Review

Unicompartmental Knee Arthroplasty vs High Tibial Osteotomy for Knee Osteoarthritis: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Prior studies have compared unicompartmental knee arthroplasty (UKA) with high tibial osteotomy (HTO) suggesting that both procedures had good clinical outcomes. However, which treatment is more beneficial for unicompartmental knee osteoarthritis is still a controversy. The purpose of our study is to obtain postoperative outcomes of revision rate, complications, function results, range of motion (ROM), and pain between the 2 procedures.

Methods: Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were followed and study protocol was published online at PROSPERO under registration number CRD42016049316. We searched the databases MEDLINE, EMBASE, Cochrane Library, and Web of Science up to May 2017. Articles that directly compared postoperative outcomes of UKA to HTO were included.

Results: A total of 10 comparative studies were included in our meta-analysis. UKA patients showed less revision rate, less complications, and less postoperative pain than HTO patients; however, HTO patients obtained more ROM. No significant difference was observed between the group accruing to the knee function scores and excellent/good surgical results.

Conclusion: UKA offers a safe and efficient alternative to osteoarthritis reduced postoperative pain, less postoperative complication, and revision. The 2 surgical techniques showed satisfactory function results for the patients; however, the HTO group achieved superior ROM compared to the UKA group. HTO may be suitable for patients with high activity requirements. Treatment options should be carefully considered for each patient in accordance with their age, body mass index, grade of osteoarthritis, and patients’ activity levels.

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Osteoarthritis (OA) of the knee, a common form of degenerative joint disease, affects individuals worldwide. Although OA may affect any one or all 3 compartments of the knee, one-third of OA patients are affected in only 1 compartment [1]. In up to 50% of patients, arthritic change in the knee is predominately found in the medial compartment of the joint, with fewer changes occurring on the lateral side or patella-femoral joint [2].

Total knee arthroplasty (TKA) is the primary treatment for symptomatic late-stage OA. However, for moderate-grade stages or isolated OA, TKA is not the preferred treatment strategy, particularly for the younger and highly active patients. Unicompartmental knee arthroplasty (UKA) and high tibial osteotomy (HTO) are established treatment methods for moderate medial compartment OA, although choosing the appropriate surgical treatment for unicompartmental OA remains somewhat controversial.

The purpose of this study is to compare the outcomes of UKA and HTO for knee OA by investigating the advantages and disadvantages of these 2 procedures in terms of indications, postoperative complications, functional result, and TKA revision rate.

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Methods

Search Strategy

We conducted this study in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [3]. The research protocol for this review was determined by all coauthors before the literature searches were begun, and the study protocol was published online at the PROSPERO International Prospective Register of Systematic Reviews (http://www.crd.york.ac.uk/PROSPERO/) under registration number CRD42016049316.

The electronic databases MEDLINE (through PubMed), EMBASE (through OvidSP), SCI (through Web of Science), and CENTRAL (Cochrane Central Register of Controlled Trials, through the Cochrane Library) were searched for relevant studies published from October 2016 to May 2017 with no language restrictions applied. The literature search strategy for these 4 databases followed Medical Subject Headings combination with terms.

Inclusion and Exclusion Criteria

Two authors independently assessed the search results for inclusion in this systematic review by scanning titles/abstracts or the full text. Disagreements between the 2 authors were resolved by consensus or through discussion with a third author. We also examined the reference lists of each comparative study and reviews to identify additional relevant studies.

The studies included were randomized controlled trials (RCTs) or nonrandomized controlled trials (nRCTs) that directly compared HTO to UKA to treat medial knee OA and reported at least one of the following outcomes: revision incidence, complications (eg, infection, thrombosis, pain), function results (eg, knee function score or range of motion [ROM]), cadaver and duplicate studies were excluded. We also excluded studies that evaluated patients with traumatic arthritis and rheumatoid arthritis.

Study Quality Assessment

We assessed the risk of bias in the RCTs using the Cochrane risk of bias tool to determine whether biases might have affected the results. The nonrandomized studies were assessed using the Risk of Bias in Non-Randomized Studies of Interventions (ROBINS-I) assessment tool [4]. The ROBINS-I tool evaluates bias from the following 7 aspects: bias due to confounding, bias in the selection of participants, bias in measurement of interventions, bias due to departures from intended interventions, bias due to missing data, bias in measurement of outcomes, and bias in selection of the reported result. These studies were independently assessed by 2 authors. Any controversy was resolved by a third author to achieve a final consensus.

Data Extraction

The first author extracted data from all included studies, and this process was repeated by 2 other authors. All authors used a standardized date extraction form that included the following topics: (1) study information (ie, author, year of publication, country, journal, and type of study), (2) study population information (ie, age, gender, body mass index [BMI], and OA grade), (3) surgery type and follow-up, and (4) principal outcomes (ie, functional outcomes, ROM, revision incidence, and complications). As for functional outcomes, if the knee score is a maximum of 100 points, then the results are classified in excellent (85–100 points), good (70–81 points), fair (60–69 points), and poor (< 60 points).

Statistical Analysis

For dichotomous outcomes, such as complications or revision rates, the odds ratio (OR) and associated 95% confidence intervals (CIs) were used to perform estimates for each study. The mean difference (MD) or standard mean difference (SMD) was used for continuous variables, including knee function scores. For studies that presented continuous data as the means and range values, standard deviations were calculated using statistical algorithms [5]. Only those studies from which the standard deviations and means could be obtained were included in the analysis. Heterogeneity was expressed as $I^2$ and $P$. The random effects model replaced the fixed effects model for heterogeneity test, $P < .1$ or $I^2 \geq 50%$.

Sensitivity analysis was performed to evaluate the stability of the results (when necessary), and subgroup analysis was conducted to obtain more specific conclusions if the data were present. Forest plots were used to present the results of the individual studies and respective pooled estimates of effect size. Funnel plots were used to assess publication bias for any of the outcomes. All statistical analyses were performed using Review Manager (version 5.3.5 for Windows, the Cochrane Collaboration, the Nordic Cochrane Centre, Copenhagen, 2014).

Results

Study Selection

A total of 2300 potentially relevant citations were extracted from the 4 electronic databases. After deleting 728 duplicates, 1527 irrelevant citations were excluded by reviewing their titles and abstracts. We reviewed the remaining 45 full-text articles, 14 of which were systematic reviews. We excluded another 17 articles for reasons such as the introduction of a surgical technique, lack of useful outcome data, and for being basic research among others.

Fourteen publications were selected. Of the 2 studies from the same institution that had different follow-up periods, only the recent study was selected [6,7]. The study by Karpman and Volz [8] was excluded because the included patients not only had OA but also had traumatic arthritis and rheumatoid arthritis. The studies by Ivarsson and Gillquist [9] and Weale and Newman [7] were excluded because the indications, expectations, and type of fixation modes varied significantly compared to more recent articles. Finally, 10 studies published from 2001 to 2017 fulfilled the selection criteria and were included in the meta-analysis [10–19]. Screening the reviews and the 10 included articles did not provide any additional studies to evaluate. The detailed study selection process is shown in Figure 1.

Study Characteristics and Quality

Of the 6173 patients (6222 knees) with medial knee OA in the 10 studies, 5305 patients (5335 knees) were in the UKA group and 868 patients (887 knees) were in the HTO group.

Six studies [11,12,15,16,18,19] compared UKA with open-wedge HTO (OW-HTO) and 4 studies [10,13,14,18] compared UKA with close-wedge HTO (CW-HTO). In one study [17], osteotomy was performed using the hemicallotasis technique and in another study [12] dome-type HTO (DT-HTO) was performed using a circular external fixator. The maximum follow-up period was >7.5 years [14] and the minimum period was 2 years [18]. The study characteristics, patient demographic details, and clinic outcomes for each study were shown in Table 1.
Survival

Survival was defined as the time to a TKA revision, second operation, or an operation failure. Eight studies [11,12,14–19] that assessed 6013 patients in total reported long-term survival rates. We conducted subgroup analysis by dividing the studies into an RCT subgroup and an nRCT subgroup. The pooled data showed no significant differences in revision rate between HTO and UKA (OR 0.83, 95% CI 0.35–2.01, P = .69, I² = 74%). When each of the 9 studies was excluded one at a time to perform a sensitivity analysis, the heterogeneity decreased only when W-Dahl et al [17] study was excluded. The final sensitivity analysis results showed that the revision rate of the UKA group was less than that of the HTO group (OR 0.52, 95% CI 0.30–0.90, P = .02, I² = 33%). Funnel plots illustrating the meta-analysis of the revision rate indicated no obvious publication bias.

Complications

Five studies [12,14–16,19] that altogether assessed 394 patients reported complication rates. The primary complications included infection, leg length discrepancy, deep vein thrombosis, peroneal palsy, and pain, among others. Significantly fewer complications occurred in the UKA groups than the HTO group (OR 0.42, 95% CI 0.20–0.89, P = .02, P = .00; Fig. 2).

Functional Results

Except for W-Dahl et al [17], the remaining 9 studies used different scoring systems for between-group comparisons of the knee score. Two studies [11,18] used the Lysholm Knee Score system to assess the knee scores between the 2 groups with no clearly significant difference observed (MD 4.99, 95% CI –3.91 to 13.09, P = .27, I² = 88%). Two studies [14,15] used the Knee Society Scoring system (MD –4.03, 95% CI –9.91 to 1.85, P = .18, I² = 78%). Four studies [10,14–16] that assessed 308 patients in aggregate reported functional results (patients having excellent/good results). No significant difference was observed between the groups (OR 2.18, 95% CI 0.58–8.23, P = .25, I² = 63%; Fig. 3).

Range of Motion and Pain

Four studies [11,13–15] that included 267 patients reported on ROM. The results favored the HTO group, which achieved superior ROM to UKA group (SMD –0.85, 95% CI –1.43 to –0.27, P = .004, I² = 79%; Fig. 4). Two studies [10,13] that included 197 patients reported on pain (no/mild). Patients in the UKA group had better results than patients in the HTO group (OR 5.65, 95% CI 1.24–25.81, P = .03).

Discussion

Main Results

In any surgical decision, patient safety is always of paramount importance. This meta-analysis of 2 RCTs and 8 nRCTs (ie, 7 retrospective studies and 1 registry study) included 6173 patients (6222 knees) and compared the clinical effectiveness of HTO and UKA in patients with unicompartmental OA. The pooled data regarding the time to revision and complications indicate that the UKA approach is superior to HTO.

Included studies adopted different study design, matching criteria, sample size, operative techniques, and measurement of outcomes. Those differences might contribute to the significant between-study heterogeneity which could affect accuracy of the results in meta-analysis. Random effects model, sensitivity analysis, or subgroup analysis was used to pooling of data might reduce the effect of heterogeneity but does not eliminate it. W-Dahl et al [17] is a registry study which did not include the diagnosis leading to surgery and matching criteria (ie, age, BMI, OA grade) may unbalance between the 2 groups. Therefore we dropped out W-Dhal from the analysis to decrease heterogeneity and show revision rates were less for UKA relative to HTO.

Traditionally, UKA has been defined by classic indications and contraindications [20,21]: (1) isolated medial or lateral compartment OA or osteonecrosis of the knee, (2) age over 60 years, (3) weight under 82 kg, (4) angular deformity <15° and passively correctable to neutral, and (5) flexion contracture <5° and ideal ROM >90°. Contraindications included a high activity level, age younger than 60 years, and inflammatory arthritis. However,
<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Country</th>
<th>Journal</th>
<th>Design</th>
<th>No</th>
<th>Age (y)</th>
<th>Male/ Female</th>
<th>BMI (kg/m²)</th>
<th>OA Grade</th>
<th>UKA Model/ HTO Type</th>
<th>Follow-Up Complication (Revision)</th>
<th>Pain (No/Mild)</th>
<th>ROM</th>
<th>Function Score/ Excellent, Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jeon et al</td>
<td>2017</td>
<td>Korea</td>
<td>J Orthop Surg (Hong Kong)</td>
<td>Retrospective</td>
<td>UKA</td>
<td>21</td>
<td>60.7</td>
<td>4/17</td>
<td>26.1</td>
<td>KL: grade 3 or 4</td>
<td>Zimmer</td>
<td>2 y</td>
<td>1 (0 revisions)</td>
<td>NC</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HTO</td>
<td>26</td>
<td>56.8</td>
<td>4/22</td>
<td>26.6</td>
<td></td>
<td>OW-HTO</td>
<td>2 y</td>
<td>2 (0 revisions)</td>
<td></td>
</tr>
<tr>
<td>Krych et al</td>
<td>2017</td>
<td>Minnesota</td>
<td>J Bone Joint Surg Am</td>
<td>Retrospective</td>
<td>UKA</td>
<td>183 (183 knees)</td>
<td>49.2</td>
<td>82/101</td>
<td>32.4</td>
<td>NC</td>
<td>Miller-Galante CW-HTO</td>
<td>5.8 y</td>
<td>11 revisions</td>
<td>NC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HTO</td>
<td>57 (57 knees)</td>
<td>42.7</td>
<td>41/16</td>
<td>31.8</td>
<td>OW-HTO</td>
<td>Oxford III</td>
<td>7.2 y</td>
<td>13 revisions</td>
<td></td>
</tr>
<tr>
<td>Petersen and Metzlaff</td>
<td>2016</td>
<td>Germany</td>
<td>Arch Orthop Trauma Surg</td>
<td>Retrospective</td>
<td>UKA</td>
<td>25 (25 knees)</td>
<td>60.7</td>
<td>9/16</td>
<td>25</td>
<td>Ab: 1 (I), 20 (II),</td>
<td>5 (III); Ab: 1 (I), 20 (II), 5 (III)</td>
<td>5 y</td>
<td>0 (1 revision)</td>
<td>NC</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>HTO</td>
<td>23 (23 knees)</td>
<td>58.9</td>
<td>14/9</td>
<td>23</td>
<td>14 (I), 9 (II), 9 (II), 0 (III)</td>
<td>OW-HTO</td>
<td>5 y</td>
<td>1 (1 revision)</td>
<td></td>
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<tr>
<td>Tuncay et al</td>
<td>2015</td>
<td>Turkey</td>
<td>Acta Orthop Traumatol Turc</td>
<td>Retrospective</td>
<td>UKA</td>
<td>94 (109 knees)</td>
<td>58.7</td>
<td>15/79</td>
<td>NC</td>
<td>NC</td>
<td>Oxford III</td>
<td>3.5 y</td>
<td>4 (4 revisions)</td>
<td>NC</td>
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<td></td>
<td>HTO</td>
<td>36 (36 knees)</td>
<td>53.5</td>
<td>8/28</td>
<td>NC</td>
<td>DT-HTO</td>
<td>2.6 y</td>
<td>6 (1 revisions)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
<td>10/42</td>
<td>51.7</td>
<td>47/45</td>
<td>NC</td>
<td>OW-HTO</td>
<td>3.4 y</td>
<td>3 (3 revisions)</td>
<td></td>
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<tr>
<td>Karamitev et al</td>
<td>2014</td>
<td>Bulgaria</td>
<td>Folia Med (Plovdiv)</td>
<td>Retrospective</td>
<td>UKA</td>
<td>65 (66 knees)</td>
<td>52.8</td>
<td>23/42</td>
<td>NC</td>
<td>Ab: 42 (I), 15 (II), 8 (III); Ab: 42 (I), 15 (II), 8 (III)</td>
<td>NC</td>
<td>4 y</td>
<td>NC</td>
<td>63</td>
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<td></td>
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<td></td>
<td></td>
<td>HTO</td>
<td>92 (103 knees)</td>
<td>NC</td>
<td>47/45</td>
<td>NC</td>
<td>LCW-HTO</td>
<td>4 y</td>
<td>78</td>
<td>114</td>
<td>80 (KSS)</td>
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<td>Yim et al</td>
<td>2013</td>
<td>South Korea</td>
<td>J Arthroplasty</td>
<td>Retrospective</td>
<td>UKA</td>
<td>50 (50 knees)</td>
<td>60.3</td>
<td>2/48</td>
<td>NC</td>
<td>NC</td>
<td>Miller-Galante CW-HTO</td>
<td>3.7 y</td>
<td>3 (3 revisions)</td>
<td>NC</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>HTO</td>
<td>58 (58 knees)</td>
<td>58.3</td>
<td>7/51</td>
<td>NC</td>
<td>OW-HTO</td>
<td>3.6 y</td>
<td>3 (3 revisions)</td>
<td>138 ± 4.7</td>
<td>89.6 ± 8.7 (LKS)</td>
</tr>
<tr>
<td>W-Dahl et al</td>
<td>2010</td>
<td>Sweden</td>
<td>Acta Orthop Register study</td>
<td>UKA</td>
<td>(4799 knees)</td>
<td>30-64</td>
<td>NC</td>
<td>NC</td>
<td>NC</td>
<td>Hemicalloptasis</td>
<td>816 revisions</td>
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<td></td>
<td>HTO</td>
<td>450 (450 knees)</td>
<td>30-64</td>
<td>NC</td>
<td>NC</td>
<td>NC</td>
<td>47 revisions</td>
<td></td>
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<tr>
<td>Takeuchi et al</td>
<td>2010</td>
<td>Japan</td>
<td>J Orthop Surg Res</td>
<td>Retrospective</td>
<td>UKA</td>
<td>18 (30 knees)</td>
<td>77 ± 4</td>
<td>4/14</td>
<td>NC</td>
<td>Ab: 11 (II), 14 (III), 2 (IV), 8 (IV), 1 (V)</td>
<td>Nakashima</td>
<td>7 y</td>
<td>3 (2 revisions)</td>
<td>NC</td>
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<td></td>
<td>HTO</td>
<td>24 (27 knees)</td>
<td>67 ± 7</td>
<td>6/18</td>
<td>NC</td>
<td>Ab: 4 (II), 17 (III), 8 (IV), 1 (V)</td>
<td>OW-HTO</td>
<td>5 y</td>
<td>2 (0 revisions)</td>
<td>146 ± 5.7</td>
</tr>
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<td>Borjesson et al</td>
<td>2005</td>
<td>Sweden</td>
<td>Knee</td>
<td>RCT</td>
<td>UKA</td>
<td>22 (22 knees)</td>
<td>63</td>
<td>11/11</td>
<td>NC</td>
<td>Ab: 7 (I), 6 (II), 9 (III)</td>
<td>Bragham</td>
<td>5 y</td>
<td>NC</td>
<td>22</td>
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<td></td>
<td>HTO</td>
<td>18 (18 knees)</td>
<td>63</td>
<td>8/10</td>
<td>NC</td>
<td>Ab: 4 (I), 7 (II), 7 (II)</td>
<td>CW-HTO</td>
<td>18</td>
<td>123 ± 0.5</td>
<td>37 ± 0.75 (BOA)</td>
</tr>
<tr>
<td>Stukenborg et al</td>
<td>2001</td>
<td>Germany</td>
<td>Knee</td>
<td>RCT</td>
<td>UKA</td>
<td>28 (30 knees)</td>
<td>67</td>
<td>6/22</td>
<td>NC</td>
<td>Ab: 11 (I), 9 (II), 4 (III), 6 (IV)</td>
<td>Tubingen pattern</td>
<td>7.5 y</td>
<td>2 (6 revisions)</td>
<td>NC</td>
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<td></td>
<td></td>
<td>HTO</td>
<td>32 (32 knees)</td>
<td>67</td>
<td>19/13</td>
<td>NC</td>
<td>Ab: 17 (I), 6 (II), 2 (III), 5 (IV), 2 (V)</td>
<td>CW-HTO</td>
<td>7.5 y</td>
<td>9 (10 revisions)</td>
<td></td>
</tr>
</tbody>
</table>

No, number of patients (the number of knees); NC, not clear; Ab, Ahlbäck system; LCW-HTO, lateral closing wedge HTO; KL, Kellgren-Lawrence system; KOOS, Knee Injury and Osteoarthritis Outcome Scores; BOA, British Orthopaedic Association score (maximum 39 point); KSS, Knee Society Scoring; BKS, Baily Knee Score (maximum 50 point); HSS, Hospital for special surgery knee score; LKS, Lysholm Knee Score.

* 23 HTOs and 69 UKAs remain for clinical assessment.
Swienckowski and Pennington [22] reported on a retrospective series of UKA patients 60 years of age and younger (range 35-60) with a survival rate of 92% at 11 years. Felts et al [23], with a mean follow-up of 11.2 ± 5 years (range 2-19), demonstrated that UKA might provide good patient-rated outcomes and their 12-year Kaplan-Meier survivorship was 94% at 60 years of age or younger. Regarding obese patients, Tabor et al [24] found that age younger than 60 years and obesity did not appear to be contraindications for the procedure. In their studies, Plate et al [25] and Cavaignac et al [26] related weight and BMI to clinical outcomes, and showed that weight was not a significant influence on UKA survival rate. The surgical indications for UKA have expanded because of improved surgical techniques and modern implant designs, along with increased experience with the procedure.

Some of the indications for HTO and UKA are the same [27], that is, (1) 55-65 years, (2) moderate activity level, (3) not being obese, (4) having mild varus malalignment, (5) absence of joint instability, (6) good ROM, and (7) moderate unicompartmental arthrosis. Appropriate patient selection, proper osteotomy types, and precise surgical techniques are essential to ensure the success of HTO [28]. HTO is indicated for young (age < 60 years), normal weight, active patients with radiographic single-compartment OA; moreover, the knee should be stable with good ROM (flexion > 120°), and pain should be localized to the tibiofemoral joint line [28-30].

Trieb et al [31] found that the risk of failure was significantly higher for HTO patients older than 65 years than for those younger than 65 years (relative risk 1.5). Additionally, Akizuki et al [32] reported that a preoperative BMI > 27.5 kg/m² was a risk factor for early failure.

Smith et al [33] used a Markov model to simulate theoretical cohorts of patients 40, 50, 60, and 70 years of age undergoing primary UKA or HTO, which showed that the 5-year and 10-year revision risks were higher in the HTO than in the UKA group for patients older than 50 years. Nwachukwu et al [34] conducted a retrospective review in the United Kingdom and found that UKA was performed most frequently in patients aged between 60 and 64 years and that HTO was more frequent in patients aged between 40 and 44 years. Choosing the right patient is the key to success. In our study, the included patients’ ages (range 52-84) and BMI (range 23-32.2) might explain why survival rate in the UKA group was better than that in the HTO group.

HTO primarily includes 4 basic techniques: OW-HTO, CW-HTO, and chevron and dome osteotomies. CW-HTO and OW-HTO are the most commonly used surgical types, and their efficacies are widely recognized. There were no differences in most of the clinical outcomes except the operation time [35,36]. At present, HTO appears popular again and worthy of attention. However, more postoperative complications were observed in the HTO group in our study, a finding supported by previous meta-analysis [37,38]. The recorded complications included the incidence of deep vein

**Table 2**

<p>| Methodological Assessment According to 7 Domains of Potential Biases (ROBINS-I). |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|</p>
<table>
<thead>
<tr>
<th>nRCT Study = 9</th>
<th>Bias due to Confounding</th>
<th>Bias in Selection of Participants</th>
<th>Bias in Measurement of Interventions</th>
<th>Bias due to Departures From Intended Interventions</th>
<th>Bias due to Missing Data</th>
<th>Bias in Measurement of Outcomes</th>
<th>Bias in Selection of the Reported Result</th>
<th>Overall Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krych et al (2017)</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Petersen et al (2016)</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Tuncay et al (2015)</td>
<td>Serious</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Karamitrev et al (2014)</td>
<td>Serious</td>
<td>Serious</td>
<td>Moderate</td>
<td>Low</td>
<td>Serious</td>
<td>Moderate</td>
<td>Serious</td>
<td>Moderate</td>
</tr>
<tr>
<td>Yin et al (2013)</td>
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<td>Low</td>
<td>Moderate</td>
<td>No information</td>
<td>No information</td>
<td>No information</td>
<td>No information</td>
<td>Critical</td>
</tr>
<tr>
<td>Takeuchi et al (2010)</td>
<td>Moderate</td>
<td>No information</td>
<td>Low</td>
<td>No information</td>
<td>No information</td>
<td>No information</td>
<td>No information</td>
<td>Critical</td>
</tr>
</tbody>
</table>

**Table 2**

<p>| Methodological Assessment According to 6 Domains of Potential Biases (Cochrane Risk of Bias Tool) |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|</p>
<table>
<thead>
<tr>
<th>RCT Study = 2</th>
<th>Random Sequence Generation</th>
<th>Allocation Concealment</th>
<th>Blinding of Participants and Personnel</th>
<th>Blinding of Outcome Assessment</th>
<th>Incomplete Outcome Data</th>
<th>Selective Reporting</th>
<th>Other Bias</th>
<th>Overall Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borjesson et al (2005)</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Unclear</td>
<td>Low</td>
<td>Unclear</td>
<td>Unclear</td>
<td>High</td>
</tr>
<tr>
<td>Stukenborg et al (2001)</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Unclear</td>
<td>Low</td>
<td>Unclear</td>
<td>Unclear</td>
<td>High</td>
</tr>
</tbody>
</table>

**Fig. 2.** Comparison of complications between UKA and HTO.
thrombosis, common peroneal nerve injury, opposite cortical fracture, infection, and so on. A recent meta-analysis [36] reported a significantly higher incidence of opposite cortical fracture but lower incidence of removal of osteosynthesis material in the CW-HTO groups compared with the OW-HTO groups; however, no significant differences were observed in other complications. Dean et al [39] analyzed 12 HTO studies and reported complication rates after HTO that ranged from 0% to 47%. The higher rate of complications in HTO might be related to long-term cast immobilization, surgical techniques, and late limb load after HTO surgery.

Considering the knee function results, the population of patients with pain (no/mild) was high in the UKA group, while the HTO group showed superior ROM compared to the UKA group. However, no significant difference was observed between the groups accruing to the knee function scores and excellent/good surgical results. The differences in functional outcomes, considering the knee scores and ROM results, suggest that additional factors might affect functional outcomes. Osteotomy aims to transfer the mechanical axis from the pathologic area to the normal compartment [40], which may be accompanied by pain relief and improved gait or function, delaying OA progression [28]. However, the degenerative compartment remains. Previously, patients in the HTO group were placed in plasters cast from the groin to the ankle for 6 weeks, and the osteotomy would require several mouths to heal after surgery. Additionally, the correction of deformity might require more time for patients to adapt to the change in leg alignment and resume normal ambulation. In contrast, UKA is a joint resurfacing procedure in which the affected degenerative compartment is treated with an implanted prosthesis and the nonaffected compartments are preserved. UKA has less blood loss, faster recovery, and no need for plaster fixation. Jeon et al [19] found that patients who underwent UKA showed improved postoperative activity levels sooner than HTO patients at 6 months, while there were no significant differences at 12 months and 2-year follow-up in 2 groups. Borjesson et al [13] reported that patients in the UKA group increased their free walking speed from 1.07 to 1.16 m/s compared with patients in the HTO group, who decreased their free walking speed from 1.07 to 0.94 m/s 3 months after surgery. However, at the 1-year and 5-year follow-up examinations there were no differences between the groups. Stukenberg-Colman et al [14] analyzed 7-year to 10-year postoperative results presented in their study showing no overall superiority of one procedure over the other. Based on the aforementioned reasons, UKA likely provides superior postoperative function improvement than HTO in short-term while no difference in long-term efficacy.

The advantage of HTO is the preserved integrity of the knee joint, and the postoperative ROM typically depended on the preoperative condition. HTO is indicated for young patients with high activity levels and good ROM (flexion >120°). In contrast, postoperative ROM after UKA depends on the surgical techniques used, prosthetic design, and preoperative condition of the patient. The indications for UKA were older patients with moderate activity level and ROM > 90°. Koshino et al [41] found that the maximum knee flexion and total ROM were 151 ± 7.48, particularly for the full flexion angle after CW-HTO.

W-Dahl et al [17] reported a 3-fold increase in UKA use, whereas HTO use was halved over the same period, according to Swedish Knee Arthroplasty Register 1998-2007. Nwachukwu et al [34] stated that between 2007 and 2011 in the United States, the
compound annual growth rate in UKA utilization was +4.7%, while for HTO it was −3.9%. Niinimaki et al. [42] report that the average incidence of osteotomy treatment of knee OA steadily decreased by 6.2% between 1987 and 2008, according to Finnish National Hospital Discharge Register. Bolognesi et al. [43] showed that the use of UKA to treat OA was increased by 6.2-fold in the United States between 2000 and 2009. Current global trends favor UKA, which may reflect greater confidence in UKA to some extent.

Limitations and Strengths

This meta-analysis has the following limitations. First, some studies were not identified or were overlooked because of searching strategy we employed, a limitation of all systematic reviews. To overcome this challenge, we consulted a professional librarian, researched synonyms, optimized the search criteria, and performed an extensive search. Second, conducting a true RCT is difficult to ensure. To address or incorporate individual factors at the patient level. Compared with previous meta-analysis, Gandhi et al. [44] and Zhang et al. [38], we included some new clinical research up to 2017, and our results are more up to date. Spahn et al. [37] included 46 studies of valgus HTO and 43 studies of medial UKA; however, the included studies did not directly compare UKA and HTO, which led to greater heterogeneity. Fu et al. [45] did not assess the quality of all their included studies. The strength of our meta-analysis was that all included studies directly compared UKA to HTO. We conducted this study in accordance with the PRISMA statement, and some authors studied at the Chinese Cochrane Center.

Conclusion

Our meta-analysis shows that UKA may be associated with reduced postoperative pain, less postoperative complication, and revision. The 2 surgical techniques showed satisfactory function results for the patients, while the HTO group showed superior ROM compared to the UKA group. HTO may be suitable for patients with high activity requirements. Treatment options should be carefully considered for each patient in accordance with their age, BMI, grade of OA, and patients’ activity levels. But given the limitation in this study, additional well-designed and large-scale clinical trials and systemic reviews are necessary to confirm these findings.

Appendix A. Supplementary Data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.arth.2017.10.025.

References

[35] Smith WD, Steinberg J, Scholtes S, McNamara IR. Medial compartment knee osteoarthritis: age-stratified cost-effectiveness of total knee


