Arthroplasty Today 3 (2017) 309–314

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Systematic review

Bicompartmental knee arthroplasty vs total knee arthroplasty for the treatment of medial compartment and patellofemoral osteoarthritis

Sahil Kooner, MD [a,*], Herman Johal, MD, MPH, PhD(c), FRCSC [b], Marcia Clark, MD, MSc, FRCSC [a]

[a] Department of Orthopedics, University of Calgary Cumming School of Medicine, Foothills Medical Centre, Calgary, Alberta, Canada
[b] Center for Evidence-Based Orthopaedics, Division of Orthopaedics, Department of Surgery, McMaster University, Hamilton, Ontario, Canada

ARTICLE INFO

Article history:
Received 16 November 2016
Received in revised form
16 February 2017
Accepted 17 February 2017

Keywords:
Total knee arthroplasty
Bicompartmental knee arthroplasty
Medial patellofemoral arthritis
Meta-analysis

ABSTRACT

Background: Interest in bicompartmental knee arthroplasty (BKA) for the treatment of medial patellofemoral osteoarthritis (MPFOA) has grown in recent years because BKA offers a bone and ligament-preserving alternative to total knee arthroplasty (TKA). BKA only resurfaces the diseased compartments, while preserving proprioception and native knee kinematics. Therefore, the objective of this study is to assess knee function, perioperative morbidity, and implant survivability in patients undergoing BKA vs TKA for MPFOA.

Methods: The databases MEDLINE, PUBMED, and EMBASE were systematically searched. Randomized controlled trials and nonrandomized comparative studies comparing BKA with TKA for the treatment of MPFOA were included for further analysis. The primary outcome of interest was knee function. Secondary outcomes included range of movement, operation length, intraoperative blood loss, hospital length of stay, postoperative complications, and rate of revision length. The quality of evidence was evaluated using the GRADE approach. Meta-analysis was performed by pooling the results of the selected studies when possible.

Results: Six studies were selected for inclusion (4 prospective studies and 2 retrospective cohort studies). In total, 274 patients and 277 knees were included for analysis. There were no significant differences between the 2 groups at any time points in terms of knee function, length of stay, complication rate, or revision rate, when monolithic BKA designs were controlled for. BKA did result in significantly decreased intraoperative blood loss, at the expense of increased operative length compared with TKA.

Conclusions: The use of modular BKA for MPFOA is comparable with TKA in terms of short-term function, complication rate, and revision rate. BKA reduces intraoperative blood losses, but it is also more technically demanding, resulting in increased operation length. The use of modular BKA has acceptable short-term outcomes, but more long-term data are needed before it can be recommended for routine use in the treatment of MPFOA. The selection of modular BKA should be determined on a patient-specific basis. Currently, there is no evidence to suggest the use of monolithic BKA designs because of their high revision and failure rate.

Introduction and background

The knee is the most commonly affected joint by osteoarthritis (OA) [1]. In the evaluation of knee OA, it becomes important to define which compartments are being affected. Medial compartment OA is 5-10 times more common than lateral compartment OA in North America [2]. In varus knee OA, cadaver and radiographic studies have shown that knee OA typically progresses in predictable fashion from medially to laterally [3]. As such, the 2 compartments that initially present symptomatically include the medial tibiofemoral compartment and the patellofemoral compartment.

Currently, the standard of treatment for bicompartmental OA of the medial and patellofemoral compartments, that has failed conservative treatment, is total knee arthroplasty (TKA). Despite its advantages and well-documented track record, TKA can also have many drawbacks in this setting as well. TKA

No author associated with this paper has disclosed any potential or pertinent conflicts which may be perceived to have impending conflict with this work. For full disclosure statements refer to http://dx.doi.org/10.1016/j.artd.2017.02.006.

* Corresponding author. Department of Orthopedics, University of Calgary Cumming School of Medicine, Foothills Medical Centre, 1403 29 Street NW, Calgary, AB T2N 2T9, Canada. Tel.: +1 403 629 8448.
E-mail address: sahilkooner@gmail.com

http://dx.doi.org/10.1016/j.artd.2017.02.006
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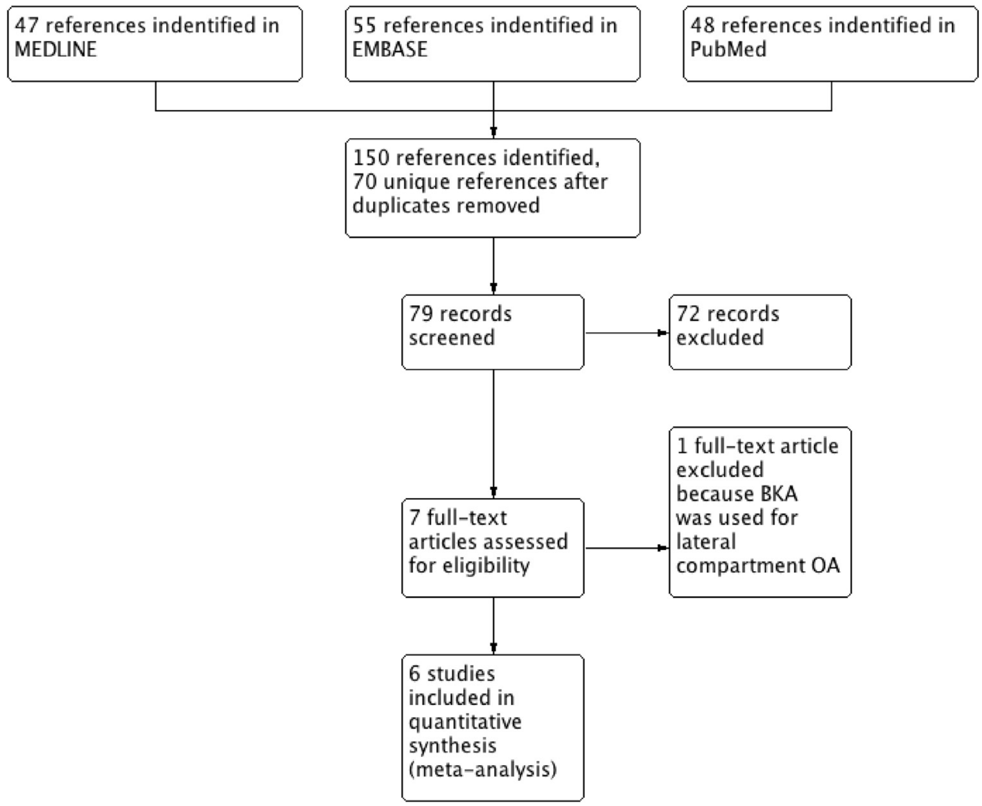

Figure 1. PRISMA flow diagram.

sacrifices the unaffected lateral compartment as well as one or more cruciate ligaments, causing disruption of normal knee kinematics and gait [4]. In addition, total knee components often require a greater amount of bone stalk, making revision scenarios more difficult. As younger patients are now presenting with isolated compartmental OA, and older patients are living increasingly longer and active lifestyles, the need for an alternative prosthesis that address these issues has become more pertinent. For these reasons, unicompartmental knee arthroplasty has seen a resurgence in its use because of its quicker rehabilitation times, decreased morbidity, and preservation of normal knee kinematics [5]. Unfortunately, bicompartmental OA is a contraindication for unicompartmental knee arthroplasty as a diseased patellofemoral compartment increases risk of revision [6].

In light of these issues, interest in bicompartmental knee arthroplasty (BKA) for the treatment of medial patellofemoral osteoarthritis (MPFOA) has grown in recent years. Two different categories of implants are currently being used for BKA, which include monolithic and modular components [4]. These monolithic implants use a single contoured femoral component to resurface the medial and patellofemoral compartments, whereas modular implants use separate components to resurface both compartments. Nonetheless, these BKA implants offer a bone and ligament preserving procedure that only resurfaces the diseased compartments [7]. Retention of both cruciate ligaments theoretically preserves proprioception, and maintains native knee kinematics. Several recent biomechanical studies have demonstrated this principle in BKA, showing improvement in 3-dimensional joint kinematics and gait analysis, which is comparable with healthy controls [8,9]. However, it is still unclear if these theoretical and biomechanical advantages will translate into significant clinical differences.

The objective of this study, therefore, is to assess knee function and perioperative morbidity in patients undergoing BKA vs TKA for MPFOA. Several recent clinical and observational studies have recently published on this topic, albeit with varying results, which we will further analyze with a meta-analysis. We hypothesize that BKA will be superior to TKA in terms of clinical and functional benefits.

Material and methods

A systematic literature search was completed by a single reviewer (S. K.) at the University of Calgary. This search was completed and is up to date as of September 11, 2015. The databases MEDLINE, PUBMED, and EMBASE were searched using engine specific strategies unique to each database to maximize sensitivity (Appendix 1). References of each study, and related citations on each search engine, were explored for any potentially eligible studies. All search results were then compiled in an online database, and duplicates were deleted. Studies were then scanned based on title and abstract for eligibility. Studies that were thought to be eligible then underwent full text review, after which only primary articles, which met all the inclusion and exclusion criteria, were included in the meta-analysis. Two reviewers selected the trails to be included from the compiled literature search (S. K. and H. J.). Disagreements were resolved by consensus, and by a third reviewer if needed. Risks of bias for each included study were then systematically evaluated using the GRADE approach as outlined in the Cochrane Handbook for Systematic Reviews [10].

Eligibility for studies included randomized controlled trials or nonrandomized comparative studies. Population-specific eligibility requirements included adult patients undergoing primary BKA for MPFOA. The intervention evaluated in the trials had to compare BKA with TKA, with a follow-up period of at least 2 years. Studies

Table 1
Included study characteristics.

Study	Design	Level	Implant	N		Age		Gender (female:male)		BMI		Follow-Up, y	Complications		Revisions	
				BKA	TKA	BKA	TKA	BKA	TKA	BKA	TKA		BKA	TKA	BKA	TKA
Parratte et al. 2015 [13]	Pseudorandomized	IIA	Modular	34	34	61 (7)	61 (8)	21:13	21:13	27.5 (4)	27.5 (4.5)	3.8 (1.7)	0	1	0	1
Yeo et al. 2015 [16]	RCT	I	Modular	22	20	63.8 (8.03)	63.1 (7.34)	21:5	16:6	27.28 (3.04)	28.15 (4.52)	6 m, 1, 2, 5	1	0	1	0
Engh et al. 2014 [18]	RCT	I	Monolith	25	25	60.3	58.3			28.8	30	1 m, 4 m, 1, 2	1	3	3	1
Tan et al. 2013 [14]	Retrospective cohort	IIB	Modular	15	12	52	60	10:5	7:5	26 (4.2)	28.3 (4.9)	6 m, 1, 2	0	0	0	0
Shah et al. 2013 [15]	Retrospective cohort	IIB	Modular	16	20	52.1 (6.4)	65.1 (7.5)	10:6	16:4	27.6 (4.4)	27.3 (3.8)	6 m, 1, 2	1	0	0	0
Morrison et al. 2011 [17]	Prospective cohort	IA	Monolith	21	33	63.2 (11.5)	67.18 (9.5)	14:6	25:6	31.7 (7.7)	33.7 (8.6)	3 m, 1, 2	3	2	3	0
Total				133	144			76:35	85:34				6	6	7	2

BMI, body mass index; RCT, randomized controlled trial.
Age and BMI are presented as mean (standard deviation).

were excluded if BKA was performed for lateral compartment OA, or if it was not specified whether patients had BKA for MPFOA. Studies were also excluded if knee arthroplasty was performed for reasons other than primary OA, including inflammatory arthropathies or arthroplasty revision. Studies were not excluded based on the type or brand of BKA or TKA being used.

The primary outcome of interest was postoperative knee function, measured using validated scoring questionnaires, such as the Knee Society Score (KSS), Knee Injury and Osteoarthritis Outcome score (KOOS), Western Ontario and McMaster Universities Arthritis Index (WOMAC), etc. Secondary outcomes included range of movement, postoperative pain, operation length, intraoperative blood loss, hospital length of stay, postoperative complications (infection, stiffness, deep vein thrombosis and/or pulmonary embolism, etc.), health-related quality of life measures, and rate of revision and reoperation.

A data extraction form, which included authors, publication date, study design, patient's characteristics, implant type, and specific outcome measurements, was developed to collect data from the selected studies. Meta-analysis was then performed by pooling the results of selected studies when possible using Review Manager 5.3. Continuous data were entered as means and standard deviations, and dichotomous outcomes as number of events or odd ratio. Statistical analysis was performed by comparing mean differences (MDs) of two or more studies when results were collected using similar measures, or standardized MD when results were collected in a heterogeneous manner. In the case of missing data, standard deviations were calculated based on the "P" value, after finding a corresponding "t" value and inputting it into the formula standard error = MD/t. If the P value was not specified or given, standard deviations were inputted from comparable studies. Similarly, if outcomes were reported as median and range, they were converted to mean and standard deviation using the formula in Appendix 2 [11]. A random-effects model was used for all analysis. Data were reported as MD with 95% confidence intervals. Heterogeneity was assessed initially by visual inspection of the forest plots. In addition, an I^2 statistic was used to quantify risk of heterogeneity between studies. A $P > .1$ and an $I^2 \leq 50\%$ were considered of no statistical heterogeneity.

Results

Our literature search produced 150 references, after which 79 remained when duplicates were removed. After the initial screening review, 7 studies where chosen to undergo full text review. One study was excluded for including patients who had undergone BKA for lateral compartment OA [12]. In total, 6 studies were selected for inclusion in the meta-analysis, as shown in the PRISMA flow diagram (Fig. 1) [13-18]. A kappa value of 0.9 was determined based on the selections of two reviewers (S. K. and H. J.), indicating excellent agreement between authors. Four of these studies were prospective in nature (2 randomized controlled trials, 1 pseudorandomized, and 1 nonrandomized prospective cohort), and 2 were retrospective cohort studies. In addition, 4 studies used modular BKA implant, whereas 2 used a monolith BKA design. In total, 274 patients and 277 knees were included for analysis, which included 133 primary BKAs and 144 primary TKAs. The average age of participants in the included studies ranged from 52.1-68.18 years; average BMI ranged from 26-33.7 kg/m^2; and follow-up period ranged from 2-5 years (Table 1). In terms of gender, 68.5% of BKA patients were women, and 71.4% of TKA patients were women. The most commonly reported outcome scores included flexion and/or range of movement, KSS, KOOS, WOMAC, and Short-Form 36 (SF-36).

The quality of evidence was evaluated using the GRADE approach described in the Cochrane Handbook for Systematic

Reviews of Intervention. The risk of bias was variable between studies, but all 6 studies included were of moderate to high quality evidence with low to moderate risk of bias (Fig. 2). Clinical trials were found to have the lowest risk of bias, whereas the non-randomized prospective cohort and retrospective cohort studies were found to have the highest risk of bias.

A total of 24 subgroup analyses were completed. Our meta-analysis did not show any significant differences between BKA vs TKA for flexion, KSS knee, KSS function, KOOS pain, KOOS symptoms, KOOS activity in daily living, SF-36 mental, or SF-36 physical at any period (Table 2). However, BKA did have a significantly lower WOMAC pain score at 1 year (MD = −8.09, 95% confidence interval

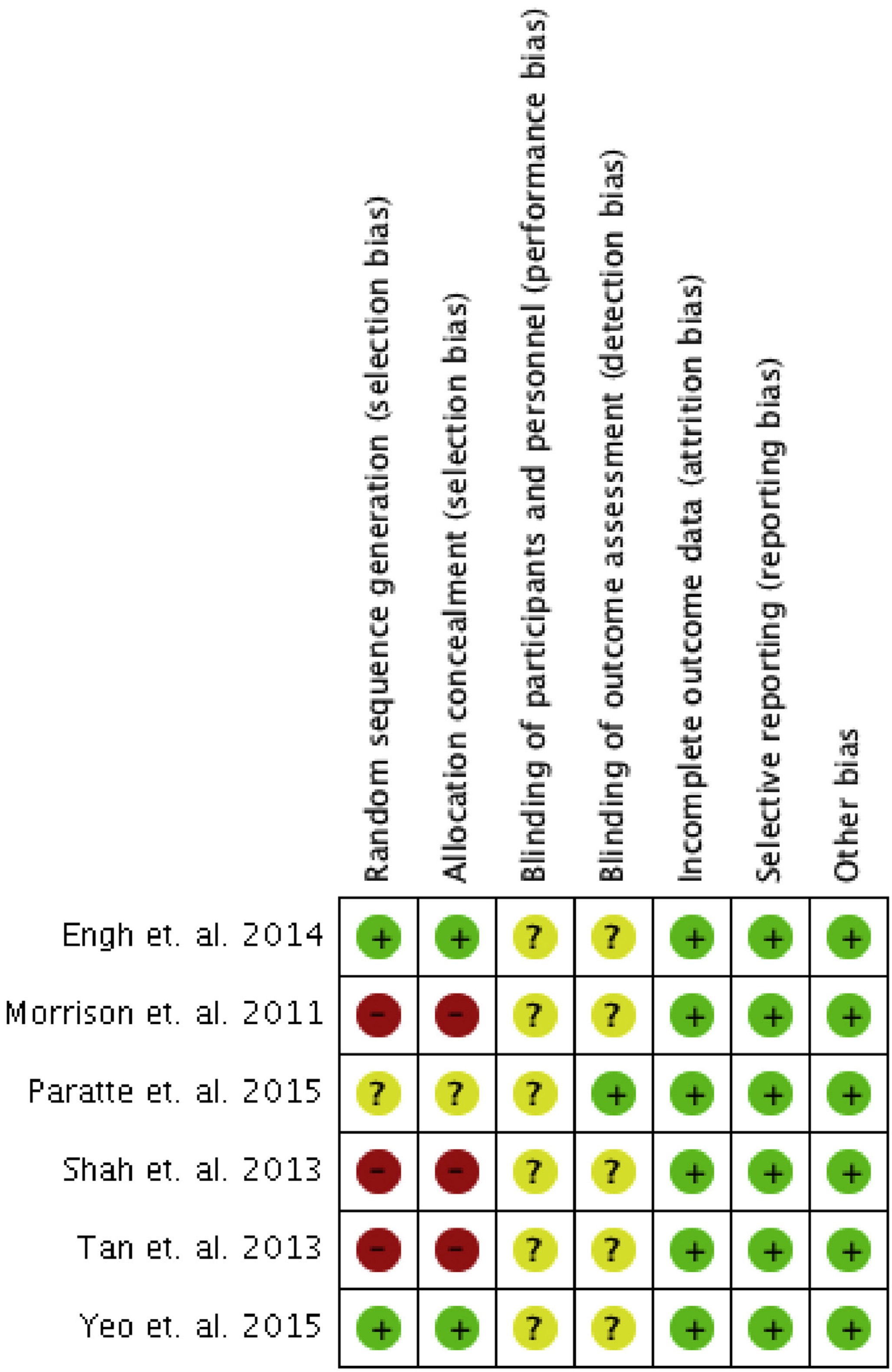

Figure 2. GRADE risks of bias for included studies.

Table 2
Subgroup meta-analysis.

Subgroup	Studies	Participants	MD [95% CI]	I^2	*P*
Knee Flexion (6 mo)	2	78	8.77 [−7.64, 25.18]	88	.29
Knee Flexion (1 y)	2	78	5.50 [−10.66, 21.66]	87	.5
Knee Flexion (2 y)	3	146	6.21 [−1.72, 14.14]	75	.12
KSS Knee (3-6 mo)	3	155	2.14 [−1.37, 5.65]	10	.23
KSS Knee (1 y)	3	105	−1.80 [−6.58, 2.98]	0	.46
KSS Knee (2 y)	5	223	1.15 [−3.48, 5.78]	72	.63
KSS Function (3-6 mo)	3	105	−1.89 [−7.52, 3.73]	0	.51
KSS Function (1 y)	3	105	1.46 [−3.92, 6.83]	0	.6
KSS Function (2 y)	4	173	3.36 [−2.70, 9.43]	69	.28
KOOS Pain (2 y)	2	104	−0.32 [−10.99, 10.36]	85	.95
KOOS Symptoms (2 y)	2	104	1.61 [−3.13, 6.36]	77	.51
KOOS activity in daily living (2 y)	2	104	1.34 [−7.74, 10.42]	59	.77
Length of Stay (d)	2	69	−0.38 [−1.33, 0.57]	66	.43
SF-36 Mental (6 mo)	2	69	2.27 [−0.80, 5.33]	0	.15
SF-36 Mental (1 y)	2	69	7.37 [−6.92, 21.66]	91	.31
SF-36 Mental (2 y)	2	69	−0.21 [−3.60, 3.17]	0	.9
SF-36 Physical (6 mo)	2	69	−8.34 [−21.67, 4.98]	95	.22
SF-36 Physical (1 y)	2	69	−2.61 [−6.38, 1.15]	0	.17
SF-36 Physical (2 y)	2	69	−1.87 [−4.62, 0.89]	0	.18
WOMAC Pain (3-6 mo)	2	90	6.19 [−11.52, 23.89]	86	.49
WOMAC Pain (1 y)	2	90	−8.09 [−12.98, −3.21]	10	.001[a]
WOMAC Pain (2 y)	2	90	−6.07 [−11.31, −0.83]	0	.02[a]
Operation Length (min)	2	63	16.58 [8.59, 24.58]	0	<.0001[a]
Intraoperative Blood Loss (g/L)	2	69	−9.11 [−13.34, −4.88]	28	<.0001[a]

Mean difference was calculated by using the formula $BKA_{mean} - TKA_{mean}$.
[a] Indicates significance.

[CI] −3.21 to 12.98, *P* = .001) and 2 years (MD = −6.07, 95% CI −0.83 to −11.31, *P* = .02) compared with TKA, indicating worse pain control in the TKA group. During our analysis, it became clear that monolith implants had a higher revision rate due to increased pain and prosthesis fracture. As such, a sensitivity analysis was performed by removing any studies that used a monolithic BKA implants. This sensitivity analysis did not demonstrate any differences between BKA vs TKA for any of the clinical or functional outcome score questionnaires at any time points.

In terms of secondary outcomes, BKA resulted in significantly less intraoperative blood loss compared with TKA (MD = −9.11 g/L, 95% CI −4.88 to −13.34, *P* < .0001; Fig. 3). Nonetheless, BKA also significantly increased operation length compared with TKA (MD = 16.58 minutes, 95% CI 8.59-24.58, *P* < .0001; Fig. 4). The number of complications, 6, was equal between both groups. The BKA group had 2 instances of manipulation under anesthesia, 2 instances of patellar subluxation (1 of which required an arthroscopic release), 1 superficial infection, and 1 patellar fracture. In the TKA group, complications included 3 instances of manipulation under anesthesia, 1 deep vein thrombosis, 1 deep space infection, and 1 instance of patellar tendonitis. In terms of revisions, the BKA group required 7 revisions, whereas the TKA group required only 2 revisions. In the BKA group, 3 revisions were due to implant fracture, 3 were due to persistent pain, and 1 was due to a traumatic periprosthetic fracture. In the TKA group, 1 revision was due to infection requiring poly exchange, and 1 was due to loosening of the tibial component. Nonetheless, when studies using monolithic BKA implants were removed from the analysis, both BKA and TKA had 1 revision.

Discussion

The objective of this study was to assess knee joint function and perioperative morbidity in patients undergoing BKA vs TKA for MPFOA. The results of our meta-analysis do not support our hypothesis that BKA is superior to TKA. In fact, there were largely no differences in terms of functional or clinical knee outcomes between both groups at all time points. As expected, BKA did result in decreased blood loss compared with TKA, likely secondary to its bone and ligament preserving qualities. This was in keeping with results of Yeo et al. [16], where this clinically significant intraoperative blood loss led to a higher rates of blood transfusion in patients undergoing TKA. However, this resulted in BKA having longer operation lengths compared with TKA. This was likely due to 2 major factors, which include the increased complexity of BKA procedures, as well as surgeon unfamiliarity with BKA implants and surgical technique due to its limited use.

In regard to postoperative complications and revisions, both groups were similar, when monolithic BKA implants were removed from the analysis. It became apparent during our study that monolithic BKA implants had a considerably higher rate of revision and failure than their modular counterparts. This was in keeping with the results of Palumbo et al. [19], which similarly showed an unacceptable revision rate in monolithic implants. This was thought to be due to 2 main issues. The first issue was material failure resulting in prosthesis fracture, which eventually resulted in the implant being recalled. The second issue was difficulty aligning the distal femoral and trochlear surface simultaneously due to

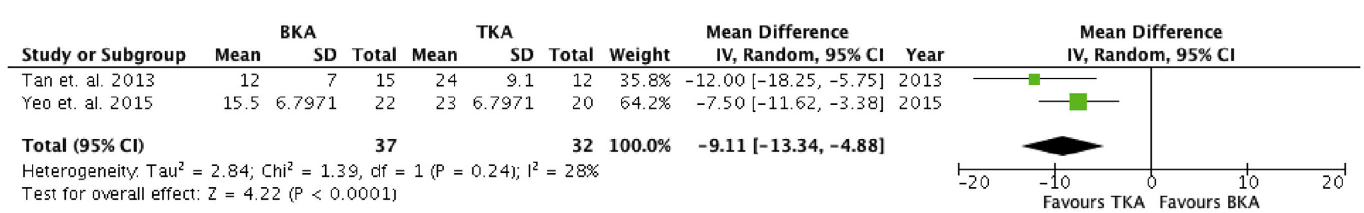

Figure 3. Intraoperative blood loss.

Study or Subgroup	BKA Mean	BKA SD	BKA Total	TKA Mean	TKA SD	TKA Total	Weight	Mean Difference IV, Random, 95% CI	Year
Shah et. al. 2013	101	16	16	82	18	20	51.7%	19.00 [7.88, 30.12]	2013
Tan et. al. 2013	99	15.1563	15	85	15.1563	12	48.3%	14.00 [2.49, 25.51]	2013
Total (95% CI)			**31**			**32**	**100.0%**	**16.58 [8.59, 24.58]**	

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.38$, df = 1 (P = 0.54); $I^2 = 0\%$
Test for overall effect: Z = 4.07 (P < 0.0001)

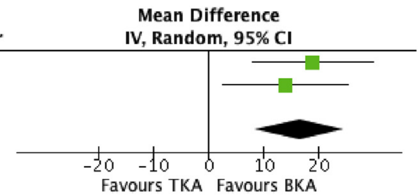

Figure 4. Operation length.

limited sizing options and anatomical variations. Based on this study, BKA and TKA had comparable survivability and complication rates at 2-5 years. More long-term data are needed to evaluate the true survivability of modular BKA implants, but some studies have shown near 80% survivorship of BKA at 17 years [20]. The problem with assessing BKA survivability is that younger patients often choose this implant because of its conservative and joint preserving nature. As such, these patients continue long active lifestyles, making revision likely due to loosening, fracture, and normal wear.

There was a trend for newer studies to show more positive effect of BKA compared with the older studies. In particular, Parratte et al. [13] and Yeo et al. [16] were the two most recent studies included in this analysis, and both prospective studies had similar inclusion and exclusion criteria, homogenous baseline groups, and low risk of bias using the GRADE approach. In the aforementioned studies, patients in the BKA group had significantly higher KSS knee, KSS function, University of California Los Angeles score, KOOS score, SF-36 score, and were 4 times more likely to achieve forgotten knee status. Conversely, many of the older studies and retrospective cohorts often failed to show any clinical or functional differences between both groups. As such, the results of our study may have underestimated the true effect of BKA given the results of these high-quality studies.

The major limitation of this review was the lack of studies and the low follow-up time length. This can likely be attributed to recent development and use of BKA implants, as well as the reluctance to adopt it given the overwhelming efficacy and evidence for the use of TKA instead. A further limitation was the lack of raw data. An attempt was made to contact authors of each study for their original data; however, given no responses, we had to use the available data and comparable statistics from other studies to achieve the most accurate results. Originally, we had hoped to only include clinical trials; however, given the sparsity of data, we chose to include retrospective studies as well, which increases the possible risk for selection bias. Nonetheless, strengths of this study include the fact that this is the only meta-analysis of this topic in the literature that we are currently aware of. In addition, all the studies included for analysis have been published relatively recently between 2011 and 2015.

Conclusions

The use of modular BKA for MPFOA is comparable with TKA in terms of short-term function, complication rate, and revision rate. Modular BKA can be an effective bone and ligament preserving procedure; however, preservation of native joint kinematics does not necessarily translate to improved clinical outcomes compared with TKA. BKA reduces intraoperative blood losses, but it is also more technically demanding, resulting in increased operation length. The use of modular BKA has acceptable short-term outcomes, but more long-term data are needed before it can be recommended for routine use in the treatment of MPFOA. The selection of modular BKA should be determined on a patient-specific basis. Currently, there is no evidence to suggest the use of monolithic BKA designs because of their high revision rate.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.artd.2017.02.006

References

[1] Bijlsma JWJ, Berenbaum F, Lafeber FPJG. Osteoarthritis: an update with relevance for clinical practice. Lancet 2011;377(9783):2115.
[2] Jones RK, Chapman GJ, Findlow AH, et al. A new approach to prevention of knee osteoarthritis: reducing medial load in the contralateral knee. J Rheumatol 2013;40(3):309.
[3] Miller R, Kettelkamp DB, Laubenthal KN, Karagiorgos A, Smidt GL. Quantitative correlations in degenerative arthritis of the knee. J Bone Joint Surg Am 1973;55(5):956.
[4] Rolston L, Bresch J, Engh G, et al. Bicompartmental knee arthroplasty: a bone-sparing, ligament-sparing, and minimally invasive alternative for active patients. Orthopedics 2007;30(8 Suppl):70.
[5] Laurencin CT, Zelicof SB, Scott RD, Ewald FC. Unicompartmental versus total knee arthroplasty in the same patient. A comparative study. Clin Orthop Relat Res 1991;(273):151.
[6] Gioe TJ, Killeen KK, Hoeffel DP, et al. Analysis of unicompartmental knee arthroplasty in a community-based implant registry. Clin Orthop Relat Res 2003;(416):111.
[7] Tria AJ. Bicompartmental knee arthroplasty: the clinical outcomes. Orthop Clin North Am 2013;44(3):281. vii.
[8] Wang H, Dugan E, Frame J, Rolston L. Gait analysis after bi-compartmental knee replacement. Clin Biomech (Bristol, Avon) 2009;24(9):751.
[9] Leffler J, Scheys L, Planté-Bordeneuve T, et al. Joint kinematics following bi-compartmental knee replacement during daily life motor tasks. Gait Posture 2012;36(3):454.
[10] 12.2.1 The GRADE approach. *handbook.cochrane.org*. http://handbook.cochrane.org/chapter_12/12_2_1_the_grade_approach.htm [accessed 17.06.15].
[11] Hozo SP, Djulbegovic B, Hozo I. Estimating the mean and variance from the median, range, and the size of a sample. BMC Med Res Methodol 2005;5:13.
[12] Chung JY, Min B-H. Is bicompartmental knee arthroplasty more favourable to knee muscle strength and physical performance compared to total knee arthroplasty? Knee Surg Sports Traumatol Arthrosc 2013;21(11):2532.
[13] Parratte S, Ollivier M, Opsomer G, et al. Is knee function better with contemporary modular bicompartmental arthroplasty compared to total knee arthroplasty? Short-term outcomes of a prospective matched study including 68cases. Orthop Traumatol Surg Res 2015;101:547.
[14] Tan SM, Dutton AQ, Bea KC, Kumar VP. Bicompartmental versus total knee arthroplasty for medial and patellofemoral osteoarthritis. J Orthop Surg (Hong Kong) 2013;21(3):281.
[15] Shah S, Dutton A, Liang S, Dasde S. Bicompartmental versus total knee arthroplasty for medio-patellofemoral osteoarthritis: a comparison of early clinical and functional outcomes. J Knee Surg 2013;26(6):411.
[16] Yeo NEM, Chen JY, Yew A, et al. Prospective randomised trial comparing unlinked, modular bicompartmental knee arthroplasty and total knee arthroplasty: a five years follow-up. Knee 2015;22(4):321.
[17] Morrison TA, Nyce JD, Macaulay WB, Geller JA. Early adverse results with bicompartmental knee arthroplasty: a prospective cohort comparison to total knee arthroplasty. J Arthroplasty 2011;26(6 Suppl):35.
[18] Engh GA, Parks NL, Whitney CE. A prospective randomized study of bicompartmental vs. total knee arthroplasty with functional testing and short term outcome. J Arthroplasty 2014;29(9):1790.
[19] Palumbo BT, Henderson ER, Edwards PK, et al. Initial experience of the Journey-Deuce bicompartmental knee prosthesis: a review of 36 cases. J Arthroplasty 2011;26(6 Suppl):40.
[20] Parratte S, Pauly V, Aubaniac J-M, Argenson J-NA. Survival of Bicompartmental Knee Arthroplasty at 5 to 23 Years. Clin Orthop Relat Res 2009;468(1):64.