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G.L. Maistrelli
S. Riaz

Advances in unicompartmental knee arthroplasty with minimally invasive techniques

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G.L. Maistrelli (✉) • S. Riaz
Toronto East General Hospital
University of Toronto
825 Coxwell Avenue, Toronto
Ontario, Canada, M4C 3E7
E-mail: gmais@tegh.on.ca

Abstract Unicompartmental arthroplasty has proved to be a reliable option for monocompartmental arthritis in well selected patients. Unicompartmental knee arthroplasty (UKA) is not a temporary procedure and its ten year survival is comparable to TKA and better than High Tibial Osteotomy. The success of the procedure depends on strict patient selection, meticulous surgical technique and proper implant selection. The renewed interest in UKA is due to improved results, more conservative nature of the procedure, faster rehabilitation, decreased cost and the minimally invasive techniques. The sedentary patient with unicompartmental arthritis is currently the primary indication for UKA. The role of unicompartmental arthroplasty in younger patients needs more investigation. Revision of UKA has not found to be as complicated as reported in the early series. Minimally invasive UKA has shown short term promising results but more long term studies showing similar implant longevity compared with the standard approach are required to establish its role. Due to high level of patient satisfaction and low morbidity and complications compared with TKA, unicompartmental arthroplasty is an attractive option for patients with predominantly unicompartmental non inflammatory arthritis.

Key words Unicompartmental arthroplasty • Osteoarthritis • Anterior cruciate ligament • Mobile bearing • Overcorrection • Revision

Introduction

Although unicompartmental knee arthroplasty (UKA) has been used clinically for more than a quarter of a century, its use is still considered controversial. The initial series showed dismal results [1–3]. With the refinement of implants, surgical techniques, component materials and fixation, the results of UKA are almost comparable to those of total knee arthroplasty (TKA) [4, 5]. In 1996 and 1997, surgeons in the United States performed only 2500 unicompartmental knee arthroplasties. At the Mayo Clinic in the 1990s, of the 8500 primary knee arthroplasties performed only 3 were unicompartmental replacements.

Despite continued controversy, there is now renewed interest in MIS unicompartmental knee arthroplasty [4]. First, because concerns about progression of arthritic symptoms in the other compartments have not been reported in the literature. Recovery time and cost [6, 7] are less than total knee arthroplasty, few surgeons have been employing it in day surgery, and unicompartmental arthroplasty is preferred by patients compared with TKA.

Thornhill and Scott [8] described unicompartmental knee arthroplasty (UKA) as a “continuum of surgical options for treatment of osteoarthritic patients” and Romanowski and Repicci [9] called it “an arthritic bypass” procedure. According to the latter concept, an additional procedure, revision, is quite likely after the proposed age of total knee arthroplasty (TKA) due to increasing activity level of today’s population. So a combination approach is used, i.e. a UKA performed earlier and used as a supplement to the TKA done later. The UKA will absorb approximately 10 years of functional capacity and so when a future arthroplasty is needed the longevity of the entire knee prosthetic system is prolonged. The UKA in conjunction with the TKA may increase the survival of the entire knee prosthetic system to 20–30 years. So UKA being a conservative arthroplasty will decrease the likelihood of any complex revision procedure in the lifetime of the patient.

Ahlback [10], a Swedish radiologist, reported that in 85% of the knee joints the radiographic evidence of degeneration was limited to only one compartment, the medial joint space being affected 10 times more often than the lateral. The involvement of the other compartments was usually mild and the progress slow. On the medial side the degenerative process starts anteriorly over both tibia and femur. It is this anteromedial disease for which unicompartmental arthroplasty is most suited. In patients with damaged or ruptured ACL, the area of deepest wear moves posteriorly and progresses to formation of osteophytes in the intercondylar notch and lateral subluxation of the tibia. Rupture of ACL prevents the proper function of the medial compartmental arthroplasty [11].

Indications and contraindications

Choosing the right patients for unicompartmental arthroplasty is of key importance in success of the procedure. This procedure is primarily done for arthritis involving a single, medial or lateral compartment of knee. Few authors do not consider erosion of the patellofemoral joint, specifically the medial facet, as a contraindication considering that this pathology is due to malalignment and as soon as the deformity is corrected the condition will improve. Similarly most authors do not consider erosions of the medial margin of the lateral femoral condyle or fibrillation of the lateral femoral condyle as a contraindication. A study by Hendel et al. [12] involving patients with primarily medial compartment arthritis but also mild involvement of the other two compartments showed good results but the patient population in this study was mainly housebound and elderly. The procedure is contraindicated in the young, elderly, obese and very active patients [13].

The fixed flexion deformity should not be more than 15 degrees [14]. Ten degrees of varus deformity or 15 degrees of valgus deformity is acceptable, but they should be passively correctable. There should be adequate range of motion of the knee which should be at least 90 degrees. The reason for not subjecting patients with severe deformity to UKA is increased chances of degenerative disease in other compartments; soft tissue release may be required in such knees which are contraindicated in UKA [15].

The absence of anterior cruciate ligament (ACL) is still considered to be a contraindication for UKA. Goodfellow and O'Connor [11] reviewed clinical results in patients with mobile bearing UKA (Oxford Knee). They found that the cumulative success rate in 165 joints in which ACL was normal at 6 years was 95% whereas in the 110 joints with a damaged or absent ACL it was only 81% ($p<0.05$). Chondrocalcinosis has been cited as a contraindication as it may lead to progression of the arthrosis into the unresurfaced compartment; however Woods et al. [16] did not find any significant difference in survival of patients with chondrocalcinosis. Patients suffering from polyarthropathy should not be considered for unicompartmental arthroplasty even when there appears to be end stage medial osteoarthritis. The results of UKA reported in the Swedish Knee Arthroplasty Register (SKAR) [17] do not support its use in rheumatoid arthritis. There was a higher revision rate for UKA in rheumatoid knees compared with knees in which the disease was likely to stay confined to one compartment [17].

In a prospective study [18] of the 228 knees in 168 patients, each compartment of the knee was graded for arthritis at the time of arthroplasty. The various criteria considered included age, weight, lifestyle, deformity of the knee in coronal and sagittal planes, presence of ACL, and cartilage erosion in the opposite compartment. Only 6% of knees qualified by these criteria for unicompartmental arthroplasty.

Chesnut [19] used a preoperative diagnostic protocol (Table 1) to predict candidates for unicompartmental

Table 1 Protocol for predicting candidates for unicompartmental arthroplasty. Modified from [19], used with permission

History
- Pain in one compartment
- Instability without pain
- Minimal patellar symptoms

Physical examination
- Mild laxity to varus or valgus stress test
- Passively correctable deformity
- Normal hip motion
- Negative McMurray test in opposite compartment
- Flexion contracture less than 15%
- Normal cruciate and collateral ligaments
- No cause of pain other than osteoarthritis of the knee

Roentgenograms
- Unicompartmental clear space loss on 45° flexion posterioanterior weight-bearing views
- Unicompartmental clear space loss on stress views (only if clinically indicated)
- No significant subluxation of the femur on the tibia
- No degenerative changes or chondrocalcinosis in opposite compartment
- Moderate patellofemoral changes on Merchant's view
- Impingement of intercondylar tibial eminence accepted if malalignment can be corrected back to midline

arthroplasty. His criteria included various aspects of history, physical exam and roentgenograms. He reported that using these criteria in his series of 208 knees, it was possible to reliably predict the presence or absence of unicompartmental disease in 202 of the knees and retrospectively in 207 knees.

Investigations

The routine investigations [14] should consist of weight-bearing radiographs of the knee in full extension and 20° flexion (Schuss view). The lateral view can also be taken at 20° flexion, which will show the wear on the tibial plateau. Wear of the posterior tibial plateau seen in the lateral view is indicative of attrition of the ACL and is considered unsuitable for unicompartmental arthroplasty. A Merchant view of the patellofemoral joint taken in 30° flexion is essential to rule out patellofemoral arthritis. Most authors recommend taking stress radiographs to document the presence of full thickness cartilage in the opposite compartment. A three foot standing radiograph is also recommended by most authors.

Plain weight-bearing radiographs generally will give adequate clinical information. Other useful investigations are magnetic resonance imaging (MRI) and arthroscopy which also are helpful in assessing the status of the articular cartilage and ACL but are not commonly used.

Evolution of unicompartmental arthroplasty prostheses

The concept of unicompartmental arthroplasty was introduced by MacIntosh [20], a surgeon from Toronto who replaced only the tibial articular surface with an acrylic uncemented component. He later used vitallium for the tibial component. McKeever [21] similarly used a metallic uncemented tibial component with a T-shaped keel on the undersurface to improve fixation. Both of these designs addressed the tibial surface only. The success rate was 60%–80% along with significant complications which were progression of disease in the untreated compartments, subsidence and migration of the components.

Marmor [22, 23] in 1973 introduced the prosthesis which involved replacement of both femoral and tibial surfaces. The femoral component was made of stainless steel and the tibial component was of polyethylene inset which was initially designed to be used as an inlay prosthesis. The designer after reporting a 10–13 year follow-up recommended that the widest tibial component be used to allow the prosthesis to also rest on the peripheral cortical rim. It has been one of the most widely used unicompartmental arthroplasties.

Gunston [24] designed the polycentric prosthesis with separate unicompartmental components. For the unicompartmental knee, the rather constrained polycentric prosthesis with its narrow tibial component, which was prone to subside, was followed by some unconstrained designs that were to become the standard for many years.

The St. George Sled prosthesis [25], introduced in Germany in the 1970s, used an all polyethylene, flat and minimally constrained tibial component. The femoral component was rounded in the sagittal plane to avoid edge loading. Both the Marmor and the St. Georg Sled prostheses were later, in the mid-1980s, also offered with metal-backed tibial components and were at the same time slightly modified as regards the femoral component, resulting in the Richard Mk III and Endo-Link prostheses, respectively.

The modularity introduced in the initial fixed bearing designs by using tibial metal base plates with decreased thickness of polyethylene in these designs, led to failure and damage of the tibial base plate. Apparently few of the causes of failure were thin polyethylene and the techniques used for manufacturing and sterilization of the polyethylene. The earlier designs also had a narrow dimension of femoral components in coronal plane, leading to subsidence into the femoral condyles [26]. The biomechanical disadvantage associated with congruent fixed bearing implants was that only one compartment was replaced and with the intact ligaments the knee would try to retain the normal kinematics of the joint. Any extra constraints posed by this arthroplasty will resist the normal kinematics with increased stresses at the implant-cement and bone interface, theoretically resulting in increased risk of loosening. So in fixed bearing UKA this issue was dealt with by designing implants with minimal constraints offered between the articulating surfaces. This is achieved by a round or flat femoral component on a flat tibial polyethylene which would allow relatively normal kinematics of the joint to take place. On the other hand it leads to high point-loading at the metal-polyethylene interface.

Mobile or meniscal bearing knees were developed and later refined by the group at Oxford [27]. The philosophy behind the design was to create an implant with a high contact area leading to low point-loading, allow normal kinematics of the knee as before by being unconstrained. Therefore, there is minimal stress at the implant-cement and bone interfaces and the forces at the juxta-articular bone should be only compressive. This implant would decrease wear as well as loosening. The original meniscal bearing design introduced in the 1970s consisted of a spherical femoral component, a flat tibial component and a plastic washer in between. The initial design (Phase I), had a high dislocation rate (3%) so it was modified (Phase II), leading to a decreased dislocation rate of 0.4% [28]. The recent Oxford Phase III knee now consists of a spherical femoral component, a tibial component and a fully congruent unconstrained polyethylene which articulates with the femoral component and has a flat surface which articulates with the tibial surface. The articulation [29] has a contact area of 5.7 cm^2. The femoral and tibial components are available in various sizes along with polyethylene spacers from 3 to 10 mm.

Cementless designs in UKA have not found comparable success with the cemented designs. Higher failure rates have been reported due to femoral and tibial component loosening.

The issue of using metal-backed or all polyethylene tibial inserts is still controversial. The metal-backed tibia (MBT) reduces the compressive loads at the bone implant interface. The disadvantages of using a MBT are that in order to get an adequate thickness of polyethylene, more tibial bone resection is required. If enough tibial resection is not done, a thinner polyethylene insert may be used which will accelerate wear and lead to failure. Another disadvantage is that one more interface is added, which might enhance wear, and there are chances of failure of the locking mechanism. The proposed advantage of MBT is that it improves fixation of the implant and only the polyethylene can be changed rather than the complete tibial base plate which is rarely the case. Hyldahl et al. [30] in a prospective randomized study analyzed the loosening of MTB and all polyethylene tibia (APT) with radiostereometric analyses at 3, 12 and 24 months. They found no significant difference in the clinical and radiostereometeric outcomes between the implants. The clinical scores for the two types of implants were also similar. They concluded that MBT is not superior in fixation to the all polyethylene tibia. In a biomechanical study [31], it was found that all polyethylene tibial components with pegs and a peripheral rim lock on the undersurface provided most resistance against tibial lift off and loosening.

Technique

Each design has its own philosophy; individual techniques for different designs as recommended by the manufacturers should be used but certain general principles are described. Few Authors advocate routine total knee anteromedial exposure for UKA because of the possibility of conversion to TKA, but now with the advent of minimally invasive techniques, small-sized anteromedial or anterolateral arthrotomy is used. Inspection of the other compartments of the knee and ACL is done. Ligamentous releases are to be avoided; a formal ligamentous release would imply that the deformity is too great for UKA. Over-correction of the deformity is avoided [32]. Generally 2°-3° of undercorrection of mechanical axis is advocated. Overcorrection may cause excessive transfer of stress to the cartilage in the unresurfaced compartment, leading to accelerated progression of arthritis. Peripheral and notch osteophytes are resected. Minimal bone should be resected. Deformity in the coronal plane can be decreased by removing peripheral osteophytes. Damage to the anterior horn of the lateral meniscus is avoided. The femoral and tibial components should have good congruency during extension. The femoral component should be placed centrally in the mediolateral dimension of the femoral condyle; a laterally placed femoral component may impinge on the medial tibial spine or can translate the tibia laterally in a constrained design leading to impingement of lateral tibial spine over the medial aspect of the lateral femoral condyle. The leading edge of the femoral component should be countersunk anteriorly into the femoral condyle to prevent its impingement against the patella during knee flexion. A femoral component that most exactly reproduces the anteroposterior dimensions of the femoral condyle should be chosen, with preference given to a larger implant in borderline cases to preserve bone. The tibial component should be well aligned with the femoral component and articulating surfaces of the two components should be rotationally congruent with each other in weight bearing [33]. The tibial cut is made perpendicular to the longitudinal axis of the tibia. The posterior slope of the tibial component should be kept between 3° and 7°. An enhanced slope may lead to abnormal anterior tibial translation and rupture of ACL, which might increase chances of tibial component loosening [34]. The ideal thickness of polyethylene will restore the height of the worn tibial plateau without overcorrection. The US Food and Drug Administration requires 6 mm as the minimal thickness of the polyethylene to be used for UKA. The components should be inserted to allow slight opening (1–2 mm) of the knee in full extension [35].

Results

The early series showed dismal results with UKA but the few reasons for failure were the poor implant design and lack of proper patient selection. Insall and Walker [1] and later on Insall and Aglietti [2] reported poor results on a series of patients undergoing UKA. At the latest follow-up according to the knee score of the Hospital for Special Surgery, only one knee was excellent, seven good, four fair and ten poor. Seven knees (28%) had been revised to

TKA. In this series, 15 patients underwent patellectomy prior to UKA. Laskin [3] in 1978 reported on 37 Marmor UKA prostheses with a minimum follow-up of 2 years. Despite following strict indications for surgery, only 65% of patients reported adequate relief of pain.

Murray et al. [5] reported results for medial UKA for knees with an intact ACL and primarily anteromedial arthritis. They used meniscal bearing Oxford Knee (Phase I and Phase II). The ten-year analysis showed survival figures of 98%. There were five reoperations: two for progression of arthritis in the lateral compartment, and one each for infection, unexplained pain and dislocation of the meniscal bearing. They had one more dislocation of the meniscal bearing which was reduced closed with a good subsequent result. They concluded that in medial compartmental osteoarthritis, unicompartmental arthroplasty with mobile bearing can survive for a long period of time with low reoperation and complication rates.

Svard and Price [36] reported a 95% survival rate at 10 years in medial UKA. They retrospectively analyzed results of 124 patients who underwent Oxford UKA for medial compartmental osteoarthritis. Revision procedures were required in 6 patients, with dislocation in 3, loosening in 2 and infection in 1 patient. Two other patients required operations for removal of loose body and closed reduction of the mobile bearing.

In another study [3], 699 Oxford knees (reported to the Swedish Knee Arthroplasty Register in 1983–1992) were identified and compared with 2364 Marmor prostheses reported during the same period. Also a time, age, and sex matched subset of the Marmor prostheses was compared by means of survival statistics and by mode of failure. The revision rate for the Oxford prostheses group after 1 year was higher than that for the Marmor prostheses. This difference increased gradually and after 6 years the revision rate was more than twice that of the Marmor group. No significant wear problems were noted in the revised Oxford prostheses. Frequent dislocation of the polyethylene meniscus was noted, and there were more cases of femoral than tibial component loosening. Exchange of the meniscus rarely prevented the need for further revision with exchange arthroplasty. Two units having done more than 100 Oxford operations had the same crude revision rate as those doing fewer, and there was no improvement in revision rate of Oxford knees over time.

Results of 51 Miller-Galante UKA prostheses were analyzed by Berger et al. [4] at an average follow-up of 7.5 years. On average, the other compartment had grade II arthritic changes. The average age of the patients was 68 years. The preoperative Hospital for Special Surgery (HSS) score improved from 55 to 92 points. Good to excellent results were noted in 98% of the knees. Three patients underwent reoperation, one for retained cement, one for knee manipulation and one for progression of arthritis in the opposite compartment and pain. No component was found to be loose radiographically. The Kaplan-Meier 10-year survival analysis with radiographic loosening or revision as the end point showed a survival of 98%.

Robertsson et al. [3] reported from the Swedish Registry that the TKA patients had lower revision rates than the UKA patients, i.e. 10-year cumulative revision rates (CRR) were 12% and 16%, respectively. After adjusting for age, gender and year of operation, UKA patients were found to have a 2-day shorter hospital stay and fewer serious complications than TKA patients. The mean estimated cost of a unicompartmental implant was 57% of that of a tri-compartmental implant.

UKA is a technically demanding procedure and the experience of the surgeon in this kind of procedure does affect the outcome. Robertsson et al. [37] analyzed the results of 10 474 UKA from the Swedish Knee Arthroplasty Register (SKAR) using three different kinds of prostheses. Two of them were fixed bearing (PCA and St. Georg Sled) and one was mobile bearing (Oxford Phase II). They found that PCA prostheses had the highest rate of revision, which was 3.24-times more than that of St. George Sled. Oxford UKA had 1.92-times greater chances of revision compared with St. Georg Sled prostheses. The group of low-volume surgeons (<23 UKA per year) had 1.63-times greater chance of revision of their UKA compared with the high-volume surgeons (>23 UKA per year). The risk of revision in Oxford UKA was 3.07-times greater in the low-volume surgeons group compared with the high-volume surgeons group, with incidence decreasing with an increase of experience. Regression analysis failed to show any improvement in results of PCA prosthesis even with an increasing number of procedures (surgical experience). It was concluded that increasing surgical exposure to this procedure does help, but not in case of implants with inferior mechanical properties.

Unicompartmental knee arthroplasty compared with other surgical options

The operative options other than UKA in a patient with unicompartmental arthritis are high tibial osteotomy (HTO) and total knee arthroplasty (TKA). The advantages of UKA include bone preservation, increased range of motion, preservation of normal kinematics and proprioception of the knee by retaining both cruciate ligaments, a low incidence of infection and low requirements for blood transfusion. Bilateral procedures can be performed for UKA in the same anesthetic with no significant problems in postoperative ambulation and rehabilitation [33].

During a validation process [38] of the Swedish Arthroplasty Register, living registered patients were sent a questionnaire to determine if they had been reoperated and if they were satisfied with the procedure or not. It was found that in osteoarthritis the procedures with the highest level of satisfaction were TKA and medial UKA. Patients with bilateral and lateral UKA were more likely to be unsatisfied. A higher proportion of revision patients were unsatisfied in TKA group compared with UKA group.

Rouggraff et al. [39] compared a group of 120 UKA arthroplasty patients with 81 patients undergoing TKA. The mean follow-up periods were 78 and 68 months, respectively. The Knee Society scores in the UKA group were significantly better than in patients with TKA. The need for postoperative transfusion was significantly greater in TKA patients. The revision rate was higher in the TKA group (4% compared with 19%).

A study by Laurencin et al. [40] compared UKA and TKA in the same patient with an average follow-up period of 81 months. The TKA patients were divided into 2 groups on the basis of patellar resurfacing. Ninety-six percent of UKA patients had mild or no pain compared with 83% of the TKA patients. Forty-four percent of the patients said that UKA was their better knee, 12% said that TKA was their better knee and 44% could not tell the difference. This proportion improved in the TKA subgroup with unresurfaced patella. Another similar study [41] consisting of 42 patients and a follow-up of 6.5 years, found that 50% preferred the UKA side, 21% preferred the TKA side and 29% could not tell the difference.

UKA decreases arthrogenous muscle inhibition (AMI) around the knee. Machner et al. [42] reported significantly improved quadriceps motor function in knees with moderate osteoarthritis treated with UKA compared with knees of same arthritic grade treated with physiotherapy alone. Voluntary activation (VA) and maximal voluntary corrections (MVC) of knees with UKA were significantly improved compared with knees treated with physiotherapy alone. Hassaballa et al. [43] observed that patients with UKA had greater ability to kneel compared with patients with TKR or patellofemoral replacement. Fuchs et al. [44] reported that implantation of UKA does not result in proprioceptive deficits. Most aspects of quality of life of patients with UKA did not differ from the control group.

There are multiple options available for a middle-aged patient with arthritis of only one compartment of the knee joint. High tibial osteotomy (HTO) is one of them. Naudie et al. [45] analyzed results of HTO in 106 knees in 85 patients. Mean age of patients was 55 years and mean follow-up was 14 years. All osteotomies except 12 were performed in the lateral closing wedge fashion. Using Kaplan-Meier survival analysis, they found that 73% of patients at 5 years, 51% at 10 years, 39% at 15 years and 30% at 20 years had the osteotomies not converted to TKA. Forty-five knees were still functioning at the 10-year follow-up, and 61 knees had been converted to TKA. Twelve of these had a revision TKA done after the primary arthroplasty.

The issue of doing a high tibial osteotomy or UKA often ignites discussion among the orthopedic group. Broughton et al. [46] analyzed a group of patients with single compartment arthritis, 49 of whom had high tibia osteotomy and 42 had St. Georg Sled UKA. The UKA group was slightly older than the high tibial osteotomy group; otherwise the groups were similar. At 5–10 years of follow-up, the UKA group performed much better than the HTO group: the results were good in 76% of UKA patients compared with 43% of HTO patients. Only 7% of UKA patients underwent revision procedures compared with 20% of the osteotomy group. Most importantly the replacement group had significantly less pain than the osteotomy group with 62% of the UKA patients completely pain free. The number of complications encountered in the osteotomy group was also higher. Weale and Newman [47] in 1994 published a 12- to 17-year follow-up of the same groups of patients, with good results in 42% of the UKA group and in 21% of the osteotomy group. At the latest follow-up, 5 knees in UKA group compared with 17 knees in the osteotomy group had undergone revision. The UKA group had 80% of patients with no or mild pain compared to 43% of osteotomy patients.

Ivarsson and Gillquist [48] reported faster rehabilitation after UKA compared with HTO. The muscle torque also improved earlier than HTO group. Additionally, there was increase in maximal gait velocity and the duration of single support in UKA group.

Results of revision after UKA

The common causes of failure in the early implants were aseptic loosening, wear of the thin polyethylene, poor bone coverage and implant subsidence with the inlay designs, cement fragmentation and osteolysis. The amount of bone loss encountered at the time of revision of UKA depends on the amount of bone resected at the index procedure, bone loss caused by the implant failure and during removal of the implant. Early designs of femoral components had a narrow coronal plane dimension, leading to subsidence, and large fixation lugs and spikes, leading to excess bone loss during removal. For these reasons, the early reports of revision of UKA by Padgett et al. [49] and by Barrett and Scott [50] described frequent technical difficulties, including the need for bone grafting and use of revision stemmed and custom implants in as high as 50%–76% of patients. The greatest bone loss was caused by failure of the components and during their removal. With the advent of the modern designs of UKA, there have been quite a few reports that describe good results. Chakraborty et al. [51] analyzed a series of revisions of UKA consisting mainly of St. Georg Sled and PCA implants. They had to employ quadriceps turn down and tibial tubercle osteotomy in three of the knees due to difficult exposure and stiffness. They reported that they encountered major bone defects in only 22% of the cases. They used primary knee implants except in 2 cases where stemmed components were used but primarily for ligamentous instability. They used cement and bone graft for reconstruction. The average tibial insert thickness used was 11.5 mm. At an average follow-up of 56 months, there were excellent results in 79%, fair 11% and poor 10%. There have been 2 rerevisions in this group.

McAuley et al. [52] reported on 32 UKA in 30 patients. The predominant cause of failure was polyethylene wear and loosening. The mean thickness of failed polyethylene was 7.3 mm. The authors described the revision procedures to be straightforward. Ten patients required autograft, but no allograft was used. Primary femoral components were used in all patients. On the tibial side 14 patients required stems and 8 required wedge augments. Three patients required reoperation at an average of 85 months after revision, all due to polyethylene causes; 2 required exchange of the tibial polyethylene and one required revision of the tibial component due to osteolysis. Levine et al. [53] similarly did not find the revision of unicompartmental arthroplasty complicated. They also reported high knee scores. Palmer et al. [54] and Bert [55] also did not require bone grafting and used primary TKR implants without wedges for revisions of UKA in their series.

Miller et al. [56] compared a group of patients with failed UKA undergoing revision with another group undergoing primary TKA. The causes of failure were predominantly failure of polyethylene and loosening along with progression of arthritis in the opposite compartment. Twenty-four percent of the knees (7 tibias and 2 femurs) required augmentation for defects encountered at revision with cement augmentation, autogenous bone graft and wedges. Two patients required cementless stem extensions. Tibial polyethylene thickness was 10.5 mm in the primary TKA group compared with 14 mm in the revision group. Sixteen percent of patients in the revision group had local wound complications compared with 8% in the primary group. Systemic complications occurred in 5% of patients in revision group compared with 7% of patients in primary group. Five patients in revision group underwent reoperation due to local wound complications. Five patients had reoperation in the revision group for polyethylene exchange, instability and loosening. The postoperative pain and function scores were significantly inferior in the revision group compared with the primary TKA group. In the subset of patients with posterior stabilized insert, there was no significant difference compared with the primary arthroplasty group. The authors pointed out that most of the series of revision of UKA used PCL sparing designs and quite thick polyethylene. The competence of PCL after resection of such amount of bone to accommodate a thick polyethylene raises doubts about the competence of PCL. This gets more support from the point that posterior stabilized knees in this series had better results than the other comparatively unconstrained polyethylene inserts.

Lewold et al. [57] analyzed results of revision of 1135 of 14 772 primary unicompartmental knee arthroplasties (UKA) done by the end of 1995 in the Swedish Registry. Number of revisions performed as an exchange UKA were 232 and 750 revisions were as a total knee arthroplasty (TKA). In medial UKA, the indication for revision was component loosening in 45% and joint degeneration in 25%; in lateral UKA, the corresponding figures were 31% and 35%. In 94 cases, unicompartmental components were added to the initially untreated compartment, in 14 with partial exchange of a component. After only 5 years, the risk of having a second revision was more than three-times higher for failed UKAs revised to a new UKA (cumulative rerevision rate, CRRR 26%) than for those revised to a TKA (CRRR, 7%). This difference remained, even if those revised before 1985, when modern operating technique was introduced, were excluded (CRRR, 31% and 5%, respectively). On failure of UKA, it should be revised to a TKA in most cases. Not even joint degeneration of the unoperated compartment can be safely treated by adding contralateral components; CRRR after this procedure was 17%, while it was 7% when converted to a TKA.

Complications of unicompartmental arthroplasty

Few of the early designs of implants had high subsidence rates of the femoral and tibial components. The mediolateral dimensions of the femoral implant in a few designs were quite narrow leading to subsidence. The tibial designs were also used as an inlay prosthesis which had a higher subsidence rate. Currently most designs use onlay tibial components supported by the strong cortical rim of the proximal tibia.

Alignment of the knee is very important in UKA. Postoperative alignment depends on the thickness of the tibial implant, on the level of resection of the tibia, on the ligamentous balance and on preoperative deformity. Overcorrection of the deformity can lead to increased stress

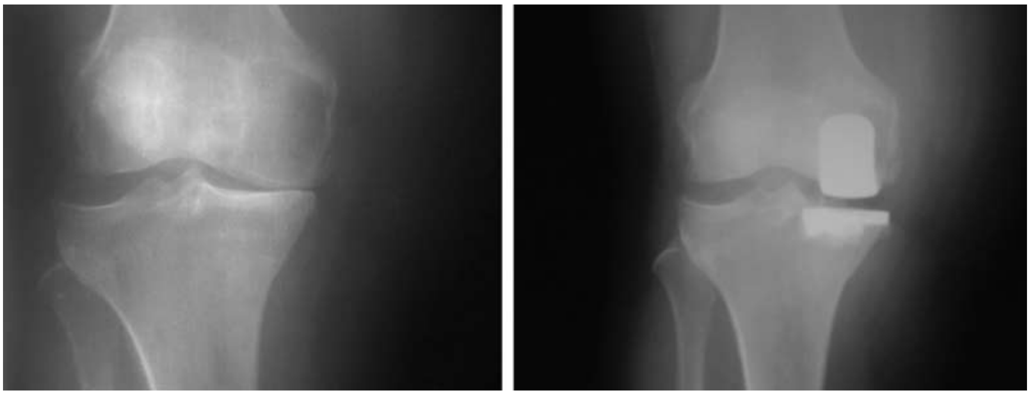

Fig. 1 Satisfactory alignment with no overcorrection on postoperative radiographs

and wear of the cartilage of the unresurfaced tibiofemoral compartment whereas excessive undercorrection can lead to increased wear of the polyethylene. So most of the Authors have consensus on keeping the knee in slight undercorrection and ligament releases are not recommended in UKA (Fig. 1). Weale et al. [58] suggested that degeneration of the unresurfaced compartment may be due to damage produced by wear of the polyethylene. Hernigou and Deschamps [59] analyzed 58 unrevised medial UKA after 10 years of follow-up. Standard hip-knee-ankle films were done on all patients pre- and postoperatively. They reported that postoperative overcorrection (valgus alignment, hip-knee-ankle angle >180°) was associated with significant wear of the cartilage of the opposite unresurfaced compartment. 60% of the knees with postoperative hip-knee-ankle (HKA) angle >180° had excessive wear in the opposite compartment, compared with 12% of the knees with HKA <170°. The annual wear of the lateral compartment in valgus knees was 0.23 mm, for knees with a postoperative HKA angle of 170°–180° it was 0.12 mm, and in patients with varus knees postoperatively (HKA<170°) wear was 0.11 mm. The subgroup with alignment between 170° and 180° had the highest knee and function scores. Radiographic study of the polyethylene revealed wear rates of 0.11 mm/year (HKA >180°), 0.14 mm/year (HKA, 170°–179°) and 0.21 mm/year in varus knees (HKA <170°). Toshihiro et al. [60] also recommended keeping the valgus knees slightly undercorrected after UKA and proposed a postoperative valgus alignment of 5°–7° to balance the forces in both compartments. Hopgood et al. [61], in a medial UKA series, reported that the amounts of correction seen with 8 mm, 10 mm, 12 mm and 14 mm inserts were 5.3°, 4.8°, 6.6° and 9.5°, respectively.

Another complication of UKA is increased wear of the polyethylene. Reasons for excessive polyethylene wear can be decreased thickness of the polyethylene, sterilization with gamma radiation in air, malalignment of the limb and defective fixation of the polyethylene to the tibial metal base plate in metal-backed components. Polyethylene mechanical toughness dramatically decreases with increasing shelf life if the tibial polyethylene is sterilized with gamma radiation in air. The polyethylene gets oxidized and free oxygen radicals are generated which tend to decrease mechanical strength and cause delamination and increased wear of the polyethylene. McGovern et al. [62] analyzed results in fixed-bearing UKA with tibial polyethylene sterilized with gamma radiation in air. All patients remained well in the early postoperative period. 51% of the knees with polyethylene shelf life more than 4 years required reoperation at 18 months. The annual wear rate of the polyethylene increased proportionately with shelf life. It was 0.9 mm per year for polyethylene with a shelf life of at least 4 years and 1.7 mm for polyethylene with a shelf life of 6 years. The few retrieved bearings analyzed by spectrometry showed a high percentage of oxidation of the polyethylene, sufficient to decrease its mechanical strength. Another study [63] from the same center showed a six-year survival rate of 96% when the shelf life of the polyethylene was less than 1.7 years compared with 71% when it exceeded 1.7 years. It is recommended that surgeons be aware of the mode of sterilization of the polyethylene.

Psychoyios et al. [29] suggested that increased congruence and mobile bearing characteristics of the Oxford UKA causes minimal wear, leading to decreased wear of the polyethylene independent of the polyethylene thickness. The average wear on upper and lower surfaces of the Oxford polyethylene was 0.036 mm per year and, in the inserts with impingement, the mean wear was 0.054 mm per year, compared to 0.010 mm per year (95% CI, 0.003 to 0.018) for the six inserts with no impingement (p<0.0001).

The use of high performance bearing materials that may reduce polyethylene wear is also being investigated (Fig. 2). In vitro wear studies have shown that oxidized zirconium surfaces (Oxinium) exhibited 4900-times less volumetric wear than cobalt chrome [64].

The most common mode of failure in knee arthroplasty is aseptic loosening of the tibial component. From 1975 to 1995, the Swedish Knee Arthroplasty Register [57] recorded 14 772 unicompartmental arthroplasties for

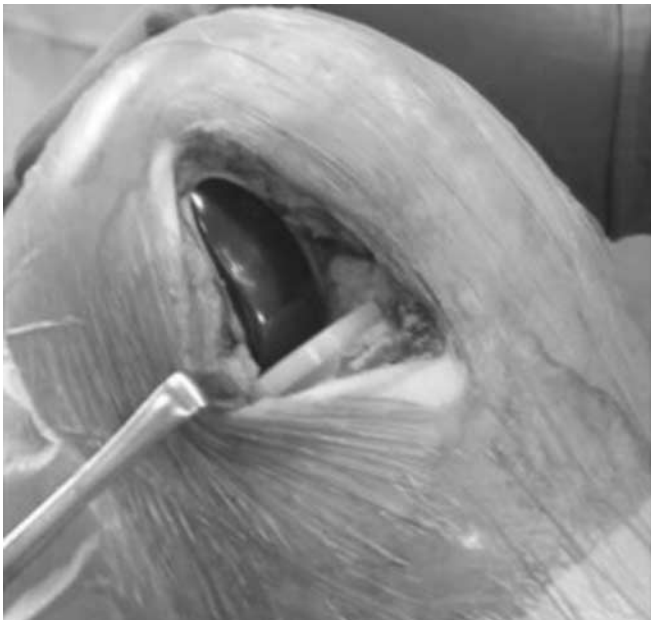

Fig. 2 Minimally invasive unicompartmental arthroplasty showing the reduced incision and implants with Oxinium femoral component in place

arthrosis: 1135 of the primary arthroplasties were revised, and 67% of the revised patients were women. In medial unicompartmental arthroplasties, indication for revision was component loosening in 45% and joint degeneration in 25%; in lateral unicompartmental arthroplasties, it was 31% and 34%, respectively. Early designs were constrained, which led to excessive force transmission to the bone and cement-implant interfaces. Later on less constrained designs were introduced. Unfortunately this introduced new modes of failure, namely excessive delamination wear of the HDPE tibial component because of higher point contact stress, as well as abrasion during the sliding and roll-back of the femoral component on the tibial plastic surface [65]. Cold flow and creep are other causes of loosening of all polyethylene components, leading to their deformation and allowing micromotion due to breakup at the cement-bone interface. Introduction of metal backing to reduce cold flow has also not solved the problem. Aseptic loosening still remains the major cause of failure. A possible explanation [66] is the different elastic modulus of metal compared to the underlying bone, leading to micromotion.

The Oxford UKA employs a meniscal unconstrained, fully congruent mobile bearing. When used on the medial side, the Oxford UKA has a dislocation rate about 1% [5]. When used on the lateral side, the dislocation rate is more than 11% (6 of 53 knees) [67]. All bearings dislocated within the first year, and 2 were converted to TKA, 4 were treated by replacing the bearing, of which 2 went on to have recurrent dislocation resulting in conversion to TKA and arthrodesis. The Authors have mentioned reasons like different kinematics and anatomy of the lateral side of the knee compared to the medial side, more laxity of the ligaments on the lateral side and the bowstringing of the popliteus tendon pushing the bearing to dislocate. Modifications in technique were made, including dividing the popliteus tendon, preserving soft tissues on the lateral side to maintain tissue tension, avoiding joint line elevation and elevating the posterior lip of the mobile bearing. Robinson et al. [68] studied the radiographs of patients of the previously mentioned series. They assessed the following variables on non weight-bearing AP and lateral views of the knee: femoral component varus/valgus, distal femoral valgus, anteroposterior tibial slope, tibial component abduction and proximal tibial varus. The only difference between the dislocated and non-dislocated group was proximal tibial varus. If this angle was greater or equal to 8° the chances of dislocation were 40%. If the angle was <8° the chances of dislocation were 4%. Overcorrection of the tibiofemoral angle occurred more in the dislocated group but the difference was not significant. Normal proximal tibial varus is 3° and an increase of 1° is equal to raising the joint line by 1 mm. So raising the joint line by 5 mm was associated with a dislocation rate of 40%.

One of the complications of UKA is impingement of the patella on the femoral component. Hernigou and Deschamps [69] analyzed 77 UKA at an average follow-up of 14 years and reported patellar impingement in 28 knees on skyline view obtained in 90° of flexion. Ten lateral compartments and 18 medial compartments were responsible for impingement. The knee scores were significantly higher during stair climbing in patients without impingement. Patients with patellar impingement also had increased incidence of pain compared to the subgroup without impingement. One patella during conversion to revision TKR fractured due to previous erosion by impingement. Three patients could not have patellar resurfacing on revision due to bone loss due to impingement. More than 10° of extension leads to anterior placement of the femoral component and patellar impingement. Different anatomy of the medial and lateral femoral condyles and similar implants for them and the excessive resection of the posterior femoral condyle are a few of the other reasons.

One rare complication is fracture of the tibial condyle. It can occur intraoperatively or present later as a stress fracture. Possible causes are a very thick resection leading to weakness of the condyle or the pin holes used for anchorage of instrumentation leading to stress fracture later in the course of treatment.

In minimally invasive surgery the space to operate and inspect the joint after implantation of the components is quite small, which can lead to retention of cement especially in the posterior portion. The all-polyethylene tibia further adds to this difficulty of posterior visualization. It is recommended to achieve satisfactory clearance of the posterior compartment using instruments like nerve hooks or dental mirrors. In case a loose cement fragment is detected postoperatively, it can be removed arthroscopically [70].

Minimally invasive UKA

With the advent of minimally invasive surgical techniques, there is an interest in developing this technique in UKA. Minimally invasive technique decreases tissue dissection, prevents dislocation of the patella, preserves the suprapatellar pouch and maintains the integrity of the quadriceps mechanism. The routine UKA approach resembles the TKA approach which requires splitting the quadriceps tendon and dislocation of the patella. This leads to disruption of the suprapatellar pouch which requires extensive physiotherapy to reverse the iatrogenic damage and regain motion at the knee.

Minimally invasive approach to the knee for UKA involves a short medial or lateral incision (approximately 8–10 cm), starting from the superior pole of the patella and continuing distally to the tibial joint line (Fig. 2). A short arthrotomy is made on the corresponding side. Flexion and extension balancing should be achieved without extensive ligament release. Repicci and Romanowski [9, 71] advocated doing an arthroscopy before the skin incision and determining the status of cartilage of the opposite compartment and its meniscus, so the option of TKA is always left open if there is unexpected opposite compartment arthritis or meniscus damage. Tria [15] considered the short incision enough to inspect the joint.

Some authors [72] advocated that minimally invasive techniques in UKA are associated with shortened hospital stay, rapid recovery and early rehabilitation. In a retrospective study of 136 UKA, all patients ambulated with a walker 4 h postoperatively and most (>98%) were discharged from hospital within 23 h. In that series, patients were discharged on a walker 4–6 h postoperatively. They recommended injecting local anesthesia in all incised areas before closure, which also decreases the requirement for narcotic analgesia postoperatively.

Price et al. [73] compared 40 Oxford UKA done with minimally invasive technique with UKA and total knee arthroplasty procedures done with open approach. The recovery time for knees treated with minimally invasive surgery (MIS) was twice that for the open UKA and thrice that for the open TKR. Accuracy of implant positioning achieved by MIS techniques was comparable in both approaches.

Due to the limited exposure, one of the concerns is the risk of implant malposition in MIS unicompartmental arthroplasty. Muller et al. [74] conducted a study using both open and MIS techniques for Oxford meniscal bearing UKA. On measurement of various variables regarding implant positioning on postoperative radiographs they found that the minimally invasive technique group scored high in 14 of the 17 measured parameters. The HSS score was significantly higher in the MIS group.

Regardless of the encouraging results with MIS approach, UKA it is a technically demanding procedure and requires adequate surgical experience to prevent complications and implant malpositioning. Rees et al. [75] in a short-term follow-up of the first 104 Oxford knees performed with the MIS technique, found that the average knee score improved from 37 to 94 points and the average functional score from 50 to 92. The average knee score during a surgeon's first ten cases was 88 points, which was significantly lower than scores achieved in the subsequent procedures (95 points).

Conclusions

There is definitely a renewed interest in MIS unicompartmental arthroplasty because of its more physiologic nature, good results, decreased cost and faster recovery. The success of the procedure depends on strict patient selection, meticulous surgical technique and proper implant selection. The sedentary patient with unicompartmental arthritis is currently the primary indication for UKA. One question which remains unanswered is the role of UKA in younger patients. High tibial osteotomy remains the best option in a patient involved in manual labor and impact sports. The concept of minimally invasive unicompartmental arthroplasty is definitely exciting but requires more long-term studies to support its role.

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