

# Archives of Orthopaedic and Trauma Surgery

## Clinical outcome of bi-unicompartamental knee arthroplasty for both medial and lateral femorotibial arthritis: a systematic review - Is there proof of concept? - --Manuscript Draft--

<b>Manuscript Number:</b>	AOTS-D-19-00993R2
<b>Full Title:</b>	Clinical outcome of bi-unicompartamental knee arthroplasty for both medial and lateral femorotibial arthritis: a systematic review - Is there proof of concept? -
<b>Article Type:</b>	Review Article
<b>Section/Category:</b>	Knee Arthroplasty
<b>Keywords:</b>	knee; osteoarthritis; arthroplasty; bi-unicompartamental knee arthroplasty; Unicompartamental knee arthroplasty
<b>Corresponding Author:</b>	Keizo Wada Department of Orthopaedics, Institute of Biomedical Science, The University of Tokushima Graduate School JAPAN
<b>Corresponding Author Secondary Information:</b>	
<b>Corresponding Author's Institution:</b>	Department of Orthopaedics, Institute of Biomedical Science, The University of Tokushima Graduate School
<b>Corresponding Author's Secondary Institution:</b>	
<b>First Author:</b>	Keizo Wada
<b>First Author Secondary Information:</b>	
<b>Order of Authors:</b>	Keizo Wada Andrew Price Kirill Gromov Sebastien Lustig Anders Troelsen
<b>Order of Authors Secondary Information:</b>	
<b>Funding Information:</b>	
<b>Abstract:</b>	<p>Introduction: Unicompartamental knee arthroplasty (UKA) is a well-accepted treatment for isolated unicompartamental osteoarthritis (OA) of the knee. In previous literature, it has been suggested that bi-unicompartamental knee arthroplasty (bi-UKA) which use two UKA implants in both the medial and lateral compartments of the same knee is a feasible and viable option for the treatment of knee OA. Given the advantages of UKA treatment, it is warranted to review the literatures of bi-UKA and discuss the evidence in terms of implant selection, indications, surgical techniques, and outcomes, respectively.</p> <p>Materials and Methods: Following the PRISMA guidelines, PubMed, Medline, Embase, Cinahl, Web of Science, and Cochrane Library were searched for studies presenting outcome of bi-UKA. Studies were included if they reported clinical outcomes using two unicompartamental prostheses for both medial and lateral femorotibial arthritis. Studies with addition of patellofemoral arthroplasty or concomitant soft-tissue reconstruction and those not published in English were excluded.</p> <p>Results: In the early literature, the procedure of bi-UKA were performed for very severe OA and rheumatoid arthritis, but indications have evolved to reflect a more contemporary case-mix of knee OA patients. Both mobile and fixed bearing implants have been used, with the latter being the most frequent choice. A medial parapatellar approach for incision and arthrotomy has been the most frequently technique used. The present review found a promising clinical outcome of both simultaneous and</p>

	<p>staged bi-UKA, although the number of long-term follow up studies was limited.</p> <p>Conclusions: Both simultaneous and staged bi-UKA has demonstrated good functional outcomes. However, the volume and level of evidence in general is low for studies captured in this review, and the data on long-term outcomes remain limited. The present review indicates that bi-UKA is a feasible and viable surgical option for bicompartamental femorotibial OA in carefully selected patients.</p>
--	---

# **Instructions for Documenting Changes Done in Revisions Submitted to Archives of Orthopaedic and Trauma Surgery**

First column: Please paste each reviewer remark on a separate row in numerical order.

Second column: Please write your response. If you disagree with the reviewer's remark, say why.

Third column: Please copy and paste the modified text from your revision. If the revision is too long, please indicate the relevant line numbers.

If you need more rows than available feel free to extend the table as you like.

Numbered Reviewer Remark and Manuscript Line Number	Author Response	Revised Manuscript Line Number and Text Change
<b>Reviewer 1:</b>		
1. Correction reading necessary (e.g. Line 175: `Recently` used twice, Line 212 choose instead of chose...). After correction reading, the revised MS is worth being published in AOTS.	<p>Thank you for review. The authors really appreciate your comments. We have corrected mistakes.</p> <p>We have corrected additional mistakes as follows. Line 22: We have changed "have" to "has". Line 69: We have changed "was" to "were". Line 200: We have changed "long term" to "long-term".</p>	<p>Line 175: More recently, Parratte et al. performed a retrospective analysis of their cases with a fixed bearing bi-UKA, and reported that implant survival was 78% at 17 years [24].</p> <p>Line 212: The optimal design for medial UKA continues to be debated [33,34], and probably the surgeon should choose the implant design that he/she is familiar with for bi-UKA.</p> <p>Line 22: A medial parapatellar approach for incision and arthrotomy has been the most frequently technique used.</p> <p>Line 69: The inclusion criteria were agreed upon by authors KW and AT prior to the identification phase.</p> <p>Line 199: Biazzo et al. matched and compared the long-term outcomes of bi-UKA with those of computer assisted TKA, and described that there were no statistically significant differences were seen for KSS, Function scores and WOMAC Arthritis Index (pain score) at latest follow-up.</p>

Reviewer 2:		
<p>1. There are just a few grammatical mistakes that need to be fixed:</p> <p>L7: change compartment to unicompartmental</p> <p>L10: change warranties to warranted</p> <p>L12: [...] outcomes, respectively. (add ,respectively)</p> <p>L15: delete 'were'</p> <p>L19: In the early literature, (add the comma)</p> <p>L22: delete 'reported'</p> <p>L26: change has to have</p>	<p>Thank you for review. The authors really appreciate your comments.</p> <p>We have corrected mistakes.</p>	<p>Line 7: Unicompartmental knee arthroplasty (UKA) is a well-accepted treatment for isolated unicompartmental osteoarthritis (OA) of the knee.</p> <p>Line 10: Given the advantages of UKA treatment, it is warranted to review the literatures of bi-UKA and discuss the evidence in terms of implant selection, indications, surgical techniques, and outcomes, respectively.</p> <p>Line 15: Studies were included if they reported clinical outcomes using two unicompartmental prostheses for both medial and lateral femorotibial arthritis.</p> <p>Line 19: In the early literature, the procedure of bi-UKA were performed for very severe OA and rheumatoid arthritis, but indications have evolved to reflect a more contemporary case-mix of knee OA patients. Both mobile and fixed bearing implants have been used, with the latter being the most frequent choice.</p> <p>Line 26: Both simultaneous and staged bi-UKA have demonstrated good functional outcomes.</p>

When finished, please upload this file at <http://www.editorialmanager.com/aots>

Archives of Orthopaedic and Trauma Surgery

April 17, 2020

Dear Editors-in-Chief,

Thank you for your letter of April 17, 2020. We are most grateful to the reviewers for fruitful comments. We have examined the reviewers' comments and taken all these comments into account.

We have revised the manuscript entitled "Clinical outcome of bi-unicompartamental knee arthroplasty for both medial and lateral femorotibial arthritis: a systematic review - Is there proof of concept? -".

Our responses were noted in "Correction Table for Revisions" file.

We believe that our study will be of special interest to the readers of Archives of Orthopaedic and Trauma Surgery.

Thank you for your consideration.

Sincerely,

On behalf of all the authors

Andrew Price, Kirill Gromov, Sebastien Lustig, Anders Troelsen

Corresponding author

Keizo Wada, M.D., Ph.D.

Department of Orthopedics, Institute of Biomedical Sciences,

Tokushima University Graduate School

3-18-15, Kuramoto, Tokushima 770-8503, Japan

Phone: +81-088-633-7240 E-mail: wadahank@hotmail.com

Clinical outcome of bi-unicompartamental knee arthroplasty for both  
medial and lateral femorotibial arthritis: a systematic review

- Is there proof of concept? -

**AUTHORS:**

Keizo Wada (M.D., Ph.D.)<sup>1, 3, 5</sup>, Andrew Price (M.D., Ph.D.)<sup>2</sup>, Kirill Gromov (M.D.,  
Ph.D.)<sup>3</sup>, Sebastien Lustig (M.D., Ph.D.)<sup>4</sup>, Anders Troelsen (M.D., Ph.D.)<sup>3</sup>

**AUTHOR AFFILIATIONS:**

<sup>1</sup> Department of Orthopedics, Institute of Biomedical Sciences, Tokushima University  
Graduate School, Tokushima, Japan

<sup>2</sup> Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences,  
University of Oxford, Oxford, UK.

<sup>3</sup> Department of Orthopaedic Surgery, Copenhagen University Hospital Hvidovre,  
Copenhagen, Denmark.

<sup>4</sup> Service de chirurgie orthopédique, Centre Albert-Trillat, CHU de Lyon-Nord, Lyon,  
France.

<sup>5</sup> Corresponding author

Address: Department of Orthopedics, Institute of Biomedical Sciences, Tokushima  
University Graduate School, 3-18-15 Kuramoto, Tokushima 770-8503, Japan

Tel.: +81-088-633-7240; Fax: +81-088-633-0178; E-mail: wadahan@hotmai.com

Clinical outcome of bi-unicompartamental knee arthroplasty for both medial and lateral femorotibial arthritis: a systematic review

- Is there proof of concept? –

Abstract

Introduction: Unicompartamental knee arthroplasty (UKA) is a well-accepted treatment for isolated

unicompartamental~~compartment~~ osteoarthritis (OA) of the knee. In previous literature, it has been

suggested that bi-unicompartamental knee arthroplasty (bi-UKA) which use two UKA implants in

both the medial and lateral compartments of the same knee is a feasible and viable option for the

treatment of knee OA. Given the advantages of UKA treatment, it is warranted~~warranties~~ to

review the literatures of bi-UKA and discuss the evidence in terms of implant selection,

indications, surgical techniques, and outcomes, respectively.

Materials and Methods: Following the PRISMA guidelines, PubMed, Medline, Embase, Cinahl,

Web of Science, and Cochrane Library were searched for studies presenting outcome of bi-UKA.

Studies were included if they ~~were~~-reported clinical outcomes using two unicompartamental

prostheses for both medial and lateral femorotibial arthritis. Studies with addition of

patellofemoral arthroplasty or concomitant soft-tissue reconstruction and those not published in

English were excluded.

Results: In the early literature, the procedure of bi-UKA were performed for very severe OA and rheumatoid arthritis, but indications have evolved to reflect a more contemporary case-mix of knee OA patients. Both mobile and fixed bearing implants have been used, with the latter being the most frequent choice~~-reported~~. A medial parapatellar approach for incision and arthrotomy ~~have~~has been the most frequently technique used. The present review found a promising clinical outcome of both simultaneous and staged bi-UKA, although the number of long-term follow up studies was limited.

Conclusions: Both simultaneous and staged bi-UKA has demonstrated good functional outcomes. However, the volume and level of evidence in general is low for studies captured in this review, and the data on long-term outcomes remain limited. The present review indicates that bi-UKA is a feasible and viable surgical option for bicompartamental femorotibial OA in carefully selected patients.

Keywords:

knee; osteoarthritis; arthroplasty; bi-unicompartamental knee arthroplasty; unicompartamental knee arthroplasty



35

## 36 Introduction

37 Unicompartmental knee arthroplasty (UKA) is a well-accepted treatment for isolated compartment  
38 osteoarthritis (OA) of the knee [1,2]. It has been estimated that medial UKA may be performed in  
39 up to 50% of all primary knee arthroplasties [3]. Refinement of indications, instrumentation, and  
40 implant designs have resulted in implant survivorship for medial UKA that are similar to those  
41 reported for total knee arthroplasty (TKA) when medial UKA is used appropriately [4,5]. Reliable  
42 outcomes after lateral UKA have also been reported [6-8]. In comparison with TKA, UKA allows  
43 for smaller implants, shorter operative times, less blood loss, preservation of both cruciate  
44 ligaments, and minimal bone resection [9,10]. The kinematics and proprioceptive activities of the  
45 native knee have been reported to be better preserved by UKA than by TKA [11-13]. Perhaps most  
46 important are the reports of a significantly higher probability of an excellent patient-reported  
47 outcome measures (PROMs) and lower rates of complications, readmissions, and mortality after  
48 medial UKA compared with TKA [14,15].

49 In early reports concerning UKA designs, unicompartmental femorotibial joint implants  
50 were used in both the medial and lateral compartments of the same knee to treat severe arthritis  
51 [16,17]. This is referred to as “simultaneous” bi-unicompartmental knee arthroplasty (bi-UKA).

Opposed to this is “staged” bi-UKA in which a lateral or medial UKA is added, due to progression of contralateral femorotibial OA, to a knee with an existing, well-functioning UKA [5,18-21] (Fig. 1). In more recent literature it has been suggested that bi-UKA is a feasible and viable option for the treatment of knee OA in the ACL intact patient [22-24], but reports are scattered and an overview is in demand. Given the advantages of UKA treatment, it is warranted to establish if there is proof of a bi-UKA concept in the existing literature. Therefore, the present paper reviews the literature on bi-UKA and discusses the evidence for bi-UKA in terms of implant selection, indications, surgical techniques, and outcomes.

## Materials and Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed [25]. An electronic database search of PubMed, Medline, Embase, Cinahl, Web of Science, and Cochrane Library was performed to identify studies reporting outcome of bi-UKA for both medial and lateral femorotibial arthrosis. The following search strategy was used: “(Knee) AND (arthroplasty OR replacement) AND (bi-unicompartamental OR bi-compartmental OR bicompartamental OR bi-condylar OR bicondylar OR bi-unicondylar).” This search returned relevant studies published between the time of inception of the databases to July 2019.

69           The inclusion criteria ~~were~~was agreed upon by authors KW and AT prior to the  
70   identification phase. Studies were included if they were reported clinical outcomes using two  
71   unicompartmental prostheses for both medial and lateral femorotibial arthritis. Studies with  
72   addition of patellofemoral arthroplasty or concomitant soft-tissue reconstruction and those not  
73   published in English were excluded. Studies that did not individually state clinical outcomes of  
74   bi-UKA or that did not specify a follow-up period were considered inappropriate to review.  
75   Studies that appeared to report on the same or similar cohorts as other studies were also excluded.  
76   The articles of review or meta-analysis were also excluded.

77           Screening was performed in three phases to identify relevant titles, abstracts and full  
78   texts. Two reviewers (KW, AT) extracted the data through a standardized data collection form and  
79   checked the data for accuracy and any inconsistent results were handled by discussion. The  
80   following data: number of knees, number of patients and patient's demographic data, type of  
81   prosthesis, inclusion criteria, contraindications, surgical approach, clinical outcome measurements,  
82   and follow-up period were extracted.

83           The risk of bias of each study has been assessed with a methodological index for  
84   evaluation of non-randomized studies (MINORS) score [26]. MINORS is a validated instrument  
85   for assessing the methodologic quality of studies and is scored on a scale from 0 to 16 for

noncomparative studies (8-item checklist scored from 0-2) and a scale from 0 to 24 for comparative studies (12-item checklist scored from 0-2), in which higher scores represent lower levels of bias.

## Results

The PRISMA flowchart for study selection is shown in Fig. 2. The initial search identified 903 studies which were screened for eligibility. After removing duplicates and reviewing the titles and abstracts, 15 studies were reviewed in full-text version. Additional 5 articles were identified through cross-referencing. After reviewing the full text articles, 12 studies were considered eligible for inclusion in the systematic review (Table 1-3).

### *Implant selections*

The results were summarized in Table 1. In 1971, Gunston described the performance of bi-UKA with the use of polycentric, fixed-bearing components [16]. At literature review, the choice of fixed bearing components has been predominant [27-30,24,22,23]. In contrast, Goodfellow and O'Connor published on the use of mobile bearing components for bi-UKA [17]. They focused on the theoretical advantages of including analogs of the natural menisci of the knee in the design of their prosthesis, which was the origin of the Oxford UKA [31]. In the report on staged bi-UKA by

Pandit et al., a mobile bearing lateral UKA was inserted with the existing mobile bearing medial UKA [19], whereas Lustig et al. used fixed bearing UKA in both compartments [20].

### *Indications*

The results were summarized in Table 2. Gunston performed bi-UKA mainly in patients with longstanding rheumatoid arthritis (RA) [16]. Walker et al. had a similar concept and used the prosthesis for both RA and OA, reporting a total loss of articular surface of less than 12 mm and a body weight of under 73 kg as their inclusion criteria [27]. Goodfellow and O'Connor considered these joints suitable for the procedure if the patient had an adequate range of motion (ROM) (at least 75° of flexion under anesthesia), flexion deformity of not more than 40°, and varus or valgus deformity of not more than 30° [17]. Absence of the posterior cruciate ligament was deemed a contraindication, but not absence of the anterior cruciate ligament (ACL). However, in their series, there were no failures in knees when the ACL was intact, and the revision rate was low. These authors suggested that the presence or absence of the ACL was a significant determinant of the outcome of bi-UKA. [17]

After the initial reports, the criteria for bi-UKA evolved to reflect more contemporary constitutions of patients undergoing knee arthroplasty. In 2005, Confalonieri et al. described the typical selection criteria for simultaneous bi-UKA as bi-unicompartamental OA, an asymptomatic

patellofemoral joint, ROM greater than 90°, axis deviation less than 10°, and no important anterior or posterior laxity, systemic articular disease, or severe postural defect [30,32]. Obesity, varus deformity associated with osteoporosis, RA, significant symptomatic patellofemoral OA, extreme laxity, and flexion contracture of more than 10° were considered absolute contraindications. Parratte et al. reported similar indications, except that the acceptable ROM was greater than 100° [24]. They also added the following contraindications: planned high tibial osteotomy, planned or previous ACL reconstruction, and revision arthroplasty.

Staged bi-UKA was mainly developed for patients with progressive OA in the retained compartment after UKA. Pandit et al. considered that patients with clear evidence of progression of OA in the lateral compartment were suitable candidates for addition of lateral UKA without any evidence of loosening of medial UKA [19]. During surgery, the authors considered TKA if there was severe patellofemoral OA or ACL insufficiency. Lustig et al. additionally stated that staged bi-UKA is particularly attractive for patients with high demands or suffering from comorbidity [20].

#### *Surgical technique*

The results were summarized in Table 2. Simultaneous bi-UKA has mainly been performed through a medial parapatellar approach with lateral dislocation of the patella

[23,24,30,29,28,17,16]. Walker et al. inserted the prosthesis through two parapatellar incisions using stereotactic jigs to ensure accuracy of alignment [27]. In the report on staged bi-UKA by Pandit et al., the medial UKA incision was opened and extended proximally and distally and the lateral compartment was approached using a lateral parapatellar arthrotomy [19]. Lustig et al. suggested to use standard lateral and medial approach for staged bi-UKA if there are at least 8cm security distance to the previous scar [20].

Goodfellow and O'Connor preserved the joint line at the same level as the natural articular surface [17]. Using an extramedullary guide, the tibial cut was made with a posterior slope of 7°. After the trial components were inserted, gap gauges with a range of thickness to match the implantable bearings were used to determine by trial and error the thickest size that each component could accept comfortably. They also stated that no effort was made to align the bone of the limb and that their focus was on prevention of soft tissue release to preserve the native soft tissue balance. In contrast, Confalonieri et al. reported making the tibial cut using an extramedullary guide [30], which allowed for correct re-alignment of the limb by replacing the most severely affected compartment first. They calculated the amount of bone to be resected to correct the limb alignment based on the preoperative radiographs and the thickness of the implanted components. They also tried to restore the original tibial slope of the different

compartments. Dettmer and Kreuzer presented usefulness of robotic arm assisted, 3D-navigation system for accurate bi-UKA [23].

#### *Outcomes*

The results were summarized in Table 3. The first report on simultaneous bi-UKA by Gunston stated that polycentric arthroplasty provided a painless knee and eliminated preoperative lateral instability in almost all patients. One (4.5%) knee was later arthrodesed because of lack of functional improvement [16]. Walker et al. performed bi-UKA using the prosthesis in the manner described by Gunston and reported that 77.3% of patients were enthusiastic about or satisfied with their results. In their report, 8 (7.6%) knees required revision or were arthrodesed because of infection or loosening [27]. Stockley et al. also reported the outcomes of using a bicondylar sledge prosthesis, stating that pain relief was substantial (75%) and that functional ability improved in a commensurate manner [28]. In their series, 3 (5.7%) of the arthroplasties failed and required revision.

In the report on mobile bearing bi-UKA by Goodfellow and O'Connor, pain was relieved in 90% of cases, the mean flexion limit was 99°, and the mean flexion deformity was 7° [17]. Failure occurred in 6 knees (4 loosening, 1 recurrent dislocation of the bearings, and 1 infection), which were arthrodesed or converted to another prosthesis. Eight (6.4%) knees required revision



surgery because of dislocation of the bearings (5 cases) or loosening of components (2 tibial, 1 femoral). They also reported that there were no failures and that the revision rate was low in knees with an intact ACL. Barret et al. reported similar result of mobile bearing bi-UKA, and stated that 57 (85 %) of the knees had significant relief of pain [31].

More recently, Parratte et al. ~~recently~~ performed a retrospective analysis of their cases with a fixed bearing bi-UKA, and reported that implant survival was 78% at 17 years [24]. The authors stated that bi-UKA alleviated pain effectively, with an increase in mean Knee Society knee and function scores. In their report, 17 knees underwent revision surgery after a mean 6.5 (range, 0.8–12) years (16 for aseptic loosening and one for symptomatic progression of OA in the patellofemoral compartment).

The literature on staged bi-UKA is limited. Pandit et al. reported a significant improvement in the mean Oxford Knee Score (OKS). In their report, there were no significant surgery-related complications and there was no need for any further surgical procedures or revisions at the final follow-up [19]. Lustig et al. described that the mean International Knee Society Score for knee and function were improved at the latest follow-up [20].

There have been some studies comparing bi-UKA with other prostheses. Fuchs et al. compared a simultaneous fixed bearing bi-UKA group to a UKA group, and stated that

implantation of bi-UKA retaining both cruciate ligaments achieved functional results as good as for UKA [29]. Confalonieri et al. reported a matched-pairs study of simultaneous fixed bearing bi-UKA and TKA for the treatment of isolated bicompartamental tibiofemoral arthritis with an asymptomatic patellofemoral joint [30]. The Western Ontario and McMaster Universities Arthritis Index (WOMAC) function and stiffness scores were significantly better in the bi-UKA group and the implants were significantly better aligned in the TKA group. The researchers concluded that bi-UKA is a viable option for bicompartamental tibiofemoral OA, with results that are at least as good as those for TKA but with preservation of a higher level of function. Dettmer and Kreuzer (n = 17 patients) also matched patients who received simultaneous bi-UKA with a similar age group of patients who received TKA, and compared the subscales of postoperative knee injury and osteoarthritis outcome scores (KOOS) of both the groups [23]. The authors concluded that bi-UKA group had significantly better score in symptoms and activities of daily living. Biazzo et al. matched and compared the long-term outcomes of bi-UKA with those of computer assisted TKA, and described that there were no statistically significant differences were seen for KSS, Function scores and WOMAC Arthritis Index (pain score) at latest follow-up.

Discussion

205 The most important finding of this literature review is the favorable clinical outcomes of bi-UKA.  
206 However, knowledge of the long-term outcome remains limited, and MINORS scores of the  
207 studies were relatively low.

#### 208 *Implant selection*

209 The choice of fixed bearing components for bi-UKA has been predominant in the present review.  
210 This is likely to reflect the preferred implant by the authors for medial and lateral UKA in  
211 isolation. The optimal design for medial UKA continues to be debated [33,34], and probably the  
212 surgeon should ~~ehose~~choose the implant design that he/she is familiar with for bi-UKA.  
213 Especially, the reports of outcome after mobile-bearing lateral UKA have been diverse [35-37].  
214 Pandit et al. used the Oxford Domed Lateral for staged bi-UKA and reported that there were no  
215 significant surgery-related complications and that there was no need for any further surgical  
216 procedures or revisions [19]. Based on the literature review, it seems the authors chose the implant  
217 that they were familiar with in UKA for bi-UKA.

#### 218 *Indication*

219 In early studies, bi-UKA was used for both medial and lateral arthrosis mainly in patients with RA.  
220 In recent reports, only knees with OA were candidates for bi-UKA. The indications and exclusion  
221 criteria described by Confalonieri et al. was used in recent studies. Although some previous

reports suggested that the presence or absence of the ACL was a significant determinant of the outcome of bi-UKA, Romagnoli et al. have introduced a surgical technique that includes bi-UKA with concomitant reconstruction of the ACL [38]. However, use of this technique should be considered carefully, given that no long-term results are available at present for patients who have undergone this procedure. Based on the contemporary reports, it seems appropriate to recommend the following inclusion criteria for bi-UKA; bicompartamental tibio-femoral OA, asymptomatic patella-femoral joint, intact ACL, correctable deformity, and preserved ROM.

#### *Surgical technique*

The medial parapatellar approach was mainly used for exposure of bi-unilateral compartments in simultaneous bi-UKA. In some reports, two parapatellar incisions were used, and Romagnoli et al. mentioned that an advantage of this approach is its ability to reduce damage to the extensor mechanism [38]. They also pointed out that the superomedial geniculate artery ensures a blood supply to the patella because the superomedial area of the knee is preserved. Nevertheless, some previous reports have warned that anatomic considerations are needed to prevent necrosis when performing multiple skin incisions on the knee [39,40]. Further discussions are required regarding prevention of complications after bi-UKA. From the view point of vascularity, it would be suggested to use the approach which was described by Pandit et al [19]. They opened the medial

UKA incision and extended proximally and distally, and the lateral compartment was approached using a lateral parapatellar arthrotomy. The benefit of this approach is performing the surgery with all ligaments in situ.

In terms of alignment and implant positioning for bi-UKA, there were too few studies to discuss about what was appropriate. In addition, discussing these parameters seems to require evaluation with implant selection [41,42]. Furthermore, to perform bi-UKA procedure accurately, it seems to be useful to use a navigation system or a robotic arm which recently reported favorable outcome after UKA [43].

#### *Outcomes*

In the present review, the favorable outcomes of bi-UKA were found. Especially in recent literature, good results of PROMs after bi-UKA were reported. However, varied scoring systems were used for outcome evaluation. In addition, there was limited data about revision surgery procedure after bi-UKA. Further long-term follow up studies using contemporary PROMs should be conducted to assess functional benefits and durability including procedure of revision surgery after bi-UKA.

Considering the good outcomes of bi-UKA, Fuchs et al. presented that bi-UKA that retains all intraarticular ligaments achieves proprioceptive results comparable with healthy

subjects of the same age [44]. The author's group also described that the clinical scores were significantly better in the bi-UKA group than in the constrained TKA group [45], and stated that the knees after bi-UKA which preserves the native ligaments, knees that undergo this procedure could be expected to show better joint kinematics than those that undergo TKA. However, previous reports have indicated that the kinematics of the native knee are not restored after bi-UKA. Banks et al. reported that knees that had undergone bi-UKA showed kinematics that were closer to those after TKA than those after medial UKA [46]. Watanabe et al. compared the kinematics of the knee in patients after medial UKA, medial UKA and patellofemoral arthroplasty, or bi-UKA and found that knees with bi-UKA showed the least femoral external rotation and posterior translation during knee flexion [47]. Nevertheless, there have been few kinematic studies of bi-UKA and no kinematic studies that have included bi-UKA with mobile bearing-type implants. Therefore, further research is needed to evaluate the kinematics after bi-UKA.

The evidence to determine the outcome of staged bi-UKA is limited. A report by Lewold et al. did not recommend addition of lateral UKA for progression of OA in a retained compartment after medial UKA [48]. However, there has been a report of favorable outcomes after staged bi-UKA: Pandit et al reported significant increases in PROMs and no cases of revision surgery [19]. Using similar indications, Lustig et al. performed medial UKA for progression of medial

compartment disease after lateral UKA with no need of revision surgery for progression of patellofemoral OA or implant loosening [21,20]. Although these reports are promising, further studies are necessary to determine the efficacy of staged bi-UKA.

#### *Limitation of review and the published literature.*

This systematic review is limited by the small number of studies reporting the outcomes of bi-UKA, and in general, the number of patients in all the studies was low. Furthermore, MINORS scores of the studies included in this review were relatively low. In the future, there is a need of more prospective, randomized controlled or comparative studies to bring forward higher level evidence in the comparison of bi-UKA with TKA for treatment of both medial and lateral arthritis. In addition, evidence considering the long-term outcomes should be further investigated.

#### **Conclusion**

Both simultaneous and staged bi-UKA have demonstrated good functional outcomes. However, the volume and level of evidence in general is low for studies captured in this review, and the data on long-term outcomes remain limited. The general experience with the procedure amongst knee surgeons must be considered low, perhaps highlighting the perceived technical difficulty of the procedure. The present review indicates that bi-UKA is a feasible and viable surgical option for

290      bicompartamental femorotibial OA in carefully selected patients.

291

292      List of abbreviations:

293      UKA, unicompartmental knee arthroplasty; OA, osteoarthritis; TKA, total knee arthroplasty;

294      PROMs, patient-reported outcome measures; bi-UKA, bi-unicompartmental knee arthroplasty; RA,

295      rheumatoid arthritis; ROM, range of motion; ACL, anterior cruciate ligament; OKS, Oxford knee

296      score; IKSS/KSS, international knee society score; WOMAC, Western Ontario and McMaster

297      Universities Arthritis Index; KOOS, knee injury and osteoarthritis outcome scores; HTO, high

298      tibial osteotomy; GIUM, a dedicated UKR outcome score developed by the Italian Orthopaedic

299      UKR's Users Group; HSS, Hospital for Special Surgery score; VAS, visual analog scale; AKSS,

300      American knee society score

301

302      Compliance with ethical standards

303      Conflict of interest: AP is a consultant of Zimmer-Biomet company. All other authors declare that

304      they have no conflicts of interest.

305



306 Figure captions

307 Fig. 1: Postoperative radiograph of the knee with staged bi-UKA. (a) Anteroposterior view. (b) Lateral  
308 view. A fixed bearing lateral UKA was added to the knee with an existing mobile bearing medial UKA  
309 due to progression of lateral compartment OA.

310

311 Fig. 2: Flow chart of the systematic search.

312

313

## References

1. Argenson JN, Blanc G, Aubaniac JM, Parratte S (2013) Modern unicompartmental knee arthroplasty with cement: a concise follow-up, at a mean of twenty years, of a previous report. *J Bone Joint Surg Am* 95 (10):905-909. doi:10.2106/JBJS.L.00963
2. Winnock de Grave P, Barbier J, Luyckx T, Ryckaert A, Gunst P, Van den Daelen L (2018) Outcomes of a Fixed-Bearing, Medial, Cemented Unicondylar Knee Arthroplasty Design: Survival Analysis and Functional Score of 460 Cases. *J Arthroplasty* 33 (9):2792-2799. doi:10.1016/j.arth.2018.04.031
3. Willis-Owen CA, Brust K, Alsop H, Miraldo M, Cobb JP (2009) Unicondylar knee arthroplasty in the UK National Health Service: an analysis of candidacy, outcome and cost efficacy. *Knee* 16 (6):473-478. doi:10.1016/j.knee.2009.04.006
4. Lisowski LA, Meijer LI, van den Bekerom MP, Pilot P, Lisowski AE (2016) Ten- to 15-year results of the Oxford Phase III mobile unicompartmental knee arthroplasty: a prospective study from a non-designer group. *Bone Joint J* 98 B (10 Supple B):41-47. doi:10.1302/0301-620X.98B10.BJJ-2016-0474.R1
5. Mohammad HR, Strickland L, Hamilton TW, Murray DW (2018) Long-term outcomes of over 8,000 medial Oxford Phase 3 Unicompartmental Knees-a systematic review. *Acta Orthop* 89 (1):101-107. doi:10.1080/17453674.2017.1367577
6. Argenson JN, Parratte S, Bertani A, Flecher X, Aubaniac JM (2008) Long-term results with a lateral unicondylar replacement. *Clin Orthop Relat Res* 466 (11):2686-2693. doi:10.1007/s11999-008-0351-z
7. Pennington DW, Swienckowski JJ, Lutes WB, Drake GN (2006) Lateral Unicompartmental Knee Arthroplasty. *The Journal of Arthroplasty* 21 (1):13-17. doi:10.1016/j.arth.2004.11.021
8. Seo SS, Kim CW, Lee CR, Kwon YU, Oh M, Kim OG, Kim CK (2019) Long-term outcomes of unicompartmental knee arthroplasty in patients requiring high flexion: an average 10-year follow-up study. *Arch Orthop Trauma Surg* 139 (11):1633-1639. doi:10.1007/s00402-019-03268-7
9. Mullaji AB, Sharma A, Marawar S (2007) Unicompartmental knee arthroplasty: functional recovery and radiographic results with a minimally invasive technique. *J Arthroplasty* 22 (4 Suppl 1):7-11. doi:10.1016/j.arth.2006.12.109
10. Hauer G, Sadoghi P, Bernhardt GA, Wolf M, Ruckstuhl P, Fink A, Leithner A, Gruber G (2020) Greater activity, better range of motion and higher quality of life

following unicompartmental knee arthroplasty: a comparative case-control study. Arch Orthop Trauma Surg 140 (2):231-237. doi:10.1007/s00402-019-03296-3

11. Argenson JN, Komistek RD, Aubaniac JM, Dennis DA, Northcut EJ, Anderson DT, Agostini S (2002) In vivo determination of knee kinematics for subjects implanted with a unicompartmental arthroplasty. J Arthroplasty 17 (8):1049-1054. doi:10.1054/arth.2002.34527

12. Heyse TJ, El-Zayat BF, De Corte R, Chevalier Y, Scheys L, Innocenti B, Fuchs-Winkelmann S, Labey L (2014) UKA closely preserves natural knee kinematics in vitro. Knee Surg Sports Traumatol Arthrosc 22 (8):1902-1910. doi:10.1007/s00167-013-2752-0

13. Isaac SM, Barker KL, Danial IN, Beard DJ, Dodd CA, Murray DW (2007) Does arthroplasty type influence knee joint proprioception? A longitudinal prospective study comparing total and unicompartmental arthroplasty. Knee 14 (3):212-217. doi:10.1016/j.knee.2007.01.001

14. Liddle AD, Judge A, Pandit H, Murray DW (2014) Adverse outcomes after total and unicompartmental knee replacement in 101 330 matched patients: a study of data from the National Joint Registry for England and Wales. The Lancet 384 (9952):1437-1445. doi:10.1016/s0140-6736(14)60419-0

15. Liddle AD, Pandit H, Judge A, Murray DW (2015) Patient-reported outcomes after total and unicompartmental knee arthroplasty: a study of 14,076 matched patients from the National Joint Registry for England and Wales. Bone Joint J 97-B (6):793-801. doi:10.1302/0301-620X.97B6.35155

16. Gunston FH (1971) Polycentric knee arthroplasty. Prosthetic simulation of normal knee movement. J Bone Joint Surg Br 53 (2):272-277

17. Goodfellow JW, O'Connor J (1986) Clinical results of the Oxford knee. Surface arthroplasty of the tibiofemoral joint with a meniscal bearing prosthesis. Clin Orthop Relat Res (205):21-42

18. Walton MJ, Weale AE, Newman JH (2006) The progression of arthritis following lateral unicompartmental knee replacement. Knee 13 (5):374-377. doi:10.1016/j.knee.2006.05.005

19. Pandit H, Mancuso F, Jenkins C, Jackson WFM, Price AJ, Dodd CAF, Murray DW (2017) Lateral unicompartmental knee replacement for the treatment of arthritis progression after medial unicompartmental replacement. Knee Surg Sports Traumatol

Arthrosc 25 (3):669-674. doi:10.1007/s00167-016-4075-4

20. Lustig S, Servien E, Neyret P, Pereira H (2008) An Original Indication for BiUnicondylar Knee Antroplasty: Subsequent Contralateral Unicondylar Knee Arthroplasty After Degenerative Changes of the Opposite Compartment. *Tech Knee Surg* 7 (4):240-250

21. Lustig S, Lording T, Frank F, Debette C, Servien E, Neyret P (2014) Progression of medial osteoarthritis and long term results of lateral unicompartmental arthroplasty: 10 to 18 year follow-up of 54 consecutive implants. *The Knee* 21:S26-S32. doi:10.1016/s0968-0160(14)50006-3

22. Biazzo A, Manzotti A, Confalonieri N (2018) Bi-unicompartmental versus total knee arthroplasty: long term results. *Acta Orthop Belg* 84 (3):237-244

23. Dettmer M, Kreuzer SW (2015) Bi-Unicompartmental, Robot-Assisted Knee Arthroplasty. *Operative Techniques in Orthopaedics* 25 (2):155-162. doi:10.1053/j.oto.2015.03.004

24. Parratte S, Pauly V, Aubaniac JM, Argenson JN (2010) Survival of bicompartmental knee arthroplasty at 5 to 23 years. *Clin Orthop Relat Res* 468 (1):64-72. doi:10.1007/s11999-009-1018-0

25. Moher D, Liberati A, Tetzlaff J, Altman DG (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS medicine* 6 (7):e1000097. doi:10.1371/journal.pmed.1000097

26. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J (2003) Methodological index for non-randomized studies (minors): development and validation of a new instrument. *ANZ J Surg* 73 (9):712-716. doi:10.1046/j.1445-2197.2003.02748.x

27. Walker SJ, Sharma P, Parr N, Cavendish ME (1986) The long-term results of the Liverpool Mark II knee prosthesis. *J Bone Joint Surg Br* 68 (1):111-116

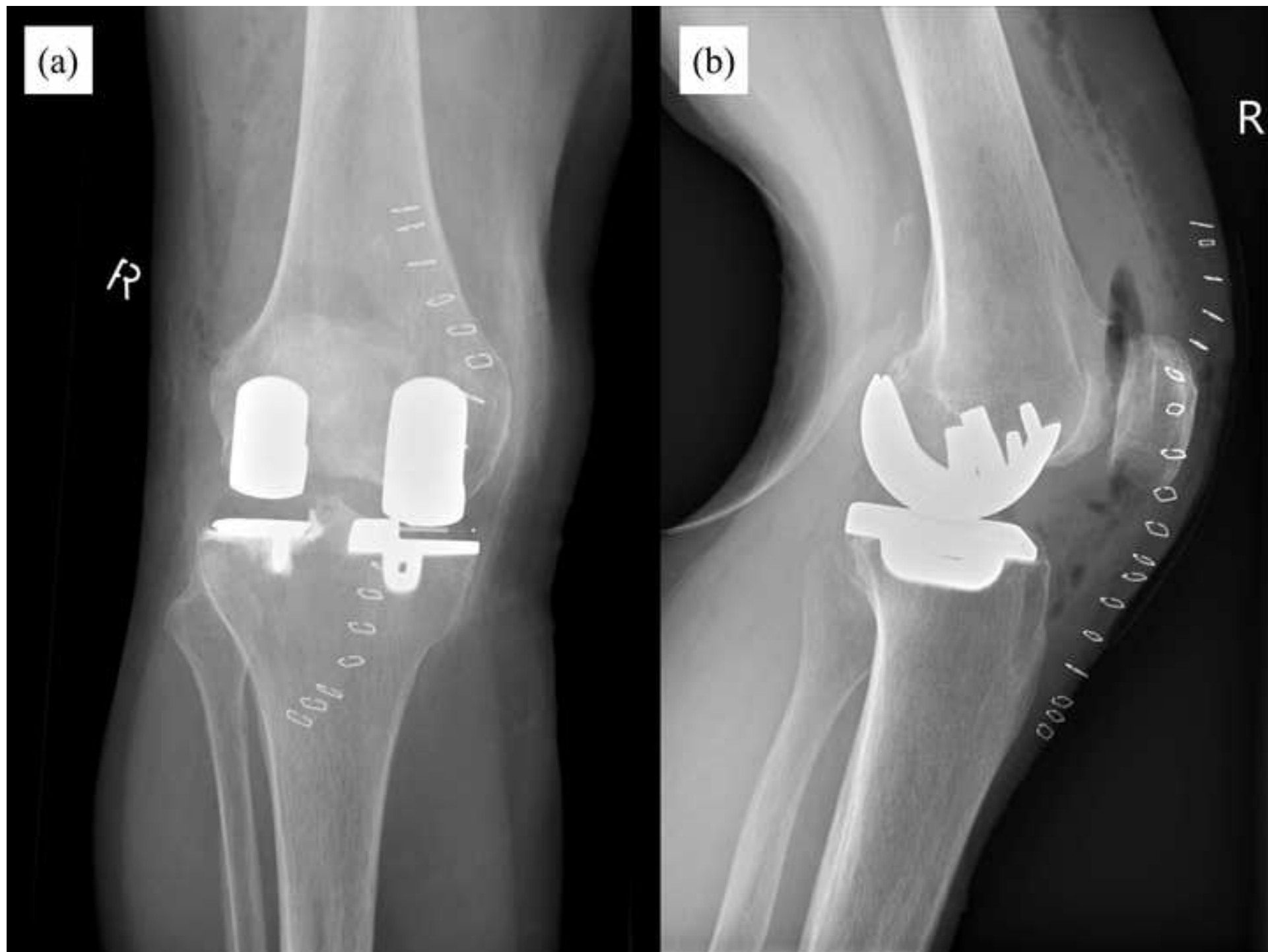
28. Stockley I, Douglas DL, Elson RA (1990) Bicondylar St. Georg sledge knee arthroplasty. *Clin Orthop Relat Res* (255):228-234

29. Fuchs S, Tibesku CO, Frisse D, Genkinger M, Laass H, Rosenbaum D (2005) Clinical and functional comparison of uni- and bicondylar sledge prostheses. *Knee Surg Sports Traumatol Arthrosc* 13 (3):197-202. doi:10.1007/s00167-004-0580-y

30. Confalonieri N, Manzotti A, Cerveri P, De Momi E (2009) Bi-unicompartmental versus total knee arthroplasty: a matched paired study with early clinical results. *Arch Orthop Trauma Surg* 129 (9):1157-1163. doi:10.1007/s00402-008-0713-8

31. Barrett DS, Biswas SP, MacKenney RP (1990) The Oxford knee replacement. A review from an independent centre. *J Bone Joint Surg Br* 72 (5):775-778
32. Confalonieri N, Manzotti A (2005) Mini-invasive computer assisted bi-unicompartmental knee replacement. *Int J Med Robot* 1 (4):45-50. doi:10.1002/rcs.56
33. Parratte S, Pauly V, Aubaniac J-M, Argenson J-NA (2011) No Long-term Difference Between Fixed and Mobile Medial Unicompartmental Arthroplasty. *Clinical Orthopaedics and Related Research®* 470 (1):61-68. doi:10.1007/s11999-011-1961-4
34. Confalonieri N, Manzotti A, Pullen C (2004) Comparison of a mobile with a fixed tibial bearing unicompartmental knee prosthesis: a prospective randomized trial using a dedicated outcome score. *Knee* 11 (5):357-362. doi:10.1016/j.knee.2004.01.003
35. Ernstbrunner L, Imam MA, Andronic O, Perz T, Wieser K, Fucentese SF (2018) Lateral unicompartmental knee replacement: a systematic review of reasons for failure. *Int Orthop* 42 (8):1827-1833. doi:10.1007/s00264-017-3662-4
36. Parratte S, Ollivier M, Lunebourg A, Abdel MP, Argenson JN (2015) Long-term results of compartmental arthroplasties of the knee: Long term results of partial knee arthroplasty. *Bone Joint J* 97-B (10 Suppl A):9-15. doi:10.1302/0301-620X.97B10.36426
37. Newman SDS, Altuntas A, Alsop H, Cobb JP (2017) Up to 10 year follow-up of the Oxford Domed Lateral Partial Knee Replacement from an independent centre. *Knee* 24 (6):1414-1421. doi:10.1016/j.knee.2017.05.001
38. Romagnoli S, Marullo M, Massaro M, Rustemi E, D'Amario F, Corbella M (2015) Bi-unicompartmental and combined uni plus patellofemoral replacement: indications and surgical technique. *Joints* 3 (1):42-48
39. Younger AS, Duncan CP, Masri BA (1998) Surgical exposures in revision total knee arthroplasty. *J Am Acad Orthop Surg* 6 (1):55-64
40. Vince K, Chivas D, Droll KP (2007) Wound complications after total knee arthroplasty. *J Arthroplasty* 22 (4 Suppl 1):39-44. doi:10.1016/j.arth.2007.03.014
41. Zhang Q, Zhang Q, Guo W, Gao M, Ding R, Wang W (2019) Risk factors of postoperative valgus malalignment in mobile-bearing medial unicompartmental knee arthroplasty. *Arch Orthop Trauma Surg* 139 (2):241-248. doi:10.1007/s00402-018-3070-2
42. Ozcan C, Simsek ME, Tahta M, Akkaya M, Gursoy S, Bozkurt M (2018) Fixed-bearing unicompartmental knee arthroplasty tolerates higher variance in tibial implant rotation than mobile-bearing designs. *Arch Orthop Trauma Surg* 138 (10):1463-1469. doi:10.1007/s00402-018-3005-y

43. Canetti R, Batailler C, Bankhead C, Neyret P, Servien E, Lustig S (2018) Faster return to sport after robotic-assisted lateral unicompartmental knee arthroplasty: a comparative study. *Arch Orthop Trauma Surg* 138 (12):1765-1771. doi:10.1007/s00402-018-3042-6
44. Fuchs S, Tibesku CO, Genkinger M, Laass H, Rosenbaum D (2003) Proprioception with bicondylar sledge prostheses retaining cruciate ligaments. *Clin Orthop Relat Res* (406):148-154. doi:10.1097/01.blo.0000038053.29678.a5
45. Fuchs S, Tibesku CO, Genkinger M, Volmer M, Laass H, Rosenbaum D (2004) Clinical and functional comparison of bicondylar sledge prostheses retaining all ligaments and constrained total knee replacement. *Clin Biomech (Bristol, Avon)* 19 (3):263-269. doi:10.1016/j.clinbiomech.2003.11.004
46. Banks SA, Fregly BJ, Boniforti F, Reinschmidt C, Romagnoli S (2005) Comparing in vivo kinematics of unicondylar and bi-unicondylar knee replacements. *Knee Surg Sports Traumatol Arthrosc* 13 (7):551-556. doi:10.1007/s00167-004-0565-x
47. Watanabe T, Abbasi AZ, Conditt MA, Christopher J, Kreuzer S, Otto JK, Banks SA (2014) In vivo kinematics of a robot-assisted uni- and multi-compartmental knee arthroplasty. *J Orthop Sci* 19 (4):552-557. doi:10.1007/s00776-014-0578-3
48. Lewold S, Robertsson O, Knutson K, Lidgren L (1998) Revision of unicompartmental knee arthroplasty: outcome in 1,135 cases from the Swedish Knee Arthroplasty study. *Acta Orthop Scand* 69 (5):469-474



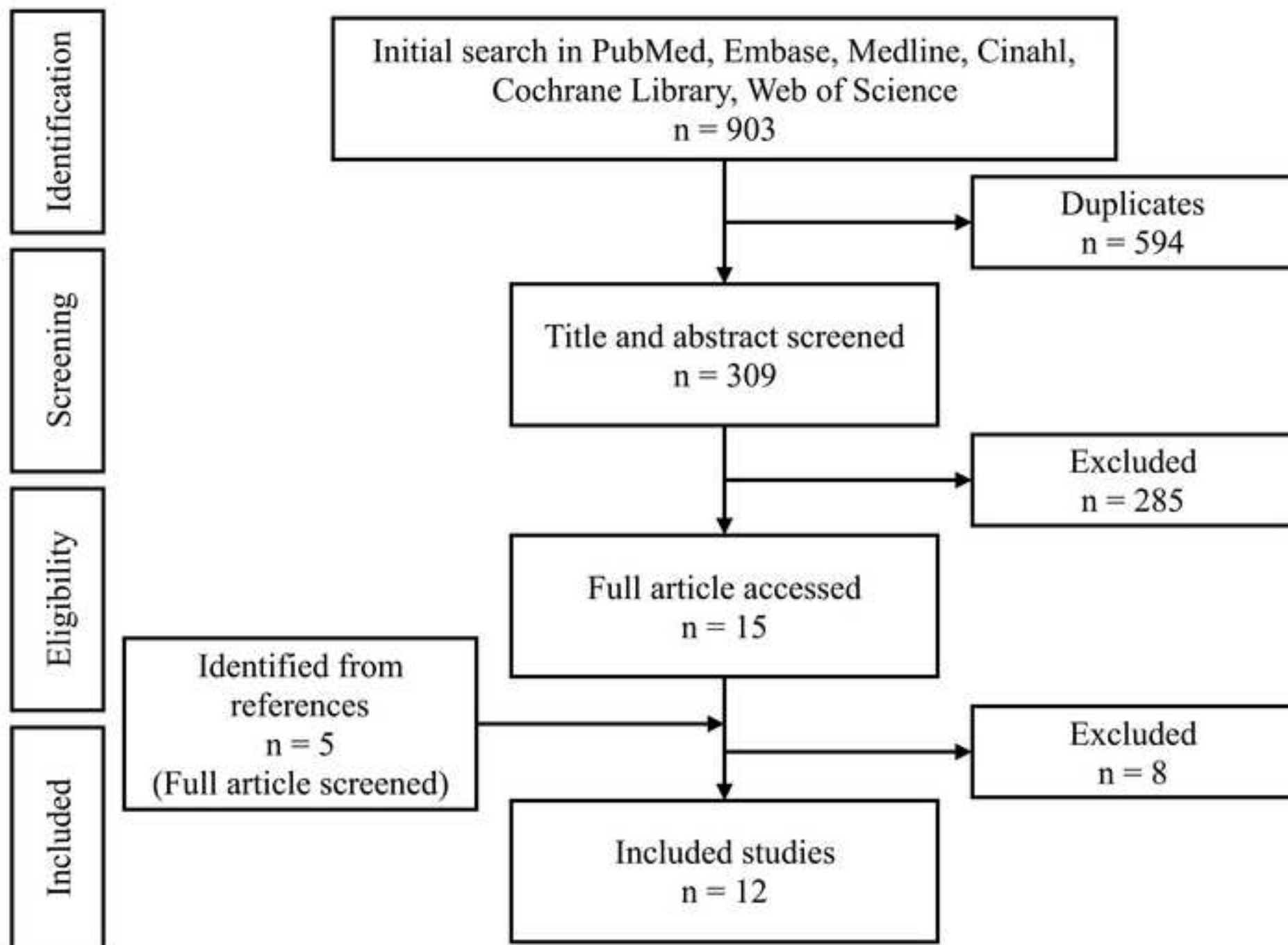




Table1

Table1: Summary of all studies included in the systematic review

Study	Year	Number of bi-UKA	Number of patients	Prosthesis type	MINORS
Simultaneous bi-UKA					
Biazzo et al. [22]	2018	19	19	UC-Plus; 16 cases GMK-Uni; 3 cases (fixed bearing)	19/24
Dettmer et al. [23]	2015	NA	17	Restoris MCK (fixed bearing)	5/16
Parratte et al. [24]	2010	94	78	Zimmer Condylar 2 Alpina Miller-Galante (fixed bearing)	8/16
Confalonieri et al. [30]	2009	22	22	UC-Plus (fixed bearing)	22/24
Fuchs et al. [29]	2005	15	15	Endo; 7 cases Search; 8 cases (fixed bearing)	16/24
Barret et al. [31]	1990	67	62	Oxford knee (mobile bearing)	7/16
Stockley et al. [28]	1990	44	35	St. Georg sledge (fixed bearing)	6/16
Goodfellow et al. [17]	1986	125	107	Oxford knee (mobile bearing)	9/16
Walker et al. [27]	1986	105	71	Liverpool Mark II (fixed bearing)	4/16
Gunston et al. [16]	1971	22	20	Polycentric knee (fixed bearing)	8/16
Staged bi-UKA					
Pandit et al. [19]	2017	27	25	medial (Primary implant): Oxford UKA (mobile bearing) lateral (Additional implant): Oxford Domed Lateral UKA; 70% (mobile bearing) Vanguard M; 30% (fixed bearing)	15/16
Lustig et al. [20]	2008	6	6	HLS Evolution Uni (fixed bearing)	8/16

List of abbreviations: NA, not available; OA, osteoarthritis; RA rheumatoid arthritis; UKA, unicompartmental knee arthroplasty; MINORS, methodological index for non-randomized studies

Table2

Table2: Summary of Indication criteria and Contraindication and Approach in all studies

Study	Indication criteria	Contraindication	Approach
Simultaneous bi-UKA			
Biazzo et al. [22]	bicompartmental tibio-femoral OA (≤ Ahlbäck classification grade IV) asymptomatic patello-femoral joint (≤ Ahlbäck classification grade II) a varus deformity less than 8° body-mass index lower than 35 pre-operative range of motion of at least 110°	ACL laxity flexion deformity	NA
Dettmer et al. [23]	OA	NA	anterior peripatellar approach
Parratte et al. [24]	bicompartmental OA (≥ Ahlbäck classification grade II) preserved status of of the patellofemoral joint preoperative ROM greater than 100° full range of extension clinical stable in the frontal and sagittal planes	valgus varus deformity greater than 10° planned HTO planned or previous ACL reconstruction revision arthroplasty full loss of cartilage on the lateral compartment fixed deformity	medial parapatellar approach; 70% subvastus approach; 30%
Confalonieri et al. [30]	medial and lateral OA (≤ Ahlbäck classification grade IV) asymptomatic patello-femoral compartment arthritis (≤ Ahlbäck classification grade II) varus deformity less than 8° body mass index lower than 35° preoperative ROM at least 110°	ACL laxity flexion deformity obesity osteopenia history of systematic articular disease significant ligamentous laxity limb deformity greater than 10°	mid parapatellar approach with anteromedial para-patellar arthrotomy
Fuchs et al. [29]	severe primary degenerative arthritis in both the medial and lateral compartment intact collateral and cruciate ligament at least 90° flexion	flexion contracture	medial parapatellar approach
Barret et al. [31]	RA, OA	NA	NA
Stockley et al. [28]	RA, OA at least 70° of motion need for strong bone	flexion contracture greter than 20° varus valgus deformity greater than 20° severe ligamentous damage	medial parapatellar incision mid vastus approach
Goodfellow et al. [17]	RA, OA at least 75° of flexion under anesthesia	absence of posterior cruciate ligament flexion deformity greter than 40° varus valgus deformity greater than 30°	antero medial approach
Walker et al. [27]	RA, OA total loss of articular surface less than 12mm	caution should be observed in patients wighing more than 73kg	two para-parapatellar incision
Gunston et al. [16]	RA, OA	NA	medial parapatellar approach
Staged bi-UKA			
Pandit et al. [19]	lateral OA progression after medial UKA no evidence of implant loosening	severaly damaged patellofemoral joint no functional ACL (decision on whether to do a TKA or a fixed-bearing lateral UKA depended on the patient's age, health and referred symptoms, with instability being an indication towards TKA)	medial UKA incision was opened and extended lateral parapatellar arthrotomy
Lustig et al. [20]	opposite compartment's knee arthritis lateral femoral condyle osteonecrosis absense of UKA wear or migration hypercorrection benath 5 degrees of first implant good initial results after UKA elective complaints in compartment opposite to UKA reducibility of frontal plane's deformity central pivot ligaments competence near normal range of motion less demanding patients (age over 65 years) higher comorbidity (higher risk for TKA)	Abolute: inflammatory arthritis history of infection cruciate and/or collateral ligament deficiency major bone loss extension deficit higher than 10 degrees Relative: associate patellofemoral arthritis body weight greater than 80 kg young and active patients	same incision after proper lengthnning standard lateral or medial approach (8-cm security distance)

List of abbreviations: NA, not available; OA, osteoarthritis; RA rheumatoid arthritis; UKA, unicompartmental knee arthroplasty; TKA, total knee arthroplasty; ROM, range of motion; ACL, anterior cruciate ligament

Table3: Summary of Outcome and Follow up period in all studies

Study	Outcome measurement	Score before surgery	Score after surgery	Follow up (months)
Simultaneous bi-UKA				
Biazzo et al. [22]	KSS GIUM WOMAC	mean KSS knee 43.65 (range 39 to 52) mean KSS function 48.45 (range 44 to 57)	mean KSS knee 78.3 (range 71 to 87) mean KSS function 80.5 (range 68 to 96) mean GIUM score 77.4 (range 67 to 88) mean WOMAC pain 4 (range 1 to 7) mean WOMAC function 7.22 (range 4 to 11) mean WOMAC stiffness 1.7 (0 to 4)	mean 180
Dettmer et al. [23]	KOOS	NA	mean KOOS symptoms 91.3 ± 9.0 (SD) mean KOOS activities of daily living 94.8 ± 6.8 (SD)	minimum 6
Parratte et al. [24]	KSS ROM	mean KSS knee 44 (range 25 to 64) mean KSS function 42 (range 17 to 59)	mean KSS knee 88 (range 65 to 100) mean KSS function 88 (range 58 to 100)	mean 140.4 range 60 to 276
Confalonieri et al. [30]	KSS GIUM WOMAC	mean KSS knee 43.95 (range 39 to 50) mean KSS function 47.95 (range 44 to 55)	mean KSS knee 80.04 (range 74 to 88) mean KSS function 82.27 (range 70 to 100) mean GIUM score 78.5 (range 67 to 90) mean WOMAC pain 4 (range 1 to 7) mean WOMAC function 7.77 (range 4 to 11) mean WOMAC stiffness 1.5 (0 to 4)	minimum 48
Fuchs et al. [29]	HSS KSS Patella score VAS for pain Proprioceptive testing Electromyographic signals Gait analysis	NA	mean HSS 80.4 ± 14.6 (SD) mean KSS 169.7 ± 27.1 (SD) mean Patella score 26.8 ± 4.5 (SD) mean VAS 8.5 ± 1.7 (SD)	mean 31.9 range 7 to 70
Barret et al. [31]	British Orthopaedic Association knee assessment chart	NA	NA	mean 54 range 48 to 84
Stockley et al. [28]	pain ROM walking ability	NA	NA	mean 70.8 range 36 to 120
Goodfellow et al. [17]	pain ROM deformity stability function	NA	NA	mean 49 range 24 to 72
Walker et al. [27]	pain gait ROM mobility deformity stability	NA	NA	range 13 to 113
Gunston et al. [16]	pain ROM instability mobility	NA	NA	range 12 to 30
Staged bi-UKA				
Pandit et al. [19]	OKS Tegner activity score AKSS	mean OKS 26 (± 8.5)	mean OKS 36.5 ± 9.2 (SD)	mean 48
Lustig et al. [20]	IKSS	mean KSS knee 62.5 (range 60 to 70) mean KSS function 65.0 (range 60 to 70)	mean KSS knee 92.5 (80 to 100) mean KSS function 87.5 (70 to 100)	mean 25.5 range 12 to 42

List of abbreviations: ROM, range of motion; ACL, anterior cruciate ligament; OKS, Oxford knee score; IKSS/KSS, international knee society score; WOMAC, Western Ontario and McMaster Universities Arthritis Index; KOOS, knee injury and osteoarthritis outcome scores; HTO, high tibial osteotomy; GIUM, a dedicated UKR outcome score developed by the Italian Orthopaedic UKR’s Users Group; HSS, Hospital for Special Surgery score; VAS, visual analog scale; AKSS, American knee society score; SD, Standard deviation



Click here to access/download  
**Conflict of Interest Form**  
COI-AOTS.pdf

