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Up to twelve year follow-up of the Oxford phase three unicompartmental knee replacement in China: seven hundred and eight knees from an independent centre

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Abstract

Purpose There have been few large sample studies reporting the midterm outcome of Oxford phase 3 unicompartmental knee arthroplasty (UKA) in Asian patients.

Methods The study included 708 consecutive medial Oxford UKAs between February 2005 and May 2014 in Chinese patients. All cases were performed for the recommended indications with a minimally-invasive surgical technique. The functional and radiological outcomes were subsequently examined. In particular, we divided patients into the spontaneous osteonecrosis of the knee (SONK) group and the osteoarthritis (OA) group.

Results All patients were reviewed with a mean follow-up of 6.2 years (range 2.7–12 years). At the latest follow up, the mean Oxford knee score (OKS) increased from 22.5 to 38.5 points, while the mean knee society score (KSS) increased from 43.6 to 86.1 points. The mean visual analogue scale pain score decreased from 7.9 to 1.5 points and the mean range of motion (ROM) increased from 112.5° to 125.2°. A total of 13 UKAs (1.88%) required revisions. The most common reason was bearing dislocation and osteoarthritis of the lateral compartment. Using revision for any cause as an endpoint, the five-year cumulative survival rate was 98.8% and the ten-year survival rate was 94.3%. There was no statistically significant difference between the SONK group and the OA group for the five-year cumulative survival rate (98.7% vs. 98.8%, $P > 0.05$).

Conclusion This study demonstrates that Oxford UKA is a good option for the treatment of anteromedial OA and SONK of the knee in Asian patients.

Keywords Unicompartmental knee arthroplasty (UKA) · China · Functional outcome · Survivorship

Introduction

Unicompartmental knee arthroplasty (UKA) has been widely used as an alternative to total knee arthroplasty (TKA) for treatment of isolated compartmental knee pathologies. The increasing popularity is mainly due to improved implant designs, minimally invasive (MI) surgical techniques, and improved survivorship. MI-UKA has many advantages including preservation of bone stock, earlier discharge, maintenance of normal joint kinematics, faster recovery, and better proprioception in comparison to TKA.

The Oxford phase 3 UKA (Biomet, Warsaw, IN, USA) was introduced in 1998 and was designed to replicate the anatomy and restore the kinematics of the normal knee. A number of single-center studies show good medium- or long-term follow-up results, whereas, like other UKA, the results are less favorable in national registers [1–4]. Few studies have examined the medium-term results of Oxford phase 3 UKA in Asian populations. Lim et al. reported that MIS-UKA can yield satisfactory clinical and functional results and has a ten-year survival rate of 94% in Korean patients [5]. Yoshida et al. reported similar good medium-term results with a ten-year survival rate of 95% in Japanese patients [6]. However, the most common reason for revision differed between the populations, being dislocation of the bearing in Korean patients and subsidence of the tibial component in Japanese patients. In addition, body size, body mass index (BMI),

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lifestyle, and knee morphology of Asian populations differ from those in western countries [7].

In China there have been no medium-term studies reporting the outcomes of MI-UKA. Consequently, the purpose of the present study is to report the functional and radiological outcome of 708 consecutive Oxford Phase 3 UKAs performed using a MI technique in an independent centre in China.

Materials and methods

Patient characteristics

Since February 2005, 652 consecutive patients (726 knees) were enrolled. We were unable to follow 18 of these patients (18 knees) because three patients (three knees) had died and 15 patients (15 knees) were lost to follow-up. The remaining 634 patients (708 knees) were followed up for at least 32 months. Patients' demographic details are shown in Table 1. All patients met the recommended indications as described by Goodfellow et al. [8]. such as anteromedial osteoarthritis (OA) with functionally intact anterior cruciate ligaments (ACL) and medial collateral ligaments (MCL); spontaneous osteonecrosis of the knee (SONK), correctable varus malalignment of less than 15° and fixed flexion deformity of less than 15°. Young age (<60 years), OA of the patellofemoral joint (PFJ), and obesity were not considered contraindications.

Considering that anatomical features of SONK are similar to anterior-medial OA (AMOA), such as focal loss of bone and cartilage in the medial compartment with the ligament intact, whether UKA can be equally successful in the treatment of SONK remains unclear. We therefore divided the patients into the following two groups: the SONK group (41 knees of 41 patients) and the OA group (40 knees of 40 patients). The study was approved by the institutional review board and patient informed consent was obtained.

Surgical technique and post-operative management

All UKA procedures were performed by one senior author (Yihui Tu). The cemented Oxford phase 3 UKA was used in all cases and was fitted by a MI technique. The operation was performed under tourniquet and through a standard medial parapatellar incision. The tibial saw guide was fixed to an extramedullary rod, after visual alignment with the tibial long axis in both coronal and sagittal planes. A narrow reciprocating saw was used to make the vertical cut and the horizontal osteotomy. The bone was subsequently removed. Next, the intramedullary (IM) guide was inserted into the femur through a drill hole 1 cm anterior to the anteromedial aspect of the intercondylar notch. A second femoral drill guide was then placed parallel to the IM guide in the anteroposterior and

Table 1 Patient demographic data

| Number of implants	$N = 708$ knees (634 patients)
Age (years)	67.8 ± 10.2
Gender (female: male)	339: 295
Side (unilateral: bilateral)	560: 74
Height (cm)	171.1 ± 4.2
Body mass index (BMI, kg/m^2)	30.5 ± 1.4
Diagnosis at admission	
Anteromedial OA	$N = 667$ knees
Spontaneous osteonecrosis	$N = 41$ knees
Operation interval (bilateral knees)	
One stage: two stage	9: 65

lateral planes, then 4-mm and 6-mm drill holes were bored through holes in the femoral guide. Using a femoral saw block, the posterior facet of the femoral condyle was resected, then using the number of spigots required by the ligament balancing technique and a spherical cutter, the femoral condyle was milled. The prostheses were cemented in sequence from the tibial side to the femoral side when a trial implant test was satisfactory. No ligament release was undertaken. The anatomical bearing was used after 2010. Post-operatively, thromboprophylaxis was routinely prescribed and patients began physiotherapy with full weight-bearing as tolerated.

Clinical and radiological evaluation

Patients were scheduled to have a routine clinical follow-up visit at the outpatient clinic after three, six, and 12 months and thereafter once a year post-operatively. The clinical assessment included the Oxford knee score (OKS) [9], the knee society score (KSS) [10], and the visual analogue scale (VAS) scores for pain and range of motion (ROM). Data on complications such as deep venous thrombosis (DVT), pulmonary embolus (PE), deep infection, arthritis of lateral compartment, or loosening requiring revision, were also recorded.

Standing anteroposterior and lateral radiographs were routinely reviewed at outpatient clinic visits. The limb alignment was determined by means of the hip-knee-ankle (HKA) angle. The progression of OA in the lateral compartments was graded according to the Ahlbäck classification [11]. Any radiolucency at the bone–cement interface around the UKA implant was assessed and classified as physiological or pathological according to the guidelines of Oxford Group [12]. In order to assess intra- and inter-observer variability, all radiographs, both pre- and post-operative, were assessed by two independent researchers (Yinchuan Zhang and Fangxin Wang).

Fig. 1 Kaplan-Meier survival curve with 95% confidence intervals showing five-year and ten-year survival of Oxford phase 3 unicompartmental knee arthroplasty with implant-related revision as the endpoint
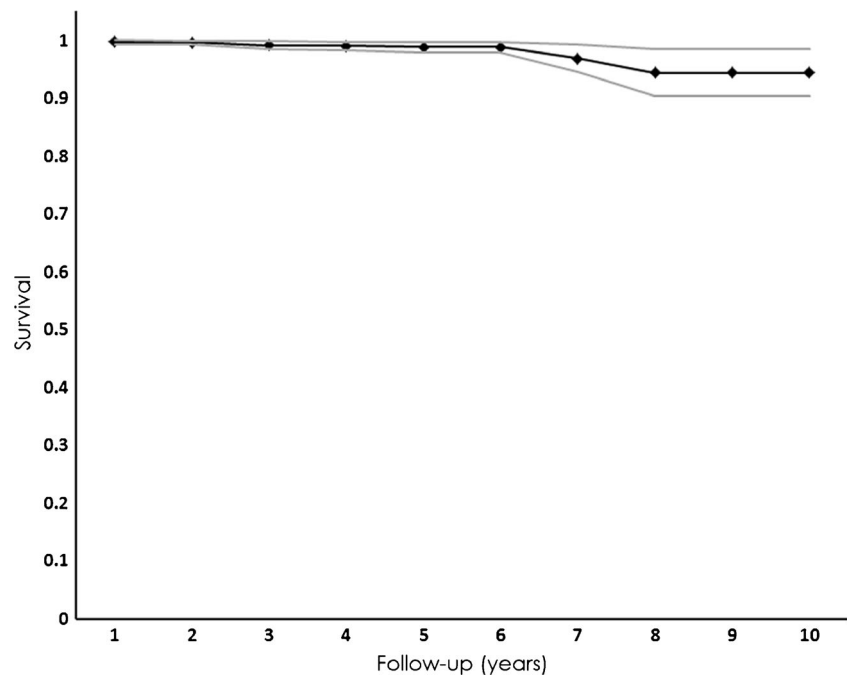
The correlation coefficients for both intra- and inter-observer data were >0.95 ($P < 0.01$).

Statistical analysis

SPSS software version 22.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. The differences between the mean pre-operative and post-operative clinical scores were analyzed using the paired Student's t-test. A P-value <0.05 was considered statistically significant. Using revision for any cause as an end-point, a life-table was constructed, and rates of survival were determined using the life-table method. The 5-year survival rate between the SONK group and the OA group was compared with Log rank methods. The 95% confidence intervals (CI) were calculated.

Results

Within a nine year period spanning February 2005 to May 2014, 708 UKAs with a mean follow-up of 6.2 years (range 2.7–12 years) were documented within our local register. By the last follow-up, the mean OKS score increased from 22.5 (range 16–28) pre-operatively to 38.5 (range 33–44) ($p = 0.034$), the mean KSS score increased from 43.6 (range 43–47) pre-operatively to 86.1 (range 76–90) ($p = 0.015$), and the mean VAS score decreased significantly from 7.9 (range, 7 to 9) pre-operatively to 1.5 (range 1–3) ($p < 0.001$). The mean ROM increased from 112.5° (range 102°–122°) to 125.2° (range 121°–126°) ($p = 0.037$). Using revision for any cause

as an endpoint, the five-year cumulative survival rate was 98.8% and the ten-year survival rate was 94.3% (Fig. 1). The mean HKA axis was 172.1° (range 165°–185°) pre-operatively and 178.2° (range 173°–188°) at final review ($p = 0.032$).

For the SONK and OA groups, the mean follow-up period were 63.5 months (range 36.2–78.1 months), 63.7 months (range 35.9–79.6 months), respectively ($P > 0.05$). The five-year cumulative survival rate of the SONK group was 98.7%. The five-year cumulative survival rate of the OA group was 98.8%. There were no significant differences between the two groups ($P > 0.05$, log rank test).

There were 13 implant-related revision surgeries with an incidence of 1.8% (Table 2). Bearing dislocations occurred in three cases (23.1% of all failures), two cases being dislocated anteriorly (Fig. 2a-c) and one case posteriorly. Two cases of fracture occurred after falls. One was an undisplaced tibia fracture and was treated with a brace; the other was a patellar fracture and was treated with open reduction and internal fixation. Tibial component loosening was noted in two cases (15.4%), both of which were mainly due to serious osteoporosis and were treated with revision TKAs. In three knees (23.1%) there was a mean HKA angle of 5.3° (range 3.6°–7.2°) valgus post-operatively. All showed progressive lateral compartment degenerative changes identified by the Ahlbäck classification (Fig. 3) and had recurrence of pain, so they were converted to TKAs. One patient suffered persistent pain after operation. In addition, two had deep infections and received two-stage revisions. Three had a deep vein thrombosis (DVT). None had a PE. Five patients with limited

Table 2 Details of 13 revision surgeries

Case no.	Cause of revision	Time to revision (years)	Operative findings	Procedure
1	Bearing dislocation	0.4	Components fixed (anteriorly)	Open bearing change
2	Tibia fracture	0.5	Undisplaced fracture	Fixation by brace
3	Arthritis of lateral compartment	6.2	Components fixed	Revision to TKA
4	Bearing dislocation	1.9	Loose MCL, smaller bearing (posteriorly)	Thicker bearing change
5	Loosening of Tibia implant	6.7	Osteoporosis and ACL deficiency	Revision to TKA
6	Loosening of Tibia implant	7.2	Osteoporosis and small tibia component	Revision to TKA
7	Patellar facture	2.6	Transverse and displaced fracture of patellar	Open reduction and internal fixation
8	Arthritis of lateral compartment	6.8	Components fixed	Revision to TKA
9	Bearing dislocation	2.8	Undersized bearing (posteriorly)	Change of a thick bearing
10	Deep infection	2.2	Infection confirmed	First stage: antibiotics, debridement and antibiotic loaded cement spacer; Second stage: revision to TKA
11	Persistent pain without loosening	4.1	Synovitis and arthritis of lateral compartment	Revision to TKA
12	Arthritis of lateral compartment	8.9	Components fixed and arthritis of patellofemoral joint	Revision to TKA
13	Deep infection	3.5	Infection confirmed	First stage: antibiotics, debridement and antibiotic loaded cement spacer; Second stage: revision to TKA

MCL medial collateral ligament, *ACL* anterior cruciate ligament, *TKA* total knee arthroplasty

flexion post-operatively required manipulation of the knee under anesthesia. There were no other complications.

Discussion

The present study reposted the results of 708 consecutive medial UKA procedures using the Oxford phase 3 implant for the recommended indications over a 12-year period. This was the first report involving a large sample with ten-year survival from China. The study was done in a high-volume district general hospital. In our Chinese series the ten year survival of the Oxford phase 3 was 94.3%. These results were similar to those of the designer's series and other subsequent western series [13, 14]. They were also similar to the two other series from Asia: In the series from Korea the ten-year survival was 94% and from Japan it was 95.4% [5, 6].

The designs of unicompartmental prostheses and key technical parameters mainly originated from European and American countries. Despite the innovation and introduction of the minimally invasive devices, there was concern that implanting the Oxford knee through a limited exposure might compromise prosthesis alignment and subsequent clinical results. We found that in some cases it does have some problems in Chinese patients. The physical size and body mass index (BMI) of Asian populations are smaller than those of Western populations [6], however, it was not clear whether anatomical parameters of knees of Chinese people were different from those of western populations. Based on our previous study, we found that the ratio of maximum transverse diameter of the patella to the femoral condyle was higher and the patella tended to be in a more medial position (data not shown). Therefore, patellar obstruction frequently occurred when inserting the intramedullary guide rod and placing a UKA trial implant simply through a mini-open incision, especially in obese patients, was difficult. In this situation, we usually extended the incision to gain a good exposure and thus avoided compromising alignment of the UKA implant. Our results with the Oxford UKA were similar to those achieved in the western and other Asian countries.

◄ **Fig. 2** Radiographs of an 82-year-old woman who underwent unicompartmental knee arthroplasty for treatment of medial compartmental knee arthritis. **a** The woman suffered a slipping trauma after 1.9 years of surgery. A lateral knee radiograph indicated anterior mobile bearing dislocation and no loosening was shown. **b** An intra-operative radiograph showed severe polyethylene wear and breakage in the front edge of the mobile bearing. No loose medial collateral ligament (MCL) was observed. **c** A lateral knee radiograph obtained one day after revision surgery, we aimed to maintain the MCL tension by replacing a new bearing of the same size

regarding patient's selection and the technical parameters compared with those of AMOA. Until now, limited studies on SONK were published. Zhang et al. reported comparable results in terms of post-operative pain, knee score, range of motion, and axial alignment between the SONK group and the OA group. In this retrospectively matched-pair study, no significant difference was found in the five-year survival rate between the groups [17]. We also obtained similar clinical results regarding post-operative ROM, functional score, and radiographic assessment (data not shown). We believe UKA is an effective method for SONK if the recommended indications are used. Nevertheless, there are still many issues worthy of further research in terms of patient's selection criteria (age, BMI, extent and stage of the necrosis lesion) and surgical techniques.

The most common cause of failure in our series was bearing dislocation, which accounted for 23.1% (3/13) of the failures. However, despite this our dislocation rate was low as it occurred in only 0.4% knees. Dislocation was also not a major problem as it was successfully treated with bearing replacement in every case. Our dislocation rate was similar to that of the designer series from Oxford, which was 0.6% (6/1000) [13]. It was also similar to the 0.8% rate reported by Yoshida et al. in Japan [6]. However, it was much lower than the 3% reported by Lim et al. in a Korean population [5]. This suggests that a low dislocation rate can be achieved in Asian populations. To ensure this is the case, correct patient selection and operative technique is first required. In addition, a new anatomic mobile-bearing knee system addressed concerns in 2004. This new significant design includes addition of "rotation tabs" anterior and posterior to minimize bearing spin out which leads to dislocation and rounded medial corners of the bearing to reduce medial soft tissue irritation. Documented reduction of bearing dislocation was reported in the Asian population [18] and UK registry [13]. Finally, for social and religious reasons high-flexion is essential in Asian cultures, so we recommend a change of lifestyle after operation and all patients are told to no longer squat and sit on the floor with high flexion angles. Bearing dislocation could also be prevented with a fixed bearing design.

There was a relatively high failure rate regarding progression of arthritis into the lateral compartment after UKA. Dervin et al. found that progression of OA in the lateral

SONK was described by Ahlbäck et al. in 1968 [15] and it has a low incidence of 0.05%–7% in patients with knee arthroplasties [16]. Its aetiology is poorly understood and the role of UKA in SONK remains uncertain, particularly

Fig. 3 An AP knee radiograph showed progression of arthritis in the lateral compartment, with progressive valgus, at 6.2 years after unicompartmental knee arthroplasty

compartment was the most common cause for revision occurring in 14 (27.5%) of the 51 revision cases [19]. Price et al. reported seven revisions due to lateral OA in their series of Oxford knees [20]. In our study, three of 13 revisions (23.1%) were converted to a TKA due to OA of lateral compartment. Laskin and Murray et al. have reported failure of UKA if the knee is overcorrected into valgus [21, 22]. Scott et al. reported that overcorrection increases the risk of degenerative change in the remaining compartment. We retrospectively reviewed the radiographs of all three patients and also found a mean post-operative valgus of >5° at the short time of the original surgery [23]. However, Emerson et al. reported this could simply be due to the natural progression of the underlying arthritic disease [1]. Despite the controversy, we advocate relative undercorrection of the alignment in the medial UKA operation. Based on our experience, minor varus alignment (less than 7° of mechanical varus) has been associated with a better outcome and better medium- to long-term survivorship of medial UKAs [24]. Furthermore, Weale et al. showed that failures due to lateral OA often occur within two years, especially in overcorrected knees [25]. However, we found this not to be the case in Chinese patients. In our series, the knee with overcorrection was revised 6.2 years after primary surgery. In any case, the history of lateral OA needs to be further explored.

Conclusion

This study demonstrates that the Oxford UKA is a good option for the treatment of AMOA and SONK in Chinese patients when appropriate indications and techniques are used.

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