

Clinical Research

Bearing Dislocation and Progression of Osteoarthritis After Mobile-bearing Unicompartmental Knee Arthroplasty Vary Between Asian and Western Patients: A Meta-analysis

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Abstract

Background Implant survivorship is reported to be lower and complications, particularly bearing dislocation, are reported to be more frequent in Asian than in Western patients with medial knee osteoarthritis (OA) undergoing Oxford® Phase III unicompartmental knee arthroplasty (UKA). To date, however, these complications have not been compared between these groups of patients.

Questions/purposes The purpose of this study was to perform a meta-analysis comparing the standardized incidence rates of (1) all-cause reoperation; (2) reoperation related to bearing dislocation; and (3) reoperation related to progression of lateral compartment arthritis in Asian and Western patients with medial knee OA who underwent Oxford Phase III UKA.

Methods We searched MEDLINE® (January 1, 1976, to May 31, 2017), EMBASE® (January 1, 1985, to May 31, 2017), and the Cochrane Library (January 1, 1987, to May 31, 2017) for studies that reported complications of Oxford Phase III UKAs. Studies were included if they reported reoperation rates attributable to bearing dislocation and/or progression of lateral knee OA after surgery with this implant. Twenty-seven studies were included in this systematic review and 16 studies with followups > 5 years were included in the meta-analysis. These rates were converted to standardized incidence rate (that is, reoperations per 100 observed component years) based on mean followup and number of involved knees in each study. After applying prespecified inclusion and exclusion criteria, the studies were categorized into two groups, Asian and Western, based on hospital location. Twenty-five studies, containing 3152 Asian patients and 5455 Western patients, were evaluated. Study quality was assessed by the modified Coleman Methodology score (MCMS). Although all studies were Level IV, their mean MCMS score was 66.92 (SD, 8.7; 95% confidence interval [CI], 63.5–70.3), indicating fair quality. Because the heterogeneity of all subgroup meta-analyses was high, a random-effects model was used with estimations using the restricted maximum likelihood method.

Results There was no difference in the proportion of Asian patients versus Western patients undergoing reoperation for any cause calculated as 100 component observed years (1.022 of 3152 Asian patients; 95% CI, 0.810-1.235 versus 1.300 of 5455 Western patients; 95% CI, 1.067-1.534; odds ratio, 0.7839; 95% CI, 0.5323-1.1545; $p = 0.178$). The mean reoperation rate attributable to bearing dislocation per 100 observed years was higher in Asian than in Western patients (0.525; 95% CI, 0.407-0.643 versus

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0.141; 95% CI, 0.116-0.166; odds ratio, 3.7378; 95% CI, 1.694-8.248; $p = 0.001$) Conversely, the mean reoperation rate attributable to lateral knee OA per 100 observed years was lower in Asian than in Western patients (0.093; 95% CI, 0.070-0.115 versus 0.298; 95% CI, 0.217-0.379; odds ratio, 0.3114; 95% CI, 0.0986-0.9840; $p < 0.001$).

Conclusions Although total reoperation rates did not differ in the two populations, reoperation for bearing dislocation was more likely to occur in Asian than in Western patients, whereas reoperation for lateral knee OA progression was more likely to occur in Western than in Asian patients after Oxford Phase III UKA. Although possible explanations for these findings may be hypothesized, additional randomized, prospective comparative studies are needed. However, better survival outcomes after UKA may require consideration of ethnicity and lifestyle choices in addition to traditional surgical technique and perioperative care.

Level of Evidence Level III, therapeutic study.

Introduction

Unicompartmental knee arthroplasty (UKA) is a treatment option for patients with medial or lateral compartment knee osteoarthritis (OA). UKA may provide advantages over TKA, including more natural kinematics, quicker recovery, lower postoperative morbidity rates, and greater preservation of bone stock, especially in relatively young patients [5, 12, 16, 27]. Fully congruent mobile-bearing UKA was devised to reduce bearing wear [44], one of the important factors affecting the long-term survival of UKA. The Oxford[®] Phase III (Zimmer Biomet Ltd, Swindon, UK) UKA is a design of congruent mobile-bearing UKA that has shown excellent long-term results in Europe and the United States [13, 29].

However, the risk of certain complications, particularly bearing dislocation, has been reported to be higher in Asian than in Western patients, raising questions on the survival of mobile-bearing UKA in Asian patients [4, 19, 28, 38]. The progression of lateral compartment OA after medial UKA is another common cause for reoperation after UKA. To our knowledge, no study to date has directly compared the survival and reoperation rates attributable to bearing dislocation and progression of lateral compartment OA of the Oxford Phase III UKA in Asian and Western patients with medial compartment knee OA.

This systematic review and meta-analysis therefore was designed to compare the standardized incidence rate of reoperation for (1) all-cause reoperation; (2) reoperation related to bearing dislocation; and (3) reoperation related to progression of lateral compartment arthritis in Asian and Western patients with medial knee OA who underwent Oxford Phase III UKA.

Materials and Methods

Literature Search

The study design was based on Cochrane Review Methods. In accordance with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement [33, 34], multiple comprehensive databases, including MEDLINE[®] (January 1, 1976, to May 31, 2017), EMBASE[®] (January 1, 1985, to May 31, 2017), and the Cochrane Library (January 1, 1987, to May 31, 2017), were searched for studies that reported the complications of Oxford Phase III UKA. There were no restrictions on language or year of publication. Search terms used in the title, abstract, MeSH, and keyword fields included (Oxford) AND (unicompartmental knee replacement OR unicompartmental knee arthroplasty OR partial knee arthroplasty OR partial knee replacement OR unicompartmental knee arthroplasty OR unicompartmental knee replacement OR UKA) AND (oxford*) AND (reoperation OR revision OR survival analysis OR survival rate OR complication OR postoperative complication OR bearing dislocation OR dislocated bearing OR prosthesis failure OR progressive osteoarthritis OR lateral osteoarthritis). Relevant articles and their bibliographies were searched manually after the initial electronic search.

Study Selection

Two reviewers (K-HR, WJJ) evaluated the titles and abstracts of all retrieved papers and selected relevant studies for full review. If the abstract did not provide sufficient data to make a decision, the full text of the article was reviewed. Studies were included in the systematic review if they (1) involved patients who underwent primary UKA using Oxford Phase III prostheses for medial OA of the knee; (2) evaluated patients undergoing reoperation surgery after the primary UKA; and (3) if they fully reported the numbers of patients and involved knees, mean followup, and reasons for reoperation, enabling calculations of the number and proportion of knees with bearing dislocation and the progression of knees with lateral OA. Studies not clearly reporting reoperation data, biomechanical and cadaveric studies, technical notes, letters to the editor, expert opinions, review articles, meta-analyses, scientific conference abstracts, other unpublished work, studies published in nonindexed journals, and case reports were excluded. Although *Clinical Orthopaedics and Related Research*[®] normally does not allow meta-analysis (data pooling) from retrospective sources, this was permitted in the current study because the research questions (comparing survivorship of UKA between Asian and Western patients and different reasons for reoperations between those populations) have never been—and are

unlikely ever to be—explored in the context of randomized or even prospective trials.

Studies of cohorts undergoing UKA for extraordinary conditions, studies of patients who underwent primary UKA for lateral OA, and studies with short-term followup (<2 years) also were excluded. In assessing and organizing pooled studies, the country and city of the hospital or institution where the UKA was performed, and the evaluation period, were checked to exclude duplicate groups of patients. If the same patient cohort was evaluated in more than one study, the study published last with the longest followup was included, whereas the others were excluded. Two studies [4, 38] included patients who underwent surgery at the same hospital during a similar period, but none of the patients included in the latter published study [4] had been included in previous survival analyses at that institution; therefore, both studies were included.

Studies were categorized into two groups, Asian and Western, based on hospital location. Studies involving international clinics and those mentioning the inclusion of nonresident patients who underwent reoperation after UKA were excluded. None of the studies reported the number or proportion of domestic patients who underwent surgery. Patient regions of origin in each study were classified as Asian or Western based not only on geography, but on sociocultural environment, including floor-based lifestyle or religious activities. The meta-analysis assumed that (1) most patients who underwent UKA were older rather than younger and had lived in the country of operation for some time, even if they were born elsewhere; and (2) few patients would be nonresidents of the country of operation. For example, although ethnic Asians live in the United States and the United Kingdom, many have adopted more Western lifestyles. Traditional Asian floor-based lifestyles are less commonly practiced by Asians in Western countries, except for a small minority who practice Islam. Therefore, studies performed outside Asia were regarded as consisting entirely of Western patients.

In terms of classifying the region of origin as Asian or Western, we considered not only the geographic, but also the sociocultural environment, because both may influence knee motion and stress after UKA. This classification was difficult for two studies, one from Turkey [7] and the other from Israel [17]. Although both of these countries are in the Middle East, which are geographically Asian, their religions and cultures differ from those in East Asian countries making their classification more difficult. Therefore, to clearly differentiate between Asian and Western subjects, these studies were excluded from this meta-analysis. Institutional review board approval and patient informed consent (written or oral) were not required because all analyses were based on previously published studies.

Data Extraction

Two investigators (K-HR, J-WH) independently recorded data from each study using a predefined data extraction form. Any disagreements unresolved by discussion by these investigators were reviewed by a third investigator (D-HL) as needed. Complications recorded included those undergoing reoperation after the medial UKA. Patients with intraoperative complications and postoperative complications who did not undergo reoperation were not analyzed. Demographic characteristics included the total numbers of patients and knees, age, sex, ethnicity, and followup period.

Identification of Studies

An electronic search yielded 154 studies in PubMed (MEDLINE), 120 in EMBASE, and 18 in the Cochrane Library (Fig. 1). After removing 118 duplicates, and adding seven additional publications identified through manual searches, 181 studies remained; of these, 73 were excluded based on review of their titles and abstracts. An additional 83 studies were excluded after reading their full texts showed that they did not contain usable information or included irrelevant data. Finally, 25 studies [3, 4, 6, 9, 10, 13, 15, 19, 22-24, 28-32, 36, 38, 39, 43, 44, 46, 51, 52, 54] were included in this systematic review.

Quality Appraisal

The original Coleman methodology score [11] uses 10 criteria to assess the methodology of a given study, resulting in total scores between 0 and 100 with a score of 100 indicating that the study largely avoids important systemic sources of bias and other confounding factors. The subsections that compose the Coleman methodology score are based on the subsections of the Consolidated Standards of Reporting Trials (CONSORT) statement for randomized controlled trials [1] but were modified to allow for other study designs [37]. The original Coleman methodology score, which was developed for surgical treatment of tendinopathy [11], was modified for arthroplasty of the knee [20]. The quality of each included study was evaluated by two independent investigators (K-HR, J-WH) using the modified Coleman methodology score. Quality was also assessed using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist [47], which contains 22 numbered items with several multiple subitems. Because all studies were case series with Level IV evidence, relevant items or STROBE was used for case series, as described previously [2]. Differences in subsections were resolved by consensus or, if necessary, by a third senior investigator (D-HL). The

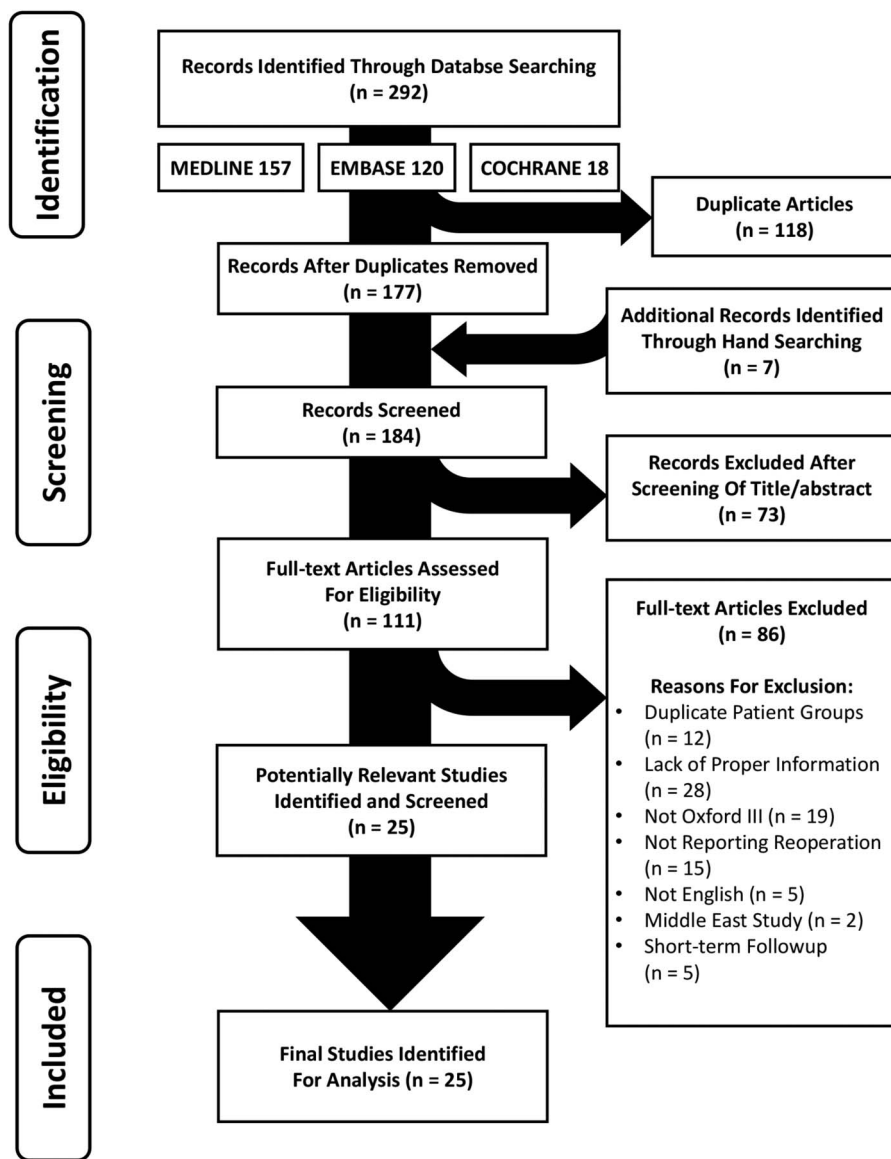


Fig. 1 The PRISMA flow diagram used in our study is shown. The initial search criteria identified 292 articles. After application of all exclusion criteria, 25 studies were identified for analysis.

quality of studies was compared between groups using Student’s t-tests with statistical significance set at a probability < 0.05.

Study Characteristics and Quality

Patient characteristics, including region of origin, evaluation period, mean age, duration of followup, body mass index, sex distribution, and modified Coleman methodology score, are summarized (Table 1). The 25 included studies evaluated 10,077 knees of 8607 patients who underwent Oxford Phase

III UKA. Ten studies included 3688 knees of 3152 Asian patients, and 15 studies included 6389 knees of 5455 Western patients. Seven studies of Asian patients and eight of Western patients reported followup > 5 years. Although all studies were Level IV, their total mean modified Coleman methodology score was 66.92 (SD, 8.7; 95% confidence interval [CI], 63.5-70.3) of 100, regarded as fair quality. Of the 25 studies, nine had mean modified Coleman methodology scores > 70, whereas two had scores < 55. The mean modified Coleman methodology scores of the 15 studies included in the subgroup meta-analysis group [4, 6, 9, 10, 13, 15, 22, 28, 29, 38, 44, 46, 51, 52, 54] were 70.3 (SD, 8.6;

Table 1. Characteristics of included studies

Study	Region of origin	Evaluation period	Number of knees (patients)	Mean age (years)	BMI (kg/m ²)	Percent male	Mean followup (years)	Followup loss (%)	MCMS
Choy et al. [9] (2011)	Korea (Daejeon)	1/2002-12/2005	188 (166)	65.3	NR	9.6	6.7	0.0	71
Ji et al. [19] (2014)	Korea (Daejeon)	5/2002-5/2010	246 (245)	64.3	NR	15.1	2.8	NR	60
Kim et al. [22] (2015)	Korea (Seoul)	1/2002-12/2012	166 (128)	61.8	NR	3.9	10	5.7	71
Lim et al. [28] (2012)	Korea (Seoul)	1/2001-1/2011	400 (320)	69.0	NR	NR	5.2	2.0	72
Mullaji et al. [36] (2011)	India (Mumbai)	7/2005-6/2007	122 (109)	62.1	27.0	29.5	≥ 2	0.0	60
Song et al. [43] (2009)	Korea (Busan)	11/2003-2/2006	100 (94)	65.7	25.6	7.4	≥ 2	NR	55
Tian et al. [46] (2017)	China (Qingdao)	1/2006 -6/2010	440 (402)	58.3	24.1	41.0	6.1	9.0	80
Xu et al. [51] (2017)	China (Zhejiang)	1/2004-6/2010	67 (64)	59.0	24.7	44.8	7.2	0.0	62
Xue et al. [52] (2017)	China (Shanghai)	2/2005-5/2014	708 (634)	67.8	30.5	46.5	6.2	2.1	80
Yoshida et al. [54] (2013)	Japan (Osaka)	1/2002-7/2011	1251 (990)	77.2	NR	18.2	5.2	0.6	76
Bergeson et al. [3] (2013)	USA (Ohio)	7/2004-12/2008	839 (688)	62.8	32.2	43.7	3.7	16.1	68
Bottomley et al. [4] (2016)	UK (Oxford)	1998-2008	1084 (947)	66.5	NR	48.6	5.2	0.3	52
Burnett et al. [6] (2014)	Canada (Victoria)	1/2003-12/2011	467 (387)	69.3	29.7	44.0	6.1	0.0	55
Clement et al. [10] (2012)	UK (Melrose)	2001-2005	49 (49)	69.7	NR	42.9	7.2	12.2	69
Emerson et al. [13] (2016)	USA (Texas)	7/2004-12/2006	213 (173)	67.0	29.9	54.9	10	16.0	66
Faour-Martin et al. [15] (2013)	Spain (Ávila)	1999-2005	511 (402)	59.0	27.1	28.6	10.4	3.4	76
Kristensen et al. [23] (2013)	Denmark (Vejle)	2002-2011	695 (579)	63.7	NR	53.4	4.6	0.3	68
Kuipers et al. [24] (2010)	Netherlands (Zwolle, Alkmaar, Groningen)	1/1991-7/2007	437 (437)	62.8	30.1	32.0	2.6	2.7	60
Lisowski et al. [29] (2016)	Netherlands (Amsterdam)	1/1991-1/2005	138 (129)	72.0	28.2	NR	11.7	1.4	71
Lloyd et al. [30] (2012)	Australia (Brisbane)	1/2003-12/2009	120 (97)	64.7	NR	NR	3.4	0.0	50
Luscombe et al. [31] (2007)	UK (Oswestry)	1/1998-11/2001	78 (68)	63.4	28.4	55.0	2	0.0	67

Table 1. continued

Study	Region of origin	Evaluation period	Number of knees (patients)	Mean age (years)	BMI (kg/m ²)	Percent male	Mean followup (years)	Followup loss (%)	MCMS
Matharu et al. [32] (2012)	UK (Birmingham)	1/2000-12/2008	459 (392)	63.0	NR	46.8	4.4	0.0	68
Pandit et al. [38] (2015)	UK (Oxford)	1/1998-3/2009	1000 (818)	66.0	NR	48.0	10.3	4.6	80
Pietschmann et al. [39] (2013)	Germany (Munich)	1998-2007	181 (171)	65.3	NR	NR	4.2	21.0	63
Streit et al. [44] (2017)	Germany (Heidelberg)	9/2001-12/2007	118 (118)	55.0	31.0	50.8	5	2.5	68

MCMS = modified Coleman methodology score; BMI = body mass index; NR = not reported.

95% CI, 65.9-74.6), 73.9 (SD, 6.3; 95% CI, 69.2-78.5) in seven studies of Asian patients [9, 22, 28, 46, 51, 52, 54] and 67.1 (SD, 9.6; 95% CI, 60.7-73.4) in eight studies of Western patients [4, 6, 10, 13, 15, 29, 38, 44], a difference that was not statistically significant ($p = 0.468$). Assessment of quality using the STROBE checklist showed that Outcome data (Item 15) were well described, shown as (+) in all studies. Setting (Item 5), Participants (Item 6), and Variables (Item 7) were also generally well described, whereas Statistical methods (Item 12) had the lowest score among all items of the checklist. Of the 25 studies, 13 were regarded as well described, nine as partly described (+/-), and three as poorly/not described (-) (Table 2).

Statistical Analysis

Reoperation data recorded in the studies included in this analysis were pooled. Because the need for reoperation was relatively rare and could be biased by differences in followup periods, reoperation rates were converted to a standardized incidence rate (ie, reoperations per 100 observed component years) based on the mean followup and number of involved knees in each study [26]. To allow for inclusion of studies with a 0% incidence of reoperations, a 0.5 correction was used.

Most reoperations after UKA occurred within 5 years of surgery. However, studies with a followup > 5 years reported a substantial rate of reoperation > 5 years after UKA. Subgroup analysis of studies with a followup > 5 years was performed to determine midterm results and to determine whether these results differed from those of the meta-analysis that included all studies. Reoperation rates per 100 observed years were compared in Asian and Western populations using independent t-tests. Analyses were performed using the Comprehensive Meta-Analysis statistical software (Biostat, Englewood, NJ, USA) and R statistical software Version 3.4.0 (the metafor Package: a Meta-Analysis Package for R; R Foundation for

Statistical Computing, Vienna, Austria) [48]. Because the heterogeneity of all subgroup meta-analyses was high, a random-effects model, with estimations using the restricted maximum likelihood method, was used. This model has been shown to allow greater generalization of conclusions for variable patient populations and different surgical techniques are grouped [18]. A summary odds ratio (OR) was calculated using a two-by-two contingency table (George Wilson University, Fairfax, VA, USA). The reoperation rates and 95% CIs for each study and the overall random-effects pooled estimate for each UKA group and its 95% CI were constructed for forest plots, which were constructed using Open Meta-Analyst (<http://www.cebm.brown.edu/openmeta>) [49]. We set statistical significance at a probability < 0.05.

Results

Reported causes of reoperations in the included studies were summarized. Total reoperation rates in these studies ranged from 0.9% to 10.3% (Table 3). Of the 10 studies of Asian patients, nine reported bearing dislocations after UKA, but only three reported the progression of lateral OA. In contrast, of the 15 studies of Western patients, 12 reported bearing dislocations after UKA, and 10 reported the progression of lateral OA.

All-cause Reoperations

The mean reoperation rates per 100 observed component years for any cause after UKA were similar in the 3152 Asian patients (1.02; 95% CI, 0.81-1.23) and the 5455 Western patients (1.30; 95% CI, 1.07-1.53; $p = 0.178$; OR, 0.78; 95% CI, 0.53-1.15) (Fig. 2; Table 4). In a subgroup meta-analysis of patients followed up for > 5 years, the OR

Table 2. Quality assessment by Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist for the case series

Study (year)	Item 5 Setting	Item 6 Participants	Item 7 Variables	Item 8 Data sources/ measurement	Item 12 Statistical methods	Item 14 Descriptive data	Item 15 Outcome data	Item 16 Main results
Choy et al. [9] (2011)	+	+	+	+	+/-	+/-	+	+/-
Ji et al. [19] (2014)	+	+	+	+	-	+/-	+	+/-
Kim et al. [22] (2015)	+	+	+	+	+/-	+	+	+
Lim et al. [28] (2012)	+	+	+	+	+/-	+	+	+
Mullaji et al. [36] (2011)	+/-	+	+	+	+	+	+	+
Song et al. [43] (2009)	+	+	-	+	-	+/-	+	+/-
Tian et al. [46] (2017)	+	+	+	+	+/-	+	+	+
Xu et al. [51] (2017)	+	+	+	+	+/-	+	+	+
Xue et al. [52] (2017)	+	+	+	+	+/-	+	+	+/-
Yoshida et al. [54] (2013)	+	+	+	+	+	+	+	+
Bergeson et al. [3] (2013)	+	+	+	+/-	+/-	+	+	+/-
Bottomley et al. [4] (2016)	+	+	+	+	+	+	+	+
Burnett et al. [6] (2014)	+	+	+	+	+	+	+	+
Clement et al. [10] (2012)	+	+	+	+	+/-	+	+	+
Emerson et al. [13] (2016)	+	+	+	+	+	+	+	+
Kristensen et al. [23] (2013)	+	+	+	+	+	+	+	+
Kuipers et al. [24] (2010)	+	+	+	+	+	+	+	+
Lisowski et al. [29] (2016)	+	+	+	+	+	+	+	+
Lloyd et al. [30] (2012)	+	+/-	+	+/-	+	+	+	+
Luscombe et al. [31] (2007)	+	+	+	+	+/-	+	+	+/-
Faour-Martin et al. [15] (2013)	+	+	+	+	+	+	+	+
Matharu et al. [32] (2012)	+	+	+	+	+	+	+	+
Pandit et al. [38] (2015)	+	+	+	+	+	+	+	+
Pietschmann et al. [39] (2013)	+/-	-	+	+	-	+	+	+/-
Streit et al. [44] (2017)	+	+	+	+	+	+	+	+

(+) = well described ; (+/-) = partly described ; (-) = poorly/not described.

of mean reoperation rates per 100 observed component years was not different between Asian and Western patients (0.73 of 3220 Asian patients; 95% CI, 0.52-0.94 versus 0.88 of 3580 Western patients; 95% CI, 0.68-1.08; $p = 0.58$; OR, 0.83; 95% CI, 0.49-1.42) (Table 4).

Reoperation for Bearing Dislocation

The mean reoperation rates per 100 observed component years for bearing dislocation after UKA were higher in Asian (0.53; 95% CI, 0.41–0.64) than in Western (0.14;

Table 3. Reported causes of reoperation in the included studies

Study	Region of origin	Number of knees (patients)	Mean age (years)	Mean followup (years)	Total reoperation cases (/total cases, %)	Number of bearing dislocations (/total reoperation cases, %)	Number of lateral OA (/total reoperation cases, %)	Other cases of reoperation (/total reoperation cases, %)
Asian								
Choy et al. [9] (2011)	Korea (Daejeon)	188 (166)	65.3	6.7	18 (9.6)	11 (61.1)	0 (0)	Aseptic loosening 7 (38.9)
Ji et al. [19] (2014)	Korea (Daejeon)	246 (245)	64.3	2.8	18 (7.3)	9 (50.0)	0 (0)	Aseptic loosening 4 (22.2); unknown pain 1 (5.6); fracture 1 (5.6); others 3 (16.8)
Kim et al. [22] (2015)	Korea (Seoul)	166 (128)	61.8	10	16 (9.6)	9 (56.3)	0 (0)	Aseptic loosening 4 (25); fracture 1 (6.3); infection 1 (6.3); others 1 (6.3)
Lim et al. [28] (2012)	Korea (Seoul)	400 (320)	69.0	5.2	14 (3.5)	12 (85.7)	0 (0)	Aseptic loosening 1 (7.1); infection 1 (7.1)
Mullaji et al. [36] (2011)	India (Mumbai)	122 (109)	62.1	≥ 2	1 (7.3)	1 (100)	0 (0)	None
Song et al. [43] (2009)	Korea (Busan)	100 (94)	65.7	≥ 2	7 (7.0)	4 (57.1)	0 (0)	Fracture 2 (28.6); aseptic loosening 1 (14.3)
Tian et al. [46] (2017)	China (Qingdao)	440 (402)	58.3	6.1	4 (0.9)	4 (100)	0 (0)	None
Xu et al. [51] (2017)	China (Zhejiang)	67 (64)	59.0	7.2	6 (9.0)	0 (0)	4 (66.7)	Aseptic loosening 1 (16.7); others 1 (16.7)
Xue et al. [52] (2017)	China (Shanghai)	708 (634)	67.8	6.2	13 (1.8)	3 (23.1)	3 (23.1)	Aseptic loosening 2 (15.4); infection 2 (15.4); fracture 2 (15.4); unknown pain 1 (7.7)
Yoshida et al. [54] (2013)	Japan (Osaka)	1251 (990)	77.2	5.2	25 (2.0)	10 (40.0)	1 (4.0)	Aseptic loosening 12 (48.0); fracture 2 (8.0)
Western								
Bergerson et al. [3] (2013)	USA (Ohio)	839 (688)	62.8	3.7	40 (4.8)	2 (5.0)	2 (5.0)	Aseptic loosening 15 (37.5); unknown 12 (30.0); infection 1 (2.5); others 8 (20)
Bottomley et al. [4] (2016)	UK (Oxford)	1084 (947)	66.5	5.2	46 (4.2)	7 (15.2)	13(28.3)	Aseptic loosening 12 (26.1); infection 7 (15.2); unknown pain 5 (10.9); fracture 1 (2.2); others 1 (2.2)
Burnett et al. [6] (2014)	Canada (Victoria)	467 (387)	69.3	6.1	45 (9.6)	3 (6.7)	18 (40.0)	Aseptic loosening 18 (40.0); unknown pain 1 (2.5); others 4 (10.0)

Table 3. continued

Study	Region of origin	Number of knees (patients)	Mean age (years)	Mean followup (years)	Total reoperation cases (/total cases, %)	Number of bearing dislocations (/total reoperation cases, %)	Number of lateral OA (/total reoperation cases, %)	Other cases of reoperation (/total reoperation cases, %)
Clement et al. [10] (2012)	UK (Melrose)	49 (49)	69.7	7.2	4 (8.2)	0 (0)	0 (0)	Unknown pain 3 (75.0); others 1 (25.0)
Emerson et al. [13] (2016)	USA (Texas)	213 (173)	67.0	10	20 (9.4)	1 (5.0)	9 (45.0)	Aseptic loosening 4 (20.0); unknown pain 2 (10.0); others 4 (20.0)
Faour-Martin et al. [15] (2013)	Spain (Ávila)	511 (402)	59.0	10.4	29 (5.7)	2 (6.9)	0 (0)	Infection 15 (51.7); unknown pain 8 (27.6); aseptic loosening 4 (13.8)
Kristensen et al. [23] (2013)	Denmark (Vejle)	695 (579)	63.7	4.6	51 (7.3)	0 (0)	14 (27.5)	Aseptic loosening 11 (21.6); unknown pain 10 (19.6); infection 4 (7.8); periprosthetic fracture 2(3.9); other 10 (19.6)
Kuipers et al. [24] (2010)	Netherlands (Zwolle, Alkmaar, Groningen)	437 (437)	62.8	2.6	45 (10.3)	4 (8.9)	8 (17.8)	Unknown pain 13 (28.9); aseptic loosening 12 (26.7); fracture 3 (6.7); deep infection 2(4.4); others 3 (6.7)
Lisowski et al. [29] (2016)	Netherlands (Amsterdam)	138 (129)	72.0	11.7	11 (8.0)	1 (9.1)	6 (54.5)	Unknown pain 2 (18.2); others 2 (18.2)
Lloyd et al. [30] (2012)	Australia (Brisbane)	120 (97)	64.7	3.4	3 (2.5)	2 (66.7)	0 (0)	Aseptic loosening 1 (33.3)
Luscombe et al. [31] (2007)	UK (Oswestry)	78 (68)	63.4	2	4 (5.1)	1 (25.0)	0 (0)	Aseptic loosening 1 (25.0); infection 1 (25.0); unknown pain 1 (25.0)
Matharu et al. [32] (2012)	UK (Birmingham)	459 (392)	63.0	4.4	20 (4.4)	0 (0)	1 (5.0)	Aseptic loosening 11 (55.0); unknown pain 6 (30.0); fracture 1 (5.0); infection 1 (5.0)
Pandit et al. [38] (2015)	UK (Oxford)	1000 (818)	66.0	10.3	52 (5.2)	7 (13.5)	25 (48.1)	Unknown pain 7 (13.5); infection 6 (11.5); aseptic loosening 2 (3.8); others 5 (9.6)
Pietschmann et al. [39] (2013)	Germany (Munich)	181 (171)	65.3	4.2	11 (6.1)	2 (18.2)	5 (45.5)	Aseptic loosening 1 (9.1); infection 1 (9.1); others 2 (18.2)
Streit et al. [44] (2017)	Germany (Heidelberg)	118 (118)	55.0	5	5 (4.2)	1 (20.0)	0 (0)	Unknown pain 3 (60.0); infection 1 (20.0); others 1 (20.0)

OA = osteoarthritis.

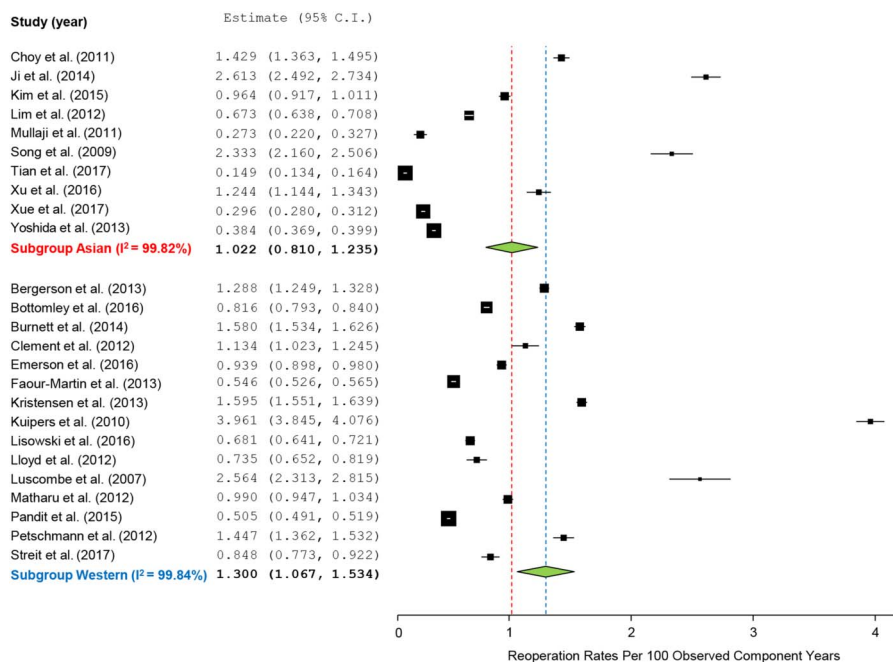


Fig. 2 The forest plot of all-cause revision is shown. The mean reoperation rates per 100 observed component years for any cause after UKA were not different between 10 studies of the Asian group and 15 studies of the Western group showed no difference (1.022 of 3152 Asian patients; 95% CI, 0.810-1.235 versus 1.300 of 5455 western patients; 95% CI, 1.067-1.534; $p = 0.178$).

95% CI, 0.12–0.17) patients ($p = 0.001$; OR, 3.7; 95% CI, 1.7–8.2) (Fig. 3; Table 4). Subgroup meta-analysis of patients followed up for > 5 years also showed that the OR of the mean bearing dislocation rate for patients undergoing reoperation per 100 observed years was higher in Asian than in Western patients (0.35 of 3220 Asian patients; 95% CI, 0.23-0.47 versus 0.09 of 3580 Western patients; 95% CI, 0.07-0.12; $p = 0.027$; OR, 3.9; 95% CI, 1.2-13.2) (Table 4).

Reoperation for Progression of Lateral OA

The mean reoperation rates per 100 observed component years for the progression of lateral OA after UKA were lower in Asian patients than Western patients (0.09 of 3152 Asian patients; 95% CI, 0.07-0.12 versus 0.30 of 5455 Western patients; 95% CI, 0.22-0.38; $p < 0.001$; OR, 0.31; 95% CI, 0.098-0.984) (Fig. 4; Table 4). Likewise, subgroup meta-analysis of patients followed up for > 5 years showed that the mean rate of progressive lateral OA in patients undergoing reoperations per 100 observed years was significantly lower in Asian than in Western patients (0.08 of 3220 Asian patients; 95% CI, 0.055-0.104 versus 0.27 of 3580 Western patients; 95% CI, 0.134-0.469; $p = 0.017$; OR, 0.25; 95% CI, 0.065-0.99) (Table 4).

Metaregression Analyses

The results of metaregression analyses are reported (Table 5). The age and the length of or loss to followup was not significantly associated with rates of bearing dislocation, lateral compartment OA, and reoperation as a result of any reason.

Discussion

Many case series, differing in length of followup and patient origin, have reported outcomes after UKA. Differences in specific causes of reoperation have been observed in studies of patients from both Asian and Western countries. Because randomized and comparative studies are lacking, we designed this meta-analysis to compare the standardized incidence rates of reoperation for all causes, for bearing dislocation and for progression of lateral compartment arthritis in Asian and Western patients with medial knee OA who underwent Oxford Phase III UKA. The most important findings of this systematic review and meta-analysis were that reoperations for bearing dislocation after UKA are more likely to occur in Asian than Western populations, but that reoperation for progression of lateral OA is more predominant in Western than Asian patients.

Table 4. Odds ratio of reoperation after UKA comparing Asian and Western groups and subgroup analysis with followup of 5 years

	Cause of reoperation		
	All-cause	Bearing dislocation	Progression of lateral OA
Total studies (Asian 10/Western 15)			
Number of knees Asian/Western		3688/6389	
Odds ratio	0.7839	3.7378	0.3114
95% CI	0.5323-1.1545	1.6938-8.2482	0.0986-0.9840
Higher frequency	Equivalent	Asian	Western
Studies with < 5 years followup (Asian 3/Western 7)			
Number of knees Asian/Western		468/2809	
Odds ratio	0.9642	4.3052	0.3645
95% CI	0.4274-2.1752	1.2869-14.4029	0.0252-5.2812
Higher frequency	Equivalent	Asian	Equivalent
Studies with > 5 years followup (Asian 7/Western 8)			
Number of knees Asian/Western		3220/3580	
Odds ratio	0.8292	3.8562	0.2526
95% CI	0.4850-1.4179	1.1228-13.2431	0.0647-0.9867
Higher frequency	Equivalent	Asian	Western

UKA = unicompartmental knee arthroplasty; OA = osteoarthritis.

The present study had several limitations. Although we observed associations between common causes of reoperation after UKA and geographic group, we could not determine a clear causal relationship. Bearing dislocation or the progression of lateral OA may be influenced by lifestyle, but may also be influenced by biologic factors or differences in knee morphology. Although our findings yield important implications regarding postoperative clinical care and radiologic evaluation, this may be difficult to apply to patients who maintain their ethnic cultural lifestyle in a foreign country with a different cultural lifestyle and patients who live in geographic areas not considered Asian or Western such as the Middle East. Second, because most studies did not report patient-level information about the number of Asian and Western patients, we could not determine the ethnic homogeneity of patients in each study. However, we assumed that patients adopted the lifestyle of their native country, not their country of origin. Studies involving a single center or many centers within a single nation would be required to assess the effects of patient ethnicity. Third, because the research questions have never been explored in the context of randomized or even prospective trials, our meta-analysis was based on studies with Level IV evidence. Thus, our meta-analysis has all of the limitations of retrospective, literature-based studies, including differences in surgical techniques, sample sizes, and other possible confounders. However, the development of meta-analytic methods has led to the analysis of many single-armed studies. Moreover, we expect that the results of our meta-analysis might contribute to the

establishment of Level I or II evidence. Another possible limitation was the potential risk of bias caused by differences in followup periods or loss to followup among studies. To mitigate the possible confounding effects of differences in sample sizes and length of postsurgical followup, we performed a subgroup meta-analysis of studies with followup durations > 5 years and reported rates of bearing dislocation and lateral OA after UKA as standardized rates (reoperation rate per 100 observed component years). This parameter, which averages sample size and followup durations, is a reliable indicator of studies with differences in these two parameters. In assessing the effects of loss to followup, we evaluated the rate in each study and performed metaregression analysis, finding no significant difference in reoperation rates after UKA. Finally, despite efforts to reduce possible bias such as the inclusion of only those studies in which patients underwent Oxford Phase III UKAs, significant heterogeneity was observed.

Although common causes of reoperation differed between Asian and Western patients, the rate of all-cause reoperation after UKA did not differ significantly. The reported reoperation rate in all included studies with a minimum 2-year followup ranged from 0.9% to 11.9%. Many patients underwent reoperation within 5 years, although some required reoperation after > 5 years. For example, one study reported that 25 of 1000 knees underwent reoperation for lateral OA at a mean 7.0 years and a second study reported that six of 129 knees underwent late reoperation as a result of symptomatic lateral OA after a mean

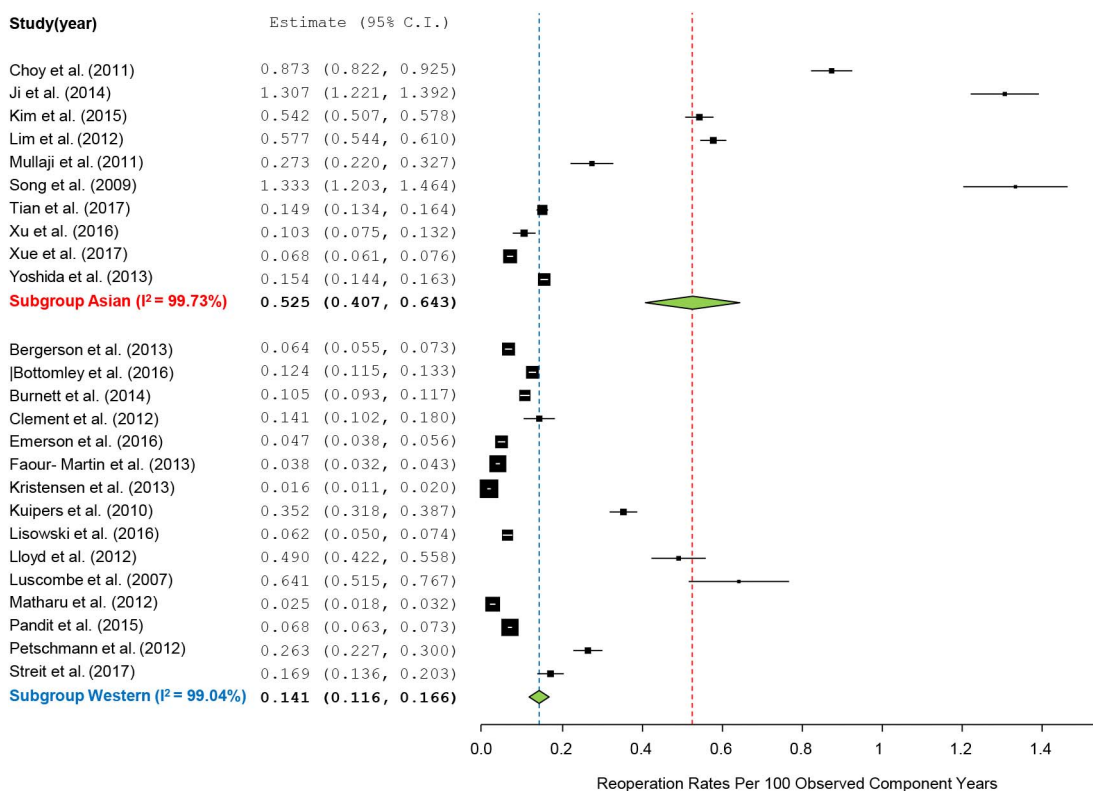


Fig. 3 The forest plot of reoperation rates for bearing dislocation is shown. The mean reoperation rates per 100 observed component years for the bearing dislocation after UKA were higher in seven studies of the Asian group than eight studies of the Western group (0.525 of 3152 Asian patients; 95% CI, 0.407-0.643 versus 0.141 of 5455 Western patients; 95% CI, 0.116-0.166; p = 0.001).

followup of 7.5 years. A study from China reported that 13 knees required reoperation, six occurring after 5 years, including one for bearing dislocation and two for lateral OA. These rates of late reoperation suggested the need for subgroup analysis after a followup > 5 years. However, a comparison of the seven Asian and eight Western studies with > 5-year followup found no difference in all-cause reoperation rate. Individual causes of midterm to long-term reoperation, including aseptic loosening, pain of unknown origin, and periprosthetic fracture, require further analysis.

We found a higher rate of reoperation for bearing dislocation in Asian than in Western patients in this systematic review and meta-analysis. Several factors may explain the higher rate of bearing dislocation after UKA in Asian than in Western populations. The most important factor is likely lifestyle. People living in many parts of Asia kneel, squat, sit crosslegged, or sit on the floor during activities of daily living or while performing religious activities. These positions demand a greater range of knee motion than those typically used by Western populations [25, 35]. Hyperflexion, common to daily activities of Asia populations, increases anterior cruciate ligament (ACL) force [40] and

may strain the ACL, resulting in anterior subluxation of the proximal tibia [36]. Exposure of knees to the biomechanical environment of deep squatting may induce slight anterior subluxation of the proximal tibia, increasing wear on posterior polyethylene bearings, whereas more limited flexion may have little or no effect [21]. A dislocated bearing may induce deformation of a reduced posterior lip while the intact ACL remains intact [9]. These results suggest that deformation of the posterior lip during deep squatting may lead to bearing dislocation. In addition, the remaining meniscus or osteophytes may impinge on the posterior femoral condyle during repetitive deep squatting with knee hyperflexion exacerbating bearing dislocation [54].

Anthropometric differences between Asian and Western populations also may predispose Asians to higher bearing dislocation rates. In particular, tibias are smaller in East Asian than in Western populations [19]. The design of the Oxford tibial component in Asians showed a tendency toward mediolateral overhang of the resected area of the medial tibial condyle. As the AP dimension of the resected medial tibial condyle increases, so does the mediolateral dimension. However, the relative increase in this

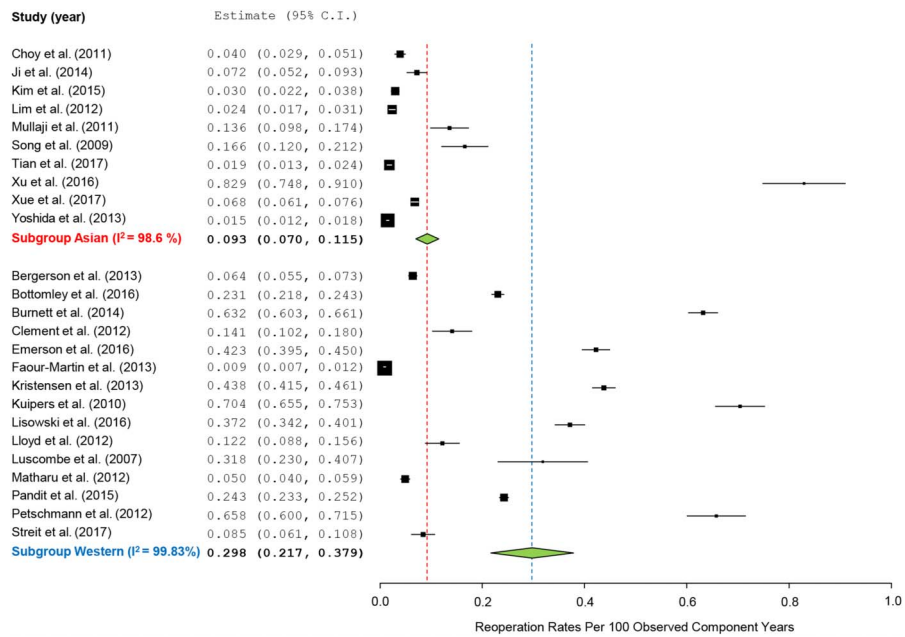


Fig. 4 The forest plot of reoperation rates for progression of lateral OA is shown. The mean reoperation rates per 100 observed component years for the progression of lateral OA after UKA were lower in seven studies of the Asian group than eight studies of the Western group (0.093 of 3152 Asian patients; 95% CI, 0.070-0.115 versus 0.298 of 5455 Western patients; 95% CI, 0.217-0.379; $p < 0.001$).

dimension is of lower magnitude in Asian than in Western populations [45]. Overhang of the tibial component could lead to a size mismatch between the resected surface of the medial tibial condyle area and the geometry of the tibial component, introducing a space between the implant and soft tissue envelopes. This extra space may increase the likelihood of a bearing dislocation because of the greater possibility of impingement between mobile-bearing and

soft tissues or remaining osteophytes [42]. In addition, this space may make the knee environment more susceptible to soft tissue imbalance, one of the most frequent causes of bearing dislocation in UKA. These knees may be susceptible to widening of the medial gap, even after minimal changes in tension on medial soft tissue owing to the inadvertent or overly aggressive release of medial collateral ligaments [14].

Table 5. Metaregression analysis evaluating the influence of age, length of followup, and loss to followup on the bearing dislocation, lateral osteoarthritis, and all-cause reoperation rates between Asian and Western patients

Variable	Coefficient	Standard error	p value	95% confidence interval
Bearing dislocation				
Age	-0.007	0.049	0.890	-0.104 to 0.091
Followup period	-0.031	0.085	0.712	-0.198 to 0.135
Followup loss	-0.006	0.008	0.403	-0.021 to 0.008
Lateral osteoarthritis				
Age	-0.011	0.061	0.852	-0.131 to 0.108
Followup period	0.148	0.098	0.089	-0.044 to 0.341
Followup loss	0.004	0.009	0.609	-0.012 to 0.021
Total reoperation rate				
Age	-0.016	0.026	0.541	-0.067 to 0.065
Followup period	0.030	0.043	0.481	-0.054 to 0.114
Followup loss	-0.001	0.028	0.969	-0.056 to 0.054

We also found that the incidence of progression of lateral OA after UKA was higher in Western than in Asian patients. This finding may be attributable, at least in part, to the higher prevalence of constitutional varus in Asians than in Western patients. This higher prevalence in Asians than in Western patients may, in turn, result from the higher rate of increased femoral varus (lateral) bowing in Asians [42]. Intense knee flexion by Asians during kneeling and deep squatting occurring at the end of their growth spurt, retarding growth of the physis and increasing compression on the medial knee compartment [8, 50, 53], may result in a higher prevalence of varus alignment in Asians than in Western patients. The incidence of constitutional varus alignment has been reported to be approximately 10% higher in Asians than in Western patients (35% versus 25%). This higher rate of constitutional varus in Asians could at least partially offset the valgus alignment occurring after UKA in Asians [41, 42, 55]. Conversely, Western patients show a greater tendency than Asians to have neutral or valgus lower limb alignment. Therefore, after UKA, Asians are less likely to have valgus alignment develop than Western patients, which may explain, at least in part, our finding that the rate of lateral knee OA was higher in Western than in Asian patients.

In conclusion, the current study showed that reoperation for bearing dislocation after UKA was more likely to occur in Asian than in Western populations. Furthermore, reoperation attributable to progression or lateral OA was more frequent in Western than in Asian patients. Nevertheless, total reoperation rates after UKA were similar in Asian and Western populations, perhaps reflecting offsetting of these two revision indications. Although we have offered some possible explanations for these findings, additional randomized, prospective comparative studies are needed. However, better survival outcomes after UKA may require consideration of ethnicity and lifestyle choices in addition to traditional surgical technique and perioperative care.

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