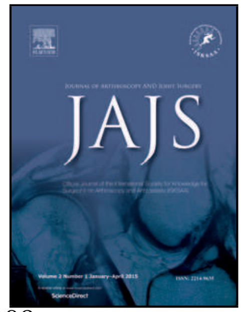
Article:

Takahashi, T, Pandit, HG orcid.org/0000-0001-7392-8561 and Phil, D (2017) Unicompartmental Knee Replacement. Journal of Arthroscopy and Joint Surgery, 4 (2). pp. 55-60. ISSN 0021-8790

https://doi.org/10.1016/j.jajs.2017.08.009

Accepted Manuscript



Title: Unicompartmental Knee Replacement

Author: Tsuneari Takahashi

PII: S2214-9635(17)30041-X
DOI: http://dx.doi.org/doi:10.1016/j.jajs.2017.08.009
Reference: JAJS 97

To appear in:

Authors: Hemant G. Pandit, D. Phil

PII: S2214-9635(17)30041-X
DOI: http://dx.doi.org/doi:10.1016/j.jajs.2017.08.009
Reference: JAJS 97

To appear in:

Received date: 28-6-2017

Please cite this article as: Hemant G.Pandit, D.Phil, Unicompartmental Knee Replacement (2010), http://dx.doi.org/10.1016/j.jajs.2017.08.009

Editorial

Title:

Unicompartmental Knee Replacement

Authors:

Tsuneari Takahashi, MD, PhD. [1, 2]

Hemant G Pandit, FRCS (Trauma and Orth), D Phil (Oxford). [1]

1. Leeds Institute of Rheumatic and Musculoskeletal Medicine, University of Leeds, Leeds UK

2. Department of Orthopedic Surgery, Jichi Medical University, Shimotsuke, Japan

E-mail addresses:

Tsuneari Takahashi, MD, PhD: tsuneari9@jichi.ac.jp

Hemant G Pandit, FRCS (Trauma and Orth), D Phil (Oxford): H.Pandit@leeds.ac.uk

Corresponding author:

Tsuneari Takahashi, MD, PhD.

Leeds Institute of Rheumatic and Musculoskeletal Medicine, University of Leeds, Leeds UK

2nd Floor, Chapel Allerton Hospital, Chapeltown Road. Leeds. LS7 4SA. UK.

Phone: +44 [0]113 3924492/0113 3924883

Fax: +44 [0]113 3924991

E-mail: tsuneari9@jichi.ac.jp

Abstract: Osteoarthritis (OA) of the knee is one of the most common causes of painful loss of mobility in middle and elderly aged population. OA is the main indication for knee joint replacement surgery. Unicompartmental knee replacement (UKR) is beneficial procedure for patient with degenerative OA which is limited in medial or lateral compartment providing reliable pain relief, improving function with significantly less morbidity and mortality as compared to total knee replacement. This editorial provides an overview of UKR, its relevance for Indian population, synopsis of results and future prospects. Abstract: Osteoarthritis (OA) of the knee is one of the most common causes of painful loss of mobility in middle and elderly aged population. OA is the main indication for knee joint replacement surgery. Unicompartmental knee replacement (UKR) is beneficial procedure for patient with degenerative OA which is limited in medial or lateral compartment providing reliable pain relief, improving function with significantly less morbidity and mortality as compared to total knee replacement. This editorial provides an overview of UKR, its relevance for Indian population, synopsis of results and future prospects.

Keywords: Medial compartment osteoarthritis; Meniscal-bearing unicompartmental knee arthroplasty; Implant survival; Functional outcome; Osteophytes; Patient selection

Introduction

Osteoarthritis (OA) of the knee is one of the most common causes of painful loss of mobility in middle and elderly aged population. OA is the main indication for knee joint replacement surgery. Unicompartmental knee replacement (UKR) is beneficial procedure for patient with degenerative OA which is limited in medial or lateral compartment providing reliable pain relief, improving function with significantly less morbidity and mortality as compared to total knee replacement (TKR). This editorial provides an overview of UKR, its relevance for Indian population, synopsis of results and future prospects.

History of UKR

The concept of UKR first dates back to Campbell who reported his preliminary results on the interposition of vitallium plates in the medial compartment of arthritic knees in 1940 which was to prevent direct bone-to-bone contact to relieve the pain [1]. This clinical trial was followed by vitallium tibial plateau prosthesis by McKeever [2], and tibial plateau insert by MacIntosh from 1950th until 1960th. MacIntosh reported that overall pain relief was achieved in most patients at a mean follow-up of six years in 1967. However, migration of the implant may lead to the unsatisfactory results [3]. So to overcome this problem, tibial plateau prosthesis with keel was developed by McKeever. The first modern design which had cemented polycentric metal femoral condyle articulating on flat polyethylene tibial components were St Georg (1969) and Marmor (1972) [4]. The problem with first generation modern UKR was distortion of the polyethylene followed by loosening [5]. It led to the introduction of metal-backed tibial implants rather than all-polyethylene components. However, this meant that the thickness of the polyethylene was reduced and this contributed to problems associated with excessive wear due to the high contact stresses.

Oxford UKR (Zimmer Biomet, Bridgend, UK) was developed in 1970s and was the first fully congruent mobile spacer with spherical concave femoral and flat and keeled tibial components [7]. This concept is to make both interfaces be congruent throughout the range of knee movement to minimize polyethylene wear and reduce contact stresses between bone-implant interface without constraint. These features of Oxford UKR phase 1 have remained unchanged up to present day. On the basis of clinical observation, good results were achieved when the anterior cruciate ligament (ACL) was intact and the arthritis was located anteromedial part of the tibia and distal part of the femur [8,9]. In 1987, Oxford UKR phase 2 was introduced along with the mill which allowed incremental bone resection to match the flexion and extension gaps intraoperatively whilst simultaneously shaping the bone to fit the implant. This system could restore not only ligament tension but also knee kinematics thus decreasing insert dislocation. Low level of polyethylene wear was observed after implantation due to the design concept of Oxford UKR and surgical technique to balance the ligament and restore the native tension. These are considered to contribute the postoperative high function and better satisfaction compared to TKR.

In 1998, Oxford UKR phase 3 was introduced and it enabled to be implanted with not an open approach with patellar dislocation but with a minimally invasive approach. Five sizes of femoral components were introduced (instead of just one) and tibial components were made side specific to reduce component overhang. The functional results of cemented phase 3 and recovery were found to be better than those of phase 1 and 2 [12].

In 2004 cementless femoral component with two pegs was introduced to reduce the incidence of physiological radiolucency around the cemented tibial components which although was asymptomatic and harmless, it did contribute to unnecessary revisions. Randomized controlled trial was conducted and similar clinical outcome (as cemented UKR) but with significant reduction in the incidence of tibial radiolucency was reported [14]. Subsequently a two peg cemented femoral component was introduced and reported to work well [15].

Indications of UKR

TKR is an effectively treatment for most types of arthritis in which both the tibio-femoral compartments were involved. On the other hand, Oxford medial UKR is indicated for the treatment of anteromedial OA (AMOA) and spontaneous osteonecrosis of the knee [16]. In AMOA, there should be (1) bone-on-bone arthritis in the medial compartment; (2) retained full thickness cartilage in the lateral compartment, best visualized on a valgus stress X-ray; (3) a functionally normal medial collateral ligament; and (4) a functionally normal ACL. The status of the patellofemoral joint (PFJ) is considered to be a contraindication only if there is a bone loss with grooving laterally [17].

Various contraindications to UKR were proposed by Kozinn and Scott. The best candidates for UKR were reported to (1) patients older than 60 years of age and weigh less than 180 pounds, (2) not extremely physically active or heavy labourers, (3) preoperative knee pain should be minimal at rest, (4) have a more than 90^0 flexion arc, with 5^0 or less of flexion contracture, (5) less than 15^0 of angular knee deformity, limits being 10^0 varus to 15^0 valgus [18]. According to these criteria, only around 6% of patients may be considered appropriate for UKR. However, candidacy for Oxford UKR is much wider accounting for 47.6% of knee arthroplasties in a series of 200 consecutive knees

[15]. Additionally, lateral osteophytes had been reported to be associated with lateral compartment disease and as such it was unclear whether medial UKR should be performed if present. Hamilton et al. performed the survey of the presence and size of lateral osteophytes, and their impact on clinical outcomes and Oxford UKR survival and demonstrated that the presence of lateral osteophytes is not a contraindication to medial meniscal-bearing UKR [19].

Contraindication of UKR

Kozin and Scott's contraindications for UKR (as outlined above) were based on their experience of fixed bearing UKR. Outcome of patients with and without these potential contraindications in a prospective series of 1000 Oxford UKRs was compared [22]. The outcome was assessed using the Oxford Knee Score (OKS), American Knee Society Score, Tegner activity score, revision rate and survival rate. Clinical outcome of patients with these potential contraindications were similar to or better than those without potential contraindications. The 10-year survival was 97% or those with potential contraindications and 93.6% without these contraindications. This difference maintained at 15 years as well, with implant survival of 94% in those with potential contraindications and 90% without these contraindications.

Based on these and various other observations, the contraindications for Oxford UKR are: inflammatory arthritis, absent or severely damaged ACL, PCL or MCL, partial thickness disease in the medial compartment, presence of a central ulcer in the weight bearing portion of the lateral compartment, bone loss with eburnation and grooving in the lateral part of the PFJ, and previous history of valgus tibial osteotomy.

Clinical results after UKR

The data from joint registries confirms that patients undergoing TKR had lower revision rates, they had higher rates of morbidity and mortality, longer hospital stays and inferior patient reported outcome measures compared with patients undergoing UKR [23].

Surgeons who perform UKR frequently significantly had lower revision rate and superior patient reported outcomes. Increasing usage of UKR leads to better results. Surgeons with optimal usage (up to 20% of knee replacements in the surgeon’s practice is UKR) achieved revision or reoperation rates similar to matched patients who undergoing TKR up to eight years postoperatively and 10 year survival is reported to be about 95% [24].

The revision rates of the UKR are reported to be much higher in national registries than in most published studies. Most surgeons perform very small numbers of UKR and the most common number implanted per year is one or two and average is five [25] [24]. Improper patient selection, inadequate surgical usage and/or unnecessary revisions can contribute to high UKR revision rates in the National Joint Registry (NJR). Matched comparison of UKR and TKA was performed based on the NJR for England, Wales and Northern Ireland including 100,000 cases of knee arthroplasty, UKR was reported to have several advantages for example, shorter hospital stay, reduced rates of readmission, intraoperative complications and need for blood transfusion as compared with TKR [23]. Additionally, frequency of major complications such as thromboembolism, postoperative infection, stroke and myocardial infarction were also less about a quarter to half as compared with TKR thus resulting in less mortality [23]. Comparing the patient oriented outcome measures (PROMs) between matched groups of UKR and TKR postoperative OKS after 6 months was significantly better with UKR than TKR and significantly more patients after UKR achieved an excellent clinical outcome [26,27]. Overall EuroQuol score was also better with UKR in four subscales relating to mobility, pain, function and self care [28].

Various cohort studies of cemented Oxford UKR have demonstrated high levels of function and excellent long-term survival rate can be achieved. In an independent study the 20-year survival was similar to the best TKR. The proposed contraindication for UKR (youth, obesity, activity, PFJ damage, and chndorocalcinosis) did not compromise the outcome. This suggests that if patients have AMOA, these proposed contraindications can be ignored. AMOA is present in about 50% of patients needing knee replacement. There is little evidence as to the optimal usage with the fixed bearing. However, there is a report that the fixed bearing should not be used with significant PF joint problems [29].

Complication after UKR

Complication rate after UKR is reported to be lower than that after TKR. Revision surgery after UKR tend to be much easier than that after TKA because latter one needs may be much more invasive to the patients. In the long term, the commonest cause of failure is progression of arthritis in the lateral compartment although incidence is not high.

Infection

The incidence of infection after UKR is about half of that after TKR [30]. C-reactive protein (CRP) or erythrocyte sedimentation rate (ESR) are the most useful diagnostic test but may not be positive in the first 2-3 weeks. Acute infection is diagnosed and treated in the same way as TKR. Early open debridement and change of meniscal bearing and intravenous antibiotics can arrest the infection and save the arthroplasty. Arthroscopic irrigation is not recommended. The earliest radiological sign may be in the retained compartment in the form of thinning of the articular cartilage and juxta-articular erosion of the non-implanted joint or progressive radiolucency line may occur around the tibial component. Treatment should include removal of the implant and excision of the inflammatory membrane followed by one or two staged revision TKR.

Medial tibial plateau fracture

In the NJR, 0.30 revisions for periprosthetic fracture per 1000 years after UKR are reported [31]. This did not include cases undergoing internal fixation so incidence may be underestimated. Periprosthetic fractures tend to occur in the hands of inexperienced surgeons both with cement and cementless implants. It mainly occurs intraoperatively or around 2-12 weeks after surgery. Weakening of the condyle by removal of its articular surface and subchondral bone plate is probably the main reason for fracture. This is unavoidable in UKR, so great care should be taken not to add any additional damage to the bones. The most potent case of that fracture is damage to posterior tibial cortex and the cancellous bone when using vertical saw blade that goes deeper than needed. Management of the tibial plateau fracture depends on the stage at which the fracture is diagnosed and the degree of varus deformity. If the fracture is diagnosed at the time of arthroplasty, it should be reduced and internally fixed. After the fixation, UKR can be completed and good result is expected [32]. If the medial fragment is comminuted, it should be fixed using buttress plate.

Dislocation of a mobile bearing

In the NJR, the incidence of the dislocation of a mobile bearing is reported to be 1.2

revisions for dislocation/subluxation per 1000 component years (95% CI 1.05-1.37) for mobile bearing UKR. Most dislocation occur early postoperative periods and incidence of dislocation using phase 3 Oxford UKR is reported 0.73% in a meta-analysis [33]. Primary dislocation is usually caused by a combination of distraction of the joint and displacement of the bearing due to impingement. They are usually due to surgical error. Secondary dislocation is the result of loss of entrapment from loosening and subsidence of the metal components. Spontaneous elongation of ligaments does not occur unless there is impingement, when forced flexion or extension may stretch ligaments. Traumatic dislocation is sometimes encountered when a normally functioning Oxford UKR has been forced into an extreme posture and MCL has been stretched or damaged. To diagnose the dislocation, radiographs demonstrate the site of the displaced bearing, and may suggest its cause such as osteophytes, retained cement, or displacement of a metal component. The dislocated bearing is most commonly found in the anterior joint space because the anterior rim of the bearing is higher than its posterior rim. Manual reduction under anesthesia succeeds on a few occasions. However, arthrotomy is almost always required to remove the bearing and determine the cause of its displacement.

When the both metal components are fixed to the bones, any bone or cement might impinge on the bearing. After removing these, usually one thicker bearing should be inserted to tighten the ligaments. In case of recurrent dislocation, MCL dysfunction, or serious mid flexion gap, conversion to TKR should be performed because revision of failed UKR to another UKR was reported to results less successful by Australian Orthopaedic Association National Joint Registry [34].

Loosening of a fixed component

Loosening of the component is one of the commonest causes of failure in the national registries. The rate of loosening is 4.01 (CI 3.73-4.32) per 1000 patient years in the NJR [31]. To diagnose the loosening, the only reliable radiographic evidence is the displacement of a metal component: for example, a loose tibial component may tilt or femoral component may rotate (as compared with serial radiographs). Stable radiolucency at the bone-cement interface is common and it does not indicate the evidence of loosening. Femoral component loosening is difficult to diagnose because of the difficulty to see radiolucency on the X-rays [35]. Radionuclide bone scan is not recommended because there is increase of uptake under the tibial component last for many years which indicates remodeling. The cause of early failures are mainly result of poor initial fixation. Late tibial loosening may be due to the accumulated effects of impact loading from impingement of the front of the bearing on the femoral condyle in full extension [36]. In early loosening without seriously eroded bone, cementing a new component is a possible option however, in late loosening with extensively eroded bone, revision to TKR is better.

Lateral compartment arthritis

In a series of 1000 cases of Phase 3 Oxford UKR with 15 years follow up, lateral OA progression that required revision occurred in 2.5% at a mean follow up of 7 years [37]. To diagnose the lateral compartment arthritis, pain which is not always on the lateral side is the main symptom. Narrowing of the lateral compartment joint space occurred first and this may long precede the onset of pain. Subchondral sclerosis and disappearance of lateral joint space ensue. Osteophyte of the lateral compartment is not portend progressive arthritis. Overcorrection of the varus deformity into valgus is an important cause of progression of lateral OA. So intact MCL is of importance so that overcorrection is avoided. If the symptom persists after conservative treatment, revision to TKR is indicated, however some surgeons may choose to perform lateral UKR in case medial UKR remains satisfactory.

Pain

Pain can be a problem and often leads to unnecessary revision. Pain can be encountered over the proximal tibia. This type of pain is not unusual in the first six months after surgery and usually settles spontaneously. The incidence is about 2% at one year after surgery [38]. The causes of pain after UKR may be multifactorial. Inappropriate indications or bone overload are the most common causes [39,40]. Impingement, soft tissue irritation, cementing errors, pes anserinus bursitis or neuroma have been implicated.

Partial thickness cartilage loss (PTCL)

It is generally thought that UKR is best used in young patients with early arthritis. However, Oxford UKR only should be offered to patients with bone-on-bone arthritis because cadaveric studies have shown that asymptomatic PTCL is common [41]. So if a patient has pain and PTCL, PTCL is not necessarily the cause of pain.

Component overhang

Medial tibial overhang of more than 3mm was associated with pain and poor function that tended to get worse postoperatively. This may be due to soft tissue irritation. The tibial component increases in size parametrically by 2mm so overhang of 2 mm or more can be avoided by selecting the appropriate component size or performing the vertical cut again further laterally. Also anteromedial femoral component overhang may cause pain [42].

Investigations

Radiographs are the most useful and AP radiographs aligned with the tibial component should be obtained at the first and subsequent follow ups. Physiological radiolucencies must be ignored because they are not source of pain [43]. If femoral component loosening is suspected, lateral views of 0 and 90 degrees should be obtained and examined the movement of the component [35]. Radionuclide bone scans are not helpful and often misleading. Even if patient is asymptomatic, they are hot lesions for many years. If the pain is located laterally, MRI scan is useful to identify meniscal tear. An ultrasound aspiration can be useful to exclude infection. Arthroscopy is useful only when lateral meniscal lesions, cement loose bodies, impingement or chondral flaps in the PFJ are suspected.

Treatment of unexplained pain

Early revision because of pain should be avoided because most patients revised for unexplained pain, could not recover from pain. For example, 75% of patients who were revised to TKR and had no mechanical problems identified at surgery had no improvement of symptoms [36]. Patients should be treated conservatively as their pain tends to settle spontaneously. Patients should be informed they are likely to have some pain for three to six months and that there is a small chance that it may take one to two years to fully settle. If patients have pain, they should decrease their level of activity and use a walking clutch. Steroid injection is recommended if the pain is focal.

Limited motion

Knee movements are usually recovered rapidly after surgery. However, occasionally manipulation under anesthesia has been employed if the knee has not recovered 90^0 of knee flexion at six weeks after surgery. In these cases, unlike manipulation of a stiff joint after TKR, there are no adhesions in the suprapatellar pouch and the knee flexes fully when a little force was applied. Extension improves spontaneously after Oxford UKR and rarely lacks more than 3^0 of knee extension at one year after surgery. If a flexion contracture persists, it is usually because osteophytes in the roof of the notch or on the tibia in front of the ACL insertion that have not been resected at the time of surgery.

Implant failure

There are some cases of fractures of Oxford UKR bearing [32,44]. Fractures often occur with the thinnest (3.5 mm) bearings and is associated with impingement that results in increasing wear. Treatment should be done by replacement with a new bigger bearing and addressing impingement.

Results of revision surgery

The re-revision rate after a UKR to UKR revision is higher than a UKR to TKA revision. Therefore, UKR to TKR revision is generally recommended. However certain circumstances when a UKR to UKR revision should be considered for example, replacing a bearing for a dislocation; a lateral or medial UKR for disease progression; and loosening with minimal bone loss that needs implanting a new component. If there is a mechanical cause for the failure such as disease progression component loosening, recurrent dislocation, or damage to deep fiber of MCL, conversion for TKR should be considered. The results of the revision surgery tend to be as good as those of a primary TKR. However, if there is no mechanical cause of pain, the results are poor. The typical case is a patient with early OA and partial thickness cartilage loss treated with UKR. Then, UKR does not relieve the pain and surgeons misinterpret the physiological radiolucency as indication revision TKR for loosening.

If there is a severe bone loss due to tibial plateau fracture, infection and deep tibial resection with ligament instability, revision TKA should be performed with stem and augment which increase constraint [45,46].

Lateral UKR

Lateral UKR is a relatively rare and said to account for about one eighth of all unicompartmental OA [47]. To identify lateral OA reliably, either a valgus stress radiograph in 45^0 of knee flexion or a Rosenberg view is necessary.

Anatomy and kinematics

The stabilizing effect of the LCL is quite different from MCL. MCL provides stability throughout the knee movement and therefore dislocation of the mobile bearing is rare. Conversely, LCL is tight only in knee extension and in 90 degrees of knee flexion, 5-10 mm distraction is possible in the lateral compartment [49]. So dislocation of the mobile bearing is a potential problem in mobile bearing lateral UKR.

History and development of lateral Oxford UKR

The results of lateral arthroplasty have been marred by dislocation of the bearing.

So it was recommended not to use mobile bearing into the lateral side but to use fixed bearing.

Indications

Requirement on the indications for successful lateral UKR are: Bone-on-bone OA in the lateral compartment. There should be a full thickness cartilage in the medial compartment and correctable intra-articular deformity. This is best demonstrated by a varus stress radiograph.

Like the medial UKR, age, activity, obesity and chondrocalcinosis would be ignored.

Due to the high dislocation rate of the mobile bearing, using the fixed bearing components is recommended for surgeons. Recently Fixed Lateral Oxford (FLO) prosthesis is introduced and used with the same instrumentation.

There have been some independent studies of the domed lateral UKR, which have confirmed good results [50,51]. Use of the modified surgical technique and new design with a domed tibial component appears to reduce the early dislocation rate. However, it is still higher than in the medial compartment. Knees that dislocated tended to be overcorrected compared with those that did not dislocate. To avoid the overcorrection, selecting the bearing thickness that just tightens the ligaments in full extension and the size of the gap between the femoral and tibial components should be minimized [52]. Dislocations commonly occur medially over the wall of the tibial component. Usually the bearing dislocation is not reduced by manipulation and the bearing should be retrieved under direct vision through old incisions. Care should be taken to identify any potential causes of bearing dislocation such as impingement, component loosening, bow stringing of popliteus or ligament injury. Dislocation is addressed when new thicker bearing is inserted but sometimes occurs.

Indian perspective

Indian patients have high prevalence AMOA and are well suited to receive Oxford UKR provided the indications are correct and surgical technique is optimal. Small components are usually needed and careful attention to prevent posterior tibial blow out is crucial. Patients with tibia vara tend to perform well with Oxford UKR although at present the follow up is up to 10 years.

Careful documentation of surgical findings, close patient follow up and data sharing will help improve outcomes of Oxford UKR in the Indian scenario and it seems that in the past two to three years there is increasing recognition amongst surgeons that indeed UKR does work and Indian patients will benefit with it due to associated reduced morbidity, better function and ability to sit cross legged and squat after Oxford UKR.

References

1 Campbell, W. C. Interposition of Vitallium plates in arthroplasties of the knee: Preliminary report. Clin Orthop Relat Res, 4-6 (1976).

2 McKeever, D. C. The classic: Tibial plateau prosthesis.1960. Clin Orthop Relat Res **440**, 4-8; discussion 3 (2005).

3 MacIntosh, D. L. & Hunter, G. A. The use of the hemiarthroplasty prosthesis for advanced osteoarthritis and rheumatoid arthritis of the knee. J Bone Joint Surg Br **54**, 244-255 (1972).

4 Marmor, L. Unicompartmental and total knee arthroplasty. Clin Orthop Relat Res, 75-81 (1985).

5 Marmor, L. The Modular (Marmor) knee: case report with a minimum follow-up of 2 years. Clin Orthop Relat Res, 86-94 (1976).

6 Bruni, D. et al. Unicompartmental knee replacement: a historical overview. Joints **1**, 45-47 (2013).

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

8 Goodfellow, J. & O'Connor, J. The anterior cruciate ligament in knee arthroplasty. A risk-factor with unconstrained meniscal prostheses. Clin Orthop Relat Res, 245-252 (1992).

9 White, S. H., Ludkowski, P. F. & Goodfellow, J. W. Anteromedial osteoarthritis of the knee. J Bone Joint Surg Br **73**, 582-586 (1991).

10 Murray, D. W., Goodfellow, J. W. & O'Connor, J. J. The Oxford medial unicompartmental arthroplasty: a ten-year survival study. J Bone Joint Surg Br **80**, 983-989 (1998).

11 Svard, U. C. & Price, A. J. Oxford medial unicompartmental knee arthroplasty. A survival analysis of an independent series. J Bone Joint Surg Br **83**, 191-194 (2001).

12 Price, A. J. et al. Rapid recovery after oxford unicompartmental arthroplasty through a short incision. J Arthroplasty **16**, 970-976 (2001).

13 Forsythe, M. E., Englund, R. E. & Leighton, R. K. Unicondylar knee arthroplasty: a cementless perspective. Can J Surg **43**, 417-424 (2000).

14 Liddle, A. D. et al. Cementless fixation in Oxford unicompartmental knee replacement: a multicentre study of 1000 knees. Bone Joint J **95-B**, 181-187, doi:10.1302/0301-620X.95B2.30411 (2013).

15 White, S. H., Roberts, S. & Jones, P. W. The Twin Peg Oxford partial knee replacement: the first 100 cases. Knee **19**, 36-40, doi:10.1016/j.knee.2010.12.006 (2012).

16 Pandit, H., Jenkins, C., Barker, K., Dodd, C. A. & Murray, D. W. The Oxford medial unicompartmental knee replacement using a minimally-invasive approach. J Bone Joint Surg Br **88**, 54-60, doi:10.1302/0301-620X.88B1.17114 (2006).

17 Beard, D. J. et al. Pre-operative clinical and radiological assessment of the patellofemoral joint in unicompartmental knee replacement and its influence on outcome. J Bone Joint Surg Br **89**, 1602-1607, doi:10.1302/0301-620X.89B12.19260 (2007).

18 Kozinn, S. C., Marx, C. & Scott, R. D. Unicompartmental knee arthroplasty. A 4.5-6-year follow-up study with a metal-backed tibial component. J Arthroplasty **4 Suppl**, S1-10 (1989).

19 Hamilton, T. W. et al. Lateral osteophytes do not represent a contraindication to medial unicompartmental knee arthroplasty: a 15-year follow-up. Knee Surg Sports Traumatol Arthrosc **25**, 652-659, doi:10.1007/s00167-016-4313-9 (2017).

20 Boissonneault, A. et al. No difference in survivorship after unicompartmental knee arthroplasty with or without an intact anterior cruciate ligament. Knee Surg Sports Traumatol Arthrosc **21**, 2480-2486, doi:10.1007/s00167-012-2101-8 (2013).

21 Mancuso, F., Hamilton, T. W., Kumar, V., Murray, D. W. & Pandit, H. Clinical outcome after UKA and HTO in ACL deficiency: a systematic review. Knee Surg Sports Traumatol Arthrosc **24**, 112-122, doi:10.1007/s00167-014-3346-1 (2016).

22 Hamilton, T. W. et al. Evidence-Based Indications for Mobile-Bearing Unicompartmental Knee Arthroplasty in a Consecutive Cohort of Thousand Knees. J Arthroplasty, doi:10.1016/j.arth.2016.12.036 (2016).

23 Liddle, A. D., Judge, A., Pandit, H. & Murray, D. W. 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 **384**, 1437-1445, doi:10.1016/S0140-6736(14)60419-0 (2014).

24 Goodfellow, J. et al. Unicompartmental arthroplasty with the oxford knee 2nd edition. (Goodfellow Publishers Lim, 2016).

25 Liddle, A. D. & University of Oxford. Failure of unicompartmental knee replacement. (2013).

26 Kalairajah, Y., Azurza, K., Hulme, C., Molloy, S. & Drabu, K. J. Health outcome measures in the evaluation of total hip arthroplasties--a comparison between the Harris hip score and the Oxford hip score. J Arthroplasty **20**, 1037-1041, doi:10.1016/j.arth.2005.04.017 (2005).

27 Goodfellow, J. W., O'Connor, J. J. & Murray, D. W. A critique of revision rate as an outcome measure: re-interpretation of knee joint registry data. J Bone Joint Surg Br **92**, 1628-1631, doi:10.1302/0301-620X.92B12.25193 (2010).

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

29 Argenson, J. N., Blanc, G., Aubaniac, J. M. & Parratte, S. Modern unicompartmental knee arthroplasty with cement: a concise follow-up, at a mean of twenty years, of a previous report. J Bone Joint Surg Am **95**, 905-909, doi:10.2106/JBJS.L.00963 (2013).

30 Liddle, A. D., Judge, A., Pandit, H. & Murray, D. W. Determinants of revision and functional outcome following unicompartmental knee replacement. Osteoarthritis Cartilage **22**, 1241-1250, doi:10.1016/j.joca.2014.07.006 (2014).

31 Board, T. N. Annual report of the National Joint Registry for England Wales Northern Ireland. (2014).

32 Berger, R. A. et al. Results of unicompartmental knee arthroplasty at a minimum of ten years of follow-up. J Bone Joint Surg Am **87**, 999-1006, doi:10.2106/JBJS.C.00568 (2005).

33 Pandit, H. et al. Minimally invasive Oxford phase 3 unicompartmental knee replacement: results of 1000 cases. J Bone Joint Surg Br **93**, 198-204, doi:10.1302/0301-620X.93B2.25767 (2011).

34 Hang, J. R. et al. Outcome of revision of unicompartmental knee replacement.

Acta Orthop **81**, 95-98, doi:10.3109/17453671003628731 (2010).

35 Monk, A. P., Keys, G. W. & Murray, D. W. Loosening of the femoral component after unicompartmental knee replacement. J Bone Joint Surg Br **91**, 405-407, doi:10.1302/0301-620X.91B3.21940 (2009).

36 Psychoyios, V., Crawford, R. W., O'Connor, J. J. & Murray, D. W. Wear of congruent meniscal bearings in unicompartmental knee arthroplasty: a retrieval study of 16 specimens. J Bone Joint Surg Br **80**, 976-982 (1998).

37 Pandit, H. et al. The clinical outcome of minimally invasive Phase 3 Oxford unicompartmental knee arthroplasty: a 15-year follow-up of 1000 UKAs. Bone Joint J **97-B**, 1493-1500, doi:10.1302/0301-620X.97B11.35634 (2015).

38 Gulati, A. & University of Oxford. Outcome after medial unicompartmental knee replacement. (2013).

39 Small, S. R., Berend, M. E., Ritter, M. A. & Buckley, C. A. Bearing mobility affects tibial strain in mobile-bearing unicompartmental knee arthroplasty. Surg Technol Int **19**, 185-190 (2010).

40 Pegg, E. C. et al. Evaluation of factors affecting tibial bone strain after unicompartmental knee replacement. J Orthop Res **31**, 821-828, doi:10.1002/jor.22283 (2013).

41 Emery, I. H. & Meachim, G. Surface morphology and topography of patello-femoral cartilage fibrillation in Liverpool necropsies. J Anat **116**, 103-120 (1973).

42 Chau, R. et al. Tibial component overhang following unicompartmental knee replacement--does it matter? Knee **16**, 310-313, doi:10.1016/j.knee.2008.12.017 (2009).

43 Gulati, A. et al. The incidence of physiological radiolucency following Oxford unicompartmental knee replacement and its relationship to outcome. J Bone Joint Surg Br **91**, 896-902, doi:10.1302/0301-620X.91B7.21914 (2009).

44 Tibrewal, S., Pandit, H., McLardy-Smith, P., Tibrewal, S. B. & Murray, D. W. Posterior dislocation of the Oxford knee meniscal bearing: a treatment option. J Orthop Traumatol **15**, 59-62, doi:10.1007/s10195-013-0250-2 (2014).

45 Berend, K. R., George, J. & Lombardi, A. V., Jr. Unicompartmental knee arthroplasty to total knee arthroplasty conversion: assuring a primary outcome. Orthopedics **32**, doi:10.3928/01477447-20090728-32 (2009).

46 Wynn Jones, H. et al. Revision of medial Oxford unicompartmental knee replacement to a total knee replacement: similar to a primary? Knee **19**, 339-343, doi:10.1016/j.knee.2011.03.006 (2012).

47 Jamali, A. A. & Scott, R. D. Lateral unicompartmental knee arthroplasty. Techniques in Knee Surgery **4**, 79-88 (2005).

48 Scott, R. D. & Santore, R. F. Unicondylar unicompartmental replacement for osteoarthritis of the knee. J Bone Joint Surg Am **63**, 536-544 (1981).

49 Tokuhara, Y., Kadoya, Y., Nakagawa, S., Kobayashi, A. & Takaoka, K. The flexion gap in normal knees. An MRI study. J Bone Joint Surg Br **86**, 1133-1136 (2004).

50 Streit, M. R. et al. Mobile-bearing lateral unicompartmental knee replacement with the Oxford domed tibial component: an independent series. J Bone Joint Surg Br **94**, 1356-1361, doi:10.1302/0301-620X.94B10.29119 (2012).

51 Weston-Simons, J. S. et al. The mid-term outcomes of the Oxford Domed Lateral unicompartmental knee replacement. Bone Joint J **96-B**, 59-64, doi:10.1302/0301-620X.96B1.31630 (2014).

52 Robinson, B. J. et al. Dislocation of the bearing of the Oxford lateral unicompartmental arthroplasty. A radiological assessment. J Bone Joint Surg Br **84**, 653-657 (2002).