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Clinical results and 12-year survivorship of the Physica ZUK unicompartmental knee replacement☆

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ABSTRACT

Background: The Physica ZUK is a fixed bearing unicompartmental knee replacement. The purpose of this prospective cohort study was to determine the mid-term clinical outcomes and survivorship of the Physica ZUK.

Methods: From 2005 to 2017 a total of 466 Physica ZUK prostheses were implanted in 398 patients by a single surgeon. The series consisted of 452 medial and 14 lateral unicompartmental knee arthroplasties (UKAs). Three hundred and sixty-seven medial UKAs with a minimum follow-up of two years (median 5.4 years) and 14 lateral UKAs with a minimum follow-up of 18 months (median 5.3 years) were analysed using the Knee Society Knee Score (KS-KS) and Function Score (KS-FS) at latest follow-up. Kaplan Meier survivorship analysis was performed with implant revision as the end point.

Results: Mean age at the time of surgery was 67 (range 42–88) and 58 (47–69) years for patients undergoing medial and lateral UKA respectively. For medial UKAs the KS-KS and KS-FS improved significantly compared to the pre-operative values from 53.6 and 54.0 to 93.4 and 91.0 respectively ($p = 0.0001$). For lateral UKAs the KS-KS and KS-FS improved significantly from 46.4 and 48.7 to 91.3 and 93.1 respectively ($p = 0.0001$). Six cases of medial UKA were revised to total knee arthroplasty. Medial implant survivorship was 97.9% (95% confidence intervals, 95.6–99.0%) at both five and 10 years. No lateral implants were revised.

Conclusion: This prospective cohort study shows encouraging short to mid-term clinical results and survivorship for the Physica ZUK unicompartmental knee replacement.

1. Introduction

Unicompartmental knee arthroplasty (UKA) is an established treatment for a selected group of patients with unicompartmental knee osteoarthritis (OA). Results of UKA have improved with better understanding of knee kinematics [1] and alignment, implant design, instrumentation, surgical technique and strict patient selection [2,3].

Advantages of UKA compared to total knee arthroplasty (TKA) include preservation of bone, cartilage and soft tissue, in particular the anterior cruciate ligament (ACL), which often leads to a better range of motion and faster recovery [4]. There is evidence UKA is associated with reduced blood loss compared to TKA and a reduced risk of requiring blood transfusion [5,6]. There is also a reduced risk of infection, thrombo-embolic events and mortality [7]. Compared to TKA patients with a

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unicompartmental replacement have better patient reported outcome scores [8–10] and a more physiological gait pattern [11]. UKA reduces length of hospital stay [12] and is associated with better cost-effectiveness than TKA [13]. Concerns however, have been raised about the increased revision rates (up to twice as high) compared to TKA in National Joint Registries [14,15].

The published literature on UKA is dominated by studies evaluating mobile bearing designs. The Physica ZUK (Lima Corporate, Udine, Italy) is a fixed bearing implant which was introduced in 2005 and can be seen as an evolution of the Miller–Galante (M/G®) Unicompartmental Knee system (Zimmer, Warsaw, Indiana) [16–19]. Compared to the M/G® the ZUK implant has an extended posterior femoral condyle to allow deeper flexion, the ZUK also has increased tibial component poly-ethylene coverage. Implant design and manufacturing have not changed since its introduction. While the results of the M/G® have been published there is a paucity of literature reporting the results of the ZUK.

The purpose of this prospective cohort study is to present the mid-term clinical and survivorship results of a consecutive series of patients who underwent either medial or lateral compartment UKA with the ZUK.

2. Patients and methods

All patients undergoing UKA with a ZUK implanted into either the medial or lateral tibiofemoral compartment at our institution since 2005 have been included in this study. Institutional review board approval was granted for this prospective cohort study and all patients gave informed consent for their inclusion.

2.1. Indications

The indications for UKA in all cases were unicompartmental symptoms and signs which had not responded to at least six months of conservative treatment, less than 10° of fixed flexion, at least 90° of knee flexion range, a correctable deformity in the coronal plane and an intact ACL. Radiographic evidence of medial or lateral unicompartmental OA (Kellgren and Lawrence III or IV) was also a requirement for patients to be offered a UKA [20]. Asymptomatic radiographic evidence of patellofemoral OA and chondrocalcinosis were not considered to be contraindications for UKA [21].

Figure 1. Physica ZUK (Lima Corporate, Udine, Italy) fixed bearing metal backed unicondylar left medial or right lateral prosthesis.

2.2. Implant

In all cases the Physica ZUK metal backed prosthesis was implanted. The ZUK is a fixed bearing prosthesis consisting of a poly-radial cobalt-chrome alloy femoral component with twin pegs, a titanium tibial tray with two lugs and a keel and a poly-ethylene liner, which clicks into the tibial tray with anterior and posterior lips (Figure 1). The poly-ethylene liner is flat, resulting in a non-congruent, round-on-flat articulation. The femoral and tibial components are inserted using bone cement. The prosthesis can be used for the medial or lateral compartment using the same instrumentation.

2.3. Surgical technique

All operations were performed by the senior author. Medial UKA was performed using a minimally invasive medial parapatellar approach. An entry hole was drilled just medial to the midline in the femoral trochlea and the intramedullary technique was used to resect the distal femur at six degrees valgus. The tibia was cut at five degrees posterior slope using an extramedullary jig referenced two millimetres below the most worn articular surface. Lateral UKA was performed using an extended lateral parapatellar approach. Preparation of the femur was performed using the same technique as for medial UKA. The posterior tibial slope cut was reduced by adjusting the extramedullary jig and the sagittal tibia cut was rotated internally compared to the technique for medial UKA. The coronal (varus/valgus) deformity was under-corrected for both medial and lateral cases. All components were implanted using Palacos® bone cement (Heraeus Medical, Wehrheim, Germany). A high thigh tourniquet was used in all cases and tourniquet time was recorded. From 2005 to 2009 patients were admitted one day pre-operatively, after this time period patients were admitted on the day of surgery. In 2013 intraoperative local anaesthetic infiltration with 120 ml of two milligrammes per millilitre ropivacaine and same day mobilisation were introduced.

2.4. Subjects

Since June 2005, 466 Physica ZUK prostheses have been implanted in 398 patients. Medial UKAs were performed in 452 knees and lateral UKAs in 14 (Figure 2). Nine patients had simultaneous bilateral procedures under a single anaesthetic and another 59 patients had staged bilateral procedures at a mean interval of 21 months (range two - 107).

2.5. Outcome measures

Clinical outcomes and knee flexion were assessed by an independent observer (orthopaedic nurse practitioner) using the Knee Society Score (KSS) pre-operatively and at six months, one, two, five and 10 years post-operatively. The KSS consists of a Knee Score (KS-KS) and a Function Score (KS-KF) both of which are scored from 0 to 100 [22]. For medial UKAs, 367 patients with a minimum follow-up of two years were analysed (range 24–150 months, median 5.4 years follow-up). For lateral UKAs, 14 patients with a minimum of 18 months of follow-up were analysed (range 18–118 months, median 5.3 years). Scores at the latest follow-up were compared to the pre-operative scores. Details of revision of any implant or any other surgical procedures performed on knees included in the study were recorded prospectively. This information was cross-checked with the National Joint Registry (NJR) to ensure no revisions were missed.

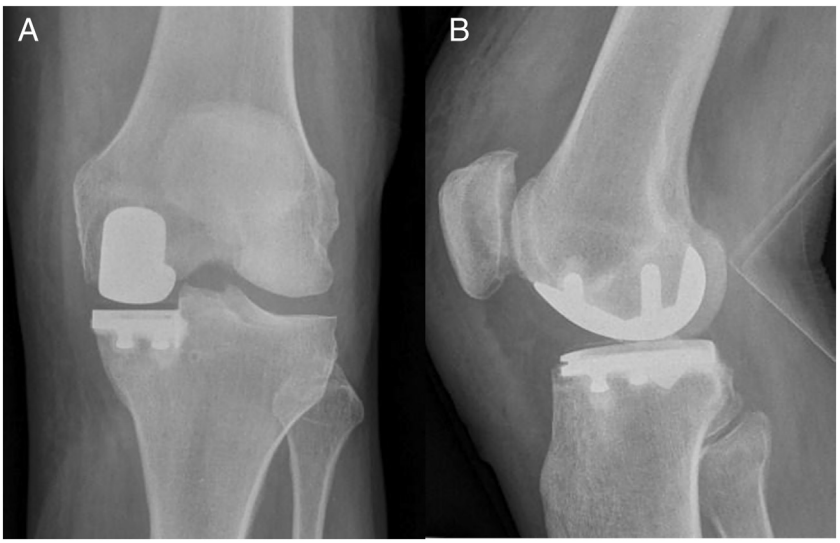

Figure 2. Radiographs of a ZUK implanted into the medial compartment. A. Anterior–posterior radiograph. B. Lateral radiograph of left knee.

Table 1
Demographic data of medial and lateral unicompartmental knee arthroplasties.

	Medial n = 452	Lateral n = 14
Age, mean (range)	67 (42–88)	58 (47–69)
Gender	Male 232	Male 7
	Female 220	Female 7
Kellgren and Lawrence grade	III 238	III 9
	IV 214	IV 5
Laterality	Right 219	Right 9
	Left 233	Left 5
BMI (kg/m^2), mean ± SD (range)	29.3 ± 4.0 (20–48)	28.3 ± 3.5 (22–35)

Table 2
Clinical outcome scores and range of knee flexion (degrees) for medial unicompartmental knee arthroplasties (mean ± standard deviation: p-value displayed for unpaired t-test).

	KS-KS	KS-KF	Flexion
Pre-op	53.6 ± 10.1	54.0 ± 12.8	117.4 ± 10.9
Latest follow-up	93.4 ± 11.5	91.0 ± 15.8	126.4 ± 12.1
p-Value	0.0001	0.0001	0.0001

2.6. Statistical analysis

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) v 25.0 (SPSS Inc., Chicago, Illinois). Clinical outcome scores were compared using the unpaired t-test, a p-value <0.05 was considered statistically significant. Kaplan–Meier survivorship analysis was performed with joint revision as the endpoint, defined as an operation in which at least one of the components or the bearing surface was changed.

3. Results

3.1. Patient demographics

Patient demographics are displayed in Table 1. Seventy-four percent of patients had macroscopic degenerative changes in the patellofemoral joint on per-operative inspection but as per the selection criteria had no patellofemoral symptoms and so proceeded to have a UKA.

3.2. Medial clinical outcomes

The KSS and flexion results for medial UKAs are displayed in Table 2. For medial UKAs the mean KS-KS and KS-FS improved significantly at latest follow-up compared to pre-operative values from 53.6 ± 10.1 and 54.0 ± 12.8 to 93.4 ± 11.5 and 91.0 ± 15.8 (standard deviation) respectively (p = 0.0001) (Figure 3). There was a statistically significant increase in mean knee flexion in medial UKAs from 117.4 ± 10.9 to 126.4 ± 12.1° (standard deviation) (p = 0.0001).

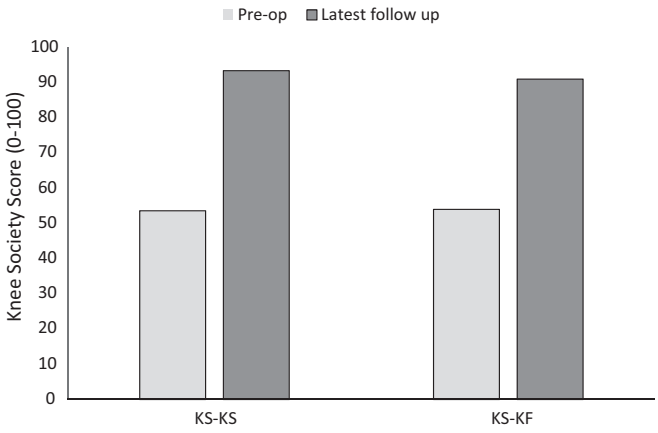

Figure 3. Bar chart showing mean pre- and post-operative Knee Society Knee and Function scores for medial UKAs.

Table 3
Clinical outcome scores and range of knee flexion (degrees) for lateral unicompartmental knee arthroplasties (mean ± standard deviation: p-value displayed for unpaired t-test).

	KS-KS	KS-KF	Flexion
Pre-op	46.4 ± 9.2	48.7 ± 5.6	115.7 ± 11.2
Latest follow-up	91.3 ± 12.6	93.1 ± 7.4	123.6 ± 10.7
p-Value	0.0001	0.0001	0.1269

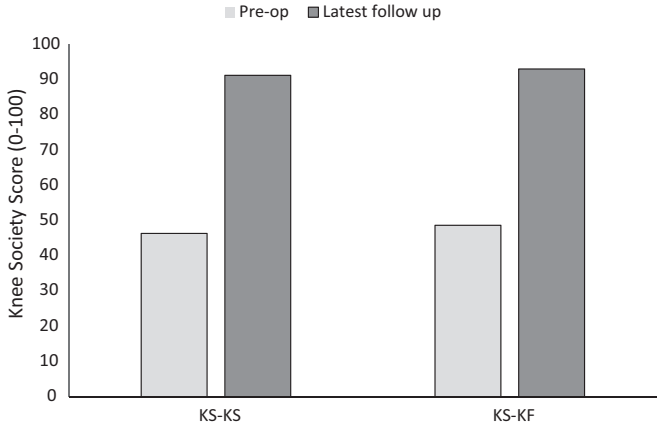

Figure 4. Bar chart showing mean pre- and post-operative Knee Society Knee and Function scores for lateral UKAs.

3.3. Lateral clinical outcomes

The KSS and flexion results for lateral UKAs are displayed in Table 3. For lateral UKAs the mean KS-KS and KS-FS improved significantly at latest follow-up compared to the pre-operative values from 46.4 ± 9.2 and 48.7 ± 5.6 to 91.3 ± 12.6 and 93.1 ± 7.4 respectively ($p = 0.0001$) (Figure 4). For lateral UKA there was a non-statistically significant increase in mean knee flexion from 115.7 ± 11.2 to 123.6 ± 10.7° ($p = 0.1269$).

3.4. Medial revisions and complications

Six medial implants were revised to TKA after a mean of 24 (range 6–54) months (Table 4). Two medial UKAs were revised due to progression of OA in the lateral compartment 18 and 54 months after UKA and one for disease progression in the patellofemoral compartment 42 months after UKA. One patient developed arthrofibrosis after excessive bleeding and was revised after one year to TKA with fibrolysis. In these four cases the unicondylar replacement was revised to a standard primary total knee replacement. Another patient had a medial collateral ligament rupture one month post-operatively and the knee became unstable after attempted conservative treatment; in this case a constrained revision prosthesis was used. In the sixth case the medial tibial condyle started to subside three months after insertion of the UKA. It is unclear whether there was a fracture at the time of implantation, however no fracture was identified on the postoperative radiographs. This case was revised to a TKA with a stemmed tibial component with elevation and fixation of the medial tibial fragment nine months after UKA. There was one case of early deep infection with *Staphylococcus aureus* three weeks post-operatively, which was salvaged with debridement, polyethylene exchange and a six-month treatment course of antibiotics. Other serious complications included one patient who developed a pseudoaneurysm of the medial genicular artery who underwent embolisation by interventional radiology six months after

Table 4
Cases of medial unicompartmental knee arthroplasty revised to total knee arthroplasty.

Age	Sex	Time (months)	Reason for revision
77	F	9	Tibial condyle subsidence
75	M	12	Arthrofibrosis
84	F	13	Medial collateral ligament rupture
54	F	18	Progression of OA in lateral compartment
77	M	42	Progression of OA in patellofemoral compartment
67	F	54	Progression of OA in lateral compartment

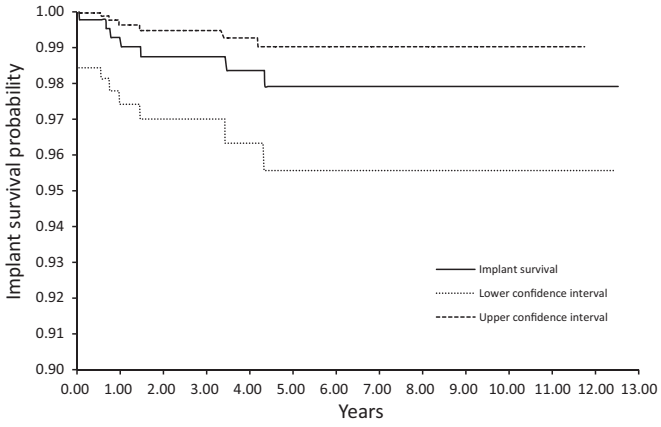

Figure 5. Kaplan–Meier medial implant survivorship plot with 95% upper and lower confidence intervals.

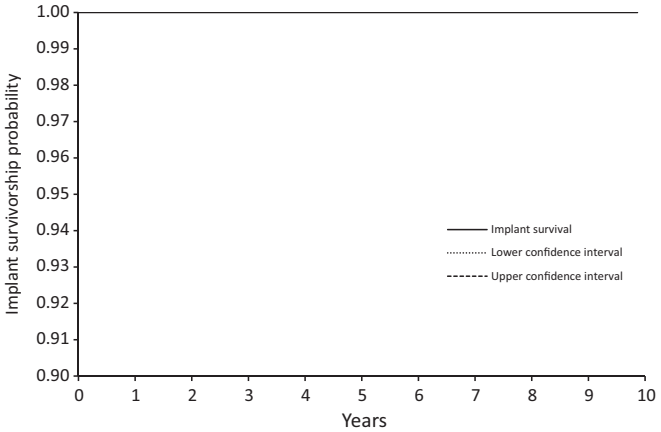

Figure 6. Kaplan–Meier lateral implant survivorship plot with 95% upper and lower confidence intervals.

primary medial UKA. Including the liner exchange seven cases of revision were included in the survival analysis of medial UKAs. Kaplan–Meier survivorship for medial UKA was 97.9% (95% confidence intervals, 95.6–99.0%) at five and 10 years (Figure 5).

3.5. Lateral revisions and complications

No lateral UKAs underwent implant revision and no complications were recorded in any patients following lateral UKA (Figure 6).

3.6. Learning curve

There was no significant learning curve in this series, with the KSS gains of the first 20 medial UKAs being similar to the mean cohort results (Table 5).

Table 5
Increase in Knee Society Scores for the first 20 medial unicompartmental knee arthroplasties (UKAs) compared to all medial UKAs in the series at latest follow-up (mean ± standard deviation: p-value displayed for unpaired t-test).

	First 20 cases	Cohort	p-Value
KS-KS gain	40.8 ± 13.6	39.8 ± 14.9	0.7693
KS-FS gain	41.6 ± 19.2	37.0 ± 18.2	0.2330

4. Discussion

Use of UKA has grown in popularity [15,23], but concerns have been raised due to increased revision rates compared to TKA. Results have improved with strict indications, better implants and improved surgical technique. Good results are also associated with performing sufficient numbers of operations each year [24,25]. In the United Kingdom 62% of surgeons perform less than 10 UKAs per year (17% of all cases) and the British Association for Surgery of the Knee has suggested surgeons carrying out this procedure should perform at least 10 UKAs each year.

Our study has shown that the ZUK has excellent survival and clinical results when used for either medial or lateral UKA. In this study survivorship of medial UKA was 97.9% at both five and 10 years following surgery. This is comparable to the survivorship presented by the only other four studies which report survivorship of the ZUK in the medial compartment. Winnock et al. reported five- and 10-year survival of 97.2% and 94.2% respectively in a mixed series of 460 metal-backed and all-poly tibial component ZUKs [26]. Baur et al. reported 95.2% five-year survival in 132 metal-backed ZUKs [27], Vasso et al. reported 97.1% survivorship in 164 metal backed ZUKs with a mean follow-up of 7.5 years [28] and Biswas et al. reported 96.5% 10-year survival in a series of 95 fixed bearing medial UKAs consisting of seven M/G® and 88 ZUK prostheses [29]. The survivorship results are also comparable to multiple longer term case series of the Oxford mobile bearing [30–36] and the M/G® UKA implanted into the medial compartment [16–19]. In the NJR for England and Wales the combined five-year survival rate for medial and laterally implanted ZUKs is 96.3% which is the highest for all unicondylar prostheses [15].

The clinical results from the present study for medial UKA are in line with the other four case series examining medial ZUKs. Baur et al. reported a five-year median KS-KS of 99 (range 50–100) and a median KS-KF of 100 (range 60–100) [27]. Vasso et al. reported a mean KS-KS of 87.2 (range 71–100) and a mean KS-FS of 89.1 (range 75–100) with mean follow-up of 7.5 years [28]. Biswas et al. reported a mean KSS of 95.1 at latest follow-up. Winnock et al. used the Oxford Knee Score to evaluate clinical outcomes and reported a mean score of 43.3 with a mean follow-up of 5.4 years [26,37]. The clinical results presented in our study also compare favourably to results published for the M/G® [17,38] and Oxford mobile bearing implants [30–34]. Knee flexion achieved at last follow-up for medial UKA was in keeping with the results published for the ZUK [27–29] as well as for case series of other fixed and mobile bearing medial UKAs [16,18,19,33,34,38].

All seven cases of revision involved medial UKA. There was one case of early deep infection which occurred in a medially implanted ZUK, this was salvaged with debridement, polyethylene exchange and antibiotics. This is in keeping with the revision rate for infection for UKAs reported by the NJR for England and Wales [15,39]. The most common reason for revision to TKA was progression of OA with two cases in the lateral compartment and one in the patellofemoral compartment. To date no cases have required revision for implant failure but longer-term surveillance will be required. Dislocation of the polyethylene bearing, reported in mobile bearing designs [40,41] is avoided in fixed bearing implants.

There were no cases of revision of lateral UKA during this study. Lateral UKAs comprised three percent of the total cohort of UKAs studied in this series. Van der List et al. conducted a systematic review comparing survivorship of medial and lateral UKAs and reported 93.2% and 91.4% survivorship at five and 10 years in 3296 lateral UKAs and determined there was no significant difference between survivorship of medial compared to lateral UKA [42]. In a study analysing data from the NJR for England and Wales, Baker et al. reported a five-year survivorship of 93.1% and 93.0% in 30,795 medial and 2052 lateral UKAs respectively [39]. Kim et al. has published the largest case series of ZUKs implanted into the lateral compartment and reported 96.7% survivorship of 30 ZUKs (one revision) at a mean follow-up of 3.2 years [43].

The clinical scores for lateral UKAs in our study are similar to those reported by other case series which have assessed the clinical outcomes following lateral UKA using other implant designs [44–49]. Kim et al. reported post-operative KS-KS and KS-FS of 86.0 and 92.4 respectively at a minimum of two years of follow-up for 30 lateral ZUKs [43]. Lateral UKA is a more technically challenging procedure compared to medial UKA due to difficulties with exposure and differences in anatomy and kinematics in the medial and lateral compartment [14,44,48,50–52]. The technical difficulties are compounded by the lower frequency with which lateral UKA is performed [53]. One of the advantages of the ZUK is that it can be implanted into the medial or lateral compartment (Figure 1). The use of a fixed bearing implant for lateral UKA eliminates the risk of polyethylene bearing dislocation. In some case series bearing dislocation is reported to be even higher for mobile bearing implants used in the lateral compartment compared to the medial compartment [54–58].

Proposed advantages in terms of wear behaviour in mobile bearing compared to fixed bearing UKAs have not been shown by a number of biomechanical studies. In vitro biomechanical wear studies comparing mobile versus fixed bearing UKAs performed by Brockett et al. [59], Kretzer et al. [60] and Burton et al. [61] all showed increased wear rates in mobile bearing compared with fixed bearing unicondylar prostheses. Kretzer et al. reported 'pronounced' abrasive back side wear on the inferior surface of the polyethylene tibial inserts in mobile bearing designs.

Learning curves have been reported for surgeons becoming familiar with some UKA designs [62,63], however that was not the case in this series. The KSS for the first 20 cases of medial UKA in this series were comparable with the mean results of the entire case series of medial UKA at latest follow-up.

There are a number of limitations associated with this study. Firstly, it is a single surgeon series with high volume experience in UKA. Secondly, only one clinical score, the KSS, was used to evaluate clinical outcomes. And thirdly, only a small number of patients underwent lateral UKA and therefore results for lateral UKA should be interpreted with caution.

5. Conclusion

This prospective cohort study of 452 medial and 14 lateral ZUKs presents encouraging short to mid-term results. The clinical results compare favourably with other unicondylar implants and support the good five-year survivorship in National Joint Registries. Patient selection remains vitally important to outcomes.

References

[1] Hernigou P, Deschamps G. Alignment influences wear in the knee after medial unicompartmental arthroplasty. Clin Orthop Relat Res Jun 2004;423:161–5.
[2] Kozinn SC, Scott R. Unicondylar knee arthroplasty. J Bone Joint Surg Am Jan 1989;71(1):145–50.
[3] Thornhill TS. Unicompartmental knee arthroplasty. Clin Orthop Relat Res Apr 1986;205:121–31.
[4] Price AJ, Webb J, Topf H, Dodd CA, Goodfellow JW, Murray DW, et al. Rapid recovery after Oxford unicompartmental arthroplasty through a short incision. J Arthroplasty Dec 2001;16(8):970–6.
[5] Schwab P-E, Lavand'homme P, Yombi JC, Thienpont E. Lower blood loss after unicompartmental than total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc Dec 26 2015;23(12):3494–500.
[6] Siman H, Kamath AF, Carrillo N, Harmsen WS, Pagnano MW, Sierra RJ. Unicompartmental knee arthroplasty vs total knee arthroplasty for medial compartment arthritis in patients older than 75 years: comparable reoperation, revision, and complication rates. J Arthroplasty Jun 2017;32(6):1792–7.
[7] Liddle AD, Judge A, Pandit H, Murray DW. 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. Lancet Oct 18 2014;384(9952):1437–45.
[8] Fabre-Aubrespy M, Ollivier M, Pesenti S, Parratte S, Argenson J-N. Unicompartmental knee arthroplasty in patients older than 75 results in better clinical outcomes and similar survivorship compared to total knee arthroplasty. A matched controlled study. J Arthroplasty Dec 2016;31(12):2668–71.
[9] Lum ZC, Lombardi AV, Hurst JM, Morris MJ, Adams JB, Berend KR. Early outcomes of twin-peg mobile-bearing unicompartmental knee arthroplasty compared with primary total knee arthroplasty. Bone Joint J Oct 2016;98–B(10 Supple B):28–33.
[10] Zuiderbaan HA, van der List JP, Khamaisy S, Nawabi DH, Thein R, Ishmael C, et al. Unicompartmental knee arthroplasty versus total knee arthroplasty: which type of artificial joint do patients forget? Knee Surg Sports Traumatol Arthrosc Mar 21 2017;25(3):681–6.
[11] Burn E, Sanchez-Santos MT, Pandit HG, Hamilton TW, Liddle AD, Murray DW, et al. Ten-year patient-reported outcomes following total and minimally invasive unicompartmental knee arthroplasty: a propensity score-matched cohort analysis. Knee Surg Sports Traumatol Arthrosc May 29 2018;26(5):1455–64.
[12] Drager J, Hart A, Khalil JA, Zukor DJ, Bergeron SG, Antoniou J. Shorter hospital stay and lower 30-day readmission after unicondylar knee arthroplasty compared to total knee arthroplasty. J Arthroplasty Feb 2016;31(2):356–61.
[13] Burn E, Liddle AD, Hamilton TW, Judge A, Pandit HG, Murray DW, et al. Cost-effectiveness of unicompartmental compared with total knee replacement: a population-based study using data from the National Joint Registry for England and Wales. BMJ Open Apr 29 2018;8(4):e020977.
[14] Johal S, Nakano N, Baxter M, Hujazi I, Pandit H, Khanduja V. Unicompartmental knee arthroplasty: the past, current controversies, and future perspectives. J Knee Surg Nov 7 2018;31(10):992–8.
[15] National Joint Registry for England, Wales NI and the I of M. 2018 15th Annual Report; 2018.
[16] Berger RA, Meneghini RM, Jacobs JJ, Sheinkop MB, Della Valle CJ, Rosenberg AG, et al. Results of unicompartmental knee arthroplasty at a minimum of ten years of follow-up. J Bone Joint Surg Am May 2005;87(5):999–1006.
[17] Naudie D, Guerin J, Parker DA, Bourne RB, Rorabeck CH. Medial unicompartmental knee arthroplasty with the Miller–Galante prosthesis. J Bone Joint Surg Am Sep 2004;86–A(9):1931–5.
[18] Argenson J-NA, Chevrol-Benkeddache Y, Aubaniac J-M. Modern unicompartmental knee arthroplasty with cement: a three to ten-year follow-up study. J Bone Joint Surg Am Dec 2002;84–A(12):2235–9.
[19] John J, Mauffrey C, May P. Unicompartmental knee replacements with Miller–Galante prosthesis: two to 16-year follow-up of a single surgeon series. Int Orthop Apr 25 2011;35(4):507–13.
[20] Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis Dec 1957;16(4):494–502.
[21] Kang SN, Smith TO, Sprenger De Rover WB, Walton NP. Pre-operative patellofemoral degenerative changes do not affect the outcome after medial Oxford unicompartmental knee replacement: a report from an independent centre. J Bone Joint Surg Br Apr 2011;93(4):476–8.
[22] Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res Nov 1989;248:13–4.
[23] Leskinen J, Eskelinen A, Huhtala H, Paavolainen P, Remes V. The incidence of knee arthroplasty for primary osteoarthritis grows rapidly among baby boomers: a population-based study in Finland. Arthritis Rheum Feb 2012;64(2):423–8.
[24] Liddle AD, Pandit H, Judge A, Murray DW. Effect of surgical caseload on revision rate following total and unicompartmental knee replacement. J Bone Joint Surg Jan 6 2016;98(1):1–8.
[25] Badawy M, Espehaug B, Indrekvam K, Havelin LI, Furnes O. Higher revision risk for unicompartmental knee arthroplasty in low-volume hospitals. Data from 5,791 cases in the Norwegian Arthroplasty Register. Acta Orthop 2014;85(4):342–7.
[26] Winnock de Grave P, Barbier J, Luyckx T, Ryckaert A, Gunst P, Van den Daelen L. Outcomes of a fixed-bearing, medial, cemented unicondylar knee arthroplasty design: survival analysis and functional score of 460 cases. J Arthroplasty Sep 2018;33(9):2792–9.
[27] Baur J, Zwicky L, Hirschmann MT, llchmann T, Clauss M. Metal backed fixed-bearing unicondylar knee arthroplasties using minimal invasive surgery: a promising outcome analysis of 132 cases. BMC Musculoskelet Disord Jul 31 2015;16(1):177.
[28] Vasso M, Del Regno C, Perisano C, D'Amelio A, Corona K, Schiavone Panni A. Unicompartmental knee arthroplasty is effective: ten year results. Int Orthop Dec 2 2015;39(12):2341–6.
[29] Biswas D, Van Thiel GS, Wetters NG, Pack BJ, Berger RA, Della Valle CJ. Medial unicompartmental knee arthroplasty in patients less than 55 years old: minimum of two years of follow-up. J Arthroplasty Jan 2014;29(1):101–5.
[30] Yoshida K, Tada M, Yoshida H, Takei S, Fukuoka S, Nakamura H. Oxford phase 3 unicompartmental knee arthroplasty in Japan — clinical results in greater than one thousand cases over ten years. J Arthroplasty Oct 2013;28(9 Suppl):168–71.
[31] Pandit H, Hamilton TW, Jenkins C, Mellon SJ, Dodd CAF, Murray DW. The clinical outcome of minimally invasive Phase 3 Oxford unicompartmental knee arthroplasty: a 15-year follow-up of 1000 UKAs. Bone Joint J Nov 1 2015;97–B(11):1493–500.
[32] Lim H-C, Bae J-H, Song S-H, Kim S-J. Oxford phase 3 unicompartmental knee replacement in Korean patients. J Bone Joint Surg Br Aug 1 2012;94(8):1071–6.
[33] Edmondson M, Atrey A, East D, Ellens N, Miles K, Goddard R, et al. Survival analysis and functional outcome of the Oxford unicompartmental knee replacement up to 11 years follow up at a District General Hospital. J Orthop Oct 2015;12(Suppl. 1):S105–10.
[34] Kim KT, Lee S, Kim JH, Hong SW, Jung WS, Shin WS. The survivorship and clinical results of minimally invasive unicompartmental knee arthroplasty at 10-year follow-up. Clin Orthop Surg Jun 2015;7(2):199–206.
[35] Svärd UC, Price AJ. Oxford medial unicompartmental knee arthroplasty. A survival analysis of an independent series. J Bone Joint Surg Br Mar 2001;83(2):191–4.
[36] Murray DW, Goodfellow JW, O'Connor JJ. The Oxford medial unicompartmental arthroplasty: a ten-year survival study. J Bone Joint Surg Br Nov 1998;80(6):983–9.
[37] Dawson J, Fitzpatrick R, Murray D, Carr A. Questionnaire on the perceptions of patients about total knee replacement. J Bone Joint Surg Br Jan 1998;80(1):63–9.
[38] Rachha R, Veravalli K, Sood M. Medium term results of the Miller–Galante knee arthroplasty with 10 year survivorship. Acta Orthop Belg Apr 2013;79(2):197–204.
[39] Baker PN, Jameson SS, Deehan DJ, Gregg PJ, Porter M, Tucker K. Mid-term equivalent survival of medial and lateral unicondylar knee replacement. J Bone Joint Surg Br Dec 2012;94–B(12):1641–8.
[40] Kim S-J, Postigo R, Koo S, Kim JH. Causes of revision following Oxford phase 3 unicompartmental knee arthroplasty. Knee Surg Sports Traumatol Arthrosc Aug 1 2014;22(8):1895–901.
[41] Cheng T, Chen D, Zhu C, Pan X, Mao X, Guo Y, et al. Fixed- versus mobile-bearing unicondylar knee arthroplasty: are failure modes different? Knee Surg Sports Traumatol Arthrosc Nov 25 2013;21(11):2433–41.
[42] van der List JP, McDonald LS, Pearle AD. Systematic review of medial versus lateral survivorship in unicompartmental knee arthroplasty. Knee Dec 2015;22(6):454–60.
[43] Kim KT, Lee S, Kim J, Kim JW, Kang MS. Clinical results of lateral unicompartmental knee arthroplasty: minimum 2-year follow-up. Clin Orthop Surg Dec 2016;8(4):386.

[44] Argenson J-NA, Parratte S, Bertani A, Flecher X, Aubaniac J-M. Long-term results with a lateral unicondylar replacement. Clin Orthop Relat Res Nov 24 2008;466(11):2686–93.
[45] Demange MK, Von Keudell A, Probst C, Yoshioka H, Gomoll AH. Patient-specific implants for lateral unicompartmental knee arthroplasty. Int Orthop Aug 3 2015;39(8):1519–26.
[46] Lustig S, Elguindy A, Servien E, Fary C, Munini E, Demey G, et al. 5- to 16-year follow-up of 54 consecutive lateral unicondylar knee arthroplasties with a fixed-all polyethylene bearing. J Arthroplasty Dec 1 2011;26(8):1318–25.
[47] Heyse TJ, Khefacha A, Peersman G, Cartier P. Survivorship of UKA in the middle-aged. Knee Oct 1 2012;19(5):585–91.
[48] Sah AP, Scott RD. Lateral unicompartmental knee arthroplasty through a medial approach. Study with an average five-year follow-up. J Bone Joint Surg Sep 1 2007;89(9):1948.
[49] Smith JRA, Robinson JR, Porteous AJ, Murray JRD, Hassaballa MA, Artz N, et al. Fixed bearing lateral unicompartmental knee arthroplasty — short to midterm survivorship and knee scores for 101 prostheses. Knee Aug 1 2014;21(4):843–7.
[50] Ashraf T, Newman JH, Evans RL, Ackroyd CE. Lateral unicompartmental knee replacement survivorship and clinical experience over 21 years. J Bone Joint Surg Br Nov 2002;84(8):1126–30.
[51] Ollivier M, Abdel MP, Parratte S, Argenson J-N. Lateral unicondylar knee arthroplasty (UKA): contemporary indications, surgical technique, and results. Int Orthop Feb 2014;38(2):449–55.
[52] Pinskerova V, Johal P, Nakagawa S, Sosna A, Williams A, Gedroyc W, et al. Does the femur roll-back with flexion? J Bone Joint Surg Br Aug 2004;86(6):925–31.
[53] Scott RD. Lateral unicompartmental replacement: a road less traveled. Orthopedics Sep 2005;28(9):983–4.
[54] Gunther TV, Murray DW, Miller R, Wallace DA, Carr AJ, O'Connor JJ, et al. Lateral unicompartmental arthroplasty with the Oxford meniscal knee. Knee Jul 1 1996;3(1–2):33–9.
[55] Pandit H, Jenkins C, Beard DJ, Price AJ, Gill HS, Dodd CAF, et al. Mobile bearing dislocation in lateral unicompartmental knee replacement. Knee Dec 2010;17(6):392–7.
[56] Streit MR, Walker T, Bruckner T, Merle C, Kretzer JP, Clarius M, et al. Mobile-bearing lateral unicompartmental knee replacement with the Oxford domed tibial component. J Bone Joint Surg Br Oct 2012;94–B(10):1356–61.
[57] Walker T, Zahn N, Bruckner T, Streit MR, Mohr G, Aldinger PR, et al. Mid-term results of lateral unicondylar mobile bearing knee arthroplasty. Bone Joint J Jan 2018;100–B(1):42–9.
[58] Fornell S, Prada E, Barrena P, García-Mendoza A, Borrego E, Domecq G. Mid-term outcomes of mobile-bearing lateral unicompartmental knee arthroplasty. Knee Dec 2018;25(6).
[59] Brockett CL, Jennings LM, Fisher J. The wear of fixed and mobile bearing unicompartmental knee replacements. Proc Inst Mech Eng H May 15 2011;225(5):511–9.
[60] Kretzer JP, Jakubowitz E, Reinders J, Lietz E, Moradi B, Hofmann K, et al. Wear analysis of unicondylar mobile bearing and fixed bearing knee systems: a knee simulator study. Acta Biomater Feb 2011;7(2):710–5.
[61] Burton A, Williams S, Brockett CL, Fisher J. In vitro comparison of fixed- and mobile meniscal-bearing unicondylar knee arthroplasties: effect of design, kinematics, and condylar liftoff. J Arthroplasty Sep 2012;27(8):1452–9.
[62] Zermatten P, Munzinger U. The Oxford II medial unicompartmental knee arthroplasty: an independent 10-year survival study. Acta Orthop Belg Apr 2012;78(2):203–9.
[63] Zhang Q, Zhang Q, Guo W, Liu Z, Cheng L, Yue D, et al. The learning curve for minimally invasive Oxford phase 3 unicompartmental knee arthroplasty: cumulative summation test for learning curve (LC-CUSUM). J Orthop Surg Res Sep 6 2014;9(1):81.