

Outcomes of Bicompartamental Knee Arthroplasty: A Review

Luigi Sabatini, Laura Ravera, Francesco Atzori, Alessandro Massè

Luigi Sabatini, Laura Ravera, Francesco Atzori, Alessandro Massè, Orthopaedics and Traumatology Unit, San Luigi Hospital Orbassano, University of Turin, Italy
Correspondence to: Luigi Sabatini, MD, Orthopaedics and Traumatology Unit, San Luigi Hospital Orbassano, University of Turin, Italy.

Email: luigisabatini.ort@gmail.com

Telephone: +390119026626

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ABSTRACT

INTRODUCTION: Total knee arthroplasty (TKA) offers high survival and high functional scores when arthritis is affecting the three compartments of the knee; however, TKA does not preserve the bone stock and the ligaments and these points can represent theoretical disadvantages, particularly for young patients with higher demand and higher risk for potential revision. Bicompartamental knee arthroplasty (BKA) is a type of resurfacing surgery where two of the three compartments of the knee joint (medial tibiofemoral, lateral tibiofemoral or patellofemoral) are replaced with preservation of the third. Smaller implant sizes, less operative trauma, preservation of both cruciate ligaments and bone stock, and a more “physiological” knee are reported advantages over TKA. BKA has been proposed to bridge the gap between UKA and TKA.

METHODS: A systematic literature search was conducted during May and June 2014. The electronic databases searched were: PUBMED/MEDLINE and Cochrane Library. No language or data restrictions were used. The search keyword was bicompartamental knee arthroplasty, BKA, unicompartmental knee arthroplasty AND patellofemoral arthroplasty, unicompartmental knee arthroplasty AND patellofemoral joint, UKA AND PFJ, which appeared in the

title, abstract or keyword fields. Initially, 129 articles were found: based on abstract and after removal of duplicates, 102 articles remained. The full text of each of these articles was read and another 13 articles were considered non-relevant and removed. The final number of articles included in this review was 89.

RESULTS: Functional and radiological results, complication, survivorship, kinematics and advantages of BKA versus TKA were analyzed.

DISCUSSION AND CONCLUSION: Advantages of a bone-sparing, ligament-sparing, such as BKA, are clearly evident. It seems intuitive that a knee reconstruction that maintains the proprioceptive and kinematic benefits of retaining the cruciate ligaments would be ideal for the treatment of advanced OA of the medial and patellafemoral compartments. Choice of monolithic or modular components remains in debate but the use of single femoral components can lead to early revision. There is a need for a prospective, randomized, long-term outcomes studies comparing BKA with TKA before definitive treatment recommendations can be made.

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Key words: Bicompartamental knee arthroplasty; Knee arthritis; UKA and PFA

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INTRODUCTION

Total knee arthroplasty (TKA) offers high survival and high functional scores when arthritis is affecting the three compartments of the knee; however, TKA does not preserve the bone stock and the

ligaments and these points can represent theoretical disadvantages, particularly for young patients with localized arthritis, with higher demand and higher risk for potential revision^[1,2].

Isolated unicompartmental knee arthroplasty (UKA) and patellofemoral arthroplasty (PFA) are effective for localized arthritis^[3-6]. Use of unicompartmental prosthesis becomes more controversial if the arthritis is present in two compartments of the knee^[6].

Preservation of all the ligaments and minimal bone excision were the main advantages advocated to originally promote the concept of uni or bicompartamental arthroplasty^[7,8].

The commonest form of bicompartamental osteoarthritis (OA) affects both the medial tibiofemoral and the patellofemoral compartment^[9]: bicompartamental knee arthroplasty (BKA) is an alternative treatment option to TKA that is approved by the United States Food and Drug Administration and is gaining interest and may become more relevant in future thanks to techniques improving, prostheses designs changing, and better clinical results achievement^[3,10,11].

Cadaveric and radiographic studies of normal age-associated wear of knee cartilage indicate that structural changes typically progress from the medial condyle to the patellofemoral compartment^[12,13].

BKA is a type of resurfacing surgery where two of the three compartments of the knee (medial tibiofemoral, lateral tibiofemoral or patellofemoral) joint are replaced with preservation of the third^[14,15]. Decreasing surgery time, preservation of both cruciate ligaments and bone stock, and a more “physiological” knee are reported advantages over TKA^[2, 8, 16-19].

BKA of the medial and lateral compartments (Bi-Uni) or medial and patellofemoral joint resurfacing are not commonly performed^[20-24], but there is increasing interest in this kind of surgery; bicompartamental knee arthroplasties have been proposed to bridge the gap between UKA and TKA.

Alternative surgical treatment of bicompartamental arthritis of the knee includes high tibial osteotomy (HTO) and/or tibial tubercle transposition^[25-28], UKA without patella resurfacing or TKA.

One of the primary aims of bicompartamental arthroplasty is to restore more normal knee kinematics and function by preserving the bone stock and the ligaments of the patient^[2,8,16,18,19,21]. Preserving cruciate ligaments knee enhance stability, decrease shear force between implant-bone surface and maintain proprioception^[14,29,30]. Sparing cruciate ligaments and bone stock are considered minimally invasive surgery more than skin incision^[2,8,16,18,19,21].

There are two philosophically different BKA femoral component designs, modular unlinked components or single monolithic with a fixed relationship between the patello- and tibiofemoral components^[8,14,31-34].

Early clinical results of BKA have shown excellent pain relief, knee function, restoration of appropriate knee alignment, less bloodloss, shorter hospital stay and rapid return to normal activity^[6,7-10,35]. But opponents stated that these advantages do not persist after 1 year postoperatively^[36].

Aside from OA involvement and age, limited indication criteria for performing partial knee arthroplasty were established by Kozinn and Scott^[37]: minimum of 90° flexion arc and flexion contracture of less than 5°, angular deformity of not more than 10° of varus or 15° of valgus, and intact ACL. Although, age and weight are not limitations^[31], this procedure is especially suitable for active patients <65 years of age and with a body mass index (BMI) <32. Bicompartamental is, in fact, suitable for young patients with high functional expectations^[3,4,6,8,31]. Main clinical signs are localized

pain while walking and climbing stairs, and effusion.

The Oxford group examined patello femoral joint OA in patients undergoing medial UKA; they recorded that full-thickness cartilage loss on the trochlear surface was observed in 13%, on the medial facet of the patella in 9% and on the lateral facet in 4% of the knees. These Authors affirmed that OA of the medial fact of the patellofemoral joint is not a contraindication to UKA, but that more caution was recommendable in case of lateral patellofemoral degeneration^[38-43]. Incidence of radiographic bicompartamental OA was reported by Ledingham *et al* In their population to be 58%^[44]. Medial and patellofemoral compartment involvement was the dominant pattern and was observed in 50% of the knees and lateral and patellofemoral OA was present in 8% of patients. Heekin *et al* demonstrated that a significant subset of patients from TKA candidates had intact cruciate ligaments. It was established that a significant pool of patients (28%) from TKA candidates could benefit from ACL/PCL preservation and bone sparing BKA^[45]. These authors recorded that women are more likely to be candidates for bicompartamental treatment as compared with men of the same age group and that bicompartamental disease pattern was common in both patients, younger than 65 years (42%) and in patients older than 65 years (58%).

This resurfacing surgery may present lower complications rate (fat embolism, blood loss, infection and venous thromboembolism), uses smaller incisions, requires shorter hospital stay, allows faster return to daily activity, improves range of motion, obtains faster rehabilitation, can obtain a highly functional implant and revision surgery, if required, is simple and at a later date^[21,31,46-49].

This review discuss further the clinical results, the kinematics, the proprioceptive function, the revision rate and the survivorship curve of BKA and if BKA surgery can be an effective and safe alternative to TKA.

METHODS

A systematic literature search was conducted during May and June 2014. The electronic databases searched were: PUBMED/MEDLINE and Cochrane Library. No language or data restrictions were used. The search keywords were bicompartamental knee arthroplasty, BKA, unicompartmental knee arthroplasty AND patellofemoral arthroplasty, unicompartmental knee arthroplasty AND patellofemoral joint, UKA AND PFJ, which appeared in the title, abstract or keyword fields. Initially, 129 articles were found: after removal of duplicates and not related articles, 89 works remained. The full text of each of these articles was read and analyzed to discuss the query

All 89 included articles were analysed for the differences in functional results, radiological results, revision, survivorship and complications of BKA compared with TKA.

RESULTS

Functional results

Although generally considered a more difficult procedure than TKA, BKA provides the same advantages as UKA over TKA as shown by preservation of the intercondylar eminence with both of the cruciate ligaments, restoration of normal kinematic and gait, preservation of bone stock, maintenance of the rotational axis, maintenance of normal leg morphology, normal patella level and tracking and maintenance of normal proprioception^[50-55].

UKA patients have better functional outcomes and increased likelihood of returning to normal functional activity and to low impact sports^[51].

Most total knee arthroplasty designs have kinematics which differ from the normal knee: cruciate retention and patellofemoral joint intact compartments are more likely to provide normal control of knee motion^[56-58]. Intrinsic knee stability is directly linked to functional performance, both in people who practice sport and in those who have had arthroplasty; bicruciate retaining knee arthroplasty might provide more normal knee motions and functional benefits compared with total knee arthroplasty. Retaining both cruciate ligaments in resurfacing knee arthroplasty maintain femoral rollback and tibial internal rotation with flexion^[18,59,60].

For the modular bicompartamental design, Argenson *et al* reported on a series of 104 BKA, performed between 1972 and 1990, satisfactory outcomes in 84% of the overall results^[11].

Cartier *et al* reported on a series of 36 BKA 85% of the overall results were good or excellent^[61,62].

But both of these articles didn't distinguish the group that underwent BKA from the group of UKA, that was also included in the study.

Parratte *et al* published improved knee society knee and functional scores at a minimum follow up of 5 years (mean 12 years; range 5-23)^[35] (Table 1).

Lonner *et al* examined a series of 12 modular BKA performed with robotic assistance with statistically significant improvement^[46] (Table 1).

Heyse *et al* observed in a series of 9 cases, treated with modular BKA, improvement in range of motion and in pain score^[9].

For the monoblock femoral components, less convincing functional and clinical results were observed: these type of arthroplasty consists of a monoblock, cobalt-chrome femoral component that resurfaces the medial condyle and trochlear groove. The tibial component is a modular design constructed of a titanium baseplate with 2 pegs for fixation. A polyethylene component is fixed statically to the tibial tray. The prosthesis is designed to be implanted using cement fixation of both the femoral and tibial components.

Palumbo *et al*^[63] confirmed that pain relief and functional outcomes after BKA in these series were inconsistent. Persistent pain was the primary indication for all revisions and was a common problem in the surviving cases. Poor KSS-F scores were seen in 39% of patients, and only 19% of patient's knees were painless after BKA. More than half of the patients were dissatisfied and stated that they would not repeat the surgery. The mean KSS-F was 65.4 (range, 30-100). Eleven knees (31%) had an excellent result (80-100 points), 6 (17%) had a good result (70-79), 5 (14%) had a fair result (60-69), and 14 (39%) had a poor result.

Tria *et al*^[33] observed in a series of 100 cases, improved knee society knee and functional scores at a minimum follow up of 5

years.

Morrison *et al*^[36] compared functional scores between 21 BKA Journey-Deuce and 33 TKAs. At 3 months postoperatively, both cohorts achieved significant improvements over baseline SF-12 physical and WOMAC pain and physical function scores. BKA cohort obtained significant improvement in WOMAC stiffness at 3 months: the TKA cohort did not achieve this until 1 year postoperatively. In addition, the TKA cohort was able to achieve a significant improvement in SF-12 mental status at 3 months, whereas the BKA cohort did not achieve this by the 2- year follow-up end point. When both cohorts were compared at follow-up, the BKA cohort had significantly better WOMAC pain (81.9±18.2 vs 66.1±23.9) and physical function (78.6±15.5 vs 65.0±19.3) scores at 3 months. There was no significant difference in SF-12 or WOMAC subscores between cohorts at 1 or 2 years postoperatively. Despite differences in preoperative flexion, comparable postoperative ROM was achieved in both cohorts at all study time points.

Radiological results

For the monoblock femoral design, Palumbo *et al*^[63] observed no radiolucencies at the bone-cement interface of the patella or femoral component in any of the cases. Of the 36 tibial components, 22 (61%) demonstrated some degree of progressive radiolucency at the bone-cement interface on PA and lateral radiographs. Seventeen (47%) tibial trays showed grade I radiolucencies, and 5 (14%) demonstrated grade II. Eight (25%) knees were evaluated with triple-phase bone scans because of persistent knee pain at least 6 months (range, 6-17 months) after BKA. All 8 (100%) painful knees demonstrated increased radiotracer uptake at the tibial bone-cement interface, and in no case was it observed at the femoral or patella components.

The significance of these lucencies and whether they represent component loosening are yet to be established, however. Various etiologies have been proposed, including inadequate packing of cement into cancellous bone, bone resorption owing to thermal necrosis during cement polymerization, and micromotion leading to a region of interposed fibrocartilaginous tissue at the bone-cement interface^[64]. Gulati *et al* reported a 67% incidence of radiolucencies occurring 5 years after implantation of Oxford III UKAs^[65]. They reported no association between lucencies and patient factors or clinical outcome, however.

For the modular femoral design, Heyse *et al* showed not progressive radiolucencies around patella (2 cases), tibial (2 cases) and femoral component (1case)^[9]. Five tibial PE inlays showed signs of wear. They also found one osteolysis around tibial fixation screws in an uncemented component. There were no cases of patella baja or alta nor of patella (sub-) luxation.

Table 1 Functional and clinical results after BKA.

Author	Knee score pre-op±SD (range)	Knee score post-op±SD (range)	Function score pre-op±SD (range)	Function score post-op±SD (range)	Mean follow up in years (range)	Pre-op flexion ±SD in degrees (range)	Post-op flexion ±SD in degrees (range)	Prostheses model	No.	Mean age (range)
Paratte <i>et al</i>	42±8 (17-59)	88±2 (58-100)	35±9 (10-57)	79±15 (58-100)	12 (5-23)	118°±9° (100°-150°)	134±6 (120-153)	Modular	71	60
Heyse <i>et al</i>	38.8±24.1	91.8±9.9	30.0±8.9	82.8±17.5	11.8±5.4 (4-17)	107°±12.1°	121.1±14.3	Modular	9	64 ± 5
Lonner <i>et al</i>	39.4	88.1	52.3	82.7	1.3 (1-1.9)	122° (110°-139°)	133 (114-150)	Modular	29	59 (44-73)
Argenson <i>et al</i>	NA	94 (53-100)	NA	NA	18	NA	NA	Modular	104	57
Goodfellow <i>et al</i>	NA	NA	NA	NA	2-6	NA	NA	Modular	114	NA
Stewart <i>et al</i>	NA	NA	NA	NA	1-13	NA	NA	Modular	156	NA
Fuchs <i>et al</i>	NA	NA	NA	NA	1.3	NA	NA	Modular	15	NA
Banks <i>et al</i>	NA	NA	NA	NA	NA	NA	NA	Modular	5	NA
Confalonieri <i>et al</i>	NA	80	NA	83	1.75 (1.5-2)	NA	NA	Modular	22	NA
Tria <i>et al</i>	49	84	57	81	5	122 (115-130)	120	Monoblock	100	70 (49-89)
Palumbo <i>et al</i>	NA	65.4 (30-100)	NA	NA	1.75 (1.2-2.2)	113 (87-130)	120 (110-135)	Monoblock	36	66
Morrison <i>et al</i>						115.5° ± 10.1°		Monoblock	21	63.2 ± 11.5

Table 2 Adverse results after BKA.

Author	Revision rate	Radiolucencies patella	Radiolucencies femur	Radiolucencies tibia
Tria <i>et al</i>	7%	NA	NA	NA
Palumbo <i>et al</i>	14%	None	None	22 (61%)
Paratte <i>et al</i>	39%	20 (28%)	None	25 (35%)
Heyse <i>et al</i>	None	2 (22%)	1 (11%)	2 (22%)
Lonner <i>et al</i>	3.4%	None	None	None
Morrison <i>et al</i>	14.3%			
Goodfellow <i>et al</i>	11.5%	NA	NA	NA
Stewart <i>et al</i>	57%	NA	NA	NA
Fuchs <i>et al</i>	None	NA	NA	NA
Confalonieri <i>et al</i>	None	NA	NA	NA

Parratte *et al* found 25 knees with radiolucencies (less than 1 mm) at the tibial bone-cement interface without any sign of progression after 5 years of followup. No femoral radiolucencies were observed^[35].

Lonner *et al*^[46] found no progressive radiolucent lines, component subsidence, or implant loosening or wear. There was no progression of joint space narrowing in the unresurfaced tibiofemoral compartment, and overall limb alignment was maintained. No cases of patellar instability was observed (Table 2).

Complications

Monoblock femoral components are more difficult to implant and forces the surgeon to compromise the position in the coronal plane to resurface the trochlea and the medial compartment. This leads to transposition of the component and may explain the high incidence of patellofemoral symptoms^[8,17].

Palumbo *et al* showed no intraoperative complications, and no patient received blood transfusion postoperatively^[63]. One patient developed a superficial surgical site infection 7 days after surgery treated successfully with oral antibiotics.

Lonner *et al*^[46] showed no symptomatic venous thromboembolic complication. One lower extremity ultrasound was performed for calf swelling in the six week post-operative period to rule out deep venous thrombosis (DVT); no evidence of DVT was seen on this imaging. No cases of patellar instability and no deep infections were observed. One patient required local debridement for a superficial wound infection.

Heyse *et al*^[9] observed that 2 knees had to be manipulated within 3 weeks after the operation due to stiffness. It remains unclear if this is a coincidental finding in the presented series or if the procedure has a tendency to provoke stiffness^[66]. Within clinical interview and evaluation none of the patients reported instability with walking. Three patients suffered from light pain when standing up from a seated position. No patient described swelling of the operated joint. One patient reported occasional pain of the patella. Six patients had difficulties with squatting and kneeling.

Morrison *et al*^[36] observed 1 manipulation under anesthesia, 2 patellar problems (including subluxation and inferior patellar fracture). The BKA cohort experienced a higher overall complication rate of 28.6% compared with their TKA cohort who experienced

a 6.1% complication rate ($P=0.045$; odds ratio, 6.2) and a near significant trend of increased revision arthroplasty rate ($P=0.054$) at 2 years of follow-up.

Tria *et al*^[33] showed that one patient developed a subluxing patella in deep flexion at 6 weeks after surgery: this patient underwent to surgery room for a lateral release without any complications. No malalignment were found. Ten patients (24%) had persistent anterior knee pain. Two tibial trays fractured in the coronal plane: both underwent revision to a TKA.

Survivorship

TKA produces predictable results^[47], but sacrifices the cruciate ligaments and lateral compartment, and alters the biomechanics of the knee joint^[59]. BKA is less invasive and more tissue-sparing, and thus more appropriate for bicompartamental osteoarthritis.

For modular components, Lonner *et al* observed that one of their cases underwent conversion of a medial UKA/PFA to total knee arthroplasty – without the need for stems or metal augments – at three years for tibiofemoral instability, in the absence of loosening or wear^[46]. No other knees required secondary surgery after the BKA.

Parratte *et al* showed that BKA obtained mixed results in regard to durability with a 17-year survival to revision, radiographic loosening, or disease progression of 54% (95% confidence interval, 0.47-0.61)^[35]. 28 knees underwent revision, 27 for aseptic loosening at a mean of 7.9 years (range, 11 months to 22 years) and one knee for septic loosening at 4 months.

Among the 27 aseptic loosening cases, 20 knees had an isolated loosening of the patellofemoral implant and seven knees had loosening of the medial UKA related to PE wear and loosening of the tibial plateau. Among the 20 loosening of the patellofemoral implant, 15 were uncemented PFA performed before 1989 and five were cemented. Revisions were performed using a conventional posterostabilized TKA with tibial stem and augments when required. The knee with septic loosening required a two-stage revision. This high revision rate may be related to early generations of implants. The results may be improved with enhanced instrumentation and techniques, better PE, and contemporary designs.

Heyse *et al*^[9] showed, after an average follow up of 11.8±5.4 (4-17) years no surgical revisions following bicompartamental arthroplasty.

Palumbo *et al*^[63] in their study performed conversion to TKA in 5 knees (14%), all for persistent pain at the anterior medial aspect of the proximal tibia. Infection was ruled out preoperatively and intraoperatively for all revisions. The mean time to conversion of this subgroup was 19 months (range, 15-26 months). All revisions were performed using primary, cemented TKA components. All components were assessed intraoperatively for stability, and all tibia baseplates were grossly loose and easily explanted. One patient with persistent knee pain was suspected to have a fractured tibial baseplate on preoperative radiographs. She was converted to TKA 15 months after the index procedure. Intraoperatively, the baseplate was found to be fractured transversely through its center, between the 2 pegs, and both halves were grossly loose.

Table 3 BKA vs TKA results .

Author	TKA	BKA	BKA model	Age BKA	Age TKA	Pre-op flexion ± SD in degrees (range) BKA group	Pre-op flexion ± SD in degrees (range) TKA group	Pre-op KSS-total BKA group	Pre-op KSS-total TKA group	Post-op at 24 months KSS-total BKA group	Post-op at 24 months KSS-total TKA group	Revision rate BKA at 2 years	Revision rate TKA at 2 years	Complication rate BKA	Complication rate TKA
Morrison <i>et al</i>	33	21	Monoblock	63.2 ± 11.5	67.18 ± 9.5	115.5° ± 10.1°	107.8° ± 12.5°	NA	NA	NA	NA	14.3%	None	28.6%	6.1%
Shah <i>et al</i>	20	16	Modular	52.1 ± 6.4	65.1 ± 7.5	112 ± 14	96 ± 14	87.3 ± 24	80.8 ± 15.4	169.5 ± 24.1	165.7 ± 26.3	None	None	6.25%	None
Tan <i>et al</i>	12	15	Modular	52 (41-62)	60 (41-63)	109° ± 21	113° ± 13	82.2	95.6	166.7	174.6	None	None	None	None

Morrison *et al* observed 3 revision arthroplasties with conversion to TKA36. The indication for all 3 revisions was persistent pain for greater than 1 year postoperatively. The BKA cohort experienced a higher overall complication rate ($P=0.045$; odds ratio, 6.2) and a near significant trend of increased revision arthroplasty rate ($P=0.054$) at 2 years of follow-up.

Kinematics

The surgical approach for BKA is either to combine UKA and patellofemoral arthroplasty (PFA) in a modular design^[9,35], or to use a non-modular femoral design^[7,8,17,67]. In BKA, the anterior and posterior cruciate ligaments (PCL) can be preserved, and the reasons for retaining the cruciate ligaments in knee arthroplasty design include enhanced stability, decreased shear force between implant-bone interface, more physiological tibiofemoral kinematics, and maintenance of proprioception.

The effect of the ACL on knee joint kinematics after bicruciate-retaining BKA may be different from that in the native knee. Although clinical data do exist^[7,9,35], no *in vitro* data is available to biomechanically evaluate the ability of the ACL to maintain knee joint kinematics after bicruciate-retaining BKA.

Müller *et al* simulated weight-bearing knee flexions to investigate the effect of bicruciate-retaining BKA (BKA+), ACL-resected BKA design (BKA-), and posterior-cruciate retaining TKA on translational and rotational knee joint kinematics^[14]. They show that the translational and rotational knee joint kinematics after bicruciate-retaining BKA resembles that of the native knee. On the other hand PCL-retaining TKA results in less rotation and similar translation during a partially weight-bearing flexion. They suggest that, provided functional ligamentous structures, bicruciate-retaining BKA is a suitable treatment option for medial and patellofemoral osteoarthritis of the knee joint with advantages in rotational characteristics compared to TKA^[68-71].

Franz *et al*^[72] showed that BKA patients performed all motor tasks at a slower cadence when compared to controls (non-involved limb). For level walking, this finding contrasts with the study of Wang *et al*^[67] who found no differences in self-selected walking speed between controls and patients with the same prosthesis design, i.e. the Journey Deuce bicompartamental knee replacement (Smith & Nephew Inc., Memphis, TN, USA). Franz *et al*^[72] believe this to be associated with the higher post-operative functional and knee society scores reported in their study. Nevertheless, also in TKA patients, reduced preferred walking speeds have been reported despite an improved functionality and reduced pain following surgery^[73-75]. This finding has been hypothesized to be correlated with a loss in quadriceps strength^[76].

Although peak knee flexion in the first half of swing is reduced for the majority of motor tasks when comparing the patients' involved to their non-involved sides, they contrastingly found better knee extension at push-off during walking in the operated limb. Although not significant, they also show this effect for walking followed by a sidestep, step ascent and descent. It is thought to result from retention at the non-involved side of the pre-operative 'stiff knee' gait pattern^[67,76-78].

The better knee extension might additionally indicate a significant improvement and stabilization of the gait pattern following BKA^[79-80].

This analysis demonstrated that, despite the presence of differences indicative for retention of preoperative motion patterns and/or remaining compensations, knee joint kinematics in BKA limbs replicate, for a large range of daily-life motor tasks, the kinematics of the contra-lateral non-affected limbs and healthy controls to a similar extent as they are replicated within both these control groups.

Similarly, outcome and kinematic studies suggest maintaining the anterior cruciate ligament in bicompartamental knee arthroplasty may be advantageous in terms of survivorship^[81-83], stairclimbing ability, patient satisfaction, and joint kinematics^[8,21,59,60,75,81].

Wang *et al*^[67] in their study performed gait analysis and isokinetic strength testing indicated that normal knee mechanics and gait are restored after BKA. Recipients can commonly rise independently and ascend stairs reciprocally^[10,67]. Despite encouraging early results, several recent studies have questioned the role of monolithic BKA, citing a relatively high incidence of patellofemoral complications and need for secondary surgeries^[33,36,63]. These reported outcomes are likely related to challenges and compromises in sizing and orienting the femoral component vis-a-vis the mechanical axes and morphologies of each compartment^[71]. On the other hand, a modular, unlinked trochlear and medial (or lateral) femoral condylar prosthesis (modular BKA) allows the individual compartmental resurfacing procedures to be performed "independently" of the other, facilitating independent orientation and alignment of the individual components relative to the critical axial and rotational axes of the distal femur^[46].

Argenson *et al* reported on short-term experience with seventeen unlinked UKA and PFA, observing mild or no pain and greater than 120° of flexion in all patients^[10]. In that series, all patients were able to rise unassisted and ascend stairs in a reciprocal manner. The mean ROM increased from 107° pre-operatively to 121° ($P=0.04$) at final follow-up^[10]. Similar to other studies of this kinematic-preserving procedure, the mean ROM of patients in Lonner *et al*^[46] study's significantly improved, and 97% of knees showed greater than 120° of flexion at the latest follow-up. In a series by Parratte *et al*^[35], six of seventy-seven knees treated with combined medial UKA and PFA developed asymptomatic progression of the lateral compartment osteoarthritis at a mean twelve-year follow-up. No revisions were necessary for arthritis progression and in those surviving prostheses, and there was substantial improvement in pain, function, and knee scores. However, in that series, twenty-seven knees failed at a mean of eight years (range, 11 months to 22 years) due to aseptic loosening of the trochlear component ($n=20$) and the tibial component ($n=7$). Of the trochlear components that failed, fifteen were cementless. Despite these failures, the authors continue to advocate for modular BKA, recognizing that cementless trochlear component fixation, crude instrumentation and techniques, and poor polyethylene quality and implant designs were responsible for aseptic loosening in the series^[35].

BKA vs TKA

TKA for advanced osteoarthritis generally provides good results. However, partial knee arthroplasty may be recommended for young patients who want an active life.

Tan *et al*^[34] in their study compared 15 BKA with 12 TKA: the prosthesis for BKA was the Zimmer Unicompartmental High Flex Knee prosthesis in conjunction with the Zimmer Gender Solutions Patellofemoral Joint System, whereas the prosthesis for TKA was the NexGen LPS-Flex Mobile Knee System. In both groups, the patella was resurfaced with the NexGen Polyethylene Patellar Button. BKA resulted in less intraoperative blood loss and greater postoperative range of movement, owing to unaltered knee biomechanics.

This contrasts with the early experience of the monolithic Journey-Deuce device, which resulted in higher complication and revision rates^[63]. In their study, no patient had any complication after 2 years^[34].

Morrison *et al* compared 21 BKAs (Deuce Journey knee arthroplasty system, Smith & Nephew Orthopaedics, Memphis, Tenn) with 33 TKAs (PS NexGen, Zimmer Inc, Warsaw, Ind)^[36].

Although both BKA and TKA result in less pain and improved physical function in the early postoperative period, BKA lead to a greater knee extension. They observed, however, that these advantages over TKA do not persist past 1 year postoperatively; and when adjusting for age, sex, BMI, and baseline status, the early postoperative advantages offered by BKA are minimal. The only significant difference they observed between these procedures was that, in the early postoperative period, patients experience a more rapid and drastic reduction in stiffness after BKA.

It is possible that the use of a posterior cruciate retaining device was a potential cause of the early stiffness noted in the TKA cohort. Balancing ligaments in cruciate-retaining devices presents its own set of challenges that can potentially cause stiffness. Inadequate release of the posterior cruciate ligament can limit flexion as can over-release, which, through erratic kinematics, can induce a paradoxical roll forward to limit flexion^[66]. It is unlikely that these technical errors resulted in the observed stiffness disparity between cohorts, as the study surgeons methodically assessed soft tissue balance in all cases. More plausible is that retention of the anterior cruciate ligament in BKA likely provides a protective mechanism against the limited flexion previously observed in posterior cruciate-retaining TKAs^[84]. In addition, it should be noted that this trend disappeared by the 1-year follow-up time point.

Observed complications in the BKA cohort included 1 manipulation under anesthesia, 2 patellar problems (including subluxation and inferior patellar fracture), and 3 revision arthroplasties with conversion to TKA. The indication for all 3 revisions was persistent pain for greater than 1 year postoperatively. It is unclear whether these failures are the result of poor patient selection^[36].

Observed complications in the TKA cohort were limited to a single patellar problem (patellar tendinitis) and 1 case of deep vein thrombosis. The BKA cohort experienced a higher overall complication rate ($P=0.045$; odds ratio, 6.2) and a near significant trend of increased revision arthroplasty rate ($P=0.054$) at 2 years of follow-up^[36].

Shah *et al*^[85] compared 16 BKAs (Zimmer Gender solutions patellofemoral joint and Zimmer Unicompartmental Knee implants, Zimmer Inc, Warsaw, Ind) with 20 TKAs (CR NexGen cruciate retaining, Zimmer Inc, Warsaw, Ind). They observed that a modular femoral component that allows independent resurfacing of the medial femoral condylar and trochlear surface may be a better alternative for BKA. Although BKA offer better outcomes compared with TKA, they didn't find any significant difference in terms of clinical and functional outcome scores between the two groups at any point in time. In terms of KSS- function, KOOS-stiffness and ADL scores, the BKA group was consistently better than the TKA group at all points in time but did not show statistical significance. Better function in the BKA group may be a result of its bone and ligament preserving nature. Postoperative knee ROM and the improvement in ROM were significantly greater in the BKA group. The incidence of complications and the outcome scores were not significantly different between the two groups (Table 3).

Chung *et al*^[76] in their study compared post operative quadriceps and hamstrings muscle strength, position sense and physical performance in patients who underwent either BKA or TKA: they observed that, although BKA seemed to be theoretically more favourable in post-arthroplasty knee kinematics with preservation of more bone stocks and cricate ligament, it was not superior in recovery of knee muscle strength as well as physical performance at 1 year compared with TKA. Compared to normal knee, ACL-deficient knee

results in significantly less isokinetic quadriceps muscle strength, which in turn is related to reductions in the dynamic quadriceps knee function during strenuous activities such as jogging or stair climbing. After TKA, knee flexor (hamstrings) strength gradually improves up to the level of the uninvolved knee within 1 year or just keeps maintaining the lower level compared to the control. On the contrary, knee extensor (quadriceps) strength is reduced even for the 2-year period after TKC compared with the knee strength in healthy control subjects. They showed no significant difference in knee muscle strength and in joint position sense between TKA and BKA group.

In terms of physical performance, BKA showed improvement in 6-min walk test only, whereas TKA showed improvement in stair climbing as well as 6-min walk test, implying that TKA performs functionally even better than BKA.

DISCUSSION

Treatment of medial and patellofemoral OA with a minimally invasive procedure such as BKA allows for the targeted arthroplasty of pathologic compartments while sparing normal bone and ligaments. This type of partial knee arthroplasty has been proposed to result in a more rapid return to normal activity, increased stability, decreased pain, restore to normal kinematics and proprioceptive function^[2,17-19,36].

In appropriately selected patients with bicompartamental knee arthritis of the medial or lateral and patellofemoral compartments (or painful chondromalacia in the "second" compartment) modular BKA is a legitimate alternative to TKA, and has superior outcomes and fewer complications than monolithic BKA^[3,86,87]. Since the procedure is relatively new, mid-term and long-term outcomes have still to be established. Further study will determine whether long-term durability compares to that of TKA or single compartment arthroplasty (such as UKA) for bicompartamental disease and characterize the disease-free survivorship of the un-resurfaced compartment^[88,89].

Preservation of the ACL and its mechanoreceptors has been made responsible for better functional results^[8]. Patients with TKA achieve worse proprioceptive results than normal age-matched controls, but they achieve better proprioceptive abilities than osteoarthritic age-matched controls^[18,30,58].

Use of a monolithic femoral component for trochlear-medial femoral condylar resurfacing faces some challenges. The varus-valgus alignment of the component is determined by the apposition of the lateral transitional edge of the trochlear component with the lateral femoral condyle. The location of the transition zone is based on the rotational orientation of the cutting block, the depth of the femoral cut and the valgus orientation of the distal femoral cut^[5,17]. With this type of BKA, persistent knee pain and reduced function were observed commonly, and there was an unacceptably high incidence of conversion to TKA^[36,63].

In modular BKA the size of the gap between the transitional edge of the trochlear component and the proximal edge of the femoral component of the UKA may vary. Problems with the transitional gap have not been found with independent resurfacing^[3,5,6].

Both BKA and TKA result in less pain and improved physical function in the early postoperative period, with better clinical results for BKA. We observed, however, that these advantages over TKA do not persist past 1 year postoperatively; and when adjusting for age, sex, BMI, and baseline status, the early postoperative advantages offered by BKA are minimal. The only significant difference we observed between these procedures was that, in the early postoperative period, patients experience a more rapid and drastic

reduction in stiffness after BKA^[36].

Improvement in implant design and fixation may improve these results in the future, particularly concerning the patellofemoral joint.

From the studies that we analyzed we found that there is no upper age restriction as long as the appropriate criteria are met: we believe that a correct indication is fundamental and that patients older than 65 years could have also other advantages from this type of treatment, such as less blood loss, earlier mobilization and less hospital stay.

The limitations of this review are that only limited peer reviewed literature is available on this subject. The few papers have small size of the study cohorts, the surgeon's experience is limited with this novel implant; in some cases they have long follow up but on small series of patients and do not discuss the modern design of implants we are using today. Prospective randomized study should be set up. The clinical relevance of this review can be found in the good functional and biomechanical results found in most study, especially in which use modular BKA.

We believe that bicompartamental knee replacement can be an important chance treatment for knee arthritis for explained good functional results compared to TKA. New implants and appropriate instrumentation can improve long term results.

CONCLUSION

The advantages of a bone-sparing, ligament-sparing, such as BKA, are clearly evident. It seems intuitive that a knee reconstruction that maintains the proprioceptive and kinematic benefits of retaining the cruciate ligaments would be ideal for the treatment of advanced OA of the medial and patellafemoral compartments.

Choice of monolithic or modular components remains in debate but the use of single femoral components can lead to early revision.

There is a need for a prospective, randomized, long-term outcomes studies comparing BKA with TKA before definitive treatment recommendations can be made.

CONFLICT OF INTERESTS

There are no conflicts of interest with regard to the present study.

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