3,5,9]. However, the retrospective study involved only two causes of aseptic loosening and bearing dislocation, and no revision cases due to bearing wear or progression of arthritis occurred. The reason is the short duration of this follow up, e.g., bearing wear and arthritic progression are more common in the intermediate and distant failure patterns [23]. Therefore, patients with a tibial component overhang of more than 3 mm should be warned that their implant survival may be shorter. They should avoid strenuous exercise in their daily life to prevent aseptic loosening and bearing dislocation.

Another noteworthy point is that 10 patients in major overhang received implants with AA-sized (smallest size) tibial components. However, the overhang distance was still greater than 3 mm (Table 1). Nine of the 10 patients were female and one was male, and two were eventually readmitted for revision surgery for bearing dislocation during the follow up time. It is well known that Oxford implants were initially designed according to the physiological as well as anatomical characteristics of Westerners. The Asian population is generally smaller than the Western population, thus surgeons tend to choose smaller prostheses during surgery. The above results suggest that the Oxford implant is somewhat limited in its use in patient populations with particularly small knee joints. Even though the smallest size component is used, it is still too large for some Asians with small knees. Based on the results of this study, this may lead to poor clinical outcomes. Previous studies have suggested that Asians have a higher dislocation rates than Westerners [24,25]. However, there are also studies holding the opposite view. They believe that the Oxford unicondyle in Asia has similar clinical outcomes to those in the West [4,17]. We suggest that comprehensive preoperative planning and adequate communication are vital for patients with small knees who have been treated with a minimal size implant but still have an overhang distance > 3 mm. In addition, without over-correcting, the surgeon can use a thicker bearing intraoperatively to prevent postoperative bearing dislocation.

There are still several limitations to our study. First, the study was a retrospective study, and there may be limitations in data inaccuracy. Second, the follow up period was short, and the effect of tibial component overhang on long-term clinical outcomes cannot yet be predicted. Third, the number of patients differed significantly between the three groups, although the distribution of numbers was not statistically significant between the groups.

5. Conclusion

This study found that a tibial component overhang of more than 3 mm medially increases the risk of short-term postoperative revision in UKA. The reasons for revision are generally bearing dislocation and aseptic loosening. Therefore, we recommend that surgeons should try to keep the overhang distance of tibial component relative to the tibial plateau to within 3 mm.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

Dr. Wang from the Imaging Department of the Second Hospital of Dalian Medical University provided imaging data of patients. Dr. Wang from the medical record room of the Second Hospital of Dalian Medical University provided the medical records of the patients.

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