REVIEW ARTICLE

Clinical Outcomes of Revision Total Knee Arthroplasty after High Tibial Osteotomy and Unicompartmental Knee Arthroplasty: A Systematic Review and Meta-Analysis

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As more high tibial osteotomy (HTO) and unicompartmental knee arthroplasty (UKA) are performed, orthopaedic surgeons realize that more HTO and UKA failures will require revision to total knee arthroplasty (TKA) in the future. To systematically evaluate the clinical outcomes of TKA after HTO and TKA after UKA, the Embase, PubMed, Ovid, Web of Science, and Cochrane Library databases were searched for studies investigating revision TKA after HTO and UKA published up to June 2021. RevMan version 5.3 was used to perform the meta-analysis. The revision TKA after HTO and revision TKA after UKA groups were compared in terms of operative time, range of motion (ROM), knee score, postoperative complications, postoperative infection, revision, and revision implants used. Nine studies were ultimately included in the meta-analysis. Results revealed that the knee score for the revision TKA after HTO group was better than that of the revision TKA after UKA group (MD 4.50 [95% CI 0.80–8.20]; $p = 0.02$). The revision TKA after HTO group had a lower revision rate (OR 0.65 [95% CI 0.55–0.78]; $p < 0.00001$) and fewer revision implants used (OR 0.11 [95% CI 0.05–0.23]; $p < 0.00001$). There were no statistical differences in operation time (MD -2.00 [95% CI −11.22 to 7.21]; $p = 0.67$), ROM (MD -0.04 [95% CI -3.69–3.61]; $p = 0.98$), postoperative complications (OR 1.41 [95% CI 0.77–2.60]; $p = 0.27$), or postoperative infections (OR 0.89 [95% CI 0.61–1.29]; $p = 0.53$). To conclude, the revision rate of revision TKA after UKA was greater, and more revision implants were required. It is important for orthopaedic surgeons to preserve bone during primary UKA.

Key words: High tibial osteotomy; Revision; Total knee arthroplasty; Unicompartmental knee arthroplasty

Introduction

Knee osteoarthritis (KOA) is the most common degenerative disease, and is characterized by cartilage degeneration, destruction, and bone hyperplasia[1]. As aging and living standards increase, the prevalence of KOA has increased significantly[2]. Mainstream surgical methods for the treatment of medial KOA include high tibial osteotomy (HTO) and unicompartmental knee arthroplasty (UKA). Both have been used in practice and have yielded satisfactory efficacy. HTO is more suitable for active younger patients, while UKA is more commonly used for elderly patients due its shorter recovery time and faster functional recovery[3,4]. HTO relieves load on the medial compartment by transferring the lower limb force line to the unaffected lateral compartment, thus delaying degeneration of the articular cartilage of the medial compartment, while UKA replaces the medial compartment. A retrospective study by Bouguennec *et al.*[5] concluded that there was no significant difference in 10-year survival rate between HTO and UKA, and good survival rates could be obtained. However, both surgical methods may still need to

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be revised for total knee arthroplasty (TKA) due to progressive osteoarthritis, loosening, and wear of the prosthesis. As the number of HTO and UKA surgeries increase, more HTOs and UKAs will need to be revised to TKA in the future. Lee *et al.* retrospectively analyzed clinical outcomes and survival rates of revision TKA after HTO or UKA; however, most of the studies mainly reported the outcomes of TKA after HTO or UKA compared with those of primary TKA without HTO or UKA[6]. Prompted by current controversy regarding clinical outcomes and survival rates of HTO and UKA revision to TKA, we performed a meta-analysis to compare the outcomes of revision TKA after HTO and revision TKA after UKA.

Data and Methods

Search Strategy

The Embase, PubMed, Ovid, Web of Science, and Cochrane Library databases were searched for studies investigating revision TKA after HTO or UKA published up to June 2021. Keywords and medical subject heading (MeSH) terms included the following: high tibial osteotomy, unicompartmental knee arthroplasty, total knee arthroplasty, total knee replacement, HTO, UKA, TKA, and TKR. These keywords and the corresponding MeSH terms were combined with the Boolean operators "AND" and "OR."

Eligible Criteria

Potentially eligible studies were required to fulfill the following criteria: (i) patients diagnosed with KOA requiring revision after HTO or UKA treatment; (ii) case–control and cohort studies published domestically and abroad, with TKA as the final treatment method; (iii) results from conversion TKA after HTO and UKA groups, sample size ≥10, with a mean follow-up of at least 2 years; (iv) and clinical results that could be compared with other studies (e.g. operative duration, ROM, complications, and revision rate). Exclusion criteria were as follows: (i) studies of cadavers or artificial models are excluded, (ii) letters, reviews, editorials, practice guidelines, and other studies with insufficient data are excluded.

Risk of Bias Assessment

All articles retrieved in the literature search were screened by two analysts, in accordance with the inclusion criteria, and differences were resolved by discussion with a third analyst. The quality of the retrospective case–control studies was assessed using the Newcastle–Ottawa scale (NOS), which is divided into three components: selection, comparability, and exposure or outcome. The NOS allocates up to four stars for "selection," up to two stars for "comparability," and up to four stars for "exposure or outcome," with one star representing one point and a total score of 10 points. Studies with an NOS score >7 are classified as high-quality, 5–7 as medium-quality, and ≤5 as low-quality.

Data Extraction

Data regarding general information and clinical outcomes were extracted from the included studies by two independent analysts. General information included author, year of publication, study design, age, sex ratio, and mean follow-up times. Clinical data included mean operative time, knee ROM, knee function score (Knee Society Score [KSS] and Oxford Knee Score [OKS], etc.), postoperative complications, postoperative infections, revision, and the use of revision implants. All documents and data were analyzed and reviewed by two analysts, and any disagreements were resolved by a third analyst.

Statistical Analysis

Data were analyzed using Revman version 5.3 (Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014). The efficacy statistic for dichotomous variables is expressed as odds ratio (OR) and corresponding 95% confidence interval (CI), and mean difference (MD) and 95% CI

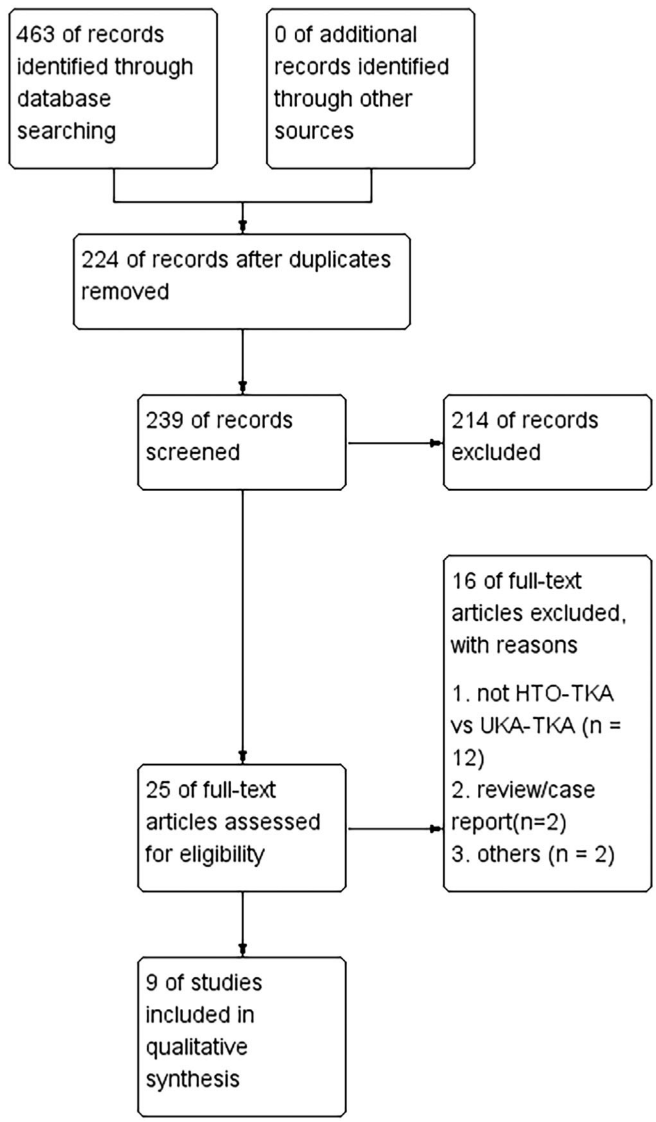

Fig. 1 Flow diagram of the included studies

Table 1 Basic information of the included studies

Study	Year	Study design	Comparison	Number	Age (years)	Female/Male	Outcomes	Follow-up (years)
Jackson[7]	1994	CCT	HTO to TKA	20 (21 knee)	70.5 (53–91)	15/5	BDE	2.8
			UKA to TKA	23 (24 knee)	68 (56–82)	17/6		3.8
Gill[8]	1995	CCT	HTO to TKA	27 (30 knee)	65 (54–80)	13/14	CDF	>3.8
			UKA to TKA	27 (30 knee)	67 (57–87)	13/14		
Pearse[9]	2012	CCT	HTO to TKA	711	62.4 (34–89)	201/510	CEFG	unclear
			UKA to TKA	205	66.4	103/102		
Cross[10]	2014	CCT	HTO to TKA	43	54.2	12/31	ABCDEFG	8.47
			UKA to TKA	49	61.5	30/19		4.56
Robertson[11]	2014	CCT	CWHTO to TKA	356	59.8c	unclear	FG	4–5
			OWHTO to TKA	482	59.1 ± 7.5			
			UKA to TKA	920	66.3 ± 8.9			
Pailhe[12]	2016	CCT	HTO to TKA	20	71.7 ± 7.1	8/12	ABCDE	4.1 (2–18.7)
			UKA to TKA	20	71.9 ± 6.8	8/12		
Lim[13]	2017	CCT	HTO to TKA	217	64.5 ± 7.3	176/41	ACDEFG	7.3 ± 3.9
			UKA to TKA	75	65.6 ± 8.1	61/14		5.2 ± 3.2
Ei-Galaly[14]	2020	CCT	HTO to TKA	1155	63 (32–90)	498/657	ACDFG	9.3 (5–13.4)
			UKA to TKA	978	66 (34–95)	654/324		4.7 (1.9–7.7)
Lee[15]	2021	CCT	HTO to TKA	1000	66.09 ± 6.47	876/124	DEF	>5
			UKA to TKA	1000	66.11 ± 6.60	867/133		

Abbreviations: A, operation time; B, range of motion; C, knee score; CCT, retrospective comparative control trial; CW, closed wedge; D, postoperative complications; E, postoperative infections; F, revision; G, revision implants used; HTO, high tibial osteotomy; OW, opening wedge; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty

Table 2 Quality evaluation form of the included retrospective studies

Study	Selection	Comparability	Exposure or Outcome	Total score
Jackson[7]	☆☆☆	☆	☆☆	6
Gill[8]	☆☆☆	☆	☆☆	6
Pearse[9]	☆☆	☆☆	☆☆	6
Cross[10]	☆☆☆	☆☆	☆☆☆	8
Robertson[11]	☆☆	☆	☆☆☆	6
Pailhe[12]	☆☆☆	☆☆	☆☆	7
Lim[13]	☆☆☆	☆☆	☆☆	7
Ei-Galaly[14]	☆☆☆	☆☆	☆☆☆	8
Lee[15]	☆☆☆	☆☆	☆☆☆	8

Note: The quality of the studies was assessed using the Newcastle–Ottawa scale (NOS), and one star represents one point.

for continuous variables. Tests for heterogeneity were performed using the I^2 test. When heterogeneity was not statistically significant ($p > 0.1$, $I^2 < 50\%$), the fixed-effect model was used. When heterogeneity was statistically significant ($p \leq 0.1$, $I^2 \geq 50\%$), the source of heterogeneity was analyzed, and the random-effects model was used for analysis. Differences with $P < 0.05$ were considered to be statistically significant.

Results

Literature Search Results

A total of 463 articles were initially retrieved in the literature search, of which 224 were duplicates, while 214 were excluded after screening the titles and abstracts. After reading the full text of 25 articles, nine were ultimately included in the systematic review and meta-analysis[7–15] (Fig. 1). A total of 7328 patients, comprising the HTO-TKA group ($n = 4031$) and the UKA TKA group ($n = 3297$) were included. General information regarding the nine included studies is summarized in Table 1. Two evaluators read the titles, abstracts, or full texts of the articles and strictly performed screening in accordance with the inclusion and exclusion criteria. In the process of extracting data, the two researchers repeated the check and, if there were any discrepancies, a third evaluator was consulted.

Quality Assessment

Nine studies, all of which were retrospective in design, fulfilled the inclusion criteria. The NOS was used for evaluation. Three studies scored 8 points, two scored 7, and four scored 6. None of the studies were of low-quality, as shown in Table 2.

Primary Outcomes

Knee Score Scales

Six studies reported knee scoring scales between revision TKA after HTO and revision TKA after UKA[8–10,12–14]. Knee scoring scales included the KSS, Knee Society Function Score (KFS), and OKS. Therefore, subgroup analysis was used to analyze postoperative knee scores of revision TKA after HTO or UKA. There was a statistical difference in heterogeneity among the studies ($p < 0.00001$, $I^2 = 96\%$); as such, the random-effect model was used for meta-analysis. Results

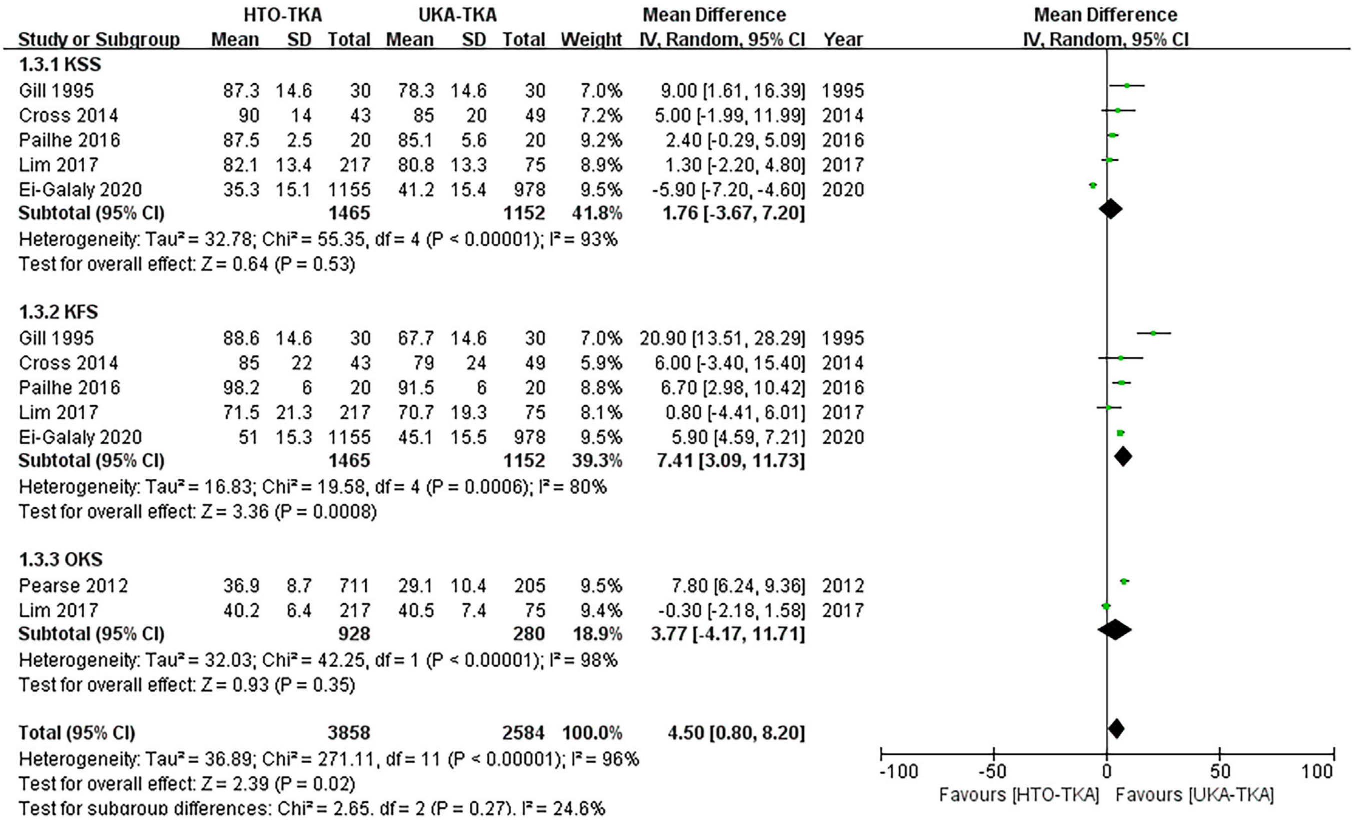

Fig. 2 Forest plot diagram of knee score comparing the two groups

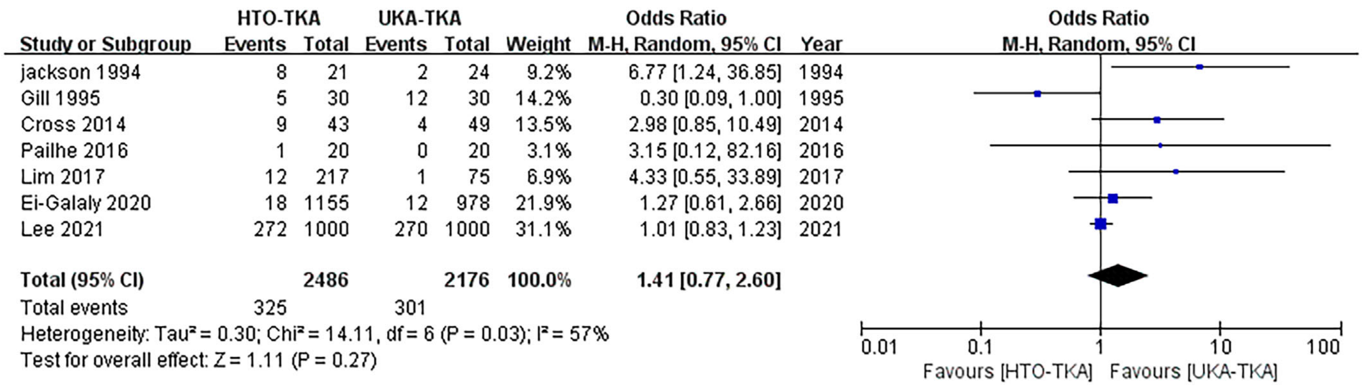

Fig. 3 Forest plot diagram of postoperative complications comparing the two groups

revealed that the knee score of the HTO-TKA group was better than that of the UKA-TKA group (MD 4.50 [95% CI 0.80–8.20]; $p = 0.02$) (Fig. 2). Subgroup analysis indicated that the KFS score in the HTO-TKA group was significantly better than that in the UKA-TKA group, with a statistically significant difference (MD 7.41 [95% CI 3.09–11.73]; $p = 0.0008$).

Postoperative Complications

Seven studies addressed postoperative complication rate of revision TKA after HTO and reversion TKA after UKA[7,8,10,12–15]. Heterogeneity among the studies was statistically significant ($p = 0.03$, $I^2 = 57\%$); as such, the random-effect model was used for meta-analysis. Results indicated no statistical difference in the incidence of postoperative

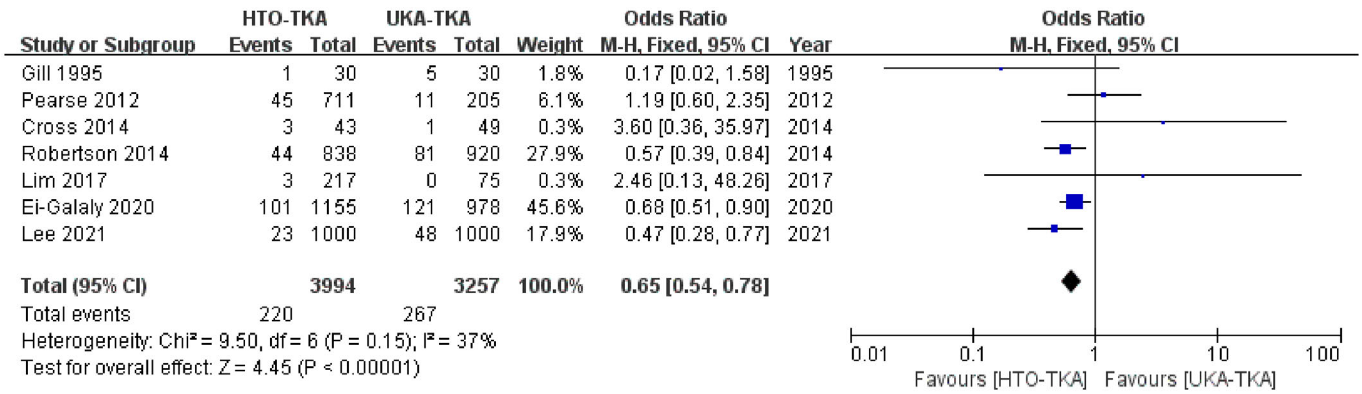

Fig. 4 Forest plot diagram of revision between the two groups

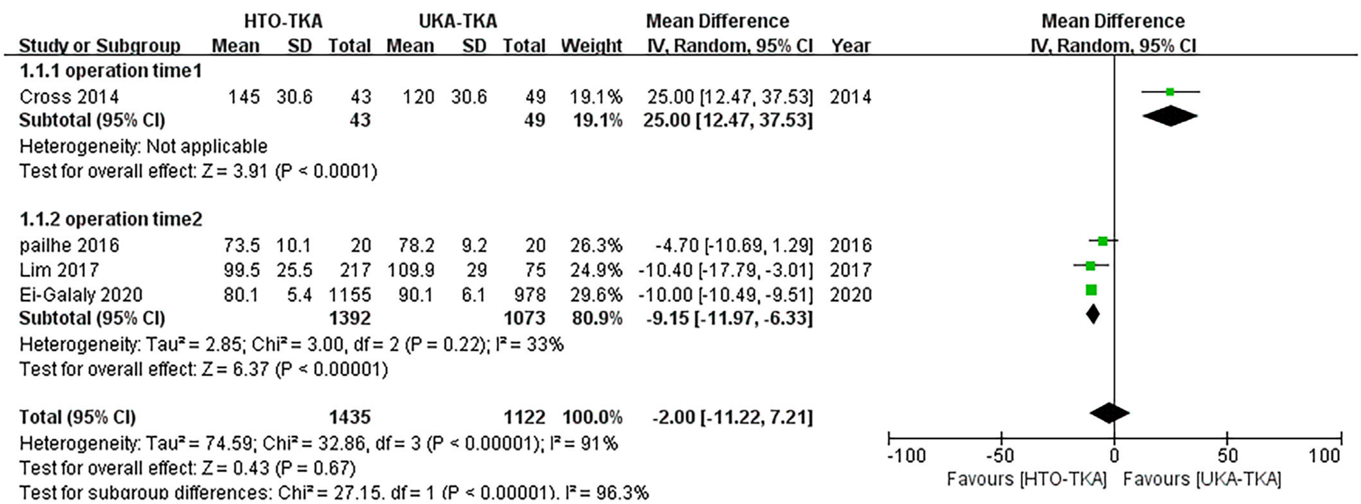

Fig. 5 Forest plot diagram of operation time comparing the two groups

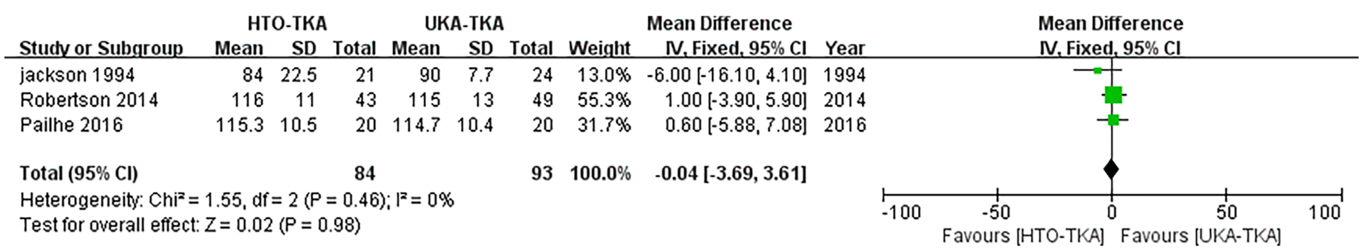

Fig. 6 Forest plot diagram of ROM comparing the two groups

complications between the HTO-TKA and the UKA-TKA groups (OR 1.41 [95% CI 0.77–2.60]; $p = 0.27$) (Fig. 3).

Revision

Seven studies investigated the revision rate between revision TKA after HTO and reversion TKA after UKA[8–11,13–15]. There was no statistical difference in heterogeneity among the studies ($p = 0.15$, $I^2 = 37\%$), and the fixed-effect model was used for meta-analysis. Results indicated that the revision rate for the HTO-TKA group was significantly lower than that of the UKA-TKA group (OR 0.65 [95% CI 0.54–0.78]; $p < 0.00001$) (Fig. 4).

Secondary Outcomes

Operation Time (min)

Among the four studies for which operative time of revision TKA after HTO and revision TKA after UKA were

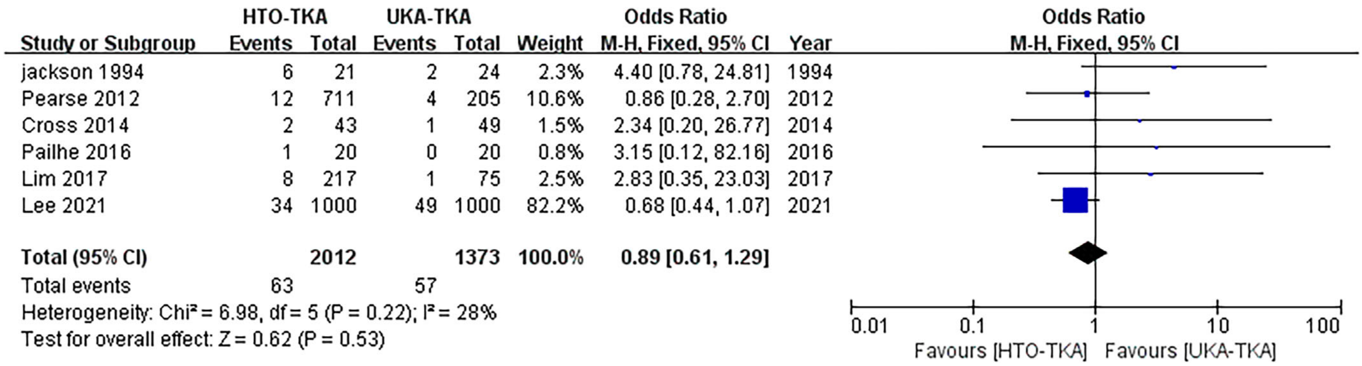

Fig. 7 Forest plot diagram of infections comparing the two groups

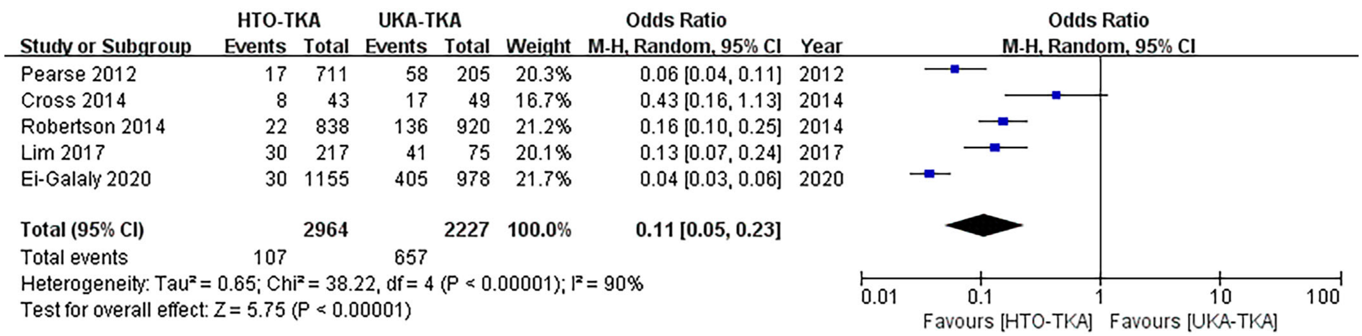

Fig. 8 Forest plot diagram of revision implants used between the two groups

compared [10,12–14], there was a statistical difference in heterogeneity ($p < 0.00001$, $I^2 = 91\%$); as such, the random-effect model was used for meta-analysis. Heterogeneity was attributed to one of the articles, and a subgroup analysis was performed. Results revealed that there was no significant difference in operative duration between the HTO-TKA and UKA-TKA groups (MD −2.00 [95% CI −11.22 to 7.21]; $p = 0.67$). Except for the study by Cross *et al.*, the operative duration of the HTO-TKA group was significantly shorter than that of the UKA-TKA group (MD −9.15 [95% CI −11.97 to −6.33]; $p < 0.00001$) (Fig. 5). The article by Cross *et al.* did not describe specific surgical procedures; as such, it was inferred that operative duration may have been affected by the surgeon's skills.

Range of Motion

Three studies compared the ROM between revision TKA after HTO and revision TKA after UKA[7,10,12], and there was no statistical difference in heterogeneity among the studies ($p = 0.46$, $I^2 = 0\%$). Therefore, the fixed-effect model was used for meta-analysis. Results revealed no statistical difference in ROM between the HTO-TKA and UKA-TKA groups (MD −0.04 [95% CI −3.69 to 3.61]; $p = 0.98$) (Fig. 6).

Postoperative Infections

Six studies investigated the postoperative infection rate of revision TKA after HTO and revision TKA after UKA[7,9,10,12,13,15]. Because some studies did not distinguish between superficial and deep infections, this distinction was disregarded in the present analysis. There was no statistical difference in heterogeneity among the studies ($p = 0.22$, $I^2 = 28\%$), and the fixed-effect model was used for meta-analysis. Results revealed no statistical difference in the incidence of postoperative infections between the HTO-TKA and UKA-TKA groups (OR 0.89 [95% CI 0.61–1.29]; $p = 0.53$) (Fig. 7).

Revision Implants Used

Five studies compared the use of revision implants between revision TKA after HTO and revision TKA after UKA[9–11,13,14]. There was no statistical difference in the heterogeneity among the studies ($p < 0.00001$, $I^2 = 90\%$), and the random-effect model was used for meta-analysis. Results indicated that the utilization rate of revision implants in the HTO-TKA group was significantly lower than that in the UKA-TKA group (OR 0.11 [95% CI 0.05–0.23]; $p < 0.00001$) (Fig. 8).

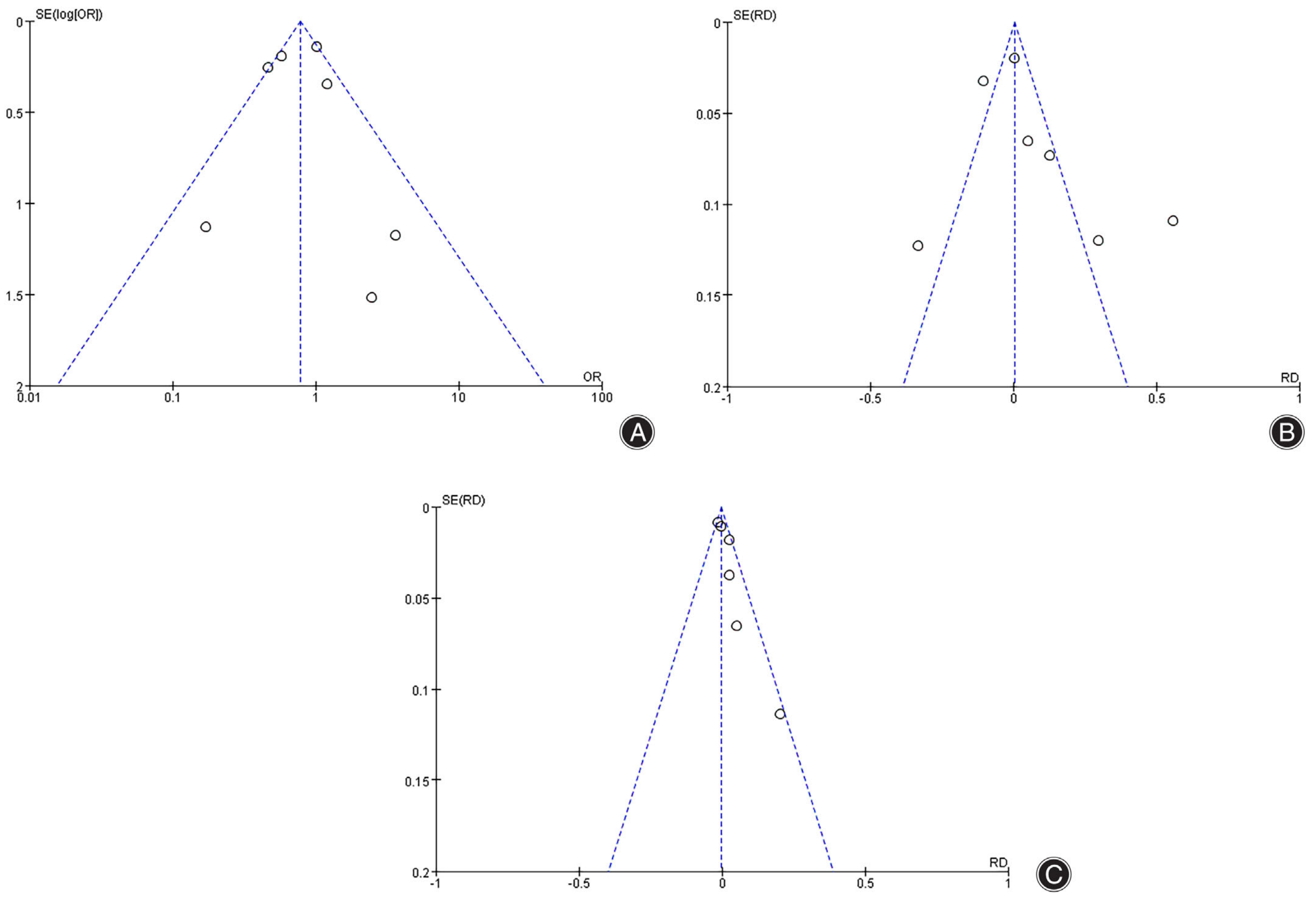

Fig. 9 (A) Funnel plot of revision between the two groups. (B) Funnel plot of postoperative complications between the two groups. (C) Funnel plot of postoperative infections between the two groups

Bias Analysis

The funnel plots were used to detect publication bias in the clinical outcomes of the included studies. The funnel plot for revision rate (Fig. 9A) was symmetric with all studies included, indicating no publication bias. However, funnel plots for postoperative complications (Fig. 9B) and infections (Fig. 9C) were asymmetric, and some studies were not included, indicating the presence of publication bias.

Discussion

The present study was a systematic review and meta-analysis of clinical outcomes of revision TKA after HTO and revision TKA after UKA. Nine retrospective studies, including a total of 7328 patients, were included. Existing clinical evidence reveals that the Knee Society Function Score of the HTO-TKA group was better than that of the UKA-TKA group. The HTO-TKA group demonstrated a lower revision rate and required fewer revision implants. Most studies reported that the operative duration of the UKA-TKA group was longer than that of the HTO-TKA group, which is consistent with higher surgical complexity and the need to use complex revision implants. There was no significant difference in ROM, postoperative complications, and incidence of postoperative infections between the two groups. A study by Pailhe[12] compared clinical outcomes of computer-assisted TKA after HTO and UKA without considering revision rates. In the present study, we found that the UKA-TKA and HTO-TKA groups appeared to experience fewer postoperative complications and demonstrated better knee function scores. Currently, it is acknowledged that computer-assisted TKA can reduce operative duration, improve radiographic alignment, and possibly improve knee function, although it may have little impact on long-term survival rates[16,17]. However, few studies have compared computer-assisted and traditional revision TKA, which may have influenced our results.

Revision Factors of HTO and UKA

The surgical indication for HTO and UKA is unicompartmental osteoarthritis. HTO is especially recommended for younger patients with high mobility needs, while UKA is recommended for patients with lesser mobility needs. Studies have shown that HTO yields good clinical outcomes and survival rates; however, the symptoms of osteoarthritis will gradually worsen with the progression of the disease. According to literature reports, the 10-year survival rate of HTO is approximately 75%–96%, with a 15-year survival of 55% to 92%[18,19]. The number of UKA applications in clinical practice is increasing annually. A systematic analysis of survival rate for UKA, including 26 studies[20], reported 5- and 10-year survival rates of 95% and 91%, respectively. The reasons for revision include aseptic loosening of the prosthesis, periprosthetic fractures, wear of the prosthesis, progression of osteoarthritis, and infection. All studies included in our analysis excluded the revision of HTO and UKA to TKA due to infection. Although both HTO and UKA yield good survival rates, a considerable proportion need to be revised for TKA. With the increasing number of HTO and UKA surgeries, the number of TKAs that eventually need to be revised has also increased.

Survival Rates of Revision HTO and UKA

Presently, controversy persists as to whether previous HTO affects the outcomes and survival rate of TKA. Some scholars[21,22] believe that previous HTO does not affect the function and survival rate of TKA. Badawy *et al.* used data from the Norwegian Arthroplasty Register to compare revision TKA after HTO and initial TKA. The 10-year survival rate was 92.6% in the TKA after HTO group and 93.8% in the primary TKA group, with no significant difference in survival rate[23]. A systematic analysis by Chen[24] suggested that, compared with primary TKA, TKA after HTO has greater complication and revision rates, and greater surgical complexity. Currently, the clinical application of UKA is increasing. It is generally believed that UKA is more minimally invasive and has fewer early complications[25]; however, it may have a higher revision rate than TKA[26]. Many scholars believe that UKA is a preoperative strategy that can delay the time to final TKA. In this regard, some researchers believe that the revision of UKA to TKA has worse clinical outcomes and a higher revision rate than primary TKA. This revision surgery is more complicated and requires greater surgical skill[27,28]. However, Lombardi *et al.* found that the revision rate of UKA to TKA was similar to that of primary TKA[29]. Similar to revision TKA after HTO, revision TKA after UKA is also controversial.

Challenge

We found that the revision rate of TKA after UKA was higher than that after TKA after HTO, and more revision implants were required during revision surgery. Challenges in revision HTO include the unclear anatomy of the proximal tibia, difficult surgical approaches, and the need to balance ligaments. The challenges of revision UKA is high bone loss, which may be related to aseptic loosening and excessive osteotomy during UKA[30]. Lewis *et al.*[31] used the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) database to analyze the survival rate of implants after revision of UKA to TKA and found that when a tibial extension stem was used, the risk for repeat revision was lower. Orthopaedic surgeons should be aware that revising UKA to TKA may require the use of revision implants, and that intraoperative management of bone loss should be a top priority.

Conclusion

Results of the present analysis demonstrated that revision TKA after HTO had a lower revision rate than revision TKA after UKA, the use of revision implants was lower, and the Knee Society Function Score was better. However, there were no significant differences in ROM, postoperative complications, and postoperative infection rates. Although previous UKA has a higher revision rate compared with HTO, the indications for HTO and UKA are not entirely the same. It also takes into account the benefits of delaying ultimate TKA, and both HTO and UKA have excellent survival rates; as such, it cannot be inferred from this which is better or worse. It should be considered in the initial UKA that it may eventually need to be revised to TKA, and bone should be preserved as much as possible during the operation.

The present study had some limitations, the first of which was that all nine included studies were all retrospective in design; moreover, two were not novel, and one investigated computer-assisted revision TKA. Orthopaedic surgeons have different clinical experience, surgical skills, and follow-up times, which will also contribute to greater heterogeneity. The included studies did not distinguish between the medial opening-wedge and the lateral closed-wedge HTO, and the UKA did not distinguish between cemented and uncemented components, and fixed and mobile bearings. In the future, it will be necessary to conduct larger-scale and multi-center studies to draw more reliable conclusions.

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Authorship declaration

All authors listed meet the authorship criteria according to the latest guidelines of the International Committee of Medical Journal Editors and all authors have approved the manuscript and agree with submission to *Orthopaedic Surgery*.

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