Unicompartmental Knee Arthroplasty

Indications, Surgical Techniques and Complications

Tad L. Gerlinger
Editor

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Foreword

I have professed the benefits of unicompartmental knee arthroplasty (UKA) at meetings and courses to trainees and thousands of surgeons for 20 years. My strong belief in the patients' benefits of UKA makes it a great honor to write this foreword.

I believe UKA is the most rewarding surgery in all of arthroplasty; done correctly in the right patient, it has the capacity to return patients to a pre-arthritic state where they forget they had arthritis and have a replacement. It becomes a "normal knee" again. As my mentor Jorge Galante told me many times, "Patients may like their total knee, but patients love their Uni and forget they have it!". Jorge taught me about UKA, and I have had the good fortune to pass it to the surgeons that I have trained.

The idea of a partial knee replacement for arthritis has been around for a long time, first with Campbell in the 1940s and then with McKeever and MacIntosh in the late 1950s and 1960s. However, most would say the modern UKA era started in the early 1970s with Marmor, who reported a high success rate in his patients. Not long after, the St. Georg Sled was introduced in Europe and also demonstrated good results.

Unfortunately, with the initial success and enthusiasm of the UKA came newer and less well-designed options, such as high conformity fixed bearings, thin polyethylene, and poor instrumentation. Also, poor patient selection resulted in poor results reversing the enthusiasm of the UKA in the 1980s. By the late 1980s, almost no one was doing UKA in the USA.

However, in the mid-1990s to late 1990s, there was a resurgence of the UKA, due in part to the good 10-year survival reported by many authors, as well as improved recovery with a minimally invasive technique for UKA. Finally, in the new era of outpatient arthroplasty in surgicenters, the UKA has excelled; it is easy to implant with minimal instruments at minimal expense and is easily done in the outpatient setting.

Currently, the use of the UKA has risen to 57,000 in the USA in 2018. Globally, there are over 200,000 implanted yearly, accounting for 7–8% of all knees in 2018.

However, with the increased popularity, UKAs have shown higher revision rates when compared with TKA. Most distressing, these revisions are now being observed early in the postoperative period. Again, these poor results are related to poor indications and poor surgical technique.

Perhaps, more than any other procedure in arthroplasty, choosing the right patient and performing the surgery correctly are vital to the success of the UKA; this book will guide you over these hurdles. The experts collected here will share their experiences, patient selection criteria, and their surgical techniques to help you with your journey.

Enjoy this book and start doing more UKAs. Your patients will be delighted.

Chicago, IL, USA

Richard A. Berger

Preface

Unicompartmental arthroplasty of the knee has seen an increased utilization in recent years as improved patient selection, precise surgical technique, and modern implants have allowed surgeons to truly give the knee "what it needs" to optimize function and longevity, as well as provide the patient with optimal satisfaction.

This book provides orthopedic surgeons with the opinions of the current world's experts on unicompartmental arthroplasty of the knee, its indications, surgical techniques, and treatment of complications.

I'd like to thank the staff at Springer for their organizational support in producing this book and of course my family for their support, as the time spent creating it was the time I wasn't spending with them. Finally, I would like to honor the legacy of Jorge Galante. He trained my mentors and has made a lasting impact on hip and knee arthroplasty worldwide.

Chicago, IL, USA — Tad L. Gerlinger

Contents

Part I General Considerations and Indications for Unicompartmental Knee Arthroplasty

1 History of the Unicompartmental Knee Arthroplasty 3
Faisal Akram and Brett Levine

2 Indications for Unicompartmental Knee Arthroplasty: Which Knees Are Best? 13
Jason L. Blevins and David J. Mayman

3 Patient Criteria for Unicompartmental Knee Arthroplasty: Are There Exclusion Criteria? 19
Alexander L. Neuwirth, Matthew J. Grosso, and Jeffrey A. Geller

4 Risk Mitigation for Unicompartmental Knee Arthroplasty 25
Daniel D. Bohl and Tad L. Gerlinger

5 Managing Patient Expectations for Unicompartmental Knee Arthroplasty 37
Daniel R. Mesko and Sheeba M. Joseph

6 Implant Choices for Unicompartmental Knee Arthroplasty . . . 43
Matthew P. Siljander, Jay S. Croley, and Donald M. Knapke

Part II Surgical Techniques for Unicompartmental Knee Arthroplasty

7 Medial Unicompartmental Knee Arthroplasty: Indications and Technique 57
Brian C. Fuller and Tad L. Gerlinger

8 The Mobile Bearing in Unicompartmental Knee Arthroplasty 69
Nicholas J. Greco, Kojo A. Marfo, and Keith R. Berend

9 Lateral Unicompartmental Knee Arthroplasty: Indications and Technique 95
Vasili Karas and Richard A. Berger

10 Treating Patellofemoral Arthritis with Patellofemoral Arthroplasty 107
Kevin J. Choo and Jess H. Lonner

11 Utilizing Unicompartmental Knee Arthroplasty for More than One Compartment 121
Brian Darrith, Jeffery H. DeClaire, and Nicholas B. Frisch

12 Unicompartmental Knee Arthroplasty and Anterior Cruciate Ligament Deficiency 133
Thomas W. Hamilton and Hemant Pandit

13 Pain Management in Unicompartmental Knee Arthroplasty 147
Adam C. Young

14 Blood Preservation Strategies in Total Knee and Unicompartmental Knee Arthroplasty 161
Dipak B. Ramkumar, Niveditta Ramkumar, and Yale A. Fillingham

15 Outpatient Unicompartmental Knee Arthroplasty 169
Robert A. Sershon and Kevin B. Fricka

16 Therapy for Unicompartmental Knee Arthroplasty: Pre-op, Day of, and Post-op 179
Peter F. Helvie and Linda I. Suleiman

Part III Complications of Unicompartmental Knee Arthroplasty

17 Disease Progression and Component Failure in Unicompartmental Knee Arthroplasty 189
Matthew J. Hall, Peter J. Ostergaard, and Christopher M. Melnic

18 Periprosthetic Fracture in Unicompartmental Knee Arthroplasty 199
Anthony J. Boniello, Craig J. Della Valle, and P. Maxwell Courtney

19 Preventing Infections in Unicompartmental Knee Arthroplasty 207
Charles P. Hannon and Craig J. Della Valle

20 Infection Remediation in Unicompartmental Knee Arthroplasty 217
Kevin C. Bigart and Denis Nam

Index 223

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Part I

General Considerations and Indications for Unicompartmental Knee Arthroplasty

History of the Unicompartmental Knee Arthroplasty

1

Faisal Akram and Brett Levine

Background

Unicompartmental knee arthroplasty (UKA) is an effective surgical procedure for treatment of patients presenting with end-stage osteoarthritis, predominately limited to a single compartment of the knee [17]. The functional knee joint is divided into three subdivisions comprised of the medial, lateral, and patellofemoral compartments. UKAs remain a viable alternative to a tibial osteotomy or traditional tricompartmental total knee arthroplasty (TKA) when degenerative joint disease and symptoms involve a single compartment within the affected knee [22]. Unicompartmental arthritic changes are associated with a variety of pathologic conditions such as mechanical malalignment of the lower extremity (varus or valgus for medial and lateral compartment overload, respectively), osteonecrosis (primary, secondary, or post-arthroscopy), or sequelae of a traumatic single compartment injury [13].

Historically, procedures to correct malalignment included tibial or femoral realignment osteotomies, which were performed to unload weight-bearing forces on the affected arthritic compartment. When done correctly and in carefully selected patients, reorientation osteotomies showed early clinical success [12, 17, 29]; however, when the patient's degenerative joint disease or meniscal pathology progresses to the adjacent compartments, the next procedure becomes a TKA. Conversion to TKA after proximal tibial osteotomy remains not only technically challenging, but may also be at increased risk for inferior outcomes and complications to include formation of excessive scar tissue, patella infera, and limited range of motion of the knee [5, 22].

Since the early 1950s, unicompartmental knee replacements have had a varying degree of acceptance and surgical implementation. Despite its emergence as a viable treatment option for unicompartmental degenerative changes more than five decades ago, the enthusiasm for this treatment modality has waxed and waned in the United States. Overall, it remains a somewhat controversial surgical option, with only 3.2% of knee procedures in the latest American Joint Replacement Registry(AJRR) report being unicompartmental (rate trending down from 6.66% in 2012 to 1.81% in 2017) [21]. There is no consensus on surgical indications or patient selection criteria, and variable results are reported in the literature [1]. It is currently estimated that only 10% of orthopedic surgeons worldwide perform UKAs, with low volume surgeons performing fewer than 13 per year [14]. Global numbers have varied as well, with some registries reporting cumulative rates of 7–8.7%, with trends varying in number each year [26, 32]. The vacillating enthusiasm for UKA in worldwide orthopedics

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stems from the controversial reports in the literature and the oft-debated recommendations of surgical indications.

Early Historical Comparisons to Total-Knee Arthroplasty

UKA was developed as a less invasive alternative to TKA to avoid replacing all three knee compartments and resection of the anterior cruciate ligament and posterior cruciate ligaments [13]. Although the potential benefits of TKA are substantial and can result in significant pain relief, restoration of mobility, and improved quality of life, it is a procedure that is generally longer in duration and more complex in nature than UKA, as well as having increased risks [29]. Despite a high-level of functional return, it has been suggested that TKA does not provide the same level of patient satisfaction as a UKA in comparative studies [15].

Early UKA surgery emphasized the anatomical correction of significant varus or valgus deformity to neutral or to an overcorrected position (similar to the osteotomy principles) [17]. In providing an option for "less surgery" than a TKA, the goals of UKA were also to preserve native bone stock, by minimizing the depth of femoral and tibial resections, as well as preserve the anterior cruciate ligament (ACL). Balance of the collateral ligaments is restored by adjusting the thickness of the tibial prosthesis, which also served to partially correct the varus or valgus deformity [29].

In general, postoperative complications have been noted to be lower when comparing UKA and TKA. The less invasive UKA surgical technique, compared to traditional TKA, results in less blood loss, decreased length of hospitalization, a quicker functional recovery, and improved range of motion [3, 27]. Campi et al. analyzed more than 100,000 total and partial knee arthroplasties and determined that patients undergoing UKA lost less blood and had a significantly lower risk of serious medical complications such as thromboembolism, myocardial infarction, stroke, and infection [27]. Liddle et al. also found TKA patients to be at a higher risk of serious medical complications when comparing adverse results associated with these procedures [16].

Early research studies evaluating recovery after surgery have shown favorable results with UKA compared to TKA. The recovery time for UKA is typically shorter than a TKA. Plate et al. analyzed more than 240 UKA cases from a registry in Minnesota and found the average hospital stay was 2.8 days, more than a full day less than TKA cases [7]. Functional recovery and return to activities are also quicker after UKA compared to TKA. Studies conducted by Hopper et al. found that UKA patients resumed participation in low-impact sports half a month (3.6 months post-op) sooner than TKA patients (4.1 months post-op). UKA patients also spent more time playing (92.1 minutes vs. 37.5 minutes for TKA) and fewer participants reported knee pain during the activity compared to TKA. Ghomrawi et al. compared lifetime costs and the quality-adjusted life year (QALY) rate of UKA and TKA [10]. For patients over 65, he saw lower costs and higher QALY for UKA. Decreased operating time, shorter length of hospital stays, reduced occurrence for transfusions, and lower component cost made UKA the more cost-effective option for both the patient and surgeon [30]. These factors, combined with the high success rates and increased levels of QALY [28], have fueled a resurgence for UKA for some surgeons. Particularly as cases shift to surgicenters, the financial benefits and enhanced patient experience have become more appealing to surgeons and patients alike.

Early History of the Unicompartmental Knee Arthroplasty

The origins of the first UKA can be traced back to the 1940s and 1950s when interposition-type implants were developed. McKeever postulated that knee function could be restored with a partial reconstruction as an alternative to TKA. He concluded a tricompartmental joint replacement was not necessary in cases of isolated, single compartment disease. He proposed a resurfacing

of the tibial plateau with a unicondylar metallic prosthetic insert, representing the earliest form of UKA. This unicompartmental device would potentially add a protective layer, preventing direct bone-on-bone contact and restore functionality to the affected compartment [12]. The design roots of this early prosthesis were based on biokinematic and mechanical properties, considering their impact on the resurfacing of the tibial plateau. McKeever used weight and femur length to calculate the amount of force exerted on the tibial plateau in selecting the appropriate shape, design, and density of his initial prosthesis [2, 19].

The early rationale for this procedure was that it provided for a more conservative approach to knee arthroplasty, minimizing native bone resection and preserving the joint anatomy. Compared to traditional TKA, a unicompartmental procedure would use a smaller prosthesis and replace either the medial or lateral joint compartment only [22]. The cruciate ligaments and the patella remain intact, conferring a less invasive approach to restore the native anatomy and structural integrity of the knee, while preserving joint proprioception and gait kinematics [13]. Ultimately, the McKeever vitallium tibial plateau prosthesis would later go on to be the first cemented UKA implanted in the United States in 1972.

Concomitantly, MacIntosh began experimenting with less aggressive approaches to surgery with a tibial plateau prosthesis, designed to treat the damage associated with varus and valgus deformities caused by advanced degenerative joint disease of the knee [17]. During this procedure to correct for severe valgus deformity, a half-cut acrylic tibial prosthesis was inserted into the lateral joint compartment. This unicompartmental procedure corrected not only the deformity, but also increased stability of the knee, restored collateral ligament tension, enhanced joint functionality, and reduced overall pain. The result for the patient was a neutral mechanical axis, flexion to 90°, and no reported knee pain for the next 12 years [13, 17].

As acrylic inserts were found to have unacceptable levels of early deterioration and wear in hip procedures, new materials were evaluated to improve clinical outcomes. McKeever and MacIntosh both emphasized the importance of an appropriate selection of prosthetic biomaterial as a significant factor for long-term success of implants [17]. The concepts of biocompatibility and biomaterials were developing at this time and had to be respected while also looking to optimize functional outcomes. Teflon was subsequently introduced as a potential substitute for the acrylic prosthesis. The results of Teflon were overall unsatisfactory with a high incidence of complications, revisions, and poor functional results. The failure of Teflon was attributed to quick mechanical wear and negative acute foreign body reactions. The trials and failures of Teflon led to the development of titanium as a potential prosthesis [22]. Titanium implants were used for a short period of time, but ultimately abandoned after complications were reported secondary to its insufficient hardness to serve as an articular surface.

McKeever later went on to introduce the vitallium-based tibial plateau prosthesis in 1957. Vitallium is a corrosion-resistant, cobalt–chromium–molybdenum alloy, which demonstrated early superior resistance to oxidative stress [5]. The McKeever vitallium prosthesis was intended to simulate a functional tibial plateau surface, designed with a slight concave and highly polished superior surface. This prosthesis also had a distinct T-shaped fin, which gave the implant additional stability and fixation when inserted into a trough in the tibial plateau. The transverse arm of the T-shaped fin sat anteriorly to additionally minimize difficulty of insertion during the procedure [19]. The correct size of the prosthesis, as intended by McKeever, was determined by fill of the joint space of the medial or lateral compartment of the tibial plateau [11].

In 1964 MacIntosh developed the MacIntosh Vitallium prosthesis, which was designed with rounded edges providing the corresponding femoral condyle with a reduced frictional surface area (Fig. 1.1). The inferior architecture of the implant was a flat surface with multiple serrations, facilitating a tight fit and enhancing stability [17]. The insert was mechanically stabilized with tension applied by taut collateral

ligaments, with no additional fixation necessary. This prosthesis came in varying thickness, from 6 to 21 millimeters, and three different diameters (Fig. 1.2). Although UKA postoperative care has progressed significantly since the early 1960s, MacIntosh restrained the knee in full extension in a compressive bandage for 5 days following the procedure, to ensure proper recovery. MacIntosh concluded that the early version of the hemiarthroplasty should be reserved for elderly patients over 70 years of age, and was a good treatment option due to the rapid postoperative recovery associated with UKA, based on standards in the 1960s.

Both MacIntosh and McKeever reported positive results, but neither's results could be

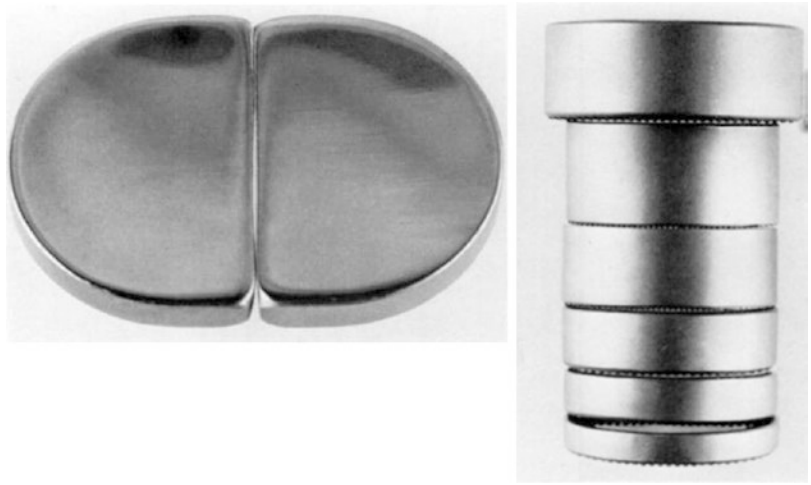

Fig. 1.1 (MacIntosh tibial insert) [17]. (MacIntosh tibial insert thicknesses) [17]

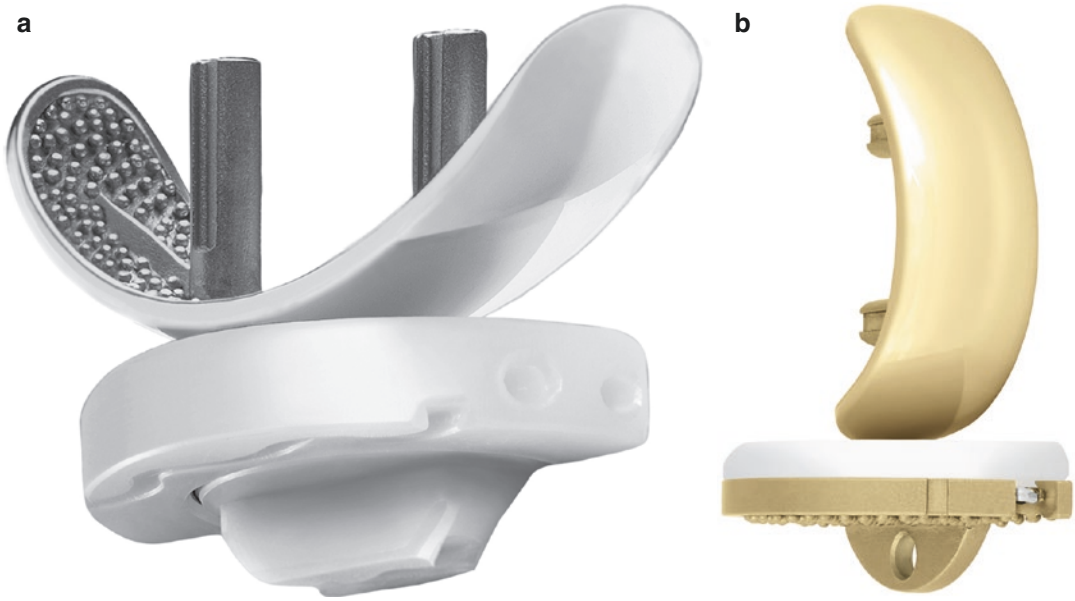

Fig. 1.2 (**a**) St. Georg sled in the all-polyethylene tibia version; (**b**) Additional version of the St. Georg sled in a coated version for patients with cobalt, chromium, or nickel allergy. This is also available in standard cobalt–chromium components as well.—Courtesy, Link, Hamburg, Germany

replicated consistently enough to be deemed successful. In 1972, MacIntosh published his results and saw an 80% success rate for osteoarthritic knees and only a 69% success rate for rheumatoid knees (Table 1.1;I). Early historical reports of UKA survivorship exhibited varying degrees of success, resulting in many surgeons abandoning the procedure as a treatment for isolated compartmental joint arthritis.

Historically, selection criteria for UKA were nonexistent, and no official consensus was available to guide surgeons. Essentially, there were believers and nonbelievers in the procedure, with no definitive algorithms available for determining appropriate candidates. Kozin and Scott developed the first widely adopted set of indications and contraindications for UKA in the late 1980s. Such criteria were held steadfast until recently, when there has been a challenge to expand the indications for UKA. While some surgeons may now recommend UKA in patients with ACL-deficient knees or patellofemoral arthritis, there remains relatively strong opposition that ascribes to the stricter indications outlined by Kozin and Scott et al. (Table 1.2) [13]. Following these relatively stringent parameters, Ritter et al. found that 4.3% out of 4021 knee arthroplasties met the indications for UKA, while 6.1% were appropriate candidates for UKA based on surgical pathology assessments [25]. These numbers are relatively consistent with current rates of UKA in the United States; however, there are centers driving these numbers up with rates as high as 20–30%.

Table 1.1 UKA Prosthesis-specific design survivorship % based on implant failures resulting in revision surgery at time of study reported follow-up

Historical UKA prosthesis design survivorship overview				
Study (years)	Prosthesis design	*n*	Survivorship (%)	Follow-up (years)
I. MacIntosh et al (1972) [17].	MacIntosh vitallum	130	95	7
II. Mackinnon and Mamor et al. (1988) [18].	St. Georg Sled	39	95 90	5 25
III. Kozinn and Scott et al. (1989, 1991) [13, 27].	Unicondylar knee	100	90 83 82	9 10 11
IV. Squire and Callaghan et al. (1998) [31].	Marmor knee	140	84	22
V. Murray et al. (1998) [20].	Oxford Phase 1 and 2	143	98	10
VI. Pandit et al. (2006) [23].	Oxford Phase 3	547	97 96	5 10
VII. Berger and Naudie et al. (2005) [4].	Miller–Galante	62	98 96	10 13

Table 1.2 Classic indications for UKA outlined by Kozinn and Scott, suggesting the ideal patient should be selected using the following inclusion criteria. Many surgeons still follow these classic indications with extended measures applied to age, weight, and level of activity

Classic indications for UKA		
Study	Proposed UKA selection criteria	
Kozinn and Scott et al. (1989) [13]	I. Isolated medial compartment disease	VI. Cumulative angular deformity less than 15°
Indications	II. 60 years age or less	VI. Preoperative range of flexion of at least 90°
	III. Low level of physical activity	VII. Both cruciate ligaments intact
	IV. Weight less than 82 kg	VIII. Flexion Contracture less than 5°
Contraindications	Inflammatory arthritis, age less than 60, high activity level, pain at rest, patellofemoral pain, opposite compartment pain, exposed bone in PF compartment	

UKA Historical Advancements and Innovation

After the initial introduction of UKA prostheses, modern changes to the implants and refined surgical techniques soon followed and have continued to develop over time. In 1969, the St. Georg Sled (Fig. 1.2) was developed in Hamburg, Germany, as a new cemented UKA option. It built upon the flat polyethylene tibial components used in earlier prosthetic prototypes and added a biometallic biconvex femoral component with two pegs for stability. This fixed-bearing prosthesis reported high levels of survivorship reported out to 25 years (Tables 1.1 and 1.3). At roughly the same time, Gunston and other polycentric knee replacement implants were being developed and brought to market.

In the early 1970s, Marmor introduced a new prosthesis known as the Marmor Modular Knee (Fig. 1.3a). Developed in 1972, this implant was designed to address both the medial and lateral compartments of the knee (Fig. 1.3b). The Marmor Knee used a nonconstrained polyethylene modular tibial component and a narrow smooth-polish finished biometallic, cementless femoral component with a single shaped peg [18]. The tibial insert, however, was smaller in comparison to the tibial component offered with the St. Georg sled. Early results were promising, with improvements in function and stability at a minimum of 2-year follow-up. The success rate declined with long-term follow-up at 10–13 years following surgery, but 86.6% still reported no pain (Table 1.1). Long-term follow-up at 15 years afforded excellent results as well, with overall mean increases in functional knee scores.

Marmor soon discovered that some of the early failures were likely due to the decreased size of his tibial component compared with the St Georg sled. Tibial polyethylene insert thickness was increased after the original version showed signs of excessive wear and deterioration [18]. Varied surgeon experiences with the Marmor UKA led to controversy in the orthopedic community, overshadowing the early successes of the UKA, and ultimately slowing widespread acceptance. The unfortunate timing of the controversy surrounding the Marmor Knee design translated into increased skepticism of the UKA procedure for the following decade.

While many studies in the 1970s and 1980s showed good results for fixed-bearing UKA, others presented less than stellar results. Bucholz and Heinert noted high rates of failure from the St. Georg sled and Laskin saw significant deterioration of the polyethylene surfaces in the Marmor knee, both leading to high rates of failure and revision [18, 22]. An alternative device that became available in the late 1970s was the mobile bearing Oxford UKA. Designed by John Goodfellow and John O'Connor, the major differentiator between this and other devices was the addition of an unattached bearing between the femoral and tibial components designed to mimic the presence of the meniscus. Goodfellow and O'Connor outlined four key aspects needed for successful knee replacement surgery [11].

Table 1.3 Oxford Knee UKA prosthesis by historical phase design and survivorship % based on implant failures resulting in revision surgery at time of study reported follow-up

Historical Oxford knee UKA survivorship overview				
Study	*n*	Oxford knee	Survivorship (%)	Follow-up (*years*)
I. Goodfellow and O'Connor et al. (1988) [11]	103	Phase 1 and 2	98	10
II. Murray et al. (1998) [20].	143	Phase 1 and 2	97	8
III. Robertsson et al. (1995) [26].	663	Phase 1, 2, and 3	92	20
IV. Faour et al. (2013) [9].	511	Phase 3	96	10
V. Yoshida et al. (2013) [33].	1279	Phase 3	95	10
VI. Edmondson et al. (2015) [8].	364	Phase 3	95	10

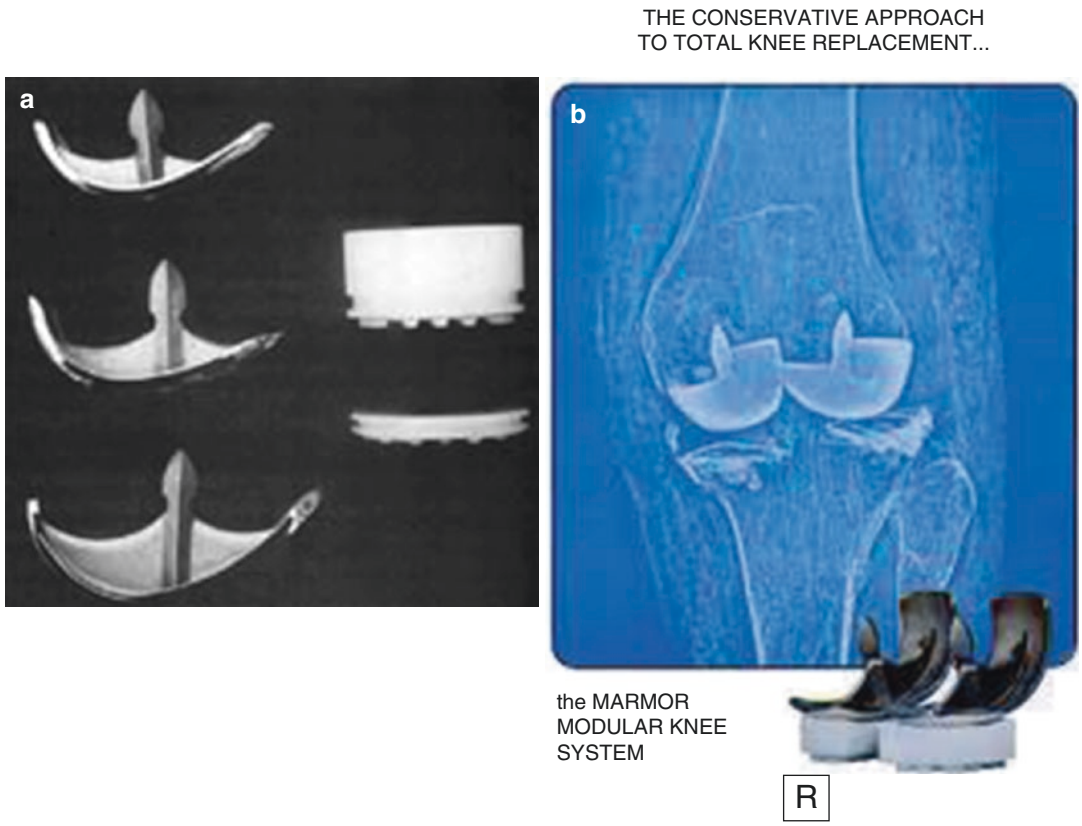

Fig. 1.3 (**a**) Marmor modular knee system [18]; (**b**) Marmor modular knee advertisement from the *Journal of Bone & Joint Surgery* (JBJS) in the 1970s. (Courtesy of Riyah H. Jinnah, M.D. and Joint Implant Surgery & Research Foundation [18])

1. The prosthetic components should be shaped to allow for all distracting, sliding, and rolling movements between the bones, without restriction.
2. The components should apply only compressive stress to the juxta-articular bone.
3. All surviving soft tissue should be kept and restored to its natural tension. The ligaments and muscles must provide stability to the otherwise unconstrained implant.
4. The areas of contact should be large enough to maintain the contact pressure under load at a level that prosthetic materials can withstand.

A key consideration in the development of Oxford UKA was reducing polyethylene wear, which was seen a major flaw in some fixed-bearing designs. This newly developed meniscal bearing was given a flat underside and a concave upper surface in order to maintain intimate contact between the tibial and femoral components [23]. The bearing, flat tibial plate, and the spherical femoral component together created a prosthesis that placed little stress on the surfaces. The preservation of the ligaments meant that the knee kept its stability, further fulfilling the four steps outlined previously. This prosthesis was indicated for unicompartmental degenerative joint disease, but showed signs of failure in knees where the anterior cruciate ligament (ACL) was missing or damaged. It was suggested that a healthy and functional ACL was a predictor of arthritis that was contained to the medial compartment of the knee [23].

The design of the prosthesis has remained largely the same since its inception.

The original prosthesis, the Phase 1, featured a single size femoral component (23.8 mm) and five tibial component size choices. Phase 2 of the Oxford UKA addressed issues with the shaping of the prosthesis as related to the affected compartment. Technical improvement allowed for the surgeon to take into consideration the flexion and extension gaps during surgery, thus simplifying the placement of the implant [11, 23]. The Phase 3 model, introduced in 1998, facilitated a smaller incision with smaller component sizes. The goal was to reduce rehabilitation time while maintaining the successful design and technique from Phase 2 [9]. All phases of the Oxford UKA have exhibited high rates of success and survivorship (Table 1.1). More recently, numerous evaluations of the Phase 3 model have shown high 10-year survival rates (Table 1.3) [33].

As lessons were learned from the early days of overcorrecting alignment with UKA, implant designs and surgical techniques have become more standardized. Surgeons who have remained dedicated to the development of the UKA procedure continue to pioneer improvements in enhanced prosthetic design, mastering surgical technique and establishing operative principles. The aforementioned early UKA prosthetic prototypes and surgical techniques were an important first step into the development of UKA as a successful orthopedic procedure. While surgical indications remain controversial, modern technique and implant design of UKAs have proven to be successful and are here to stay.

The Future of the Unicompartmental Knee Arthroplasty

The advancements in both prosthetic design (Fig. 1.4) and surgical technique have quelled some of the past controversy of UKA. A more apt understanding of appropriate conditions of osteoarthritis amenable to UKA, as well as more strenuous and selective patient indications [3], has yielded more positive results [26]. While it is still performed far less frequently than TKA [29], its minimally invasive technique [27], cost-effectiveness [30], and shorter recovery time make UKA a viable treatment with high levels of both success and patient satisfaction [16]. The advancements in technique and prosthesis design have also made revision to TKA less complex and likely improved outcomes (particularly when modern revision implants are employed). Furthermore, it is generally accepted that with a shorter length of stay and lesser degree of surgical intervention and morbidity, UKA procedures are safe to perform at outpatient surgery centers [7, 28].

Robot-assisted surgery has recently been employed in numerous medical fields and has now been used in knee arthroplasty procedures for several years. The use of robotics is meant to improve the accuracy of the placement of implants, which in turn may potentially lead to improved outcomes and survivorship. Components implanted with robotic assistance have been found to be positioned within 1° of error [6]. Also, computer-assisted surgery systems that monitor and provide real-time surgical feedback have been shown to provide more precise and accurate component placement. When computer-guidance was enabled, component placement was within an average of 2° of its intended placement. In cases without assistance, upward of 60% of components were incorrectly positioned [24]. Robotic-assisted surgeries may also help surgeons adhere more closely to their preoperative plan. Surgeons are provided with instantaneous tactile and haptic assistance provided by the robotic devices monitoring the radiological images. Functional benefits and effect on the longevity of components are currently being investigated.

As UKA enters the modern era of surgery centers, less invasive surgical techniques, and rapid recovery protocols, many surgeons have again considered this procedure, leading to a resurgence in its popularity in some areas of the USA and worldwide. With careful and stringent patient selection criteria and meticulous surgical technique, surgeons are seeing higher patient satisfaction, greater overall success rate, and increasing implant survivorship. Patient optimization and specific multimodal clinical pathways now routinely lead to more rapid discharge

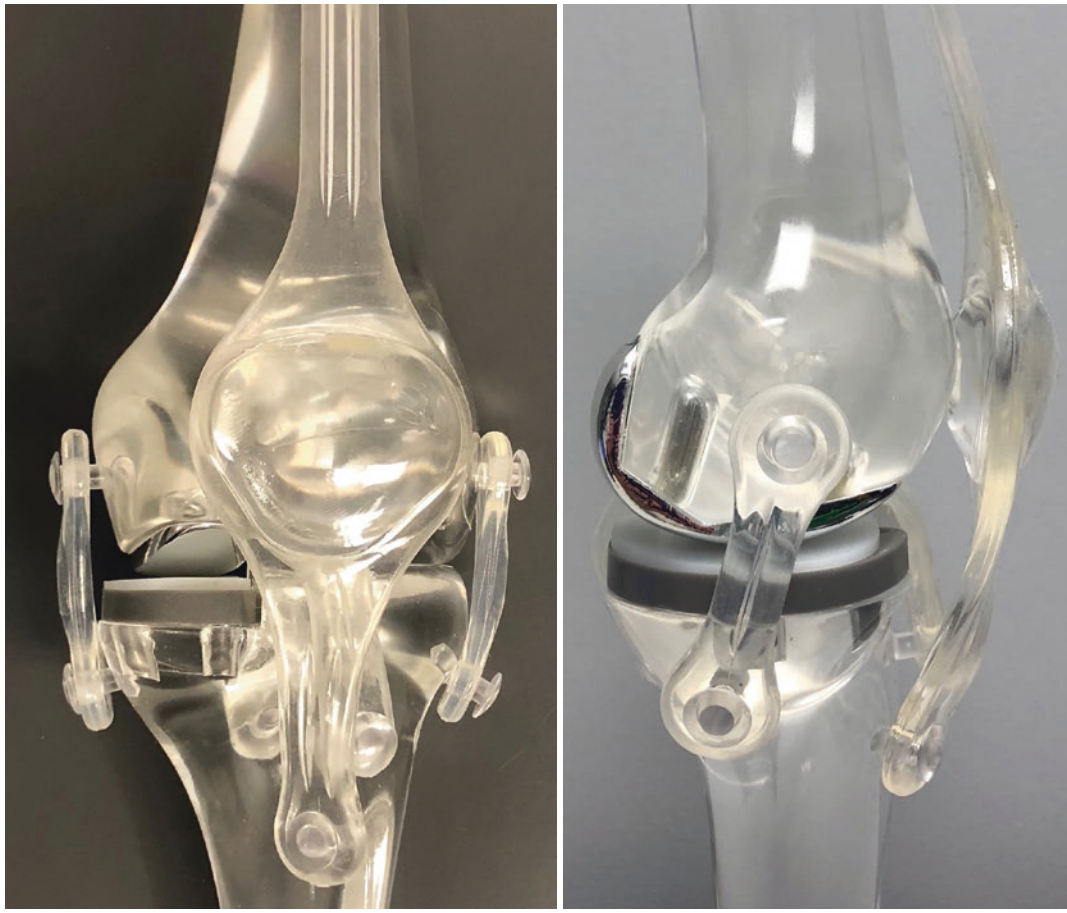

Fig. 1.4 Views of a modern fixed bearing UKA model

and return to function after UKA. Although the technical aspects of the UKA can be challenging, refined surgical technique have led to excellent survivorship that rivals that of TKA. As the orthopedic community continues to debate on the broad implementation of this procedure, additional questions will undoubtedly arise as surgical technology advances.

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2 Indications for Unicompartmental Knee Arthroplasty: Which Knees Are Best?

Jason L. Blevins and David J. Mayman

The incidence of joint replacement procedures has increased in recent years due in part to an increase in life span, an increasingly active population, and rising obesity rates [1]. Total-knee arthroplasty (TKA) has been reported as the gold standard for treatment of patients with severe knee osteoarthritis (OA). However, there continues to be patient dissatisfaction with modern implant designs. Part of this dissatisfaction is related to postoperative pain, stiffness, and a lengthy and difficult rehabilitation [1]. Initially, unicompartmental knee arthroplasty (UKA) was controversial [2]. As techniques and implant designs have improved, studies have demonstrated that UKAs are durable and reliable procedures and are a viable surgical option for treating a subset of OA of the knee [2, 3].

Unicompartmental knee arthroplasty currently constitutes 8–10% of arthroplasties performed in the United States and the United Kingdom [4]. The potential advantages of UKA over TKA include improved functional outcomes, gait, proprioception, faster recovery, and less blood loss in addition to preservation of native bone stock and the cruciate ligaments [4]. Numerous studies have reported faster recovery and clinical benefit of UKA compared to TKA [5–7]. However, concerns regarding long-term survivorship have been voiced for UKA. Changes in implant designs and techniques have sought to improve long-term survivorship and function. Lyons et al. (2012) reported Kaplan–Meier survivorship at 5 and 10 years of 95% and 90% for UKA versus 98% and 95% for TKA in a large retrospective database analysis [8]. Price et al. (2011) reported on long-term follow-up of 682 Oxford mobile bearing medial compartment UKAs with 91% survivorship at 20 years [2]. A recent multicenter study reported 98.8% survivorship at 2.5 years and 97.5% survivorship of 432 robotic-arm-assisted fixed bearing medial UKAs at mean 5.7 years follow-up [3, 9]. Recently, a meta-analysis of survivorship of UKA versus TKA reported annual revision rates of 0.49% in TKA patients compared to 1.07% in medial UKA patients [10].

Prior studies have sought to compare results of unicompartmental versus total-knee arthroplasty [1, 7, 8, 11, 12]. Despite controlling for a number of different factors such as comorbidities, BMI, and age, these study groups did not control for the severity of osteoarthritis in each compartment of the knee. It is not a fair assumption that patients with tricompartmental OA are the same as patients with primarily medial compartment osteoarthritis. There are a small number of studies who have attempted to compare outcomes in patients with comparable preoperative radiographs with limited medial compartment OA and symptoms [5, 13, 14].

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Siman et al. (2017) performed a retrospective review of registry data from the Mayo Clinic of patients over the age of 75 years who underwent TKA or UKA. They analyzed preoperative radiographs and included those who met criteria for a medial UKA with a final comparison of 120 UKA and 188 TKA at mean 3.5 years follow-up. The authors found no significant difference in Knee Society Scores (KSS) between the included UKA and TKA patients (85.4 vs. 84.0) at minimum 2-year follow-up. They found no difference in 5-year survivorship estimates of UKA and TKA at 98.3% versus 98.8% respectively in their analysis [5]. Newman et al. (2009) reported their 15-year results of a randomized trial of UKA versus TKA for treatment of medial compartment OA and reported no difference in survivorship or complications with improved clinical outcomes in the UKA group [13]. Yang et al. (2003) compared the 6-month outcomes of patients who underwent UKA or TKA with primarily medial compartment OA, and found quicker recovery of function, improved range of motion, and shorter hospitalization with UKA [14].

Cost-effectiveness analyses have evaluated UKA versus TKA and have demonstrated that results are sensitive to survivorship and risk of revision for UKA [11, 12]. In addition, cost-effectiveness analyses have generally assumed that functional outcomes are similar with UKA and TKA [15, 16]. Baker et al. (2013) demonstrated that survivorship has been associated with surgeon volume with reported 96% 5-year survivorship in centers with >50 procedures performed per year [17].

There continues to be a debate over what is the most effective treatment for symptomatic primary medial compartment OA. The importance of accurate restoration of ideal alignment in the prevention of opposite compartment degeneration and component failure is critical in UKA [1]. Recently, robotic-assisted UKA has been employed to improve postoperative alignment with demonstrated accuracy in a randomized controlled trial comparing MAKO® robot-assisted versus traditional Oxford instrumentation UKA [4].

Return to activity continues to be an important factor after knee arthroplasty. Patients often present with the expectation of return to the activities they enjoyed prior to their limitations from knee OA. A recent systematic review by Waldstein et al. (2017) reported that patients following a UKA were physically active, and had a significant increase in low-impact activities and a decrease in high-impact activities [18]. Furthermore, the return to activity rate ranged from 87% to 98% [18]. Walton et al. (2006) demonstrated a higher rate of return to sport after UKA versus TKA [7]. Naal et al. (2007) demonstrated a return to activity rate of 95% in a cohort of UKA patients [19].

Indications for an UKA vary widely with no consistently agreed-upon treatment path among surgeons. In addition to clinical exam, radiographic imaging is performed during the preoperative workup and evaluation (Fig. 2.1) to identify whether a patient meets the radiographic criteria for a UKA. Deshmukh et al. (2001) defined unicompartmental candidates as having (1) noninflammatory arthritis, (2) a mechanical axis that deviates no more than 10 degrees from neutral for a varus knee or 15 degrees for a valgus knee, (3) an intact anterior cruciate ligament without signs of mediolateral subluxation of the femur on the tibia, and (4) the patellofemoral compartment can have Grade II or III Kellgren–Lawrence changes without patellofemoral joint (PFJ) symptoms [20, 21]. These criteria are more inclusive than the traditional Kozinn and Scott criteria, which included additional parameters of age > 60 years, weight < 82 kg, not heavy laborers or extremely active, reproducible pain with weight-bearing and activity with minimum pain at rest, range of motion to 90° of flexion with no more than a 5° flexion contracture, no more than 10° of varus or 15° of valgus that is passively correctable, intact ACL, noninflammatory arthritis, no chondrocalcinosis, and no PFJ symptoms [22].

Recently, the indications for UKA have expanded. With traditional selection criteria, 6% of osteoarthritic knees may meet criteria for an UKA [23]. However, using expanded criteria for the Oxford UKA, it has been reported that up to half of patients may benefit from a UKA [24]. Hamilton et al. (2017) published a consecutive series of 1000 mobile bearing UKA in which the traditional Kozinn and Scott criteria were not fol-

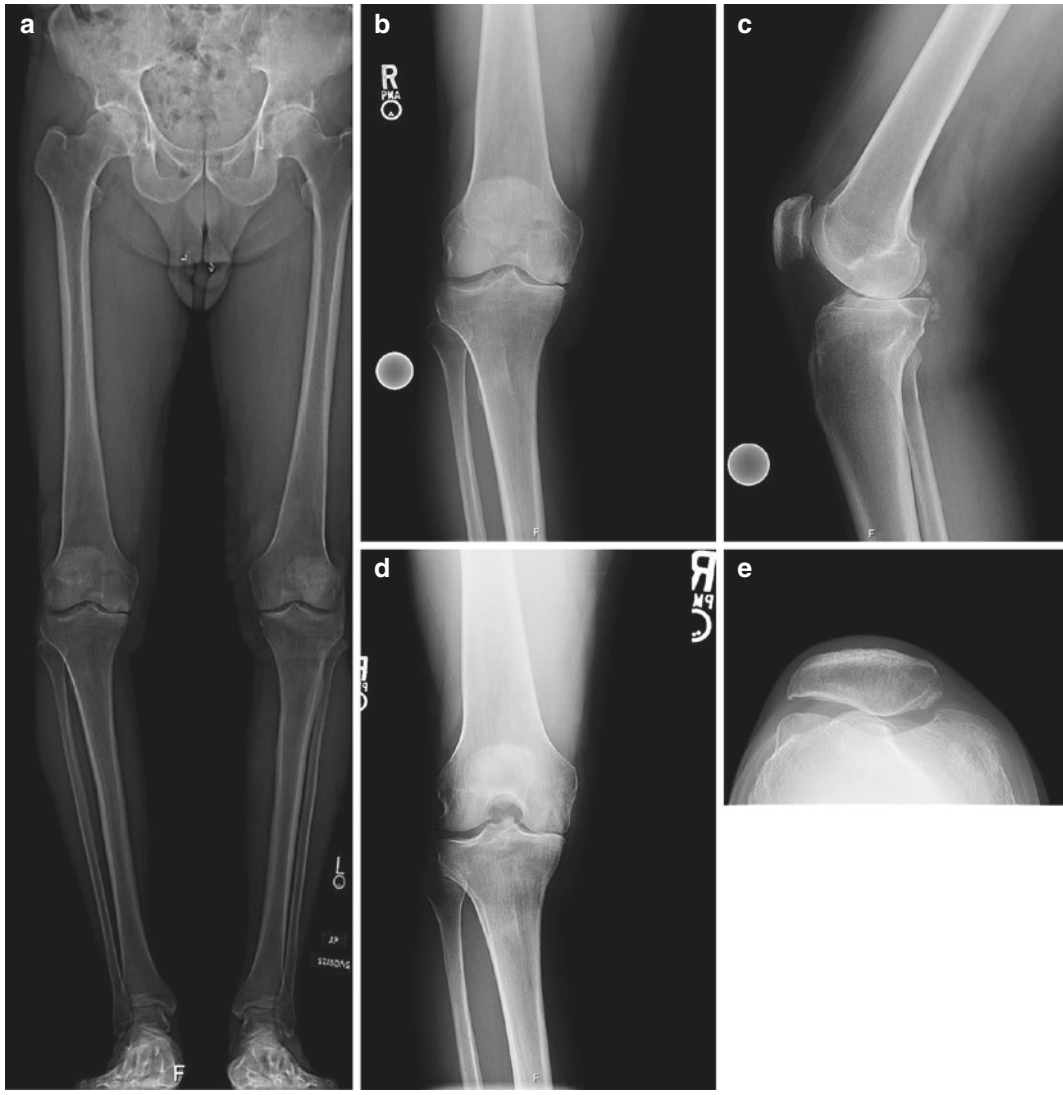

Fig. 2.1 Preoperative radiographic workup of 63-year-old male patient with primary complaints of medial joint line tenderness with ambulation who had failed conservative measures. Standing full length lower extremity films (**a**) in addition to anteroposterior view (**b**), lateral view (**c**), posteroanterior flexed view (**d**), and merchant view (**e**) are shown

lowed [25]. Of these, 68% of the UKAs would have been excluded by traditional criteria for an UKA in their series. The authors used their previously reported indications for Oxford medial UKA for the treatment of anteromedial osteoarthritis and spontaneous osteonecrosis of the knee including (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 anterior cruciate ligament. The status of the PFJ, with the exception of bone loss with grooving laterally, was not considered a contraindication to Oxford UKA. They reported no difference in American Knee Society Objective Scores or Oxford Knee Scores at a mean follow-up of 10 years, with a significantly lower number of poor outcomes in those who did not meet all criteria and no difference in 15-year implant

survival (90.7% in contraindication group vs. 88.5% in no contraindication group) [25].

Patient demographics are often controversial as well. Some studies do not recommend UKA for young active individuals or obese individuals due to the increased forces, which could overload the joint [1, 3]. Hamilton et al. (2017) performed a subgroup analysis of their cohort of patients who did not meet traditional restrictions of age > 60 years, weight < 180 pounds, increased activity, chondrocalcinosis, and patellofemoral joint disease, finding no difference in survivorship at 15 years [25].

The effects of weight and BMI on UKA outcomes and survivorship have been studied by multiple groups [26]. Pearle et al. (2017) reported a higher annual revision rate in those patients with a BMI ≥ 35 kg/m^2 (1.36% vs. 0.28% in BMI 18.5–24.9 kg/m^2) [3]. Haughom et al. (2015) demonstrated in a NSQIP database analysis of 2316 UKAs that increased BMI was a significant risk factor for revision [27]. Similarly, Kandil et al. (2015) performed an analysis of 15,770 UKAs in the PearlDiver database and demonstrated that obesity (BMI 30–39 kg/m^2) and morbid obesity (BMI ≥ 40 kg/m^2) were risk factors for complications and revisions [28]. Interestingly, Bonutti et al. (2011) showed decreased survivorship of 88% versus 100% at 3 years in patients with BMI ≥ 35 kg/m^2 [29]. Berend et al. (2005) also found that a BMI > 32 kg/m^2 was predictive of failure in their consecutive series of 79 UKA at minimum 2-year follow-up [30].

Other studies did not find a correlation between high BMI and revision rates at mid- and long-term follow-up. Murray et al. (2013) found no association with increasing BMI and implant survivorship in their analysis of 2438 medial Oxford mobile bearing UKAs at 5-year follow-up. Cavaignac et al. (2013) also found no difference in 10-year survivorship results when divided by weight (93.5% in weight ≥ 82 kg vs. 92.5% in weight < 82 kg) and BMI thresholds (92% in BMI ≥ 30 kg/m^2 vs. 94% in BMI <30 kg/m^2) [31].

Hamilton et al. (2017) compared those patients who underwent Oxford mobile bearing UKA, who met weight restriction of 180 pounds and those who were above this threshold (45%) [25]. The overweight group weighed on average 209 pounds (range 180–408 pounds) and they found no difference in 15-year implant survival or means of failure between the groups and reported no significant difference in 10-year functional outcome measures [25]. Similarly, van der List et al. (2016) performed a large meta-analysis of 31 comparative cohort studies and 6 registries demonstrating no significantly increased likelihood for inferior outcomes or revisions in patients with obesity defined as BMI ≥ 30 kg/m^2 (revision rate of BMI < 30 kg/m^2 group OR 0.71, 95% CI[0.48–1.06]) [32]. Patients with an increased weight or BMI should be counseled on the preoperative risks and the conflicting evidence regarding implant survivorship and be encouraged to lose weight to help improve this modifiable risk factor.

Age over 60 was initially reported as a threshold for UKA in the Kozinn and Scott criteria [22]. Multiple studies have examined this threshold and its effect on outcomes and survivorship. Harrysson et al. (2004) demonstrated that younger patients had an increased risk of revision after UKA in the Swedish Knee Arthroplasty Registry [33]. In a meta-analysis of reported outcome measures and revision rates from 31 cohort studies and 6 registries, age < 60 years was not found to be associated with a significant difference in functional outcomes or an increased risk of revision surgery (in studies: OR, 1.52; 95% CI, 1.06–2.19; in registries: OR, 2.09; 95% CI, 1.70–2.57) [32]. In contrast, Hamilton et al. (2018) reported that in their cohort, with 25% of their cohort (245 UKA) under the age of 60, there was no difference in 15-year implant survival (94.8% in <60 year group vs. 91.3% in ≥60 years group, p = 0.7), time to failure, or mechanism of failure for age < 60 [25]. Additionally, the authors found a significant benefit for the under 60 group with improved American Knee Society Scores, Oxford Knee Scores, and Tegner Activity scores at 10-year follow-up [25]. Younger patients should be counseled preoperatively about their potential

risk for higher revision rates, as reported in the literature, for both UKA and TKA.

Patellofemoral joint osteoarthritis is not a contraindication to medial UKA if the patient is asymptomatic. Careful clinical exam and intraoperative assessment should be performed to determine if UKA is appropriate. A long-term study by Berger et al. (2004) identified progression of PFJ disease as a the primary mode of failure after fixed bearing medial UKA [34]. This differs from the findings of the meta-analysis performed by van der List et al. (2016) where preoperative patellofemoral osteoarthritis was not found to have an association with inferior clinical outcomes or survivorship [32]. These results are also supported by the findings of Hamilton et al. (2017): no significant differences in functional outcomes or implant survivorship were demonstrated in patients with exposed bone in the PFJ [25].

Most authors agree that ACL deficiency is a contraindication to medial UKA [20, 22]. However, a recent meta-analysis showed no difference in revision rates or clinical outcomes in those with ACL deficiency [32]. This finding is supported in a study by Boissonneault et al. (2013), where 46 medial Oxford mobile bearing UKA were implanted into ACL-deficient knees and compared to a matched cohort of ACL intact UKA [35]. At 5-year follow-up, no difference was reported in survivorship or functional outcomes [35]. The integrity of the ACL should be carefully assessed preoperatively and if a patient has complaints of pain and instability, consideration should be made for a TKA in these patients.

Overall, indications for UKA vary widely in the literature. Importantly, isolated compartment symptoms with activity, a correctable deformity, and noninflammatory arthritis are agreed upon. A detailed history and exam, in addition to radiographic workup, should be performed to identify ideal candidates for this operation. The exclusion of those patients with patellofemoral OA, under the age of 60 years, or over 180 pounds are not consistently supported and a discussion with the patient should be performed preoperatively regarding the risks of revision reported in those cohorts.

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3 Patient Criteria for Unicompartmental Knee Arthroplasty: Are There Exclusion Criteria?

Alexander L. Neuwirth, Matthew J. Grosso, and Jeffrey A. Geller

Introduction

The first documented formal indications for unicondylar knee arthroplasty (UKA) were introduced in 1989 [1]. Although these remain controversial and are still debated, they provide an important framework in the surgical decision-making consideration of determining if a patient may be an appropriate candidate for a UKA. These indications include age greater than 60 years, degenerative changes isolated to a single hemicompartment of the knee, weight less than 82 kg, intact anterior cruciate ligament (ACL), less than 5° flexion contracture and less than 10° fixed varus malalignment for a medial arthroplasty, arc of motion greater than 90°, low activity level, and absence of inflammatory arthritis. [1] The recent popularization of UKA as a minimally invasive alternative to TKA (Fig. 3.1), along with the advent of modern implant designs (Fig. 3.2), has led to surgeons performing UKAs in patients who would have classically been contraindicated based on original criteria. Inclusion criteria have significantly expanded, with consideration for successful outcomes in the younger population (<60 years old), patients with significant deformity (varus up to 10°, valgus up to 5°, and flexion contracture up to 15°), and patients with a degree of patellofemoral arthropathy. Even the long-held tenant of intact ACL has been questioned, with reported success in certain ACL-deficient populations [3].

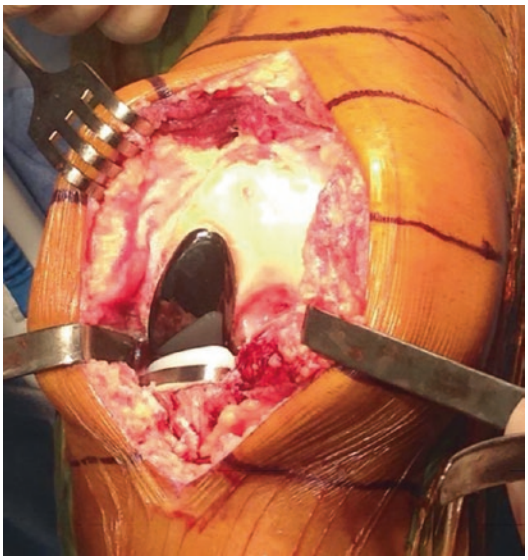

Fig. 3.1 Intraoperative photo of a unicondylar arthroplasty

Age

Traditional criterion for UKA includes age over 60 years old. With the recent popularization of UKA and good results found in

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Fig. 3.2 Example of current unicompartmental knee arthroplasty design [2]

increasingly younger patients, the traditional guidance recommending UKA in older patients has slowly changed and age is no longer considered a strict exclusion criterion. For the majority of surgeons, UKA has replaced high tibial osteotomy as the treatment choice for the midrange age population (40–60 years old). Faour et al. noted good results at 12 years in young patients following UKA [4]. Walker et al. looked at patients under the age of 60 retrospectively and noted that those patients were able to return to regular physical activity and that a majority of them were able to reach a higher activity level postoperatively [5]. Streit et al. demonstrated that the Oxford UKA had good results in patients under the age of 60 with an estimated 97% survival at 5 years and only 2% of patients had developed symptomatic arthritis in the other compartments of the knee at 5 years [6].

The thinking on UKA has changed significantly over the last 20 years, as UKA has shifted from an operation well suited for an elderly population, unlikely to develop symptomatic arthritis in other compartments of the knee, to one for young active patient who wish to preserve native knee kinematics.

Weight

While obesity was traditionally thought of as a contraindication to UKA due to the increased compartment pressures, risk of early loosening and the perceived increased risk of progressive degeneration in other compartments of the knee, more recent data suggests that Kozin's original exclusion criteria of weight greater than 82 kg may warrant revision.

Obesity, and in particular BMI >40, is nearly universally noted to be associated with increased risks of short-term complications following knee arthroplasty, and particularly of infection. Kandil et al. found that obesity and morbid obesity were found to have significantly increased risk of 90-day complications when compared to nonobese patients [7]. However, Molloy et al. found in a prospective cohort that BMI was not associated with worse outcomes postoperatively. Furthermore, BMI was not found to be a risk factor for loosening at a mean of 10 years, and the best reported outcomes were in patients with BMI in excess of 35 [8]. Plate et al. found that at 24 months, using robotically assisted UKA, BMI did not influence clinical outcomes or readmission rates following UKA [9]. BMI was noted to be associated with higher narcotic analgesic use, as well as increased PT sessions. Van der List et al., in a large meta-analysis, noted no inferior outcomes following UKA in obese patients compared to nonobese patients [10].

The evidence-based shift away from strict exclusion of obese patients warrants further investigation. Furthermore, many factors related to poor outcomes following arthroplasty, which were initially thought to relate to BMI, may actually relate more closely to nutrition status and glycemic control. Further research of these possibly confounding factors will clarify their specific risks for short-, mid-, and long-term failure.

Deformity

While large deformities are still a contraindication to UKA, the accepted degree of deformity has expanded from Kozin and Scott's original criteria

of <5° of varus and < 5° flexion contracture. Classically, this exclusion criterion was based on the principle of minimal soft tissue releases performed in UKA that limited the surgeon's ability to correct a large deformity to near-neutral. There was also concern that an under-corrected deformity may lead to increased compartment pressures, aseptic loosening, and early failure rates [11, 12].

In the early 2000s, Scott re-evaluated his criteria [13, 14]. By examining his long-term outcomes over the previous decades, he suggested expanding the criteria to <10° of varus deformity and <5° of valgus deformity (Fig. 3.3). More lenient deformity acceptance largely revolved around the belief that a certain amount of residual varus is acceptable [11, 12, 15]. These outcome studies supported similar long-term survival for up to 7° of residual varus deformity. In a recent article by Kleebald et al., they discussed correcting knees in patients with a large preoperative deformity (>7° of varus), and concluded that patients with large deformities (7–18°) may be considered a surgical candidate for UKA [16]. Similar findings were found for valgus deformity, but to a lesser degree [17].

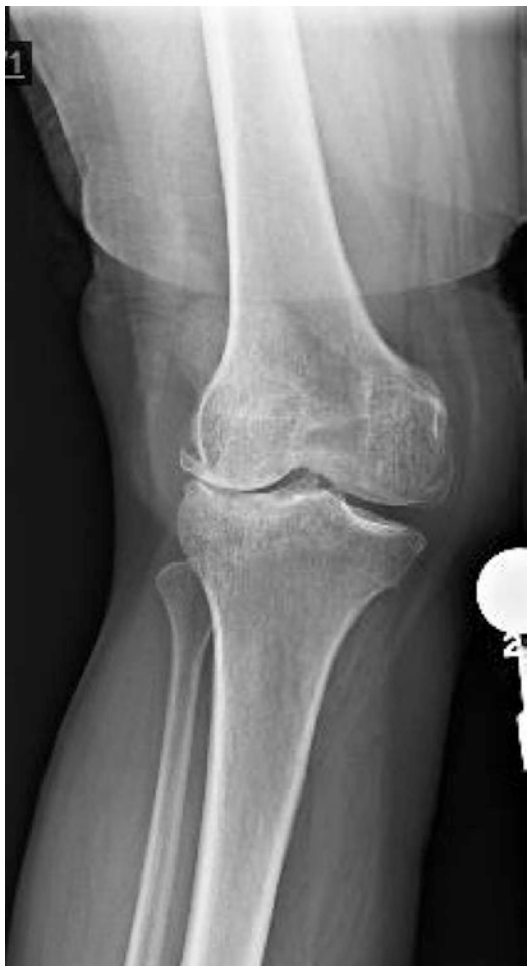

Fig. 3.3 AP radiograph of knee with severe valgus deformity (> 5°)

ACL Integrity

Since Kozin's original article, ACL deficiency has been perceived as a contraindication to UKA due to the inherent alteration in knee kinematics and abnormal contract stresses. While Kozin et al. defined ACL deficiency as an exclusion criterion for UKA, recent literature suggests that ACL deficiency without instability may not be a strict contraindication to partial-knee replacement. Biomechanical data suggests that leveling of the tibial slope may compensate for anterior translation in the ACL-deficient knee without restoring the pivot shift to normal [18].

Engh et al. noted at a mean of 6-year follow-up, that UKA in ACL-deficient knees and that in ACL-intact knees had similar survivorship (93% vs. 94%). Of note, this series excluded patients with clinical instability and only included those with stable knees in spite of their ACL deficiency [19]. Boissonneault et al. showed in a retrospective study that patients undergoing Oxford UKA in ACL-deficient knees had satisfactory results at a mean of 5 years with survivorship comparable to a cohort with intact ACLs [20].

Technical advances and the widening of surgical indications have culminated in the advent of combined UKA and ACL reconstruction surgery, which has shown promising results. In vivo kinematic evaluation of patients following combined ligament reconstruction and UKA demonstrated native knee kinematics in patients who

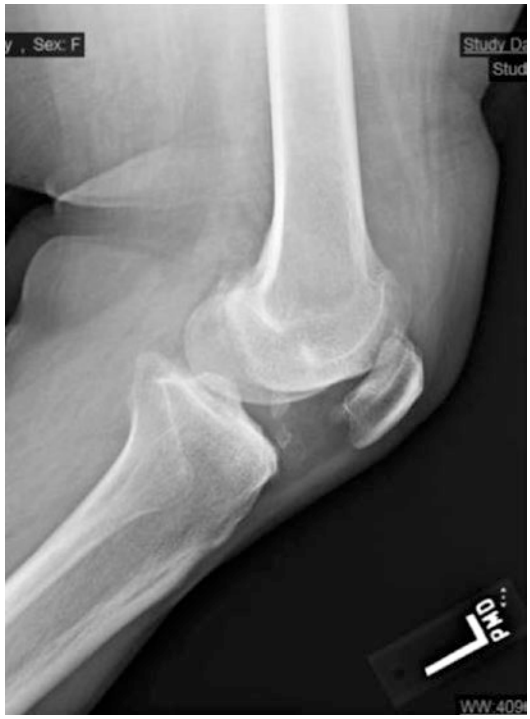

Fig. 3.4 Lateral X-ray of knee demonstrating subtle anterior subluxation of the tibia and advanced posterior wear consistent with ACL deficiency

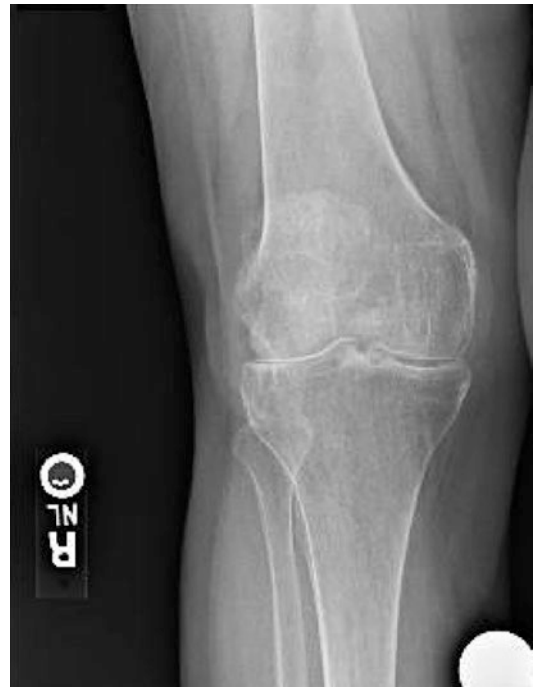

Fig. 3.5 Radiograph of knee of patient suffering from severe rheumatoid arthritis demonstrating characteristic peri-articular erosions

underwent Oxford UKA and ACL reconstruction [21]. Further, in young active patients, at a mean of 53 months, results of combined surgery showed improved knee society scores, good stability, and no revisions [22].

These recent studies suggest that conventional wisdom is being challenged regarding UKA in patients with ACL-deficient knees. Through careful patient screening, altered intraoperative technique, and via concurrent ligament reconstruction, patients with ACL-deficient knees may benefit from UKA in knees with isolated single compartment disease (Fig. 3.4).

Inflammatory Arthritis

Classically, a contraindication, there is a paucity of literature on unicompartmental arthroplasty in patients suffering from inflammatory type arthritis. As novel biologic drug therapies have helped limit the impact of autoimmune conditions on the knee, there is currently no literature on the use of disease-modifying agents and unicompartmental arthroplasty in patients suffering from inflammatory arthritis.

Conventional wisdom continues to support the Kozin contraindication of inflammatory arthropathy, as these conditions are likely to involve more than a single compartment, and likely place the patient at risk of dissatisfaction and progression of knee pain from arthritis following arthroplasty (Fig. 3.5).

Pre-Existing Patellofemoral Disease

Although patellofemoral disease was often quoted as a contraindication to UKA, recent evidence suggests that patients may have satisfactory outcomes despite degenerative changes on the patella and/or trochlea. This topic has become extremely controversial with some surgeons

advocating completely ignoring the patellofemoral joint altogether [23–26]. Song et al. compared UKA patients with and without PF arthritis classified as less than grade 2 changes at a mean of 5.4 years and noted excellent results regardless of disease in that compartment [26]. Lim et al. evaluated 263 knees following UKA, 41 of which had patellofemoral disease and found no significant difference in functional outcome scores. Thein et al. also found that patellofemoral disease was not associated with worse outcomes following medial UKA, and hypothesized that this was secondary to improved patellofemoral congruence postoperatively [24]. Intraoperative chondrosis of the patellofemoral joint was also noted to not be associated with worse outcomes following UKA in patients with anterior knee pain preoperatively [25].

Konan et al. however, found that the location of chondral lesions on the patella was an important determinant of results following UKA. Centrally and laterally located chondral lesions significantly affected results and, according to the author, should be evaluated critically when considering patients with anterior knee pain and patellofemoral disease for UKA [23].

The recent plethora of data supports UKA even in the setting of patellofemoral disease. While some data suggests ignoring the severity of patellofemoral arthrosis intraoperatively, even in the setting of anterior knee symptoms, the authors' preference is to proceed with TKA in this patient population.

Summary

UKA has become an increasingly popular operation over the last two decades. With more and more studies demonstrating successful outcomes across a range of patient populations, its indications have rapidly expanded and warrant a redefinition of the classic contraindications. Nevertheless, meticulous preoperative evaluation is critical to determine appropriate candidates for successful UKA, and to minimize the potential risk for conversion to TKA.

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4 Risk Mitigation for Unicompartmental Knee Arthroplasty

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Case

A 62-year-old female presented with a 4-year history of right knee pain that had failed conservative management (Fig. 4.1a–c). She had a medical history notable for colitis, diabetes (diet-controlled), hypertension, iron deficiency, scleroderma, and lupus. On examination, she was 5′5″ and 225 pounds, for a BMI of 37.4 kg/m^2. She had tenderness to palpation at the medial but not lateral joint line, and she had a negative patellar grind test. Range of motion was 0–100, and she was ligamentously stable and neurovascularly intact. She was indicated for medial unicompartmental knee arthroplasty (UKA) and sent for preoperative laboratories.

Preoperative laboratories were normal with the exception of a HbA1C of 11.0. This was a surprise to the patient, but she admitted that she was not following the diet that had been recommended to her as the best means through which to control her diabetes. Surgery was delayed. With the help of an endocrinologist and her primary care provider, she started metformin and glimepiride (two oral hypoglycemics). Within 4 months, her HbA1c had fallen to 7.1. She was reindicated for medial UKA, and the procedure and postoperative recovery were without incident. One year postoperatively, she has an excellent result (Fig. 4.1d–f).

Introduction

The vast majority of literature regarding medical and surgical complications of knee arthroplasty has been written about patients undergoing total knee arthroplasty (TKA) rather than medial, lateral, or patellofemoral UKA. This is largely because TKA is much more common than UKA, and the research is therefore more easily powered and potentially more relevant analyzing TKA[1]. A secondary explanation is that due to the more invasive nature of TKA compared to UKA, TKA is thought to have overall higher rates of postsurgical complications [2].

Nevertheless, due to the similar nature of UKA to TKA, much of the TKA research likely applies to UKA. Each section of this chapter will first cover key takeaways from the TKA literature, with respect to optimization of the knee arthroplasty host, and will then highlight literature specific to UKA and compare and contrast it with the literature published for TKA. We will conclude with our own recommendations as derived from the literature.

With respect to optimization, this chapter breaks down potential areas of optimization

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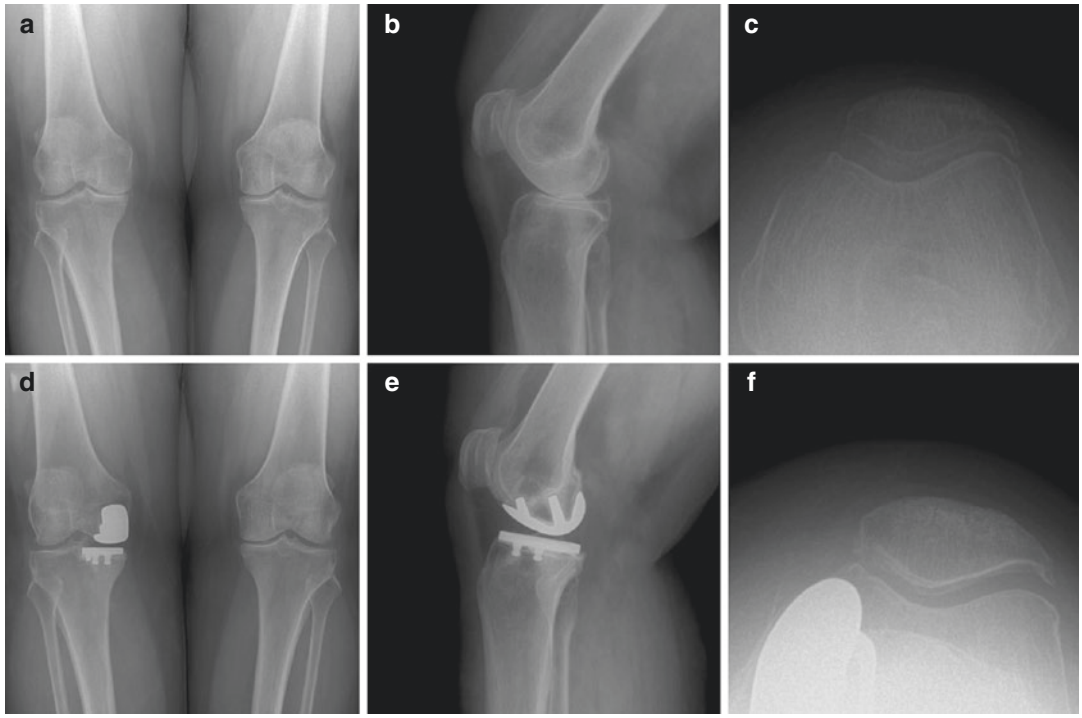

Fig. 4.1 (**a–c**) Anterior-posterior, lateral, and sunrise views of a right knee showing medial compartment osteoarthritis with well-preserved lateral and patellofemoral facets. (**d–f**) Same views one year s/p medial compartment unicompartmental knee arthroplasty

into the following *modifiable* patient factors that are predisposing of early postoperative adverse events:

- Obesity
- Diabetes
- Malnutrition
- Atherosclerosis
- Tobacco use
- Intra-articular injections
- Hypercoagulability

Obesity

Defining the Epidemic

Body mass index (BMI) is an imperfect, but easy-to obtain, measure of the extent to which a patient's weight correlates with his or her overall size. It is calculated by dividing the patient's weight by the patient's height (by convention reported in kg/m^2). The World Health Organization classifies BMI as follows: <30 kg/m^2 normal; 30–35 kg/m^2 overweight; 35–40 kg/m^2 obese; 40–50 kg/m^2 morbidly obese; and ≥ 50 kg/m^2 super obese.

The obesity epidemic has rapidly spread throughout the world, and in particular the United States, with more than 1 in 3 adult Americans now classified as obese [3]. More to the point, among a population of patients undergoing UKA captured in the American College of Surgeons National Surgical Quality Improvement Program (NSQIP), more than 1 in 4 patients qualified as obese at a minimum [4].

Impact of Obesity on Short-Term Outcomes

Obesity complicates arthroplasty in terms of anesthetic options, positioning, exposure, and closure. There is overwhelming evidence of its association

with complications following TKA: Obesity has been shown to increase operative time [5], overall complications [5], renal complications [6], wound-healing complications [6–8], deep infection [6, 7], urinary tract infection [9, 10], cardiac arrest [11], reintubation [11], reoperation [11], superficial infection [11], death [11], readmission [12], length of stay [12], venous thromboembolism (VTE) [13], and blood loss [14]. On the whole, these associations appear to present themselves most strongly with BMI rising above 40 kg/m^2, and strengthen somewhat linearly beyond that point. For example, while patients who qualify as morbidly obese (BMI $\geq$ 40 kg/m^2) have about 1.5 times the odds of a postoperative complication [15], superobese patients (BMI $\geq$ 50 kg/m^2) have 3.1 times the odds of complication [16].

Less work has examined the impact of obesity specifically with respect to UKA; however, the work that has been conducted suggests that the above-noted associations similarly apply. For example, in a large study of the NSQIP, greater BMI was independently predictive of overall complications and prolonged length of hospitalization [2]. Similar findings were confirmed using Medicare and private payer databases [17].

Impact of Obesity on Long-Term Outcomes

A second concern is that rates of failure for UKA may be higher in patients with greater BMI. The theory is that the increased load on the knee may contribute to increased prosthetic wear, progression of arthritis in the un-resurfaced compartments, subsidence, fracture, and loosening. This concern is supported by a study of 40 UKAs with BMI $\geq$ 35 kg/m^2 versus 33 UKAs with BMI < 35 kg/m^2 that demonstrated 5 revisions to TKA among the high BMI group, but none among the low BMI group [18]. However, several larger studies have contradicted these results, finding no difference between obese and normal-weight patients in terms of mid-term and long-term results [19–21].

Does Lowering BMI Prior to Surgery Decrease the Risk of Early Complications?

It seems logical that by putting an obese patient on a weight-loss regimen and offering surgery only once that patient's BMI has reached a certain level, a surgeon could lower the risk of postoperative complications. Unfortunately, we are aware of no level-1 study that has attempted to evaluate whether weight loss through nutritional or surgical intervention decreases the rate of postoperative complications following any type of knee arthroplasty procedure. A number of retrospective studies have found that bariatric surgery prior to TKA can improve outcomes following TKA [22–26]; however, these studies are limited by lack of appropriate control, retrospective designs, and small sample sizes. Fortunately, a randomized controlled trial specifically attempting to answer the question of whether bariatric surgery prior to TKA reduces complications and improves function after TKA is currently underway [27]. We will tentatively apply findings of this study to UKA, as we are aware of no such study planned specifically for UKA at this time.

Our Recommendation

In our practice, we initially recommend against UKA for most patients with BMI greater than 40 kg/m^2 (obese category) due to the increased risk of potentially devastating postoperative complications. Such patients are provided with nutritional information from our office and also referred to a nutritionist. Such patients are also offered the opportunity to meet with a bariatric surgeon to consider surgical options prior to UKA. Patients who are able to decrease their BMI below 40 kg/m^2 are offered surgery. Patients who present with BMIs well above 40 kg/m^2 may also be offered surgery if they can demonstrate a meaningful reduction in their BMI, even if not achieving 40 kg/m^2.

Diabetes

The Epidemic

Possibly in conjunction with the increasing prevalence of obesity, the spread of diabetes mellitus has come at a shocking rate, with approximately 1 in 10 Americans affected [28]. Interestingly, about a quarter of those affected are undiagnosed. As such, the arthroplasty consult may represent an important point of diabetic diagnosis and general health intervention for patients with this commonly comorbid disease. Among an NSQIP population, diabetes was present in 1 of 7 patients undergoing UKA [29].

Hyperglycemia Increases the Risk of Surgical Site Infection

Overwhelming evidence exists to suggest that diabetes and perioperative hyperglycemia increase the risk of surgical site infection following TKA [30–32]. Interestingly, however, these same studies tended not to find any specific association between HbA1c values and surgical site infection. HbA1c is a proxy for blood glucose levels, so this finding is somewhat surprising. Nevertheless, it is clear that hyperglycemia near the time of surgery inhibits the immune response and/or wound-healing potential, increasing the propensity for bacteria to colonize and persist in the joint.

To our knowledge, similar associations for UKA have not been demonstrated. Likely this is due to lower overall infection rates and a lower sample size in parallel studies. Despite the lack of research specifically supporting the association, we operate under the assumption that diabetes does increase the risk for surgical site infection in UKA, albeit perhaps not as powerfully.

We are aware of no level-1 study that has demonstrated that control of diabetes decreases the risk of surgical site infection in any form of knee arthroplasty. Indeed, the ethics of such a study may be questioned in the presence of such convincing evidence that perioperative hyperglycemia contributes to infection risk.

Our Recommendation

We obtain a HbA1c in every patient considering UKA. For most patients with HbA1c > 8.0, surgery is delayed and patients are referred to their primary care provider, a nutritionist, and/or an endocrinologist. In most cases, medical therapy is initiated, and we have seen remarkable responses in HbA1C in several patients (see case at beginning of chapter). Surgery is offered once HbA1c is below 8.0. For patients with HbA1c well above 8.0 on presentation, surgery may be offered if a meaningful reduction in HbA1c can be demonstrated, even if the threshold of 8.0 is not quite reached.

Nutritional Status and Albumin

Markers of Nutritional Status

Recent literature has emphasized the fact that "malnutrition" is a multifaceted concept that is in no way limited to low calorie intake [33]. Rather, even obese patients (with excessive calorie intake) may be protein- or micronutrient-malnourished. The best laboratory measure of these forms malnutrition has been debated, but authors have emphasized the use of serum albumin using 3.5 g/dL as a reasonable cutoff for protein malnutrition [33–35]. Other serum markers used in orthopedics include total lymphocyte count, vitamin D, and transferrin [33]. The prevalence of malnutrition, defined using the albumin cutoff of 3.5 g/dL, in the total joint arthroplasty (TJA) population is about 1 in 6 [35]; we have not seen this number documented in the literature for the population undergoing UKA.

Nutritional Status Impacts Short-Term Outcomes

A flurry of recent literature has suggested that serum nutritional markers impact the short-term outcome of arthroplasty procedures [34–37]. For example, Bohl et al. demonstrated that

hypoalbuminemia independently predicts pneumonia, readmission, length of stay, and surgical site infection for TJA (both hips and knees) [35]. Across the literature, the most significant impact appears to be on the risk for surgical site infection.

Of course, less work has been focused specifically on UKA. An association between serum albumin, or the other nutritional markers, and postoperative complications has not been specifically demonstrated. Nevertheless, we operate under the assumption that the same biologic principles apply, and that malnourished patients undergoing UKA are likely at increased risk.

Nutritional Intervention

Nutritional interventions have yet to show improved outcomes following elective arthroplasty procedures (although they have for hip fracture surgery [38–40]). However, to conduct such a study would require a very large and possibly unobtainable sample size, given the low complication rate and overall study complexity and involvedness of the intervention. Despite the lack of evidence of efficacy, nutritional intervention prior to arthroplasty is widely employed in those thought to be malnourished.

Our Recommendation

We obtain serum albumin levels in all patients prior to UKA. For patients with serum albumin <3.5 g/dL, we recommend that surgery be delayed during an attempt to optimize nutritional status. Patients are referred to a nutritionist and we attempt to improve nutritional status over the course of at least 3 months. Albumin does not always respond, but diet and overall nutrition status may nevertheless improve. While we do not use 3.5 g/dL as a hard cutoff, we do use this as an opportunity to intervene prior to UKA to hopefully enhance the result.

Atherosclerosis

Scope of the Problem

Cardiovascular disease is a common contributor to perioperative complications among patients undergoing noncardiovascular procedures. Knee arthroplasty has historically been designated as intermediate-risk noncardiac surgery; however, cardiovascular events do occur at a meaningful rate [41]. Of patients undergoing UKA, 0.3% report preoperative angina, 5.6% report a history of angioplasty, and 4.0% report a history of myocardial infarction.

Diagnosis

Current clinical practice guidelines demand evaluation of all patients for cardiovascular disease prior to arthroplasty procedures [42]. This is typically performed by the primary care physician, and/or cardiologist, providing medical and cardiac clearance. The Revised Cardiac Risk Index (RCRI) is perhaps the most commonly used tool to estimate risk [42, 43]. Patients with functional limitations or potential cardiac symptoms should undergo noninvasive risk stratification evaluating for myocardial ischemia [42]. Myocardial perfusion imaging and stress echocardiography are both validated predictors of cardiovascular events postoperatively [42].

Medical Management

Four primary classes of medication are used to manage perioperative cardiac risk for patients undergoing UKA. First, aspirin has been shown to decrease platelet aggregation and, in doing so, reduce thrombotic risk. While aspirin is routinely used as a preventative measure for cardiovascular events among the high-risk general population, the extent to which arthroplasty patients benefit from a cardiovascular perspective is uncertain [44, 45]. It should be

noted that aspirin does confer increased risk of intraoperative and postoperative bleeding, and the AAOS currently recommends discontinuation of aspirin prior to UKA [46]. For patients on daily aspirin for cardioprotective effect, aspirin can be resumed the evening of surgery. The second class of medications are statins and other lipid-lowering medications. In one analysis of over 200,000 patients undergoing noncardiac procedures, those taking lipid-lowering medications during the postoperative period had lower in-hospital mortality [47]. While such an impact has never been specifically demonstrated for arthroplasty procedures, the available evidence certainly suggests that it is safe to continue a statin during the perioperative period and that those with indications for statin use may be safely started on a statin prior to surgery. Third, beta-blockers decrease cardiac myocardial wall stress, contractility and inotropy, and increase cardiac perfusion as well as the length of diastole. These effects may help to mitigate forces predisposing to perioperative myocardial infarction. Trials of routine beta-blocker use in all patients undergoing noncardiac procedures have yielded mixed and controversial results [47–49]; hence, recommendations for routine use for all patients in the perioperative setting have diminished. However, patients who normally take a beta-blocker should receive that beta-blocker throughout the perioperative period. Other patients with cardiac ischemia or elevated RCRI may receive a recommendation for initiation of a beta-blocker prior to UKA. It is recommended that the beta-blocker be initiated well in advance of UKA, rather than on the day of surgery[42]. Finally, angiotensin-converting enzyme (ACE) inhibitors are another class of medication used to manage cardiac disease that may be initiated prior to surgery in patients at risk. Data to support their use in the arthroplasty setting is quite limited. The current recommendation is to continue ACE inhibitors during the perioperative period for patients already taking them [42].

Angiographic Management

A proportion of patients with positive noninvasive testing will benefit from angiographic intervention prior to their elective orthopedic procedures [42]. This underscores the importance of a systematic cardiac evaluation well in advance of the scheduled arthroplasty.

Our Recommendation

We require all our UKA patients to obtain preoperative clearance from a primary care physician or internist, and cardiology clearance is requested if a relationship with a cardiologist already exists or if the need is determined by the primary care physician or internist. This may result in the initiation of medical therapy or further noninvasive or invasive cardiac testing prior to UKA. We prefer and encourage patients to use the internists in the preoperative clinic at our institution for their clearance. We find that this standardizes recommendations. Moreover, all patients spending at least one night in the hospital are comanaged by an internist while an inpatient. These internists are from the same team as those clearing patients in the preoperative clinic, which we find further streamlines care. We believe strongly in this uniform clearance and comanagement system and have received few objections from patients.

Smoking

Epidemiology

Smoking is the leading cause of preventable death in the United States and results in disability and disease in nearly every organ of the body [50]. Currently, about 1 in 6 adults in the United States smoke. Among patients undergoing UKA, current smokers constitute about 1 in 10 patients [4]. Smoking is more common among men, middle-aged adults, and lower socioeconomic groups [50].

Smoking Increases Risk for Surgical Site Infection and Other Postoperative Events

Clear evidence exists that smoking increases the risk for developing a surgical site infection following an arthroplasty procedure. The risk increase has been documented as approximately 1.5-fold [51, 52]. Moreover, current smoker status appears to be more important than former smoker status: The rates of wound complication in one study were 1.8% for current smokers, 1.3% for former smokers, and 1.1% for nonsmokers, with no statistical difference between former smokers and nonsmokers [52]. Correspondingly, it has also been shown that smoking is associated with earlier time to revision of TKA [53]. But the effects do not appear to be limited to wound infection: Rates of both mortality and total complications are greater for current smokers than for nonsmokers [52]. As with the other areas, our knowledge draws primarily on the TJA literature, as few studies have specifically examined smoking and UKA.

Smoking Cessation

The good news is that smoking is one of the most modifiable risk factors for elective surgical interventions. Cessation of smoking 4 weeks or more prior to elective surgical procedures decreases total and wound-related complications [54–57]. In particular, two randomized studies have drawn this conclusion [55, 56]. Although this effect has never been demonstrated specifically for arthroplasty, wound complications are so devastating for arthroplasty patients that this evidence seems particularly important to heed in the setting of arthroplasty, including UKA.

Our Recommendation

A detailed smoking history is taken for all patients considering UKA in our clinic. For patients who endorse current smoking, extensive counseling is performed with respect to the increased risk smoking poses. Most are agreeable to attempting to cease smoking at least 4 weeks prior to surgical intervention. A large proportion are successful, although some are not. We do perform arthroplasty on current smokers who lack other risk factors, but we make every attempt at cessation before we proceed.

Intra-articular Injections

The Evidence

Intra-articular injections of steroid, hyaluronic acid, and platelet-rich plasma have increasingly been performed among patients attempting to avoid or delay knee arthroplasty. Although the evidence is conflicting [58], several studies have raised the possibility that preoperative injection of these substances may increase the risk of periprosthetic joint infection [59, 60]. Specifically, using a national database, one group of authors found an increase in the rate of periprosthetic infection when the ipsilateral knee was injected within the 3 months prior to surgery (but not within 6 months or 1 year) [59]. This study carries with it all the caveats of a large database study, including the potential for confounding by an array of factors unmeasurable with this study design.

Our Recommendation

Although we remain not entirely convinced by the conflicting reports with respect to the risk-increase associated with intra-articular injection, we believe there is enough evidence to support delaying UKA until 3 months after such an injection. Hence, before potential UKA candidates are injected in our clinic, they are warned that this will delay any subsequent UKA by 3 months.

Hypercoagulability

Etiology

Intravasation of marrow fat during cement pressurization is thought to be the major impetus for the systemic hypercoagulable state that may follow UKA. Stasis and intimal injury (from venous kinking) likely play additional incremental roles in local thrombogenesis, completing Virchow's triad. As a result, patients are predisposed to the development of venous thrombosis. The incidence of symptomatic VTE has been documented at 0.5–1.2% after UKA [4, 61].

Prophylaxis

A discussion of the merits of specific chemoprophylactic agents is well beyond the scope of this chapter. We would also refer the reader to the AAOS guidelines for prevention of VTE for specific recommendations rather than reiterating them here [46]. It should be noted, however, that there has been a general shift in the field of arthroplasty from more to less potent chemoprophylactic agents (e.g., from warfarin to aspirin). This shift has been supported by a body of literature suggesting that these less potent agents are as effective at preventing VTE but carry lower risk of bleeding, and consequently of wound healing and infectious complications [62–65]. This research has been conducted primarily in the setting of TJA. However, given the lower risk for VTE in UKA than TKA [61], the shift toward less potent agents likely makes particular sense in the case of UKA.

Risk Stratification

Although good data is sparse regarding some of the most powerful risk factors, most surgeons consider familial thrombophilia, active metastatic cancer, use of estrogen replacement therapy, smoking, or a history of VTE to be particularly worrisome. Many surgeons who routinely use less potent chemoprophylaxis will consider increasing their chemoprophylaxis above the normal regimen among patients with any of these factors.

For patients without these risk factors, several studies from the TJA literature have provided useful risk stratification systems to help surgeons understand how various other comorbid factors increase risk [66, 67]. In one validated system, patients are assigned specific point values based on the presence of age $\geq$ 70 years, female gender, BMI, and anemia [66]. Based on each patient's total score, the risk of pulmonary embolism can be determined. In order to find the ideal balance between VTE and bleeding risk, surgeons might consider selecting the potency of chemoprophylaxis required based on the degree of risk using systems such as this. Similar studies have not been conducted for UKA, but the studies from the TKA literature likely apply.

Our Recommendation

We recommend use of SCDs on the contralateral lower extremity on all patients undergoing UKA during the procedure and while in house for cases of inpatient UKA. We routinely initiate Aspirin 81 mg twice daily for 30 days starting the evening of surgery. We have found Aspirin 81 mg to provide an acceptable balance between bleeding risk/wound healing and the development of VTE following UKA. For particularly high-risk patients (i.e., patients with familial thrombophilia, active metastatic cancer, use of estrogen replacement therapy, smoking, or a history of VTE), we turn to our medical colleagues to help select the optimal agent. Finally, we routinely encourage early mobilization in the form of early physical therapy and ambulation.

Conclusion

With the marked strides made in the functional outcome of UKA over the last decade, an increased emphasis has been placed on mitigating the risk for early complications following UKA. Perhaps the most powerful means of

doing so is through optimization of the UKA host. Obesity, diabetes, malnutrition, atherosclerosis, tobacco use, exposure to intra-articular injections, and hypercoagulability are all host factors with the potential for modification to diminish the risk for an early adverse outcome. This chapter reviews the current arthroplasty literature regarding weight loss, diabetes control, improved nutrition, atherosclerosis detection and management, smoking cessation, delay of surgery following intra-articular injection, and VTE prophylaxis. Consideration of this literature, as well as the guidelines provided by the AAOS and associated medical societies, should help the orthopedic surgeon provide a well-functioning UKA at the lowest risk.

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5 Managing Patient Expectations for Unicompartmental Knee Arthroplasty

Daniel R. Mesko and Sheeba M. Joseph

Success following a surgical operation is the result of developing shared goals between patients and surgeons. The definition of success may vary between the patient and provider and must be clarified. If patients have unrealistic expectations following a unicompartmental knee arthroplasty (UKA), it may leave them feeling limited and unhappy despite a technically optimized surgery. Successful patient outcomes are a result of many factors, including correct indications, implant selection, correct soft tissue balance, minimal soft tissue trauma, and effective rehabilitation protocols, among other aspects of the process. However, despite attending to the technical demands of the procedure, a surgeon cannot dictate a successful outcome to the patient.

Engaging patients as active participants in their own care, prior to any operation, sets a solid foundation for building success. This can be accomplished by a variety of methods ranging from utilizing industry literature regarding UKAs, testimonials of prior patients, and/or engaging in question and answer sessions with the physician and their care team. In doing so, answering some of the most common questions preemptively may address items that patients either may have forgotten to ask or did not think to ask, and allows for full engagement in the surgical decision and direction for their care, as well as clarifying expectations for their recovery.

One format utilized by a Midwest tertiary referral center is to first have patients arrive for an initial appointment where their case is reviewed, exam is performed, radiographs reviewed, and recommendations are ultimately made. If a unicompartmental knee arthroplasty surgery is offered, discussion is conducted by the physician initially and next with a member of his/her team while scheduling a surgical date. In addition to medical clearance, the patient is also scheduled to attend a small group arthroplasty class, where they meet with the surgeon's midlevel providers. Unicompartmental knee implants are passed around so that the patients can handle the physical pieces of the arthroplasty and gain a better understanding of the surgical operation. Questions are addressed to the group and the most common questions/concerns are preemptively discussed to minimize, as much as possible, the discrepancies between patient expectations and realistic UKA outcome goals.

Common questions and topics addressed are as follows:

1. *Is a unicompartmental knee a temporary solution*?

A common question of patients is whether or not a UKA is just a temporary bandage for an

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inevitable total knee arthroplasty (TKA). Some patients express the desire to avoid the need for two surgeries and instead request to undergo a TKA, despite being candidates who may benefit from a UKA. Currently available long-term objective data for UKA outcomes can greatly aid patients in the decision-making process. Multiple studies have now been completed looking at 10-year outcomes of UKAs with survival rates of the implants ranging between 88% and 98% [1–3]. Most recently, a 2018 study out of Belgium found a 94% survivorship rate of medial UKA (mUKA) at 10-year follow-up [4]. Furthermore, 12–15-year data have also been published with success of the original implant ranging from 90.6% to 95.7% [2–4]. Lateral UKAs (lUKAs), though less common than mUKA, have also shown similar survival rates as mUKAs out to 8 years at 93% (versus 93.1% for mUKAs) [5].

While a UKA is not a guarantee that a future revision, including conversion to a total knee, will be avoided, the data favorably show that approximately 90% of UKAs avoid conversion to a TKA out to 15 years. Thus, a UKA, when properly indicated, should be viewed as a definitive treatment option as opposed to stage one of an inevitable TKA.

2. *Are there any benefits of a UKA over a TKA*?

In a 2014 national registry database publication, just over 25,000 UKAs were compared to almost 76,000 TKAs [6]. While UKAs had a higher revision rate, they carried half the risk of thromboembolism, myocardial infarction, and deep prosthetic infection, 1/3 the risk of stroke, and ¼ the risk for blood transfusion compared to TKAs [6]. There was a 4-fold increased mortality rate in the first 30 days and 15% increased mortality rate in the first 8 years for the TKA cohort [6]. Brown et al., in a multicenter analysis, found risk of complications with a UKA to be 4.3% compared to 11% with TKAs, with an odds ratio of 2.8 after accounting for demographic differences [7].

In addition to the medical risk reduction, another proposed benefit of a UKA derives from a UKA's maintenance of more of the native knee, its cartilage, and the ACL. Thus, there may be some functional benefit as well. This preservation of more native anatomy translates to closer-to-normal knee kinematics compared to a TKA [8]. One study found similar satisfaction between TKA and UKA patients; however, at both 6 months and 2 years, the UKA group had significantly greater knee flexion than the TKA group [9]. Isaac et al. specifically looked at patient proprioception of a TKA compared to a UKA [10]. Though proprioception improved significantly in both TKA and UKA patients, the UKA group had dynamic proprioception that was twice that of patients who underwent a TKA [10]. In addition to greater motion benefits [11, 12], another study found 75% of patients reported that a UKA felt closer to a normal knee than their contralateral TKA [13]. In fact, patients with a UKA are also more likely to have less perception of their artificial joint during daily activities as compared to patients with a TKA [14]. We believe that appropriate patients may experience greater satisfaction and benefit from a UKA as opposed to TKA.

3. *Can you play or continue sports following a UKA*?

In addition to activities of daily living, the ability to return to sport has been investigated following UKA. Naal et al. reported that over 90% of patients felt surgery maintained or improved their ability to participate in sports and recreational activities [15]. Walker et al. found a 93% return to activity at 4.4 years follow-up after UKA, 77% of which were able to achieve this by 6-months [16]. However, the authors noted a significant decrease in high impact activities such as soccer, tennis, jogging, and skiing, secondary to patients choosing to be cautious, rather than truly being unable to perform at a higher level [16]. Fischer et al. similarly found a 93% return to sporting/physical activity level post-UKA [17]. Two other studies also compared the rate of return to activity between UKA and TKA patients; both studies found greater rates with a UKA [18, 19]. We encourage patients that they may be more likely to return to a desired level of play and activities with UKA than TKA.

4. *Are there age cut-offs for UKA*?

Candidate selection for UKA is also an important topic that is addressed. Multiple studies have investigated age as a factor for success in both younger and older patient populations. Classically, one of the indications for a UKA was patients aged 60 years or older, with the thought that those under this age would be too active and that the UKA may not be a durable solution [20]. This has since been challenged in multiple series. Two such studies have looked at outcomes of UKA in people 50 or younger [21, 22]. Parratte et al. reported an 80.6% survival rate at 12 years for the studied cohort of 35 patients [22]. Four of the six revisions in this cohort were performed secondary to polyethylene wear [22]. More recently, Greco et al. studied the same young age group and found a 96% predicted 6-year survival rate and an 86% predicted 10-year survival rate. Twenty revisions were undertaken in their cohort of 340 patients, none of which were for polyethylene wear [21]. Australian and Swedish registry data reported on UKAs found a 19% revision rate at 7 years in those under 55 years of age [9]. Price et al., in a comparison of the under 60-year-old age group to over 60-year-old age group, found a 10-year all case survival of 91% versus 96%, respectively, both of which are comparable to TKA survival rates [23]. Von Keudell et al. concluded that those under the age of 55 had 2.9× the odds of expectations being met with UKA as compared to a TKA [24]. In particular, pain, range of motion, patient satisfaction, and ability to kneel were found to be higher in UKA patients under 55 compared to those that underwent a TKA [24].

Similarly, on the other end of the spectrum for age group, studies have looked into the success rates of UKA in an older patient population. Siman et al. compared patients 75 or older who had a mUKA with those who had a TKA. They found shorter operative times and hospital stays, lower transfusion rates, and greater postoperative range-of-motion among those with an mUKA as compared with those with a TKA [25]. There was also no statistical difference in Knee Society Scores (KSS) or the 5-year survivorship estimates [25]. In a French matched, controlled study performed on patients older than 75 years, there were similar revision rates between UKA and TKA, but UKAs had higher function and superior forgotten joint scores [26]. We suggest to patients that age may influence outcomes, but that UKA is not contraindicated in the young or old.

5. *What are the most common failure modes of a UKA*?

When discussing durability of UKA with patients, we also cover the main reasons for UKAs to fail and require revision. Patients need to have an understanding that, different from a TKA, two of the three compartments of the knee are preserved and that their own cartilage remains. As a result, they are subject to the osteoarthritic disease process that precipitated the UKA progressing in the remaining compartments of the knee. The two most common reasons for revision are progression of osteoarthritis (OA) in native compartments and aseptic loosening [27–29]. Though disease progression is one of the most common reasons for revision, UKA surgery has been found to improve upon mechanical alignment [30]. Along these lines, there has been suggestion that through the correction of mechanical alignment via a UKA, the remaining compartments are more physiologically loaded and therefore a potential arrest in the progression of OA was suggested in one study at 10-year follow-up [31]. Other revision indications include pain of unidentified etiology [1, 5], polyethylene wear [32, 33], periprosthetic fracture [34, 35], infection [36], and mobile-bearing dislocation [36], which is a complication unique to a particular design of UKA.

6. *What happens if my UKA needs to be revised? Am I better off with a primary TKA than a UKA Converted to a TKA*?

The etiology of failure influences the technical aspects of revision of a UKA to TKA and patients are educated that a UKA does prevent them from having a TKA in the future should

the need arise. The question that follows is, "What are the outcome differences of a TKA performed primarily compared to a conversion to a TKA from either a UKA or often their other option, a high tibial osteotomy (HTO)?" In most cases, a UKA to TKA revision can be accomplished using primary TKA components [37]. Cross et al. compared revising an HTO to a TKA versus a UKA to a TKA to see if functional outcome was more similar to a primary TKA or a revision TKA [38]. Both conversion surgeries produced outcomes more similar to a primary TKA. Reoperation rates and complication rates were found to be 8% and 8%, respectively, for a UKA to TKA revision (similar to primary TKA rates), but higher for an HTO to TKA revision (17% and 21%, respectively) [38]. Most recently, Lombardi et al. found similar results, revision of a UKA to TKA has similar outcomes to a primary TKA, and reinforced that not all failures of UKAs are the same complexity [27]. Leta et al. used the Norwegian registry data to report on converting UKA to TKA secondary to aseptic loosening and compared that procedure to revising a primary TKA to another TKA. Overall, outcomes of both revision procedures were similar; however, primary TKA to revision TKA had statistically significant more re-revisions secondary to deep infection, along with a longer operative time, more utilization of revision style components, including stems and constrained components, compared to UKA to TKA conversion [39]. Levine et al. also supported results of UKA to TKA as having similar outcomes to that of primary TKA and being superior to a revised TKA or an HTO to TKA [33]. While UKA is a successful surgery, the need for revision surgery always remains a possibility as with almost any surgical procedure. Most of the available data support that an appropriately indicated UKA not only positions patients for long-term success, but also, should revision surgery be necessary in the future, the conversion of UKA to TKA may optimize success rates as compared to a revision TKA or revision to TKA from a prior HTO.

Conclusion

Through open dialogue, educating patients and engaging them as active participants in their care, surgical expectations after UKA can be best managed and addressed. Providing a pathway for patients to have hands-on time with the surgical components preoperatively and to ask questions and/or learn more information in a small-group setting has the potential to aid patients to better understand the procedure itself. No surgery comes without potential risks, but objectively providing data from peer-reviewed sources can reassure patients of the meticulous care and thought being put into their case as well as to help address preconceived notions. The presurgical discussion and appointments help patients develop realistic expectations in regards to outcomes and effectively minimize potential disappointment from a preoperative expectation-to-post-operative outcome mismatch. UKAs have an excellent track record for properly indicated patients in both old and young patients alike.

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6 Implant Choices for Unicompartmental Knee Arthroplasty

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Introduction

Unicompartmental knee arthroplasty (UKA) design originated in the 1950s [1] and has evolved over several decades to the current options available today, including mobile- versus fixed-bearing (FB) components, metal-backed (MB) modular versus all-polyethylene (AP) tibia designs, and cemented versus cementless fixation techniques. With improvements in implant design, surgical instrumentation, and preoperative patient selection, UKA is gaining popularity with some national joint registries reporting UKA approaching 10% of primary knee replacements [2–5]. This chapter will aid the arthroplasty surgeon in selecting an implant by briefly discussing the history of UKA designs and then summarizing the available literature on different design features available in the market.

Forward-thinking surgeons such as Duncan McKeever posited several early principles of joint arthroplasty and designed the first iteration of UKA implants consisting of a cementless flat metal Vitallium baseplate that relied on a T-shaped keel for fixation [6–8]. Other surgeons of the same era inserted baseplates consisting of acrylic, Teflon, or various metals with a superior smooth, concave surface and a roughened undersurface instead of a keel; these designs relied on soft tissue constraints to maintain the position of the implant [7]. Both of these early hemiarthroplasty designs did not address the ipsilateral femoral side and ultimately failed due to loss of femoral articular cartilage [8].

After understanding the failures of earlier designs, Marmor became the first surgeon to perform a cemented UKA in the United States when he inserted a prosthesis that included a stainless steel femoral component with an AP tibia [8, 9]. The original design called for a tibial inlay cementation technique in which the AP component was cemented within the cortical rim of the tibial plateau [4, 10]. Although this design did not include standard instrumentation or cutting guides for insertion, 15-year survivorship as high as 71% has been reported for the Marmor modular UKA (Smith & Nephew, Memphis, TN) [11]. In the 1980s, an MB design was developed as a method of decreasing anteromedial strain imparted to the tibia by AP designs [10]. The MB design is thought to reduce the risk of medial tibial subsidence and has the added feature of allowing for modularity of the tibial component [10, 12].

In 1978, Goodfellow and O'Connor introduced four seminal design concepts regarding the relationships among articular constraint, range of motion tolerances, bone-implant stresses, and the stability of the surrounding soft tissues for joint

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arthroplasty [13]. The authors identified the balance needed between maximizing contact surface areas in order to reduce polyethylene wear and keeping the level of articular constraint low to reduce the risk of aseptic loosening. Based on these principles, they designed the first meniscal mobile-bearing prosthesis consisting of a flat metal-backed tibial baseplate, a metal spherical femoral component, and a fully congruent polyethylene insert, which allows for translational, rotational, and flexion-extension moments of the knee [5]. This implant, known as The Oxford mobile-bearing prosthesis (Zimmer Biomet, Warsaw, IN), was designed so that the superior surface of the polyethylene fully conformed to the spherical femoral component at all angles of flexion to simulate a mobile, congruous meniscus. The inferior surface of the polyethylene is flat against a flat tibial baseplate, which allows for translational and axial rotational movements. Although the Oxford mobile bearing has since undergone its fourth iteration in 2009, the primary features of its original design remain largely unchanged [5, 14].

In 1987, the designers introduced the Oxford Phase-II with new instrumentation that included a spherical end-mill to prepare the distal femur [5, 13]. The new instrumentation addressed the frequent complication of bearing dislocation resulting from unbalanced flexion and extension gaps [4]. Instead of making three separate femoral cuts, surgeons could now mill the distal femoral condyle in 1-millimeter increments until the extension gap matched the flexion gap [5, 13]. The Oxford Phase-III was released in 1998 with increased femoral component sizing options, tibial components with right and left laterality, and minimally invasive surgery (MIS) instrumentation that allowed for implantation without everting the patella [5, 13].

The most recent generation of the Oxford includes a cementless fixation option with the addition of a layer of porous titanium coated with hydroxyapatite on the inner surfaces of the components [15, 16]. The femoral component has two pegs for additional rotational stability; the central peg is conical in the cemented design and cylindrical in the cementless design to assist with primary fixation [15, 17]. The anterior flange of the femoral component was also extended for better implant-bone surface contact area, which confers additional stability to the anterior peg and allows for better implant-bone contact in deep flexion [15, 17–20]. To assist with more reproducible implantation of the modified femoral component, an intramedullary femoral guide with an anti-impingement guide was developed (Microplasty Instrumentation, Zimmer Biomet, Warsaw, IN) [18]. Early reports have demonstrated excellent clinical results with improved radiographic outcomes at 2 years with the newest version of the Oxford unicompartmental knee arthroplasty [17, 18].

Design Concepts

The available UKA designs can largely be classified into several categories: inlay versus onlay prostheses, mobile-bearing versus FB, MB versus AP tibia components, and cemented versus cementless designs. UKA designs utilizing a resurfacing or inlay technique rely on minimal bone removal and placement of an AP prosthesis directly on subchondral bone. Conversely, an onlay technique requires angular cutting guides and prepares a bed of cancellous bone to match the inner dimensions of the implant similar to techniques used in total-knee arthroplasty [7]. Advantages to inlay designs include conservation of bone and being amenable to minimally invasive surgical techniques because bulky jigs are not required. Onlay designs have the advantage of being more familiar to surgeons who regularly perform total-knee arthroplasty because the distal femoral cut can be made using an intramedullary jig and the tibial resection can be made using an extramedullary guide. Onlay designs do not require a burr and posterior referencing can be used with most systems to produce a consistent flexion gap [21].

Historical implants relying on the resurfacing technique include the St. Georg modular prosthesis (Waldemar Link, Hamburg, Germany), the original Marmor, and the Repicci (Zimmer Biomet, Warsaw, IN) [4, 7]. The St. Georg Sled

was first introduced in 1969 and consisted of a cemented, flat AP tibial component with a biconcave metal femoral component. The curved-on-flat design of the curved femoral component articulating with a flat polyethylene concentrated stress over a small surface area. The original intent of the curved-on-flat St. Georg Sledge design was to minimize constraint and allow for increased freedom of femoral motion on the tibial component. In theory, this would allow the soft tissue tension to guide the motion of the tibiofemoral articulation and reduce stresses imparted on the implant-bone interface [8]. Despite the contact stresses imparted over a small surface area, the implant demonstrated good long-term results, with Anasari et al. reporting 87% survivorship at 10 years with 92% of patients reporting good-to-excellent results [22].

The Repicci prosthesis is a modification of the Marmor implant designed to improve femoral component fixation by the addition of a post and keel construct [8, 23]. The Repicci utilizes an AP tibial component with a unique cobalt chrome femoral design that consists of a larger central post with a sagittally oriented fin. In the coronal plane, the radius of curvature was also modified to reduce edge wear of the AP tibial component. On the tibial side, the polyethylene thickness was increased and the undersurface was striated to improve cement fixation [23]. This prosthesis is more conforming than the St. Georg Sledge in order to increase the femur-tibia surface area and reduce contact pressures. While both designs require minimal bony resections, the Repicci design is also unique in that the distal femur is milled with a motorized burr instead of performing bony cuts [8].

Historical implants that utilize an onlay technique include the porous coated anatomic knee (PCA; Stryker, Mahwah, NJ) and the Miller-Galante (Zimmer, Warsaw, IN) [4]. The PCA UKA was introduced in the 1980s with a single-peg femoral component designed to replicate the natural femoral contours and a relatively convex tibial component design, which created a small surface contact area between the two articulating components [8, 24]. The MB tibial design also called for a thinner polyethylene insert. Combined with a heat treatment that made the early generation polyethylene more fragile, the PCA UKA was prone to pitting and delamination with failure rates as high as 20% at 26 months reported [4, 7, 8, 24, 25].

The Miller-Galante UKA consists of a cobalt chrome femoral component with either a modular titanium MB tibial component or an AP tibial design [4, 8]. This implant represents the features of modern-day FB designs consisting of a flat-on-concave articulation with minimal constraint and a thicker polyethylene insert [4]. Compared to the PCA, the Miller-Galante has a flatter tibial component and has demonstrated better survival with the decreased amount of articular constraint. Argenson et al. reported their 20-year follow-up on 62 patients (70 knees) who received Miller-Galante unicompartmental prostheses between 1989 and 1997. Fourteen (20%) of patients required revision of either the femoral or tibial component and five patients required isolated polyethylene exchange resulting in a Kaplan-Meier survival rate of 74% ± 7% at 20 years [26]. Berger et al. reported a survival rate of 98% ± 2% at 10 years and 95.7% ± 4.3% at 13 years for the Miller-Galante UKA using Kaplan-Meier analysis [27].

Cemented Versus Cementless

Different fixation options available for UKA include cemented designs, cementless fixation, and hybrid fixation involving cementless fixation of the femoral component with a cemented tibial component [28]. National registry data indicate that cemented fixation is currently the most popular technique [1, 28]. Aseptic loosening at the implant-cement or cement-bone interface remains the most common mode of failure for cemented prostheses [28, 29], and the cumulative revision rate of UKA is approximately three-fold that of TKA [2, 3, 5, 13, 15, 30, 31]. The increased revision rate of UKA compared with TKA is likely multifactorial. UKA patients are more frequently a younger and more demanding patient population; there is a potentially lower threshold for revision given the ease of

revising a UKA to a TKA, and the more technically demanding nature of UKA is less forgiving among inexperienced surgeons [2, 13, 21, 32]. Given the increased comparative revision rate in national joint registries, there has been a growing interest in cementless fixation for UKA [1].

Published studies on cemented UKA have demonstrated excellent clinical outcomes and implant survivorship utilizing modern cemented designs, strict preoperative patient selection, and improved instrumentation [27]. Implant survivorship as high as 98% at 10 years has been reported using the Oxford medial UKA [33]. A recent systematic review identified aseptic loosening as the most common cause for early failure, and progression of OA to other compartments was the most common cause of failure in mid- and late-term follow-up in UKA [29]. Cemented fixation also has additional disadvantages of potential third-body wear from cement debris, increased prevalence of radiolucent lines on radiographs, and extended surgical times compared with cementless techniques [15, 16, 34, 35].

Historically, cementless fixation has demonstrated poor implant survivorship, but there has been increased interest recently due to design improvement and the potential for biologic fixation. Early to mid-term failure rates as high as 12–20% [2, 36, 37] for cementless UKA fixation have been reported in the literature. Recent design developments, including utilizing porous titanium surfaces that allow for osseous ingrowth and coating the prosthesis with biological active materials such as hydroxyapatite, have demonstrated improved clinical and radiographic outcomes [2, 28, 35]. A 2017 systematic review found a 94% 10-year survivorship for cementless UKA designs consisting of porous titanium coated with hydroxyapatite [28].

van der List et al. published a systematic review on 2218 cementless UKA procedures and found a revision rate of 2.9% at an average of 4.1 years [28]. Using a calculated annual revision rate (ARR) of 0.71%, the authors extrapolated 5-, 10-, and 20-year survivorships of 96.4%, 92.9%, and 89.3%, respectively, for cementless UKA fixation. The authors reported the most common modes of failure were progression of OA (32%) and bearing dislocation (25%). Unlike cemented UKAs where aseptic loosening is the most common reason for failure, aseptic loosening was only implicated in 13% of revision procedures following cementless UKA.

Several authors have suggested that cementless fixation may be more beneficial in UKA compared to TKA because restoring the normal ligamentous tension of the knee with minimal articular constraint in UKA applies compressive forces across the components with minimal shear forces [2, 15, 28]. Compressive loads transmitted across the bone-implant interfaces of the femoral and tibial components are ideal for achieving osseous ingrowth with cementless fixation [15]. Liddle et al. further suggest that soft tissue releases performed during routine total-knee arthroplasty require increased tibiofemoral constraint in the form of a cam-and-post mechanism or dished polyethylene, which increases the shear forces imparted to the implant-bone interface and predisposes the prosthesis to aseptic loosening [2].

Uncemented implants may also be associated with fewer unnecessary revisions because inexperienced surgeons often attribute "physiologic" radiolucencies seen along bone-cement interfaces as aseptic loosening [2, 15, 21]. Liddle et al. explain that physiologic radiolucencies are often misinterpreted on radiographs. The authors define these radiolucencies as narrow, nonprogressive, and representing an incomplete fibrocartilage layer that does not negatively impact implant survival [2]. The radiolucencies are often surrounded by a sclerotic margin and are less than 1 mm in width [35]. In the Oxford medial UKA, the vertical wall of the tibial component is not coated with porous titanium and therefore often has adjacent radiolucencies when evaluated on radiographs postoperatively. These can be safely ignored [2].

There are very few studies in the literature that directly compare cemented versus cementless fixation for the same implant design. Pandit et al. performed a prospective, randomized controlled trial comparing the cemented versus cementless Oxford Phase III UKA design [38]. At 5-year follow-up, 20/31 patients in the cemented subgroup

demonstrated a physiologic radiolucency around the tibial component compared with 2/27 in the cementless subgroup ($p < 0.001$); none of the radiolucencies in either group were determined to be progressive. The study found no significant difference between the Oxford Knee Scores of either group but did find a statistically significant difference between the Knee Society functional scores at 5 years (92.0 ± 12.7 in the cementless subgroup versus 78.8 ± 18.4 in the cemented subgroup; $p = 0.003$). The authors concluded that cementless fixation was associated with significantly fewer periprosthetic radiolucencies postoperatively while achieving equivalent or possibly superior functional outcomes at 5 years.

Akan et al. reported on a retrospective review of 263 medial Oxford UKA (141 cemented, 122 uncemented) implanted in 235 patients between 2008 and 2011 [35]. Mean follow-up was 30 months in the uncemented group and 42 months in the cemented cohort. There were no differences in the mean postoperative Oxford knee or Knee society scores between the cemented and cementless groups. Revision rates were 7.09% in the cemented group versus 4.91% in the cementless group ($p = 0.155$). The authors found no significant differences between the two groups in terms of clinical outcomes or survivorship [35]. However, there was significantly longer surgical time for cemented UKA (45.3 minutes with cemented vs. 36.1 minutes cementless, $p < 0.001$). The authors suggest that the shorter operative time with cementless fixation may be associated with decreased infection rates and tourniquet pain, and improved operating room efficiency [35].

Schlueter-Brust et al. published a prospective study of clinical outcomes and 10-year survivorship for cemented and cementless medial Uniglide prostheses (Corin Ltd., Cirencester, United Kingdom) [39]. The authors implanted 240 Uniglide prostheses in 234 patients (152 cemented, 78 cementless, 10 hybrid fixation) between 1990 and 1999. No patients were lost to follow-up with a mean clinical follow-up of 10.7 years. The authors reported a 10-year survival rate of 95.4% for cemented, 97.4% for uncemented, and 90% for hybrid fixation [39].

In summary, both cemented and modern cementless UKA designs offer excellent functional outcomes and implant survivorship: 10-year survivorships are expected to be greater than 90% for both designs [34, 39], with the most common mode of failure being aseptic loosening in cemented UKA and progression of osteoarthritis in cementless UKA [28, 30, 34]. Based on the most recent literature, cementless designs may offer a very slight edge over cemented prostheses in terms of shorter operative times [16, 35] and long-term implant survivorship [28, 34, 39].

All Polyethylene Versus Metal-Backed Tibia

Designs of UKA systems include variations in the baseplate, the most common being an AP tibia and an MB tibial component. MB tibia were introduced to reduce the incidence of wear and tibial subsidence and allow for increased intraoperative options secondary to modularity. Benefits of the AP tibia include cheaper cost, less bony resection, decreased backside tibial wear, but with potentially diminished cement fixation. MB designs potentially have improved load transfer and cement fixation, but at a cost of more bone resection [40].

A finite element analysis model evaluating contact stresses in AP and MB tibia UKA designs found low conformity MB tibia have higher anterior and medial polyethylene contact stresses [41], with more edge loading in AP tibia, resulting in overload and subsequent medial tibial collapse [42]. Although MB tibia have a potential for improved load transfer, this comes at a cost of increased bone resection and a thinner polyethylene, with a potential for more polyethylene wear problems [43].

The 10-year survivorship of AP designs has been reported at 88–96.1% [44, 45], but results have been controversial [46–48]. In early designs, Marmor reported a 30% failure rate at 10–13-year follow-up due to high rates of aseptic loosening [48], and Mariani et al. found a 38% failure rate at 12-month follow-up secondary to loosening of the femoral component [47]. Tibial

subsidence with wear has been reported in 10.4% of 140 Marmor cemented UKA knees, at 15-year follow-up [49]. In this same cohort, 10.2% of knees were revised for tibial loosening, the most common reason for revision in the series [49]. Manzotti et al. and Saenz et al. also reported that aseptic tibial loosening was the most common reason for revision [45, 50], and Manzotti *et al* found changes in mechanical axis associated with radiolucency at long-term follow-up, particularly in female patients [45]. The literature seems to show a higher early loosening failure rate with AP tibia as compared with MB tibia.

The 10-year survivorship in MB designs has been reported to be 90–98%, in the Miller-Gallante prosthesis [26, 27, 51–53], and 97% in 143 knees with the Oxford meniscal prosthesis [33]. Argenson et al. in a follow-up evaluation of Miller-Gallante prostheses reported 83% and 74% survivorship at 15 and 20 years, respectively [54], while Berger et al reported a 95.7% 15-year survivorship in 59 consecutive UKA patients [55]. Argenson et al reported late polyethylene wear that was treated with isolated polyethylene exchange in five patients at an average 12 years postoperatively [54]. MB UKA appears to have more consistent survivorship as compared with AP tibia.

Theoretically, metal-backed base plate designs would potentially require increased frequency of tibial augments during revision surgery given the increased amount of bone resection required. This is because an MB design requires either the use of a thinner PE or increased bone resection. This thought is not necessarily supported in the literature. Aleto et al. retrospectively reviewed 32 consecutive revisions from UKA to total-knee arthroplasty (TKA) [46]. The most common failure mode was medial tibial collapse (47%), and of these, 87% had an AP design. Approximately half of these failures (7 of 15) failed in 16 months or less and were associated with a more complex reconstruction [46]. On the contrary, Scott et al found the use of standard cruciate retaining TKA without augments or stems was less likely following MB designs (32%) as compared with AP (71%) [56]. MB designs were more likely to require a stem or cruciate substituting design, while the use of medial augments was no different in the two groups [56]. The authors found AP designs were associated with earlier revision secondary to unexplained pain, while MB tibia were most commonly associated with progression of arthritis as a reason for revision. AP designs required earlier revision (4.8 vs. 8.2 years) perhaps secondary to different failure modes [56]. Irrespective of indications, it is important to better understand the potential of implant design factors influencing the complexity of a subsequent revision.

There has been a wide range of reported survival rates at 10-year follow-up [27, 43]. There is, however, no consensus on superiority of outcomes between MB and AP designs, as some studies have reported high short-term failures with an AP design [46, 47, 57], while others have found no differences in failure rates or clinical outcomes [58]. An MB tibia allows for easier cement removal and may potentially decrease aseptic tibia loosening [59]. However, in 45 patients randomized to AP or MB tibia, there was no difference in tibia migration, revision rates, or clinical outcomes at 2 years with the Miller-Gallante prosthesis [58]. Hutt et al with the Accuris UKA (Smith and Nephew, London, United Kingdom) in 63 knees with mean 6.4 year follow-up, reported a 41% revision rate at mean 5.8 years in the AP group, giving a 7-year survivorship of only 56.5%, as compared with a 93.8% survivorship in the MB group [60]. Koh et al. compared 51 AP to 50 MB tibia and found no difference in clinical and radiographic outcomes [61]. However, there were 6 early failures in the AP group and none in the MB group within 2 years. Many of the benefits between the designs remain theoretical (modularity, wear at interface). MB tibia by nature of their modularity allows better intraoperative options, an option for a bearing only revision if needed, and potentially better distribution of forces on the tibia [12], but are more expensive and create another potential mode of wear [62]. Additionally, bearing only revisions are not common. AP designs are cheaper and may require less bony resection with a potential for increased bone stock in revision surgery [63]; however, clinical outcomes are

more variable, and these designs may be associated with more complex reconstruction during revision.

Mobile Versus Fixed Bearing

Survivorship as high as 98% at 10 years has been reported with both mobile- and fixed-bearing designs [27, 33], and can provide benefits when compared with TKA [64, 65]. Survival rates over 90% when extended out over 15 years have also been reported [38, 49, 55], increasing popularity of these implants more recently. Mobile bearings were introduced to provide a theoretically improved benefit secondary to reduce wear to increase longevity, but this has not borne out clinically [51, 66–69]. Mobile bearings continue to be commonly used.

Longevity of FB designs, including both AP and MB designs, has a 10-year survivorship of 88–98% [27, 44, 45, 51, 52, 70, 71]. Mobile-bearing designs have a more variable survivorship of 74.7–98% at 10 years [33, 38, 51, 71–75], with 15-year survivorship of 70–93% [38, 75, 76]. Mobile-bearing designs are technically demanding and can be associated with a learning curve. They require careful attention to appropriate tissue balancing to avoid bearing spinout, which is a complication unique to this design [40]. Some concerns with this design are related to the frequency of complete tibial radiolucent lines that have been reported, particularly in the Oxford knee design [76]. While there is not a clearly defined criteria for when this constitutes failure secondary to aseptic loosening, if similar results were seen in TKA implants, these would be categorized as loose.

When looking at factors for revision, time to revision for FB implants has been found to trend longer (41.5 months) as compared with mobile bearings (24.1 months), although this was not statistically different [77]. Peersman et al., based on a systematic review of mobile versus fixed bearings, suggested that the shorter time to failure in the mobile-bearing group is related to the technical factors and susceptibility for surgical error in these designs [78]. Emerson et al. reported a 99% survival for mobile bearing and 93% survival for FB at 11 years, and found FB bearing failed more often secondary to tibial component failure and mobile bearings trended to fail more commonly with arthritis progression [79]. Bloom et al. also reported that mobile-bearing designs much more frequently required tibial augments (46.7%) than did FB implants (11.1%) [77]. While Neufeld et al. found similar timing and etiology for revisions between these two groups, the 1/3 of revisions that required stems or tibial augments were all of mobile-bearing design [71].

Many studies evaluating the clinical difference between these designs have been performed and do not demonstrate a clear reason to recommend one of these designs over the other [51, 66–68, 79, 80]. A recent systematic review with meta-analysis showed no difference in designs as measured by survivorship or functional outcomes [78]. The only significant difference between the designs was seen in short-term follow-up of young patients; in this patient cohort, a high revision rate secondary to loosening was seen with the mobile bearing [78]. Neufeld et al. retrospectively reviewed 38 Phase 3 Oxford mobile-bearing UKA and 68 fixed-bearing UKA, either Miller-Gallante or Zimmer Unicompartmental High Flex Knee System (Zimmer, Warsaw, IN) [71]. The authors reported a 10-year survivorship of 82.9% and 90.9% for mobile and FB, respectively, with similar patient outcomes. Gleeson et al. compared complications and short-term follow-up between 47 Oxford mobile-bearing UKR and 57 St. George Sled, a fixed-bearing UKR [80]. The authors reported higher revision rates in the Oxford and better pain relief in the St George Sled, with similar functional outcome scores. Fixed-bearing designs are either MB or AP, with variability of results attributable to the AP designs [44, 45]. Mobile bearings are all of MB designs, and while outcomes have been no different as compared with FB designs, similar to the AP designs, these mobile-bearing designs have shown more variability in survivorship. The tenants for successful longevity of these implants remain the same, regardless of the design chosen, including appropriate preoperative patient selection, meticulous surgical

technique, and surgical experience that is associated with a learning curve [40].

Burton et al., in an in vitro study comparing wear rates of mobile and FB designs, found reduced wear with FB UKA [81]. In both designs, the lateral side had an increased amount of wear, suggesting that increased motion on the lateral side seems to play a larger role in wear generation than increased weight bearing, as is seen medially [81]. Kwon et al., in a finite element analysis model, found lower contact pressure and stress in the opposite compartment in mobile bearings as compared with FB, and they concluded this imparts a theoretically increased risk of OA progression in FB knees [82].

Overall, comparative studies evaluating fixed- and mobile-bearing designs have found no differences in terms of survivorship or clinical and functional outcomes [51, 66–68, 79, 80]. Some suggest that mobile designs are associated with better kinematics [68], but they also have a unique failure mode – bearing dislocations [80]. Mobile-bearing designs can be more technically challenging, with a more pronounced learning curve, which can lead to the variability in the results seen in the literature, particularly in studies including heterogenous high and low volume centers. With experienced or high-volume surgeons, the outcomes of either the mobile- or fixed-bearing designs may be great. Given more variability with the mobile-bearing designs, as these are more technically challenging, Bonutti et al. recommended that for lower volume surgeons, an FB design could potentially provide more predicable high rates of survival [40].

Conclusion

Current UKA designs include mobile versus FB, MB modular versus AP tibia, and cemented versus cementless fixation. Cementless designs may be associated with shorter operative times and slightly improved long-term implant survivorship. MB tibia allow for more intraoperative options, an option for a bearing only revision, and potentially better distribution of forces on the tibia, but are more expensive and create another potential mode of wear. AP designs are cheaper and may require less bony resection, but clinical outcomes are more variable, and these designs may be associated with more complex reconstruction during revision. With experienced or high-volume surgeons, the outcomes of either the mobile or FB designs can be high. Mobile-bearing designs have more variability in survivorship, as these are more technically challenging. For lower volume surgeons, an FB design could potentially provide more predicable high rates of survival.

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Part II

Surgical Techniques for Unicompartmental Knee Arthroplasty

7 Medial Unicompartmental Knee Arthroplasty: Indications and Technique

Brian C. Fuller and Tad L. Gerlinger

Case Example

Active 70-year-old male with chief complaint of medial right knee pain. Patient has a past medical history of hypertension and coronary artery disease and past surgical history significant for right knee arthroscopy with medial meniscectomy 2 years previously. His symptoms are recalcitrant to conservative treatment with activity modification, physical therapy, anti-inflammatory medications, and multiple intra-articular injections. On physical examination, he stands 5′10″ tall and weighs 265 lbs. with a BMI of 38. He walks with a shortened stance phase on the right side, has focal tenderness isolated to the medial joint line, range of motion 10–115°, and is ligamentously stable in all planes. Radiographs reveal osteoarthritis localized to the medial compartment (Fig. 7.1).

Introduction

Unicompartmental knee arthroplasty (UKA) was introduced in the 1970s by Marmor and was initially met with great enthusiasm, promising an alternative to osteotomy [1]. Early excitement disappeared with poor results reported by several authors. Laskin reported on 37 patients in 1978, finding contralateral compartment degeneration at 4–7 years and results inferior to bicompartmental and tricompartmental arthroplasty of the knee [2]. In 1980, Insall and Aglietti also reported poor results, with early deterioration at an average follow-up of 6 years [3]. These early failures were likely due to the degree of constraint of the initial implants, poor implant design, imprecise instrumentation, and unclear indications. A unicompartmental knee arthroplasty could not be treated as "half" a total knee arthroplasty (TKA) and in that early form, with excellent results being reported with TKA, most surgeons abandoned UKA.

Learning from the initial mistakes, indications were proposed, instrumentation improved, and implant designs were refined. Proposed indications addressed age, weight, level of activity, pain, range of motion, and angular deformity, and limitations in the degeneration of the remaining compartments [4]. Several authors then began to publish promising results. In 1999, Berger et al. found 98% survival at 10 years in 62 knees [5], and more recently 90% survival at 20 years [6]. Pandit also published results from 1000 cases, showing 94% survival at 10 years and 91% survival at 15 years [7]. These promising results suggest that solutions had been found to the early challenges and partial knee replacements were once again a viable treatment option for select patients with knee arthritis.

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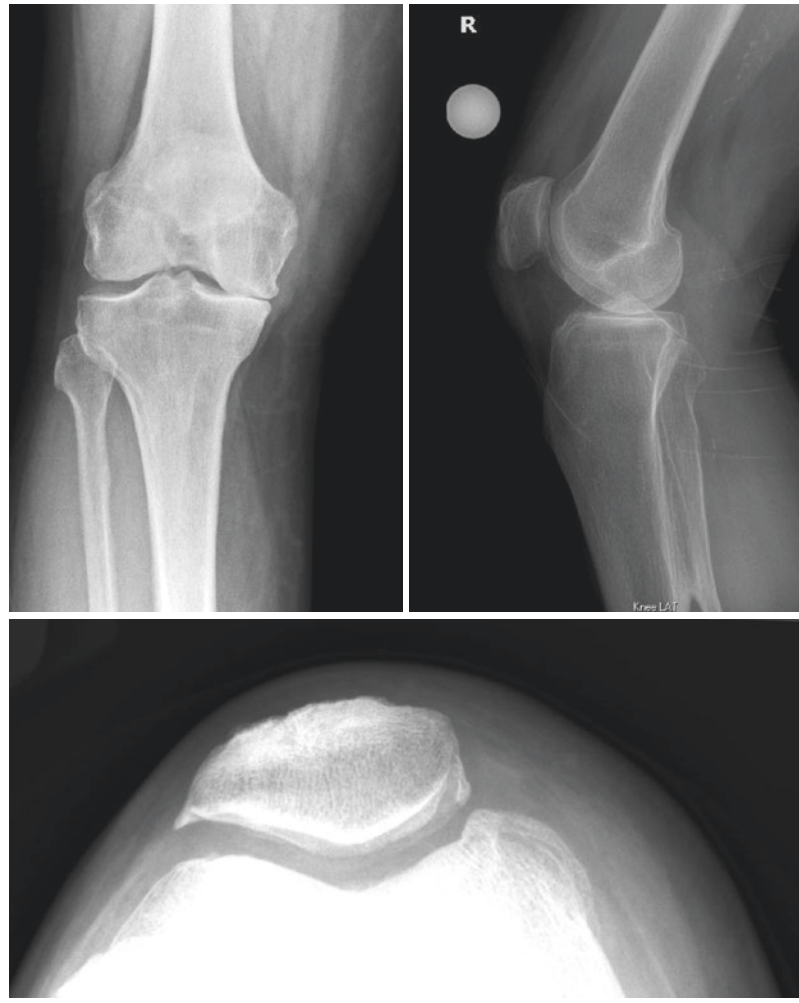

Fig. 7.1 Preoperative radiographs of case example demonstrating bone-on-bone medial compartment arthritis on the AP, maintained posteromedial tibial plateau on the lateral, and maintained joint space between the lateral facet and trochlea

Current Trends

With the development of surgical pathways, multimodal pain strategies, improvement in surgical technique and the advent of same-day surgery protocols, patient's expectations about unicompartmental knee replacement surgery have changed. The promise of simpler, quicker surgery, and faster recovery has led to a significant increase in the frequency of UKA [8], particularly for isolated medial compartment arthritis. Additionally, indications have expanded with continued excellent results [9–11]. Long-term follow-up has shown encouraging longevity and function from the implants currently available and published data suggests increasing utilization of ambulatory surgery centers (ASC) is safe and effective for same-day procedures [12–14]. To that end, Centers for Medicare and Medicaid Services has designated partial knee replacements as an outpatient procedure and indications for hospital stays greater than 23 hours must now be well indicated.

Indications/Contraindications

The primary indications for medial UKA are isolated anteromedial arthritis and spontaneous osteonecrosis of the knee [15–17]. Approximately three decades ago, Kozinn & Scott described their ideal candidate as less the

60 years of age, weighing less than 180 pounds, and low demand with minimal pain at rest, less than 5° flexion contracture, a preoperative arc of flexion of 90°, and a passively correctable angular deformity of less than 10° of varus. Additionally, patellofemoral joint arthritis, inflammatory arthropathy, chondrocalcinosis, and cruciate ligament deficiency were suggested as contraindications [4].

Modern indications do not strictly exclude patients based on age, weight, activity level, having chondrocalcinosis, or the presence of arthritis within the patellofemoral joint [11, 18, 19]. Contraindications are limited to active infection, inflammatory arthropathy, ligamentous instability, contracture of the medial collateral ligament, a functionally absent ACL, and previous high tibial osteotomy [18, 20]. Medial UKA has been shown to be a viable option in patients 75 years and older [21–23] as well as in younger, active patients [24–27]. Good results and survival have also been demonstrated in the obese population [28–31]. Patellofemoral arthrosis of the medial facet and/or central trochlea have not been shown to adversely affect medial UKA outcomes [32, 33]. Furthermore, the presence of lateral osteophytes does not preclude excellent results at 15-year follow-up [34]. Acceptable results have been achieved in ACL-deficient patients without subjective instability by decreasing the posterior slope of the tibial component [35, 36]. Moreover, respectable results have also been reported with medial UKA performed concurrently with ACL reconstruction [37, 38]. A more detailed discussion of appropriate patient selection and the necessity of the ACL are discussed in Chaps. 2 and 11 of this book (Fig. 7.2).

Technique

The patient is positioned supine on the operating room table. All bony prominences are well padded. A tourniquet is placed high on the operative thigh and Foley catheter may be inserted. The operative extremity is prepped and draped in

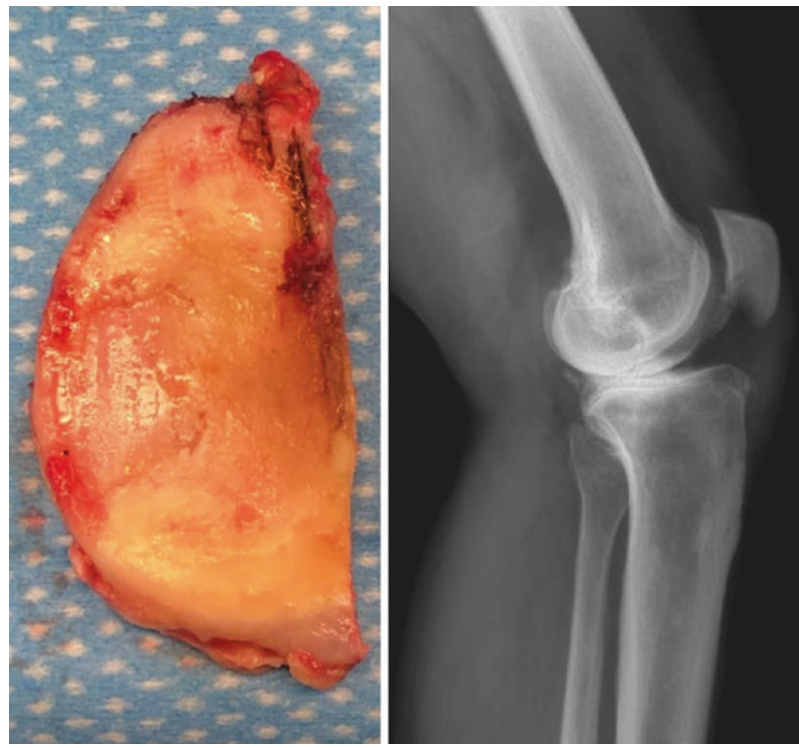

Fig. 7.2 Clinical photo of resected medial tibial plateau showing focal anteromedial arthritis. Lateral radiograph illustrating posteromedial wear secondary to nonfunctional ACL

normal sterile fashion. Antibiotics are given within 1 hour of incision. The leg is exsanguinated and tourniquet inflated. With the knee in moderate flexion, incision is made medial to midline, extending from the proximal pole of the patella to just medial to the tibial tubercle. Full-thickness skin flaps are developed, and underlying extensor mechanism and joint capsule are exposed. The knee joint is accessed via a mini-midvastus arthrotomy, taking great care to avoid damage to the intact cartilage at the superior aspect of the arthrotomy. All compartments of the knee are inspected to confirm moving forward with UKA is appropriate. The patella is subluxed laterally and a portion of the retropatellar fat pad is excised to facilitate visualization. Marginal osteophytes are removed with combination of osteotome and rongeur. The anterior horn of the medial meniscus is released from its coronary ligament attachment laterally and subperiosteal medial release is performed as needed along the medial face of the tibia utilizing Bovie electrocautery. Partial medial meniscectomy is carried out to improve exposure. Extramedullary tibial cutting guide is placed parallel to the long axis of the tibia in the coronal plane and matching the tibia's native slope in the sagittal plane (up to 7°). A conservative horizontal cut is performed with an oscillating saw, typically 1–2 mm below the arthritic surface, depending on the amount of cartilage and bone loss. Resection is completed with a vertical cut, utilizing a narrow, reciprocating saw blade, just medial to the peak of the medial tibial eminence. Care is taken to avoid disrupting the cruciate ligament attachments laterally, the tibial collateral ligament medially, and breaching the posterior tibial cortex distally. Proximal tibial bone fragment, residual meniscus, and guide are removed. Flexion and extension gaps are checked with a spacer block and ensured to be equal before turning attention to the distal femur. In extension, the resection guide is placed flush with the distal femoral condyle, perpendicular to the tibial shaft, and rotationally parallel to the resected tibial surface. The anatomic angle of the distal femoral cut is typically 4–6° of valgus relative to the anatomic axis of the femur, matching the tibial cut in the coronal plane. The cut is made using an oscillating saw with retractors positioned to protect the medial collateral ligament and adjacent soft tissues. The guide and excess bone are removed. Extension gap is again checked using a spacer block before sizing the femoral component with the knee in flexion. In an effort to avoid patellar impingement, the appropriate sized femoral component will have 1–2 mm of exposed bone between the anterior edge of the guide and the cartilage tidemark with the posterior aspect of the guide resting against the posterior femoral condyle and parallel to the tibial resection. The appropriate resection guide is then secured in position with the posterior surface parallel to the tibial resection and biased laterally toward the intercondylar notch. Lug holes are drilled, and posterior femoral condyle and chamfer cuts completed. The tibia is then sized to maximize coverage without generating overhang of the tibial cortex. Trial components are inserted, and all retractors are removed. The knee is taken through a range of motion and stability tested. Gap spacers are used to assess the flexion and extension gaps. The joint should have 1–2 mm of laxity in both flexion and extension, ideally just a touch looser in flexion. Care should be taken to avoid overstuffing the joint. Unacceptable tightness or asymmetry should be addressed by adjusting the thickness of the polyethylene insert, resecting additional tibia, altering its slope, or changing the size of the femoral component. Once adequate balance is achieved, femoral and tibial preparation is completed. Supplementary anchorage holes are created in particularly sclerotic bone as needed. All components and retractors are then removed. The wound is copiously irrigated using pulsatile lavage. Bone is then carefully dried. Vacuum mixed polymethylmethacrylate (PMMA) is used for fixation of the final components. Cement is placed on the components first and subsequently pressurized into the bone using cement gun. Final components are inserted, and excess PMMA is carefully removed. The cement hardens with trial polyethylene insert and the knee in approximately 30° of flexion. A 1-mm gap spacer can be used to help pressurize the

components while the cement cures. Once the cement is mature, knee range of motion, stability, and gap balance are again verified prior to insertion of definitive polyethylene liner. The wound is then copiously irrigated and closed in layered fashion (Fig. 7.3).

Implant Options

Initial failures suggest that constraint is best limited in implant design [2, 3, 39]. Learning from early design limitations has led to reliable survivability in multiple designs. Options

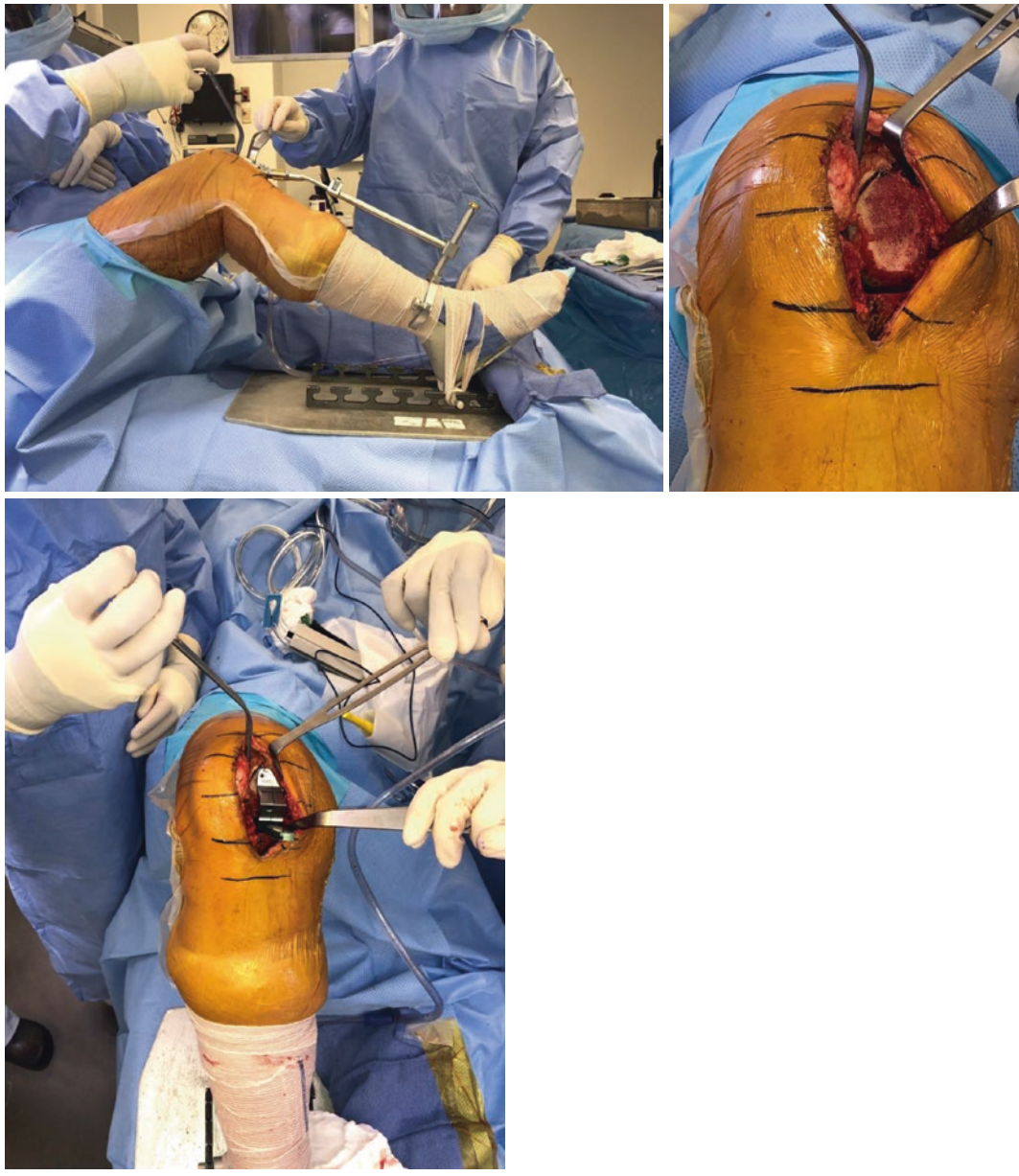

Fig. 7.3 Photos demonstrating the leg position and slope in tibial guide, incision and exposure as well as tidemark, and appropriate sizing of femoral component beneath tidemark

for the medial compartment of the knee include fixed- and mobile-bearing designs, monoblock and modular tibial options, and cemented and cementless implants. Functional outcomes and longevity appear similar between fixed- and mobile-bearing designs [40–43], although progression of lateral compartment arthritis is more common in the mobile-bearing group and polyethylene insert dislocation is a complication unique to mobile-bearing implants [20]. Retrospective analysis has also shown that fixed-bearing implants better tolerate suboptimal rotation of the tibial component [44]. While reasonable midterm results have been reported in an all-polyethylene tibial designs [45, 46] and there is valid concern regarding bone loss in revision of metal-backed modular tibial components [47], the literature more consistently shows superior survivability with metal-backed designs and the risk of early failure with monoblock all-polyethylene tibial implants [48–51]. Biomechanical data help support and explain these findings, with significantly greater strain on the cancellous bone of the proximal tibia with all-polyethylene tibial components [52, 53]. Cementless implants offer the potential for faster surgery, avoidance of cementation errors, and diminished aseptic loosening. The limited available evidence is promising, with survival, reoperation rate, failure, and clinical outcomes similar to cemented implants [54, 55]. However, the majority of results are restricted to a single, mobile-bearing implant design, and include only midterm follow-up of 5 years. Long-term follow-up is necessary to validate these findings.

Technology

Interest in leveraging technological advances in surgical technique continues to grow among surgeons, researchers, manufacturers, and patients. The goal of robotics and patient-specific instrumentation (PSI) is to minimize limb malalignment and component malposition in an effort to improve implant durability and outcomes. However, these technologies are expensive and have failed to show significant clinical benefit as of yet. Two Level 1 studies have been conducted using PSI guides for medial unicompartmental knee arthroplasty [56, 57], and neither showed an advantage when compared to conventional instrumentation. The majority of studies investigating robotic-assisted UKA have reported on accuracy of component placement and shown a statistical advantage when compared to conventional techniques, but there are few reports documenting clinical outcomes and long-term follow-up results are lacking [58, 59]. It remains unknown if more accurate component position leads to improved clinical outcomes or enhances long-term survival of implants.

Outcomes and Survival

Although there is some debate regarding improvement in patient-reported outcomes when compared to TKA [60–63], it is generally accepted that appropriately selected patients have high satisfaction rates and improved function following UKA. Nevertheless, UKA is associated with a lower occurrence of complications, readmission, and mortality [64, 65]. If 100 patients receiving TKA received UKA instead, the result would average one fewer death and three more reoperations in the first 4 years following surgery [65]. It is important to point out that the threshold for revision of UKA is much lower, and UKA still compares favorably in economic evaluations of estimated cost and health outcome even when considering slightly higher rates of revision [66].

The results of UKA have significantly improved in the past few decades, with greater than 94% survival at 10 years for metal-backed, fixed-bearing medial UKA in multiple cohort studies [6, 67, 68] and an average of 91% for all medial UKA in a systematic review [69]. Of note, registry data consistently shows worse outcomes, with an average 10-year survival of only 84.1% in the aforementioned systematic review [69]. A plausible explanation for this trend is that registry data includes multiple implants performed by multiple surgeons with varying levels of experience. The revision rate is significantly lower for surgeons performing at least 30 UKAs per year

[70]. Cohort studies may allow better understanding of how specific implants perform at single center institutions by high volume surgeons [16].

Complications

A recent systematic review found the most common modes of failure for fixed-bearing medial UKA are progression of adjacent compartment arthritis (36%) and aseptic loosening (28%). Instability (12%), polyethylene wear (12%), tibial subsidence (4%), unexplained pain (2%), and infection (2%) are less common. When looking at all medial UKAs, that is, mobile- and fixed-bearing, early failures (<5 years) were most commonly caused by aseptic loosening (25%), progression of osteoarthritis (20%), and bearing dislocation (17%) [71].

Newer designs and better instrumentation have significantly reduced the incidence of aseptic loosening. Varus deformity, younger age, and weight have been advocated as possible risk factors for mechanical failure [72]. Mechanical loosening is also likely influenced by undercorrection of constitutional deformity, component malalignment, excessive tibial slope, and anterior cruciate ligament deficiency. In addition, all these factors may contribute to wear-induced periprosthetic osteolysis, with a further increase in component subsidence and/or loosening [73]. Progression of adjacent compartment arthritis was responsible for 38% and 40% of midterm (5–10 years) and late failures (>10 years), respectively [71]. Overcorrection of the leg mechanical axis may cause degenerative changes in the contralateral compartment [74]. Degeneration of the patellofemoral joint may occur in the presence of an oversized femoral component [6]. Disease progression and component failure are discussed further in Chap. 17.

Revision

Revision of UKA to TKA results in poorer outcomes than primary TKA, but that may be a result of poor preoperative function rather than complexity of the surgery. Revision results were once thought to be equivalent to a primary TKA, but it has been recently suggested that the results may more closely approximate that of a revision total knee, as reported by several authors [75–80]. Revision UKA more frequently requires augments, stems, bone graft, and thicker polyethylene components than primary TKA [78]. It may also be associated with longer operative times, higher reoperation rates, and worse postoperative clinical outcome scores [79]. However, the mode of UKA failure affects the complexity of revision. Isolated liner exchange for polyethylene wear has been shown to be a valuable treatment option in a well-fixed, metal-backed fixed-bearing UKA [81] (Fig. 7.4).

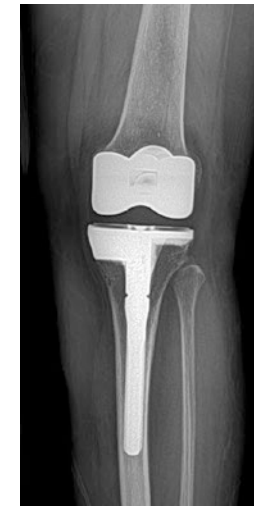

Fig. 7.4 Example of UKA to TKA conversion requiring medial augment and stem

Conclusion

In appropriately selected patients, medial UKA is an excellent surgical option for the treatment of isolated medial compartment arthritis of the knee. The procedure is well suited to rapid recovery protocols and outpatient surgery through a well-structured surgical pathway. Long-term results suggest high patient satisfaction and survivability rivaling TKA. Revision occurs most commonly as a result of progression of arthritis within the remaining compartments of the knee and for component loosening. Results of revision to TKA may more closely approximate that of revision TKA than primary arthroplasty.

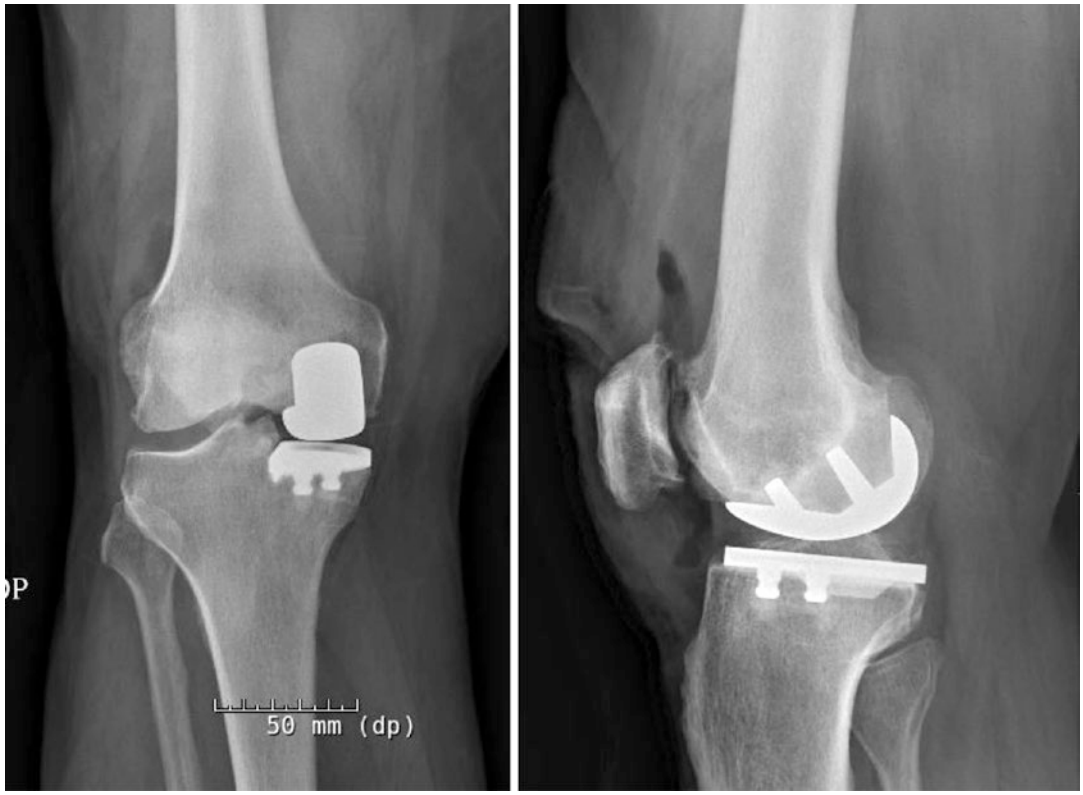

Fig. 7.5 Postoperative radiographs of a 70-year-old patient introduced at the beginning of this chapter

Case Example

The patient underwent uncomplicated medial UKA for isolated medial compartment arthritis. Note maintained constitutional varus, subtle lateral bias of the femoral component, native slope of tibial component, and penetrating cement mantle. The patient achieved an excellent result and looks forward to having his contralateral side done soon (Fig. 7.5).

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8 The Mobile Bearing in Unicompartmental Knee Arthroplasty

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Introduction

Mobile-bearing unicompartmental knee arthroplasty (UKA) was conceived by John Goodfellow and John O'Connor in the release of the "Oxford Knee" in 1974. Prior to its inception, UKA consisted of the St Georg design released in 1969 and the Marmor released in 1972 [1]. Both of these unicompartmental devices displayed a rounded femoral articular surface articulating with a flat all-polyethylene tibial component. These designs fluctuated between all-polyethylene and metal-backed tibial components as issues were seen with wear and distortion of the polyethylene component [2]. With the release of the Oxford Knee, the design was comprised of a mobile polyethylene bearing that was instead fully congruent with the femoral and tibial components, and that was also unconstrained in its ability to pursue motion [3]. These modifications were meant to maximize bearing contact area and decrease stress at the implant interface addressing problems with the previous unicompartmental devices. While the first implant was meant to be used bicompartmentally for total joint arthroplasty, the current mobile-bearing implant is used primarily in the medial compartment. It was believed that through retention of the cruciate ligaments and preservation of bone in uninvolved compartments, patient functional results would be improved. Early clinical outcome scores supported this hypothesis [4].

In the original implant design, termed Phase 1, the superior surface of the bearing was concave to articulate with the spherical metallic femoral component, while the inferior surface was flat to interface with the flat metallic tibial component. This articular geometry has not changed in more recent updates to the prosthesis but instead has remained constant since inception. The femoral articulation with the meniscal bearing allows flexion and extension, while the tibial articulation with the bearing enables translational movement. This geometry allows the bearing to move freely through the knee range of motion in an effort to reproduce natural kinematics dictated by the soft tissue structures around the knee. Furthermore, polyethylene contact area is maximized, and the prosthesis is subjected to primarily compressive forces, which is intended to limit polyethylene wear and risk of component loosening [5]. The femoral component was applied through a series of three inclined bone cuts made with cutting blocks in order to fit the three facets of the component and single central peg, while the tibial component was applied with a keel slot through the tibial surface.

Early failures consisted of bearing dislocation and wear in the contralateral compartment. Anecdotally, it was observed that a higher rate of these failures occurred in patients with a

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defective anterior cruciate ligament (ACL) [4]. Therefore, in 1982, the implant began to be used for the treatment of unicompartmental disease.

History

Updated Phase 2 components followed in 1987 with the specific use for unicompartmental arthritis. The link between ACL function and implant survival facilitated an understanding of the phenomenon of anteromedial osteoarthritis [6]. With functional cruciate and collateral ligaments, the degenerative process was localized to the anteromedial portion of the tibial articular surface and the posterior cartilage was preserved. This corresponded with cartilage wear on the distal part of the medial femoral condyle. In the Phase 2 design, the articular surface of the femoral component remained spherical to mate with the congruent polyethylene bearing; however, preparation of the femur was altered. The posterior femur was cut at an inclined angle, and the distal femur was prepared with a spherical bone-mill. While the posterior femur resection was replaced with an equal thickness of the femoral implant, the distal femur bone milling process enabled incremental bone resection in order to balance the extension gap with the flexion gap. This was intended to allow restoration of the medial collateral ligament tension to improve knee kinematics and limit risk of bearing dislocation. As with the Phase 1 prosthesis, the Phase 2 prosthesis was implanted through a traditional medial parapatellar arthrotomy similar to that employed for total knee arthroplasty (TKA), and the patella was routinely dislocated. There remained a single size femoral component that had to be fit to each patient regardless of boney anatomy, and the tibial plateau was universal. With an updated surgical technique that allowed balancing of the flexion and extension gaps, there was an improvement noticed in the knee kinematics and a decrease in the observed rate of bearing dislocations [7].

Murray, Goodfellow, and O'Connor studied 143 consecutive knees between 1982 and 1992 treated with a mix of Phase 1 and 2 implants. Mean follow-up in the study was 7.6 years with a maximum of 13 years, and based on the data from this study, the authors projected a 10-year survival rate of 98% with the use of a mobile-bearing implant [8]. In contrast to this designer series, Vorlat et al. reported on outcomes of an independent series of 149 operations performed in Belgium between 1988 and 1996 utilizing Phase 2 implants. Mean follow-up was 10.5 years in this study, and the estimated 10-year survival rate was 84% [9]. In another smaller independent study from a private hospital in Sweden, Svard and colleagues reported a10-year survival rate of 94% with primarily Phase 2 implants. This study was composed of 124 knees treated with Phase 1 and 2 implants over a mean follow-up period of 12.5 years (range 10–15 years) [10].

With an increasing knowledge of the disease-specific indications and shortcoming of prior mobile-bearing designs, the Phase 3 implant was released in 1998 for application in the medial compartment [11]. The instrumentation was created in order to allow implantation through a minimally invasive approach that did not require subluxation of the patella. The femoral component was now available in 5 parametric sizes, and the tibial plateau was right and left specific. The mobile-bearing was changed from a universal design with symmetric medial and lateral edges to an anatomic design with elongated medial wings that more closely mimics the "D" shape of the medial condyle in the transverse plane and has unique parts for left and right knees. Improvements in the femoral design, effectively a "Phase 4" and marketed as the Oxford Twin Peg, were initially introduced in 2003 in the United Kingdom and later implemented worldwide [12] (Fig. 8.1). These changes consisted of a more rotund undersurface to match the femoral bone cut, a twin-peg design to improve fixation and stability, and 15° of femoral articular surface was added to increase contact in deep flexion. The polyethylene bearing general articular surface remained unchanged, but alterations were made in order to limit the risk of impingement through range of motion. Function and time of recovery were improved with this new method [13].

The first mobile-bearing UKA design was cleared by the US Food and Drug Administration

Fig. 8.1 The current design of the mobile-bearing Oxford, marketed as the Oxford Twin Peg Partial Knee, was initially introduced in 2003 in the United Kingdom and later implemented worldwide. An explanted device is shown. Improvements in the femoral design, effectively a "Phase 4," consist of a more rotund undersurface to match the femoral bone cut, a twin-peg design to improve fixation and stability, and an additional 15° of femoral articular surface to increase contact in deep flexion

for use in the United States in April 2004 with a physician training requirement prior to use. In June 2004, the FDA Orthopaedic Advisory Panel recommended the reclassification of mobile-bearing knee systems for general use; however, the FDA has not currently accepted this recommendation. It follows that less than 8% of all knee arthroplasties in the United States are unicompartmental procedures [14].

The mobile-bearing implant has also been investigated for use in the lateral compartment; however, the revision rate has been projected as high as 15% at 5 years postoperatively [15]. The primary reason for this high failure rate is a high propensity for dislocation of the mobile bearing. This is believed to be the result of unique kinematics in the lateral compartment as the posterior femoral condyle translates a greater amount posteriorly in flexion compared to the medial femoral condyle. However, adjustments to the mobile-bearing design to maintain a full congruous spherical femoral articulation with a biconcave tibial plateau reduced the dislocation rate to 1.7% at 4 years in a new cohort of 101 patients [16]. Nevertheless, due to this kinematic difference in the lateral compartment, a fixed-bearing implant has become the preferred type of lateral UKA implant [17].

Design Rationale

The Oxford mobile-bearing UKA consists of a dual articulation between polyethylene insert and metallic femoral and tibial components. The conformity between the spherical femoral component and concave polyethylene bearing surface has been a design feature of the Oxford Partial Knee System present since its inception. Finite-element analysis predicts reduced contact stress due to an articular conforming design that distributes forces over a larger surface area. Ten-year in vivo measurements have demonstrated linear wear rates of 0.02 mm/year [18]. Therefore, revisions for wear in long-term studies remain uncommon [19]. However, impingement on retained osteophytes or cement particles remains a cause of not only bearing dislocation but also polyethylene wear [20]. Kendrick et al. studied the impact of impingement on the polyethylene bearing as it related to wear rate. In a retrieval study of 47 Phase 1 and 2 bearings, the wear rate was 0.07 mm/year in the 31 bearings that demonstrated signs of impingement compared to 0.01 mm/year in those that did not [21]. Moreover, the bearings demonstrating impingement affecting the articular surface had a penetration rate 2.5 times higher than those demonstrating extra-articular impingement. In general, the mobile-bearing design is believed to lessen the rate of polyethylene wear compared to fixed bearing designs in exchange for the risk of bearing dislocation [22].

This implant conformity and mobile-bearing design are also meant to decrease stress at the

bone-cement interface. This has resulted in a small probability of aseptic component loosening, which has been estimated as low as 0.2% in some independent studies [23]. This is believed to be an even smaller issue with the use of cementless components, which have been used in European countries since its release in 2004. In a randomized compared trial, fixation of cementless components was observed to be improved compared to cemented components as per lower amount of radiolucent lines [24]. Currently, cementless components are under investigation in the United States, but are not currently approved for general use at the time of this writing.

Microplasty Instrumentation

The Microplasty instrumentation platform was subsequently introduced, designed to streamline the surgical procedure, and make it more efficient overall. The specific changes included a sizing spoon-stylus combination to decrease the need to recut the tibial plateau, an intramedullary femoral alignment guide, and a guide for reducing impingement. The spoon-based stylus references the posterior femoral condyle and removes 6.5 (3 "G-clamp") to 7.5 mm (4 "G-clamp") of tibial bone. The accuracy afforded by the spoons decreases the need for another resection of the tibial plateau as well as increases the likelihood of implanting smaller bearings (3 and 4 mm bearings). Femoral alignment in the Microplasty platform is performed via an intramedullary rod, whereas the Phase 3 instrumentation required visualization and adjustment of 6 separate variables. Removal of impinging osteophytes with Phase 3 instruments involved using an osteotome and then repeatedly checking for impingement in full-knee extension. The Microplasty guide for removing anterior osteophytes allows this step to be done once with no need to recheck impingement-free ROM.

We previously reported that the use of the new Microplasty instrumentation results in more accurate and reproducible femoral component placement [25]. In another prior study, we analyzed whether the new Microplasty instrumentation improved efficiency and reduced operative time compared to the Phase 3 instrumentation [26]. Patients in both groups were matched for gender, age, body mass index, preoperative ROM, and Knee Society pain and clinical scores. Operative time was defined as the time from skin incision until the final dressing was applied. Both groups were compared, and statistical significance was defined as $p < 0.05$. The mean operative time was significantly shorter with the Microplasty instrumentation (49 minutes) compared to the Phase 3 (58 minutes). Additionally, the standard deviation was significantly lower in the Microplasty group (14 minutes) versus the Phase 3 (17 minutes). The minimum and maximum operative times were also less in the Microplasty group compared with the Phase 3 (24–88 minutes versus 30–126 minutes).

The efficiencies of the Microplasty instrumentation resulted in an average of 9 minutes less per surgical case compared to Phase 3 instrumentation. This correlates to a 15% reduction in the time it takes to implant the Oxford mobile-bearing UKA. This 15% reduction in operating time should translate into the ability to perform more surgeries, decreased infection, decreased tourniquet use, and overall better experience for surgeon and patient alike.

Indications

Beginning in 1989, the classic article by Kozinn and Scott detailed contraindications to unicondylar arthroplasty procedures including both disease- and patient-specific criteria [27]. They stated that patients exceeding an age of 60 years, weight of 180 pounds, or those extremely physically active heavy laborers were contraindicated for the procedure given an increased risk for mechanical loosening based on their anecdotal evidence. Disease-specific criteria, which included chondrocalcinosis on preoperative imaging or at the time of surgery and exposed subchondral bone within the patellofemoral joint, were identified as factors portending worse outcome. These principles stemmed from an unpublished study of 100 consecutive unicom-

partmental arthroplasty procedures performed by the authors with 10-year follow-up in which 13 failures from mechanical loosening were attributed to either surgical inadequacy, or patient-specific or disease-specific factors as categorized above. Other authors have echoed this sentiment when indicating patients for the procedure [28].

These historical patient indications severely restrict the number of patients considered as appropriate candidates for unicompartmental arthroplasty. One retrospective study of TKA cases declared that 21% of the cases may have been eligible for UKA based on disease-specific criteria, which included intact lateral cartilage, an intact ACL, no patellofemoral arthritis, ROM greater than 90°, and varus deformity less than 10° [29]. Multiple investigations have aimed to refine appropriate indications for a unicompartmental arthroplasty with a mobile-bearing implant. In a prospective cohort of 1000 Oxford partial knee arthroplasties, Pandit et al. showed that the Oxford Phase 3 implant revision rate at 10-years was relatively similar for patients with one contraindication based on the Kozinn and Scott criteria as compared to those satisfying all criteria (2.4% vs. 4.0%) [30]. The projected survival free of component revision from life-table analysis was higher in the contraindicated patients as compared to the ideal patients (97.0% vs. 93.6%). The causes of failure were different between these two groups as those ideal patients developed a higher rate of lateral compartment osteoarthritic progression, while the contraindicated patients suffered more mobile-bearing dislocations requiring revision surgery. This cohort of patients was comprised of 68% for whom the Kozinn and Scott principles would have contraindicated them for unicompartmental knee arthroplasty. In the updated study of this cohort, cumulative 15-year survival rate was not statistically different between those highly active male patients older than 60 years with weight greater than 180 pounds as compared with those patients without any of these contraindications (92.7% vs. 89.9%) [31]. Furthermore, clinical outcomes as measured by Knee Society objective score, Oxford Knee score, and Tegner activity scale were similar or better in the Kozinn and Scott contraindicated patients. Further studies have demonstrated that age and activity do not compromise results of mobile-bearing unicompartmental arthroplasty, and these patients may be able to successfully attain a high level of activity postoperatively [31–33].

In contrast, Goodfellow and colleagues believed that treatment with a mobile-bearing unicompartmental arthroplasty should instead be applied in patients demonstrating the appropriate pathoanatomy independent of patient-specific factors. The specific applications included anteromedial osteoarthritis and spontaneous medial osteonecrosis of the knee. Anteromedial osteoarthritis (AMOA) is defined by medial compartment bone-on-bone joint space narrowing with intact posterior cartilage. In addition, the lateral compartment should contain full-thickness cartilage and both the anterior cruciate and medial collateral ligaments should be functional. This pathoanatomy manifests specific clinical signs and symptoms. Varus deformity is most noted in full extension due to the pattern of wear on the anterior portion of the tibial plateau and the inferior articular surface of the femoral condyle [34]. This deformity is not fixed and can be corrected with a valgus stress at roughly 20° of flexion relaxing the posterior capsule. This is possible because joint space contact in flexion retains normal cartilage, therefore maintaining normal tension on the medial collateral ligament (MCL) and keeping its length constant. It is believed that the presence of functional cruciate ligaments correlates with the disease pattern observed as they maintain normal femoral roll-back in flexion.

Hence, unicompartmental arthroplasty should not be offered in cases with an impaired ACL. In some cases, the ACL may fail secondarily after the advent of anteromedial disease, causing a progressive erosion of the posterior cartilage and therefore a fixed varus deformity. In other instances where the medial compartment disease develops secondary to ACL rupture, the posterior cartilage is usually affected first due to anterior subluxation of the tibia. Still attempts have been made to reconstruct the torn ACL while performing unicompartmental arthroplasty with promising short-term results [35].

There has also been some confusion when it comes to application of unicompartmental arthroplasty in patients with anteromedial osteoarthritis who demonstrate arthritic changes in the patellofemoral joint. In a cohort of 677 patients, the Oxford group found that there was no relationship between implant survival at 15 years postoperatively and the presence of anterior knee pain preoperatively, nor with the degree of cartilage loss within the patellofemoral joint intraoperatively [36]. The authors did document difficulty with stair descent in those patients treated with medial mobile-bearing unicompartmental arthroplasty demonstrating intraoperative evidence of full-thickness cartilage loss on the lateral aspect of the patella. Similarly, in a retrospective review of 100 consecutive Oxford medial unicompartmental arthroplasties with a minimum 8-year follow-up, patients with grade 3 change in the central and lateral aspect of the patellofemoral joint were found to have lower mean satisfaction with pain and function compared to the remainder of the cohort [37]. Stair climbing ability was also significantly decreased in those patients with central and lateral lesions observed intraoperatively in the patellofemoral joint. For this reason, severe damage to the lateral side of the patellofemoral joint with bone loss and grooving is defined as a contraindication to the procedure; however, less severe damage to the lateral articulation, medial patellofemoral disease, and anterior knee pain should not be considered contraindications.

Rheumatoid arthritis is another contraindication to medial unicompartmental arthroplasty as the inflammatory process primarily affects the synovium, resulting in tricompartmental disease. Therefore, in patients with this underlying diagnosis, it is recommended that total knee arthroplasty be performed as there is a risk of rheumatoid progression when a unicompartmental arthroplasty is performed [38].

Based on these principles, a strict preoperative clinical evaluation should be implemented in order to determine the ideal candidate for medial mobile-bearing UKA [39]. Clinically the patient should have varus malalignment in extension that corrects in flexion. Flexion contracture should not exceed approximately 15° and total range of motion should be greater than 100°. The ACL should be competent on clinical exam. Imaging should demonstrate significant loss of medial compartment joint space in either the anteroposterior weight-bearing view or the posteroanterior 45-degree flexion view. Lateral radiographs should display bony erosion of the anterior portion of the medial tibial plateau in contrast to an ACL-deficient knee in which the femoral condyle will be articulating with the posterior portion of the plateau, causing posterior erosion. A valgus stress view taken at 20-degrees of knee flexion should also be taken to confirm full-thickness cartilage within the lateral compartment and demonstrate a correctable deformity through a competent MCL. The patellofemoral joint should be imaged in order to exclude patients with significant bone-on-bone arthritis of the lateral patellar facet. Otherwise, moderate lateral facet disease or advanced diseased of the medial patellofemoral compartment should not preclude the use of UKA.

These criteria were elucidated in a radiographic decision aid, which was developed by a collaboration of joint arthroplasty surgeons after review of current literature [40]. In a retrospective review of over 500 patients, those meeting the radiographic standards irrespective of patient factors such as age and weight displayed a 5-year implant survival rate of 99% compared to 93% in those patients failing to meet these standards. Furthermore, functional outcomes measured by knee flexion, Knee Society score function component, and University of California Los Angeles activity score were significantly higher in those patients meeting the radiological criteria.

Osteonecrosis

Spontaneous osteonecrosis of the knee (SPONK) that is focal and localized to the medial femoral condyle or the medial tibial plateau is also an indication for mobile-bearing UKA [41]. In the early stages of disease, SPONK may only be detected on MRI prior to subchondral collapse, while also ruling out secondary osteonecrosis, which frequently involves both condyles [42].

As the disease progresses, some patients may demonstrate subchondral collapse in conjunction with joint space narrowing as the osteonecrosis is accompanied by a degenerative process. In all forms of the disease, the pathoanatomy resembles anteromedial osteoarthritis in that it is limited to the medial compartment and both the ACL and MCL are functionally intact. This should not be confused with secondary osteonecrosis, which occurs frequently in younger patients after corticosteroid, renal, or systemic disease [43]. This entity is often bilateral and involves both compartments, thus making unicompartmental arthroplasty futile. More recently, osteonecrosis in the postoperative knee (ONPK) has been described following arthroscopic surgery and is similarly focal in extent and localized to the medial femoral condyle in most cases [44, 45]. Outcomes and survival of UKA for SPONK or ONPK localized to the medial compartment have been encouraging [46, 47]. Furthermore, the success appears to be independent of the size of the osteonecrosis lesion as we have found a survival rate of 94.6% at 5 years in a cohort of 64 patients with mean lesion width amassing 64% of the medial femoral condyle width. Only one patient suffered from aseptic loosening of the femoral component in this cohort [48].

Surgical Principles and Technique

Before beginning surgery, there are a number of items that should be available to successfully perform the operation. Radiographs should be available demonstrating the classic pattern of AMOA with correction of the varus deformity with valgus stress (Fig. 8.2). The operation can be performed supine on a regular operating table or the leg can be held over the side of the bed in a hanging leg holder. We prefer to use the hanging leg holder with the hip flexed 30° and a tourniquet applied to the proximal thigh. There should be enough abduction for the operative leg to flex between 90° and 135° without impingement on the operative table (Fig. 8.3). The contralateral leg is placed on a well-padded foam leg holder, and the bottom of the bed is dropped perpendicular to the floor. A stiff, narrow reciprocating saw, a 12-mm wide oscillating saw, and a double-armed vertical toothbrush saw are utilized during the operation.

The goals of the operation are to relieve pain and restore function through resurfacing of the medial compartment. The surgical principles and technique employed to achieve these goals stem from the relevant disease pathoanatomy. The technical aims of the operation are to restore native MCL tension through a series of bone cuts and to attain stable fixation of the components. As a result of the MCL being of normal length in anteromedial osteoarthritis and osteonecrosis, there is no deformity to correct in UKA procedures [6]. Thus, no medial release should be carried out. After making the skin incision (Fig. 8.4) and subsequent arthrotomy, the subperiosteal tissue sleeve that is created during exposure should only be performed to improve visualization of the anteromedial tibia and care should be taken not to affect the MCL.

The tibial cut will affect the balance in both extension and flexion, as with total knee arthroplasty, while the distal femur and posterior femoral cuts will affect only the extension or flexion gap, respectively. Using a resection guide, the depth of tibial resection should be as conservative as possible to allow placement of the smallest implant bearing. A standard depth of resection is made with instrumentation for the Oxford Partial Knee System (Fig. 8.5). A conservative tibial resection will ensure that the implant is resting on robust proximal tibial metaphyseal bone with a larger cortical rim [49]. The vertical limb of the tibial resection should be flush with the medial intercondylar tibial spine to maximize the size of the tibial component that can be applied. Larger tibial components allow greater contact area and thus decrease contact stress within the proximal tibia [50]. Additionally, the angulation of the vertical saw cut in the sagittal plane should match that of the desired tibial slope that has been set into the tibial resection guide (Fig. 8.6). Inadvertently cutting further through the posterior cortex increases the risk of medial tibial plateau fracture [51]. A standard amount of

posterior femoral bone is resected corresponding to the thickness of the posterior aspect of the femoral component (Figs. 8.7 and 8.8). Osteophytes should be resected from the medial aspects of the femur and tibia prior to determining the gap balance as they will tend to distract the collateral ligaments. The flexion gap is now established first. Accounting for inclination in the posterior femoral and tibial resections with the Oxford Partial Knee System, trialing of the flexion gap is performed at 110° because this is the point at which the gap is rectangular. As

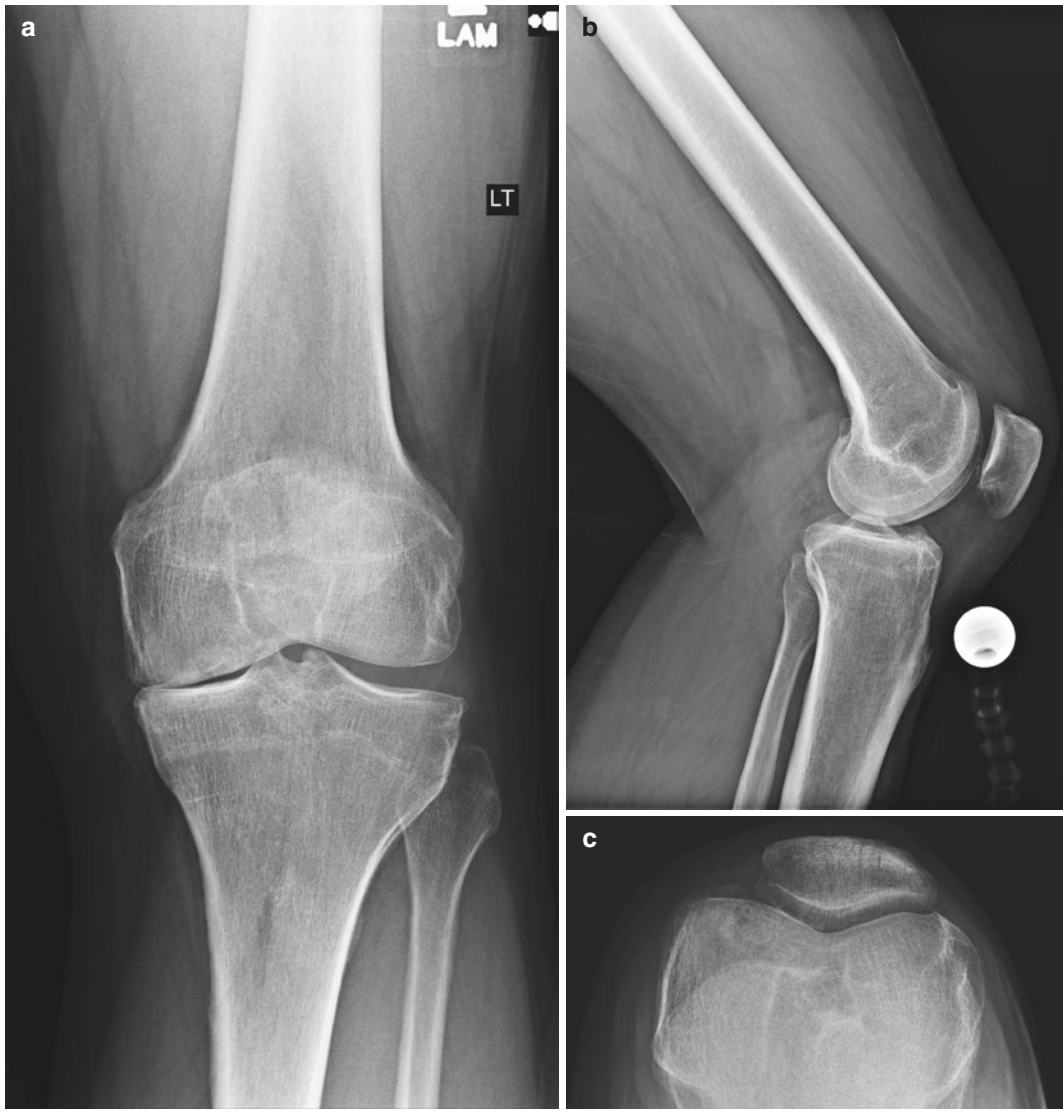

Fig. 8.2 A 43-year-old male patient with a BMI of 27.1 kg/m^2 presented complaining of severe medial pain and swelling of the left knee with progressive worsening over the past 14 months. Previous treatments of arthroscopy, physical therapy, corticosteroid injection, nonsteroidal anti-inflammatories, self-directed home care, and pain medication have not relieved his pain. Radiographs were obtained including standing anteroposterior (**a**), lateral (**b**), merchant patellar (**c**), posteroanterior weight bearing in 45° of flexion (**d**), and valgus stress test (**e**) views, which demonstrate severe joint space narrowing, sclerosis, and osteophyte and cyst formation. The valgus stress test (**e**) revealed restoration of normal limb alignment without collapse of the lateral compartment and an intact medial collateral ligament

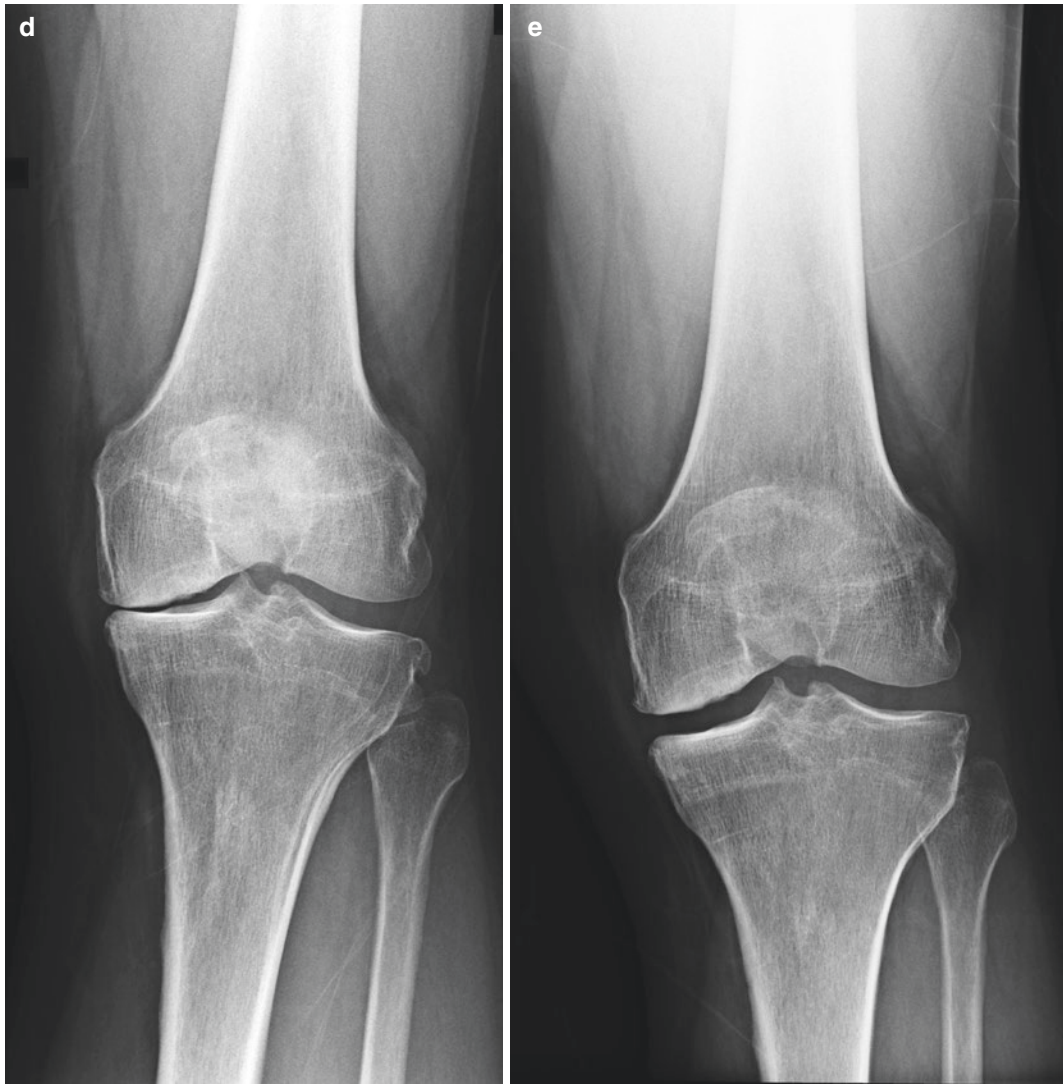

Fig. 8.2 (continued)

the wear pattern in anteromedial osteoarthritis does not affect the middle to posterior tibia or the posterior femur, and given that the depth of tibial resection and amount of posterior femoral resection are standardized with instrumentation, the flexion gap should simply restore the native tension within the collateral ligament using the smallest polyethylene bearing thickness. Overtensioning the ligament with a larger bearing, and thus overloading the lateral compartment, should be avoided. With the flexion gap established, an appropriate amount of bone is resected from the distal femur in order to balance the extension gap. In anteromedial osteoarthritis, the extension gap is primarily affected by the disease process causing decreased tension within the MCL near full extension. Hence, the amount of distal femoral bone that is resected will depend upon the degree of disease. With more significant cartilage and bone erosion, there is less tension within the medial compartment in extension and less bone will be resected to restore normal MCL tension. The extension gap is trialed at 20° because

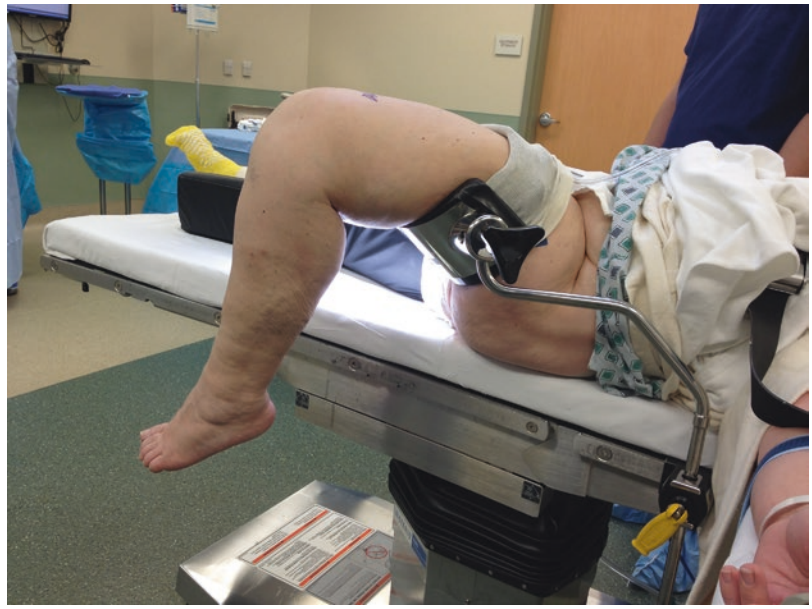

Fig. 8.3 The patient is positioned with the operative extremity in the hanging leg holder. A tourniquet is placed on the upper thigh. The hip is flexed approximately 30° and abducted to allow at 90–135° of knee flexion without impingement on the operative table

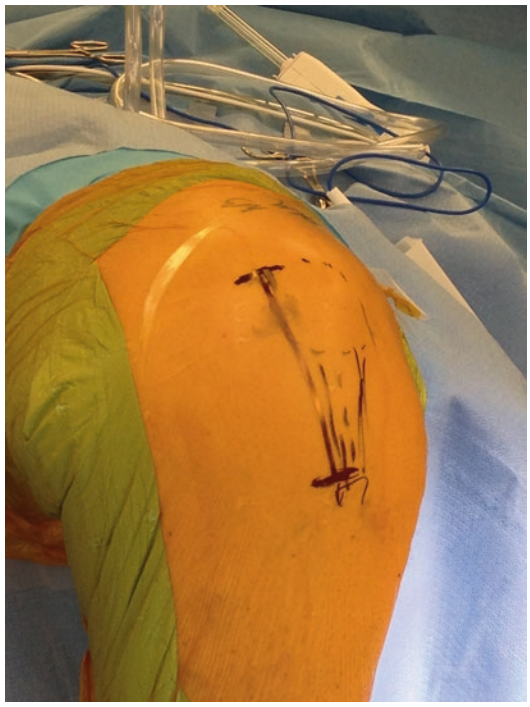

Fig. 8.4 Planned incision is marked on a left knee

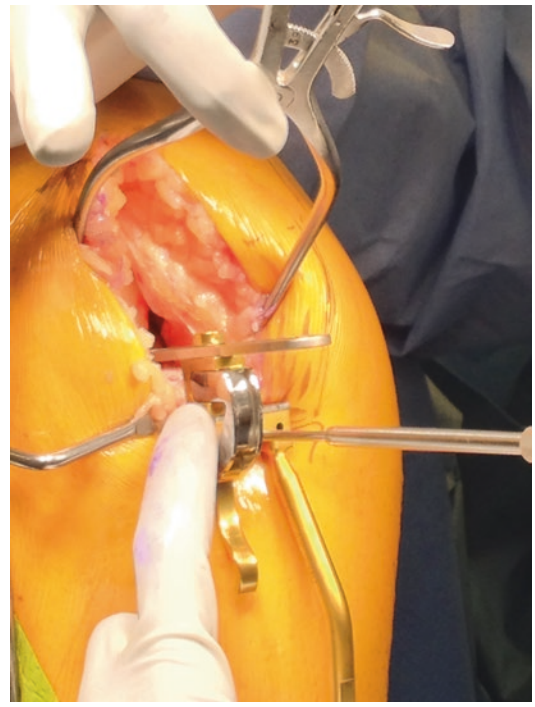

Fig. 8.5 Oxford Microplasty spoon and tibial resection guide linked by the G-clamp. Drill is securing the tibial resection guide to the medial proximal tibia

the posterior capsule is typically shortened, which creates excessive strain near full extension. Flexing the knee 20° relaxes the posterior capsule, allowing the tension in the medial compartment to be controlled by the MCL and cruciate ligaments alone. The MCL tension at 20° should now match the tension at 110° with the appropriately selected bearing (Fig. 8.9).

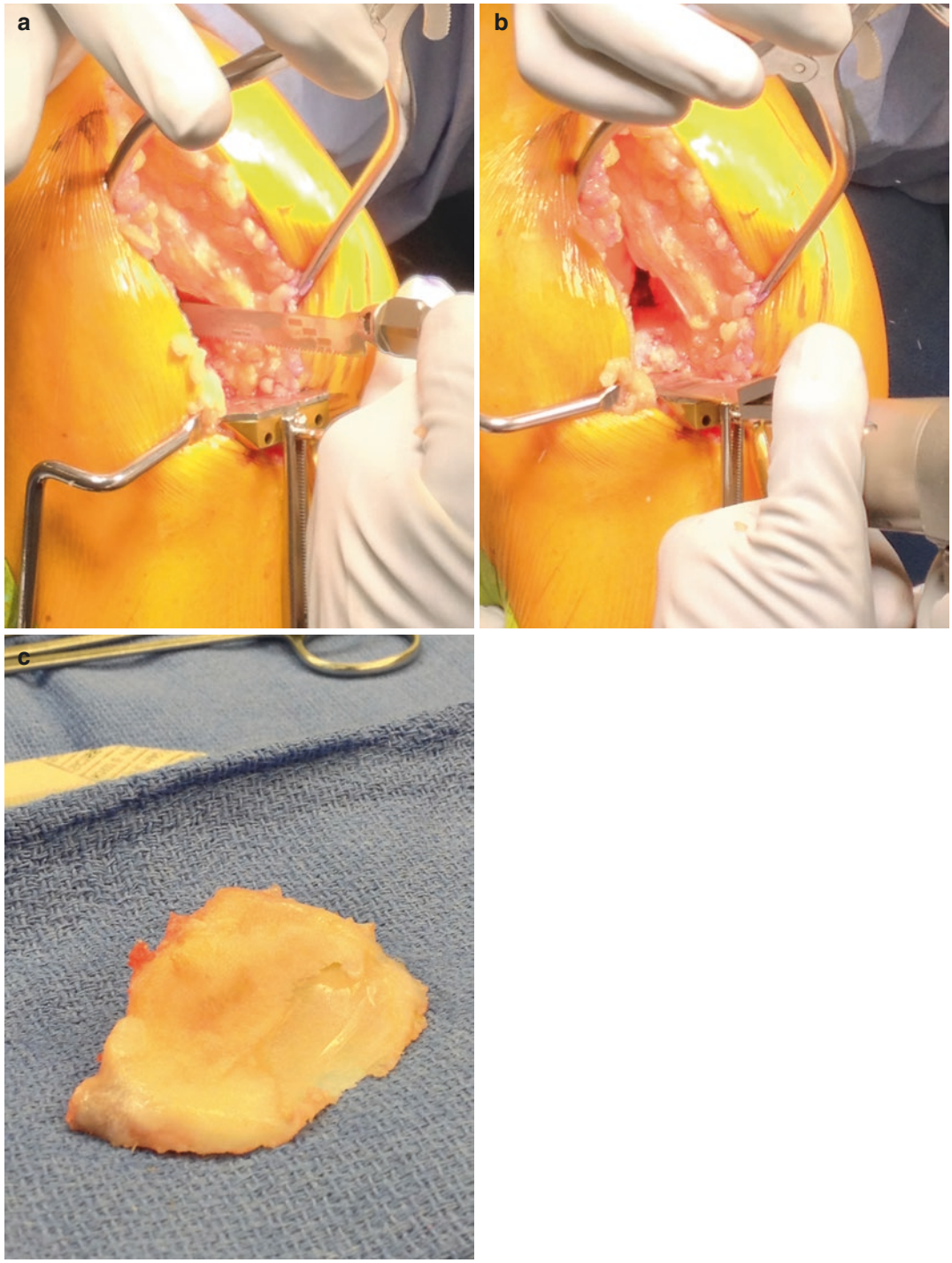

Fig. 8.6 (**a**) Intraoperative photograph demonstrating the vertical saw cut on the tibia. The saw should be in line with the flexion axis of the knee and should be adjacent to the lateral aspect of the medial femoral condyle and medial edge of the ACL on the tibia. (**b**) Horizontal cut of the proximal tibia. (**c**) Excised tibial bone from the left knee demonstrating classic anteromedial arthritis with preserved posterior cartilage

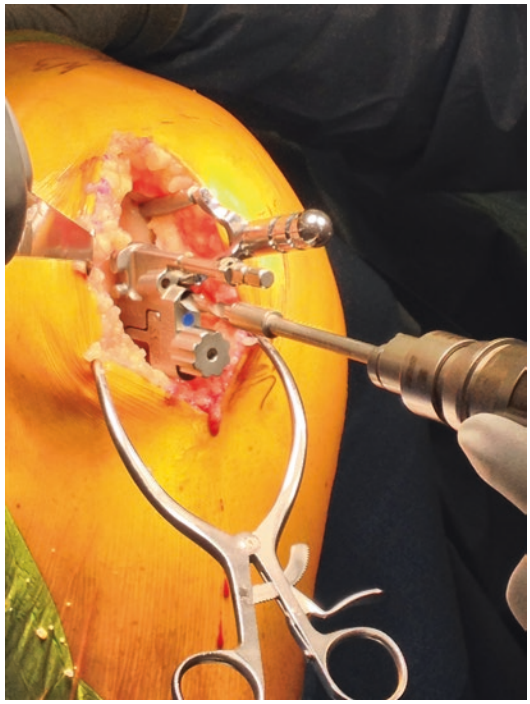

Fig. 8.7 Intraoperative photograph demonstrating the Oxford Microplasty flexion gap spacer coupled to the intramedullary rod by the linkage bar. The 4-mm hole has already been drilled, and now the 6-mm hole is being drilled in the center of distal medial femoral condyle

Appropriate MCL and cruciate ligament tension are crucial to restore kinematic motion and to ensure stability of the mobile bearing. Excessively tensioning the MCL risks overloading the lateral compartment, which could lead to arthritic progression, a primary reason for failure of unicompartmental arthroplasty procedures. Conversely, failure to restore tension will create inappropriate laxity within the medial compartment and put the bearing at risk of dislocation.

After the knee is balanced, the keel is cut for the tibia, and the Oxford Microplasty 2-in-1 anterior mill and posterior osteophyte resection tool is placed (Fig. 8.10). This device removes anterior as well as posterior osteophytes, which could cause impingement in extension and high flexion, respectively. These obstructions can cause bearing impingement and may lead to dislocation. Testing with a mobile-bearing trial will allow the surgeon to determine if any impediments remain and need to be addressed prior to implantation of the final components.

While cementless components are available in Europe, bone cement is required for fixation currently in the United States. Small 2-mm drill holes should be made in the femur and tibia for cement interdigitation prior to implantation. When implanting components, efforts should be made to extrude cement from posterior to anterior when impacting the tibial prosthesis into place and only a small amount of cement should be placed on the posterior aspect of the femoral prosthesis. These efforts limit the amount of cement that can extrude posteriorly, which can be very difficult to remove. Stable fixation of the components is ensured by placing the knee at 45° with the mobile-bearing inserted while allowing the cement to cure (Fig. 8.11). This position may prevent inappropriate rocking of components that can occur at greater degrees of extension or flexion. Errors in cementation or failure to remove excess cement have been linked to pain, premature loosening, and rapid bearing wear [21, 52].

Surgical Pearls

There are a number of surgical pearls that help make the Oxford mobile-bearing UKA more successful (Fig. 8.12). If in between two sizes, it is generally recommended to use the smaller size bearing so that the knee is not too tight or overcorrected. Tibial plateau fractures occur more often when the vertical saw cut goes below the desired resection level, so the surgeon should avoid raising his or her hand during this cut. We also recommend only drilling one hole to secure the tibial resection guide. If possible, avoid placing the drill hole where the keel will ultimately be cut, and use gentle impaction blows when inserting the tibial component. The MCL should never be released during the procedure, and retractors should always be used during all bony resection steps. If the MCL is transected, the procedure

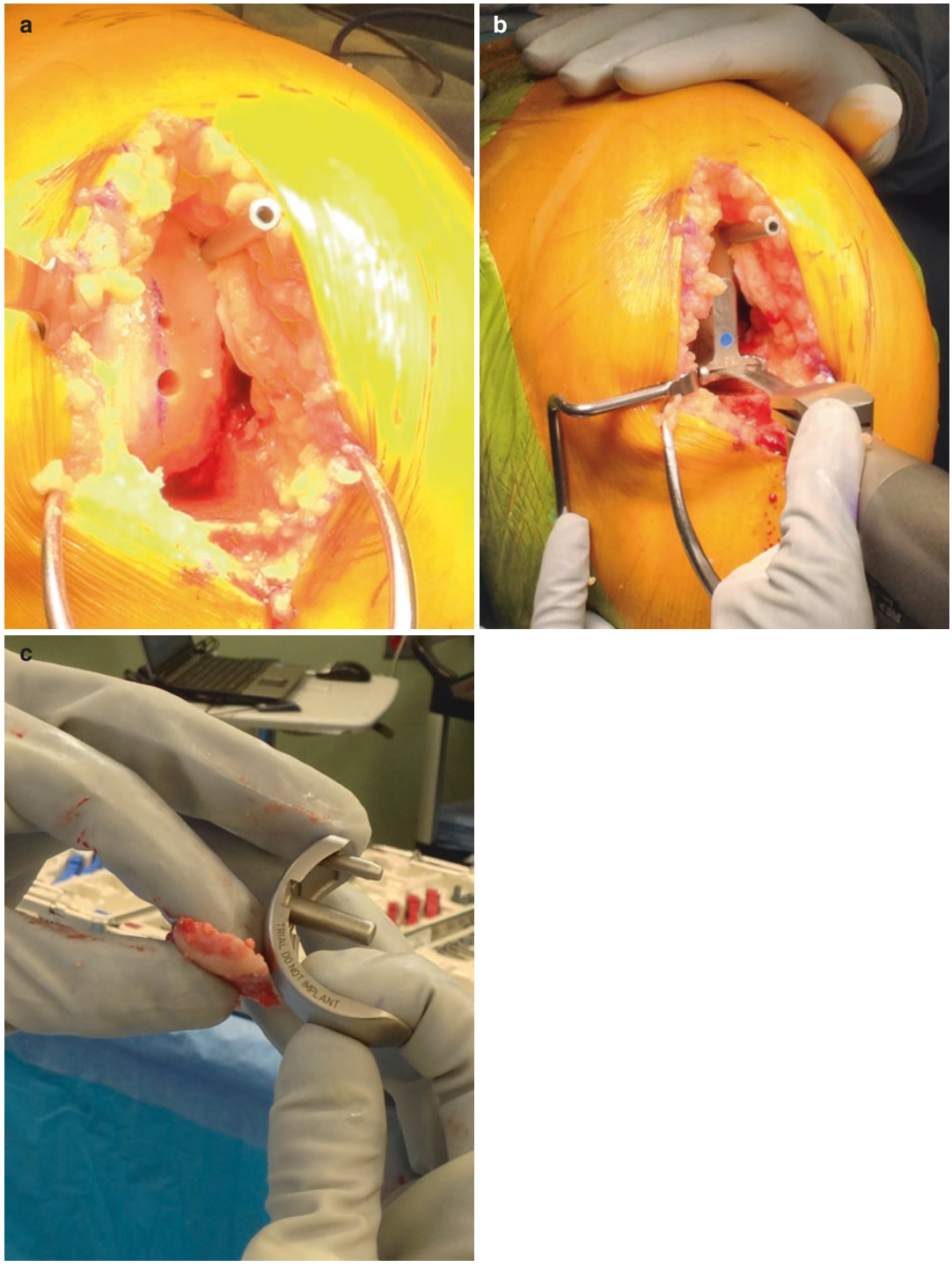

Fig. 8.8 (**a**) 4- and 6-mm holes have been drilled in the center of the distal medial condyle. (**b**) Posterior femoral condyle resection guide is inserted and the cut is made while the MCL is protected with a retractor. (**c**) Photograph demonstrating that the removed bone is of the same size as the posterior aspect of the implant

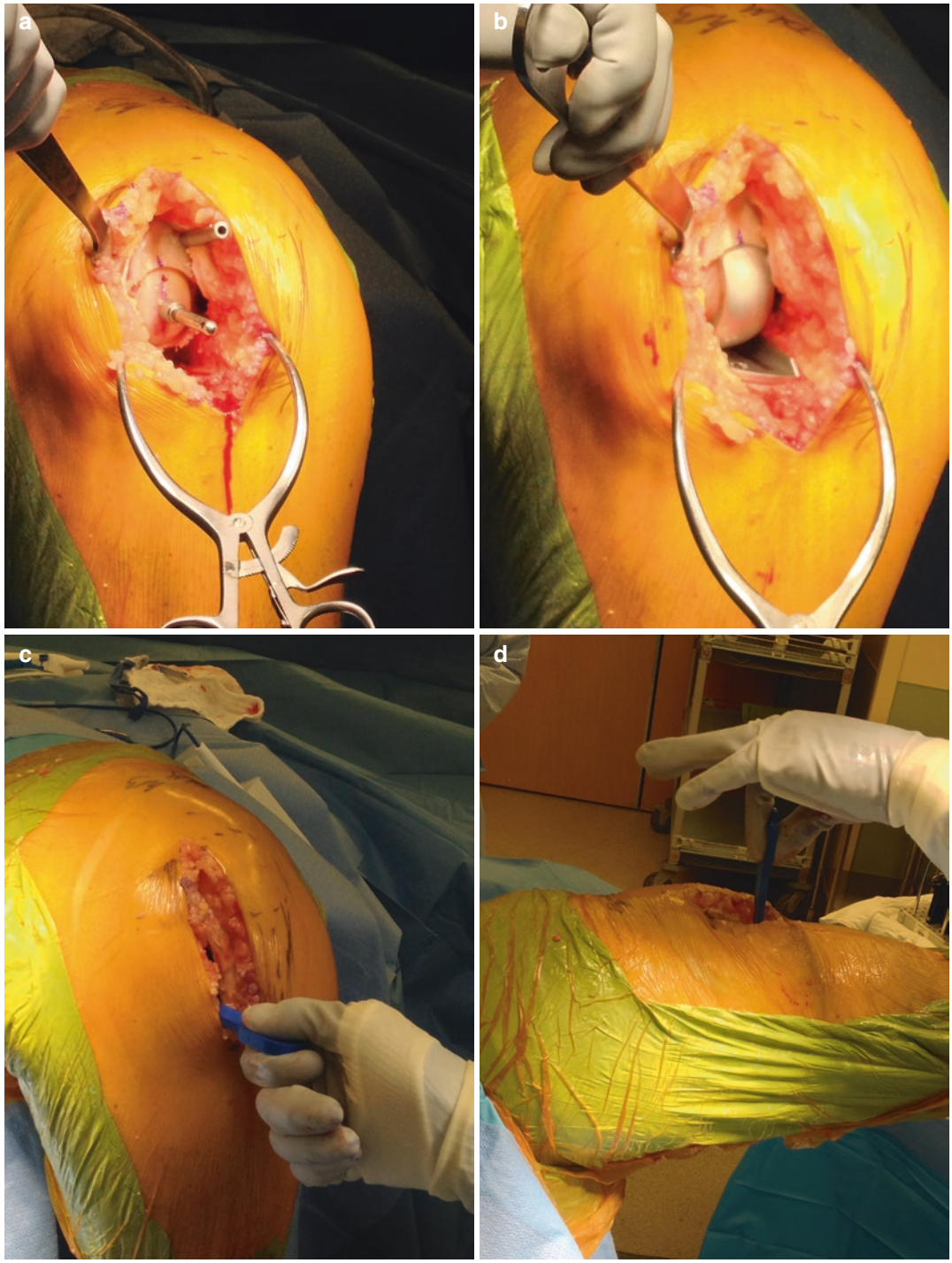

Fig. 8.9 (**a**) Zero spigot inserted into the 6-mm pilot hole. After incrementally milling the distal femur to try and match the gaps, (**b**) trials are reinserted, and the (**c**) flexion gap and the (**d**) extension gap are checked to make sure they are equal

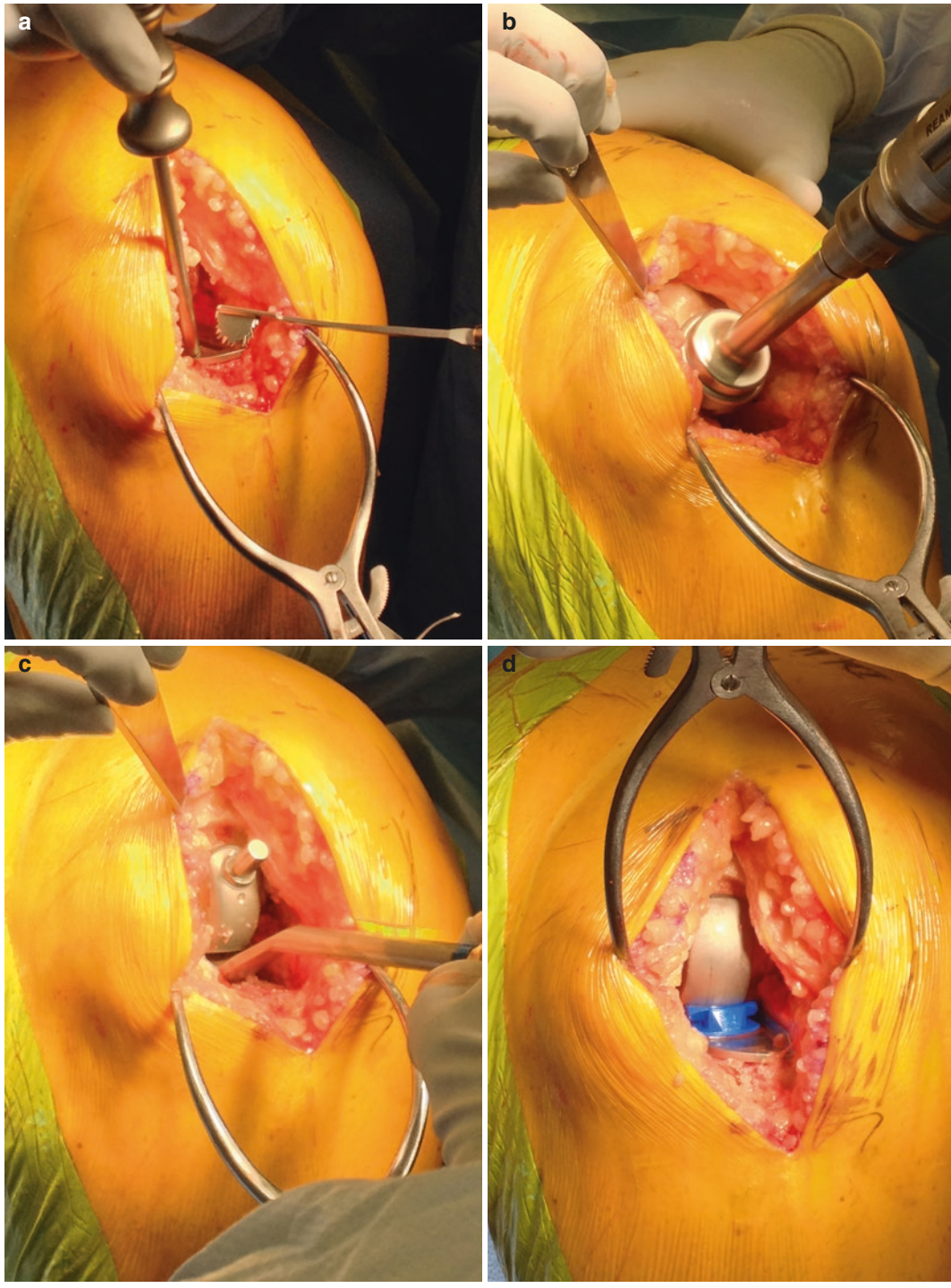

Fig. 8.10 (**a**) After stabilizing the tibial base plate template with the tibial nail, the toothbrush saw is used to prepare the keel slot. (**b**) The 2-in-1 anterior mill guide and (**c**) posterior osteophyte resection guide are used to remove potentially impinging osteophytes. (**d**) Trial components and bearings are inserted and taken through a full range of motion to make sure motion is smooth throughout

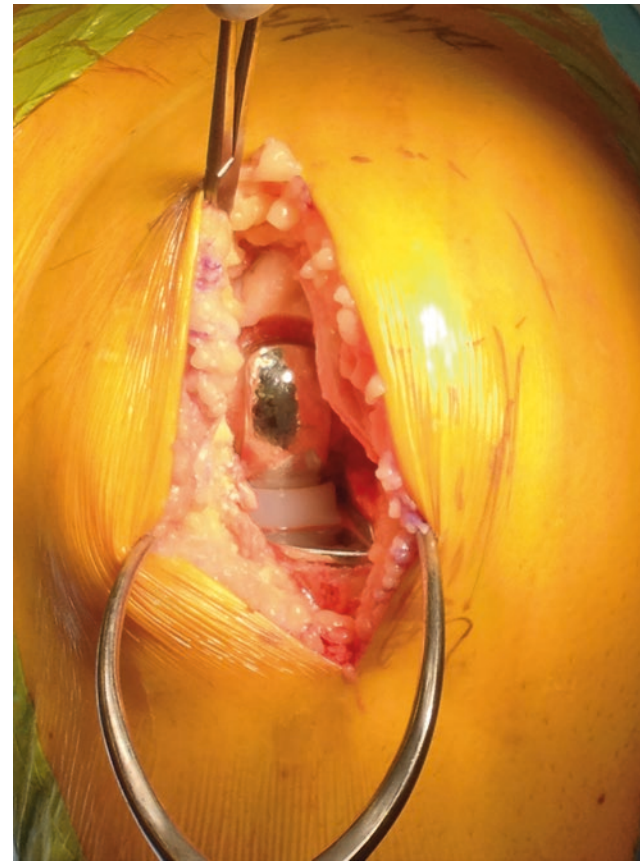

Fig. 8.11 Final components are cemented into place, and the anatomic meniscal bearing is inserted

should be converted to a TKA with the appropriate amount of constraint. Finally, the goal of the tibial resection is 7° of posterior slope, which is usually built into the resection guide. Avoid additional slope, which is a known cause of posterior collapse and failure. Before anesthesia is reversed and the patient is taken out of the operating room, good-quality postoperative radiographs should be reviewed.

Complications

Bearing Dislocation

Dislocation of the mobile bearing is a shortcoming that is unique to this type of unicompartmental arthroplasty. It has been estimated to occur in nearly 0.58% of cases using the Phase 3 prosthesis [53]. Primary dislocations are usually the result of technical error during the procedure. This stems from inadequate tensioning of the collateral ligament or failure to remove sources of impingement such as osteophytes or retained cement particles.

Meticulous surgical technique is crucial in preventing bearing dislocation events. Care should be taken to not release the medial collateral ligament or cause damage to it while using the saw. The femoral component should be aligned centrally in relation to the tibial cut surface. As the mobile bearing follows the movement of the femur, alignment of the femoral component excessively medial or lateral will allow the bearing to track too far or close to the tibial sidewall, which could increase risk of impingement and dislocation [54]. Tension in the collateral ligaments should be equal when tested at 20° and 110° of flexion. The trial bearing should gap open roughly 1–2 mm when tested with the

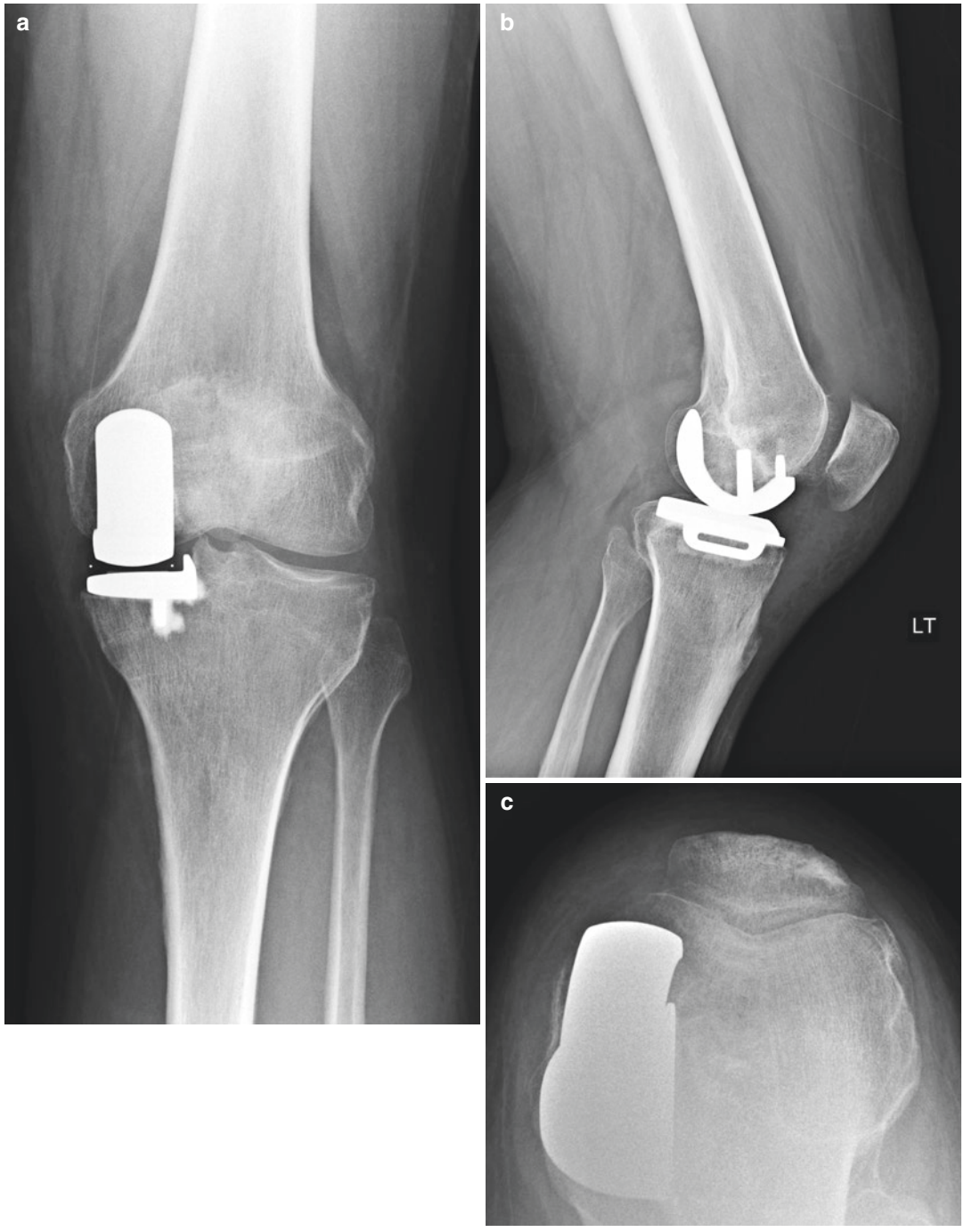

Fig. 8.12 The patient shown previously (Fig. 8.2) was treated at an ambulatory surgery center with outpatient cemented medial unicompartmental arthroplasty of the left knee with a mobile-bearing device. The twin-peg femoral component was size large, the anatomic meniscal bearing was 3 mm thick, and the medial tibial tray was a size D. Postoperative radiographs, including standing anteroposterior (**a**), lateral (**b**), and merchant patellar (**c**) views reveal well-fixed components in satisfactory position and alignment

insertion instrument throughout range of motion. Increased movement of the bearing will allow the possibility for dislocation; however, care must be taken not to make the bearing excessively large in which case inappropriate load is transferred to the lateral compartment, increasing risk of lateral arthritic progression [55]. Osteophytes must be removed from the anterior and posterior femoral condyle using the anti-impingement tools as these can contact the bearing inappropriately. Residual meniscal tissue may also have the same effect. Final trial of the bearing will help to confirm that there is no residual impingement. Finally, steadfast excision of excess cement particulate should be performed as this is another source of impingement.

In cases of dislocation, the diagnosis is usually made with a radiograph demonstrating direct contact between the femoral and tibial components, while the radiopaque marker within the polyethylene is identified in either the anterior or posterior aspects of the knee.

Closed reduction of the bearing is difficult and only successful in rare cases. Surgical intervention consisting of an arthrotomy is usually required. During this procedure, the cause of the dislocation must be identified. Inspection of the MCL, gap balance, and sources of impingement should be performed. These sources should be addressed prior to placement of new mobile bearing.

Arthritic Progression in Lateral Compartment

Progression of lateral compartment arthritic disease remains one of the most common reasons for failure following medial mobile-bearing UKA. In the study with the longest follow-up, the reoperation rate for lateral compartment progression was found to be 2.3% at 20 years [56]. In a 15-year study by the Oxford group, the rate was similarly found to be 2.5% [57].

Causes include inappropriate surgical indications or technical surgical error. Preoperative evaluation must confirm a diagnosis of either anteromedial osteoarthritis or osteonecrosis of the medial femoral condyle. In both cases, the ACL should be intact, and the deformity should be flexible. Valgus stress radiograph should help to confirm the presence of full-thickness cartilage in the lateral compartment. It has been shown that a higher rate of success is seen when these criteria are met [35, 40]. Furthermore, during intraoperative examination, there should be no full-thickness lesions in the lateral compartment. If any lesions are appreciated, then UKA should be aborted and TKA should be performed. Unicompartmental arthroplasty should also not be performed in patients with a history of rheumatoid arthritis even if radiographs more closely resemble those of anteromedial arthritis. In these cases, progressive disease in the lateral and patellofemoral compartments is more likely. Flaws in surgical technique also represent a key reason for arthritic progression. Overcorrection of the varus deformity transfers the weight-bearing load to the unaffected lateral compartment, which may cause accelerated cartilage wear. Therefore, it is recommended that the prosthesis be left in slight varus deformity and a bearing size should be selected to restore native tension on the MCL. If the MCL is released inadvertently, then a larger bearing size may be selected to tension the ligament, which may allow overcorrection of the deformity.

If symptomatic lateral compartment arthritis is diagnosed, then addition of a lateral TKA or conversion to a TKA should be considered. Addition of lateral unicompartmental arthroplasty has demonstrated successful results at mid-term follow-up [58]. Furthermore, conversion of a UKA to a TKA may be a less complicated operation with lower risk compared to revision of a TKA to a TKA [59].

Aseptic Loosening

Aseptic loosening of components can occur either early due to improper fixation or years later due to causes intrinsic to the components. Inadequate initial fixation may result from inability to secure cement within the tibial keel or femoral peg holes. Later causes of loosening may relate to

technical error or intrinsic flaws of the components. The tibial component size should be maximized in order to obtain optimal cortical contact without overhang. Cortical bone provides more robust support of the tibial baseplate to prevent abnormal settling that can occur in cancellous bone. The femoral component should be aligned centrally with the tibial baseplate in order to centralize the weight-bearing stress. This should prevent misaligned stress concentration that could enable tilting of the tibial baseplate over time [60]. Finally, the updated twin-peg design may add rotational stability to the femoral component, which has lessened the concern for aseptic loosening of the femoral component as compared to the single-peg design [61].

Diagnosis of component loosening should be made on successive radiographs taken with the same rotation of the leg as judged by overlap of the tibia and fibula. There should be clear evidence of change in position of components on the radiographs in order to diagnose aseptic loosening. Stable radiolucent lines at the bone-cement interface are a normal finding and should not be misinterpreted as component loosening [62]. These physiologic radiolucencies are well-defined lines that are stable on successive imaging and may represent suboptimal cement fixation from a layer of fibrocartilage in between the bone-implant interface [63]. This contrasts with pathologic radiolucencies, which are thick, poorly defined areas representing large amounts of soft tissue within the bone-implant interface [64].

Early cases of loosening may be treated with revision unicompartmental arthroplasty if the bone is relatively well preserved and the prime issue was cement technique. Causes diagnosed after long-term follow-up usually require conversion to total knee arthroplasty given the degree of bone loss that typically results.

Unexplained Pain

Unexplained pain located anteromedially remains a cause for concern of some patients following mobile-bearing medial unicompartmental arthroplasty. The pain is ordinarily situated on the tibial side of the joint and experienced within the first 6–12 months following the surgical procedure. In few cases, the pain has been shown to linger longer than this time interval. In all instances, this pain is correlated with poorer patient functional outcome scores [65].

Unexplained medial knee pain has several potential etiologies. Soft tissue irritation from medial tibial component overhang or impingement on retained osteophytes or cement debris may be attributable to technical error during the surgery [66]. Similarly, overstuffing the medial compartment with consequent lengthening of the MCL may inflame and irritate the ligament substance. Poor cementation of components and early aseptic loosening may be another cause that can be related to surgical technique. Benign soft tissue irritation such as pes anserine bursitis is yet another source that has been linked to this clinical presentation.

Once these other sources of pain have been excluded, then a diagnosis of medial tibial bone overload must be considered. Strain in the proximal medial tibia bone beneath the tibial component increases following unicompartmental arthroplasty, as demonstrated in various studies. One study employing finite analysis proclaimed that this strain increases on average by 40% following the unicompartmental arthroplasty [49]. Different explanations for these changes have been demonstrated and hypothesized. Tibial components with decreasing implant stiffness such as all-polyethylene designs cause an increase in cortical strain and cancellous bone structural damage [67]. Surgical factors have also been implicated. During preparation of the tibia, the potential causes include a deep vertical saw cut beyond the boundary of the horizontal cut, a medially placed vertical saw cut, deeper tibial resections, and excessive varus malalignment [49]. Placement of the component relatively medial as well as tibial tray overhang of 3 mm or greater has also proven to cause increases in tibial strain [68]. Efforts should be made during the surgical procedure to avoid miscalculations associated with tibial preparation and component placement. Updated Microplasty instrumentation

has also been developed in order to safeguard against these mistakes and make tibial preparation more standardized.

Most authors anecdotally proclaim that unexplained anteromedial pain that may be attributable to proximal tibial strain peaks within 6–12 months following the unicompartmental arthroplasty. It is believed that as the proximal tibial bone remodels, the pain settles spontaneously within 1–2 years of surgery. During this time period, the characteristics of the patient's pain should be monitored, and activity should be limited as needed. Without clear evidence of another source of the pain, patients should be reassured that symptoms will gradually improve as the bone remodels. Early revision surgery should be avoided as the pain will usually improve. Unindicated revision arthroplasty for unexplained pain is believed to be a reason for the higher early revision rate of UKA compared to TKA in large registry studies [69].

Long-Term Outcomes

Over the last decade, several small independent studies with long-term follow-up have been published demonstrating successful results with use of the updated Phase 3 implant. Keys et al. studied 40 prospective patients treated with Phase 2 and 3 implants at a small district hospital in the United Kingdom [70]. The author performed roughly 8 mobile-bearing unicompartmental arthroplasties per year. At a mean follow-up of 7.5 years, there were no component failures or revision surgeries required. Emerson and Higgins studied 55 consecutive patients treated with Phase 2 and 3 implants at a private hospital in the United States [71]. Patients were followed for a mean of 11.8 years postoperatively and the 10-year survival rate was 85%. In their updated series including only Phase 3 components implanted between 2004 and 2006, the authors reported on 213 knees with a mean follow-up of 10 years [72]. Using life-table analysis, the projected survivorship was 88% at 10 years. The revision rate was just over 9%, with nearly half of the revisions being attributed to lateral compartment arthritic progression. Only one bearing dislocation was witnessed in this cohort. Lisowski reported on 129 consecutive patients with an average age of 72 years treated with Phase 3 implants at a single center in Amsterdam [73]. Mean follow-up was over 11 years, and the projected 15-year all-cause revision rate was 90.6%. Most of the revisions were due to lateral compartment arthritic progression, with none due to bearing wear or aseptic loosening of components. Of interest, radiolucency below the tibial component was observed in 27% of cases without signs of component loosening.

As previously presented above, Pandit et al. reported on the first 1000 Phase 3 Oxford partial knee replacements between 1998 and 2009 [57]. The operations were performed by two surgeons utilizing a minimally invasive approach, which did not require dislocation of the patella. Mean follow-up was 5.6 years (range 1–11 years) and 547 of the cohort were followed for at least 5 years postoperatively. Of note, the authors excluded 97 patients from the final analysis who did not meet the now accepted criteria for medial unicompartmental arthroplasty, which included a fragmented ACL, lateral compartment near full-thickness defect, uncorrectable varus deformity, and patients treated with concurrent ACL reconstruction. Patients demonstrated significant improvement in the Oxford Knee score of 17 points, increase in flexion of 13°, and 94% were pleased with the outcome of the operation. Reoperation requiring component revision occurred in 2.9% with 20 of these 29 revisions due to arthritic progression in the lateral compartment and 4 due to bearing dislocation. Only 5 septic revisions were reported. Comparatively, in the 97 patients excluded from the analysis, the survival rate was estimated to be 88% at 8 years, while in patients meeting the current indication, 10-year survival rate was 95.6%. The overall survival rate of the study cohort was 95%.

A similar multicenter study was partaken in the United States to document the first 825 Phase 3 unicompartmental arthroplasties performed by 5 surgeons nationwide [74]. The average fol-

low-up for these cases was 9.7 years, and Knee Society overall and function scores had increased from 49 to 90 and 55 to 77, respectively, between pre- and postoperative time points. The projected 10-year implant survival rate was 90%, and survival free of any revision procedure was 85%. There were a total of 93 revision procedures, with 22 of these for lateral compartment progression and 31 for aseptic component loosening. Only 5 bearing dislocations were reported. It was observed that 14.8% of patients with a bearing thickness between 5 and 7 mm required revisions compared to 10.5% in patients with a thinner bearing between 3 and 4 mm. It is theorized that a use of larger tibial bearing may be due to technical error in which the surgeon either overstuffed the medial compartment leading to lateral compartment overload or the surgeon resected an excessive amount of tibial bone that forces the tibia to rest on weaker metaphyseal bone.

Price and Svard presented the longest patient follow-up in the mobile-bearing literature to date [56]. They reported on a consecutive series of 682 knees treated with mobile-bearing unicompartmental arthroplasties between 1983 and 2005 with a median patient follow-up of 5.9 years ranging from 0.5 to 22 years postoperatively. The data were collected from three surgeons operating at three different hospitals in Sweden. While 142 patients (172 knees) died during the follow-up period, no others were lost to follow-up. The mean age at the time of index surgery was 69 years and 55% of patients were females. Implants in the study include 125 Phase 1, 271 Phase 2, and 286 Phase 3 implants. The 16-year cumulative all-cause revision rate was 91% in 100 knees. This rate was maintained at 91% in the 16 knees that were still available for follow-up at 20 years. Interestingly, 31 of the 34 failures requiring component revision occurred less than 10 years postoperatively. This included 8 conversions to total knee arthroplasty for lateral compartment arthritic progression with the majority clustered around 5 years postoperatively, and 6 cases of aseptic loosening occurring between 5 and 8 years. Revision for bearing wear was a minor cause of complication with only a few reported cases. The high number of early failures may be due to inappropriate patient indications or poor surgical technique, causing overloading of the lateral compartment.

Comparison to Total Knee Arthroplasty

While cohort studies of mobile-bearing unicompartmental arthroplasty have demonstrated good results with estimated 10-year implant survival rates greater than 90%, registry studies continue to question the durability of unicompartmental arthroplasty compared to total knee arthroplasty. The Finnish arthroplasty registry presents long-term data extending over a 27-year span from 1985 to 2011 [75]. A study was published from this registry data examining differences between 4712 unicompartmental arthroplasties as compared to 83,511 total knee arthroplasties. The mean patient age was lower in the unicompartmental group (63.5 vs. 69.5 years); however, mean follow-up was roughly 6 years for both groups. Kaplan-Meier analysis was adjusted for age and gender differences between the groups, but unicompartmental arthroplasty was still projected to have lower 5-, 10-, and 15-year survivorship relative to total knee arthroplasty (89% vs. 96%, 81% vs. 93%, 70% vs. 88%). Similarly, in a German registry study of 20,946 unicondylar knee arthroplasties, the 5-year survival rate free of one component exchange or complete revision was estimated at 87.8% [76]. This patient cohort was comparable to the Finnish cohort in that mean patient age was 64 years and 60% of patients were female. Younger age, diabetes, obesity, and lower surgical volume hospitals were associated with higher risk of failure.

Despite lower implant survival rates in registry studies, larger registry studies do not account for differences in patient indications, surgeon technique, and implant use that may dramatically affect the rate of revision surgery. First, the proper pathoanatomy must be identified as explained by Goodfellow, as higher rates of failure of mobile-bearing implant have been reported in patients not meeting these criteria. In many of these studies, outcomes of mobile-bearing and

fixed bearing components are not differentiated. Mobile-bearing UKA implants theoretically have a lower rate of wear. Surgical technique is important to avoid overcorrection of deformity as lateral arthritic progression is an important reason for failure and conversion to TKA. Finally, there may be differences in surgeon threshold for conversion from a UKA to a TKA as compared to the revision of a primary TKA given that the conversion procedure is typically less technically demanding.

These theories have been supported in smaller studies directly comparing unicompartmental arthroplasty to total knee arthroplasty [77]. In a systemic review and meta-analysis evaluating randomly controlled trials of UKA versus TKA, the UKA patients demonstrated a trend toward higher patient outcome scores and flexion and a lower rate of short-term complications, which included aseptic loosening, arthritic progression, bearing dislocation, deep venous thrombosis, and infection. Despite these findings, there was a higher overall revision rate following UKA as compared to TKA. More recently when examining the National Joint Registry of England and Wales, UKA again has been shown to produce significantly higher patient outcomes, higher patient satisfaction, and lower complications or readmissions compared to TKA [78].

Surgeon Volume

There has been a focus in examining unicompartmental arthroplasty outcomes as they relate to surgeon experience with the procedure. Applying the historical Kozinn and Scott criteria unnecessarily lowers the number of patients indicated for unicompartmental arthroplasty. It is believed that only 5% of patients with medial compartment osteoarthritis may fit these patient-specific standards, whereas as many as 50% may be appropriate candidates for the operation based on the pathoanatomic criteria laid out by Goodfellow and colleagues [70, 79]. This excessive exclusion of candidates adversely affects patients and surgeons as it limits the number of unicompartmental operations performed and hence decreases surgeon comfort with the procedure while overtreating a large portion of patients [80].

Research has demonstrated a clear linear relationship with number of unicompartmental arthroplasties performed annually by a given surgeon and the consequent implant survival rate, as performing less than 10 procedures per year was shown to significantly decrease survival compared to greater than 30 per year in the National Joint Registry for England and Wales [81]. This relationship between surgeon caseload and outcomes was also shown to be stronger in unicompartmental arthroplasty as compared to total knee arthroplasty in this same study. These findings have also been replicated specifically with use of a mobile-bearing prosthesis. Examination of over 23,000 cemented Oxford partial knee arthroplasties in the National Joint Registry for England and Wales over an 8-year study period from 2003 to 2010 demonstrated that risk of revision of one or both components was 30% in hospital centers performing less than 100 procedures per year as compared to centers performing greater than 200 per year [82]. Furthermore, risk of revision was twice as high for surgeons performing less than 100 procedures annually as compared to those performing more than 100 per year. This dependence between surgeon volume and survival of cemented Oxford partial knee arthroplasties was similarly corroborated in the Nordic Arthroplasty Register Association database studied between 2000 and 2012 [83]. The authors also showed that the risk of revision for unexplained pain was 40–50% higher when the index surgeon performed less than 11 Oxford medial unicompartmental procedures per year compared to those surgeons performing more than 11 per year. This discovery further illustrates the subjective nature when determining the need for revision of a unicompartmental replacement. One potential explanation is that surgeons less familiar with the procedure may have greater haste in converting to a TKA in cases of unexplained pain.

Conclusion

Medial mobile-bearing unicompartmental arthroplasty represents a proven treatment to relieve pain and restore function in patients diagnosed with anteromedial osteoarthritis or focal spontaneous osteonecrosis of the knee in the medial compartment. Current indications for the procedure are centered on disease-specific clinical criteria and are independent of patient age, body habitus, and activity level. The Oxford partial knee is currently the most commonly used mobile-bearing medial unicompartmental arthroplasty device worldwide. The spherical femoral component and conformity with the mobile polyethylene bearing have been designed to limit the contact stress on the polyethylene and decrease forces at the implant interfaces to improve longevity of the prosthesis. Surgical principles are aimed at resurfacing the medial compartment and re-creating native tension on the medial collateral ligament in an effort to restore knee kinematics and relieve pain from the arthritic or osteonecrotic process. The technical principles are important in order to limit risk of complications related to bearing dislocation, lateral compartment stress overload, proximal medial tibial strain, and component loosening. With the improved Microplasty instrumentation, the procedure is more reproducible and efficient. This decreases operative time, which is beneficial to the patient and surgeon. Long-term outcomes from various clinical settings have demonstrated 10-year survival rates ranging from 85% to 95%. Surgeon caseload and experience with UKA have correlated to improved survival and clinical outcomes of this treatment.

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9 Lateral Unicompartmental Knee Arthroplasty: Indications and Technique

Vasili Karas and Richard A. Berger

Introduction

The treatment of isolated lateral arthritis of the knee is an important component of managing the arthritic knee. However, due to prevailing myths about isolated lateral arthritis of the knee, most surgeons simply treat this condition as tricompartmental arthritis. Isolated lateral gonarthrosis is a diagnosis surrounded by three prevailing myths: (1) It does not exist with enough prevalence to warrant discussion, (2) its treatment in isolation does not yield reliable outcomes, and (3) the level of difficulty in performing a lateral unicompartmental arthroplasty, as compared to total knee arthroplasty, is prohibitive.

Osteoarthritis of the knee affects approximately 37% of patients 45 years and older and 47% of those 65 years and older [1]. Of those, reports differ on the prevalence of unicompartmental osteoarthritis ranging from 5% to 40% [2]. In isolation, the lateral side of the knee accounts for 10–23% of unicompartmental procedures done at high volume arthroplasty centers [3–6]. With projections showing knee arthroplasty is slated to reach 3.8 million procedures per year in the United States by 2030 [7], several hundred thousand lateral unicompartmental arthroplasties may be performed annually by that time.

With proper indications, implant selection, and surgical technique, recent literature demonstrates that lateral UKA achieves similar outcomes to medial as well as total knee arthroplasty [2, 5, 8–12]. Moreover, lateral UKA is associated with less complications and a lower cost compared to total knee arthroplasty [10]. Finally, lateral UKA can be performed safely, reproducibly, and with relative ease with appropriate repetition and attention to a few details that will be highlighted in this chapter.

Clinical Pearls

- Selection: Valgus that can be corrected some or fully, but not over correctible, isolated lateral compartment disease, minimal loss of ROM, mild-to-moderate bone loss.
- Selection: Active patients who wish to return to high-level activity with a natural feeling knee and accepting of the possibility of occasional soft tissue symptoms. Also, those who may not tolerate TKA well.
- Technique: Lateral approach for surgeons who would like to limit soft tissue

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dissection and incision size, medial approach for surgeons who would like familiar anatomy and familiar approach should TKA be required.
- Counseling Patients on Results: Lateral UKA has similar outcomes and survival (90–95% at 15-year follow-up) as does medial UKA and TKA.

Indications

History

The ideal candidate for any unicompartmental arthroplasty presents with a history of noninflammatory arthritis, reports symptoms isolated to a particular side of the knee with activity. History specific to lateral UKA includes predominant pain about the lateral joint line rather than patellofemoral or diffuse pain as the primary complaint. In addition, some patients may experience either feeling of the knee giving out or frank instability leading to falls. Lastly, the instability from lateral cartilage loss may lead to recurrent and significant effusions. These effusions can cause lateral peripatellar pain and even medial pain; it is important to distinguish between this capsular pain due to effusion, and patellar pain or medial pain due to arthritis in those areas.

Physical Examination

On physical examination, lateral UKA candidates have good range of motion, a stable ligamentous examination, and minimal, correctable valgus deformity. Limited correction of contractures and malalignment can be performed when only one condyle is accessed for unicompartmental arthroplasty. Clinical assessment of the location of tenderness to palpation and provocative tests for patellofemoral disease must also be part of the examination. Routine evaluation of joint line tenderness as well as patellar grind test is required to confirm predominantly lateral compartment disease.

Attention must be given to competence of the anterior and posterior cruciate ligaments (ACL/PCL). Unlike select medial unicompartmental arthroplasty patients, lateral UKA is not recommended in any patient, even with the use of a fixed bearing, in the absence of a competent ACL. This is due to instability that would result from a relatively flat and unconstrained lateral bearing and the loss of rotational stability conferred by the ACL. Finally, the medial and lateral collateral ligaments should be tested with a varus and valgus moment, while also assessing that any coronal plane deformity is correctable but not overcorrectable. A knee presumed to have isolated lateral disease that is correctable past neutral into varus likely also has medial arthritis that is allowing this overcorrection. If medial arthritis goes unrecognized, it could lead to rapid deterioration of the medial compartment after lateral UKA.

The Patient

The goal of adult reconstructive surgery of the knee is to reduce patient pain and restore function. To that end, the whole patient must be thoughtfully evaluated and counseled prior to deciding on a treatment plan. When considering lateral UKA for a patient, age, activity level, and tolerance for the possibility of some postoperative discomfort must be considered.

Age of the patient should not necessarily steer the decision to perform a lateral UKA versus a TKA but should steer the counseling provided to the patient. Younger patients should be counseled that any arthroplasty may be just their first surgery and that due to their longevity and level of activity, they may require another operation. The elderly should be indicated with the assumption that this is the last surgery performed, and the aforementioned guidelines should apply to the decision to perform a lateral UKA.

Activity level and tolerance for some residual symptoms postoperatively speak to patient motivation to undergo surgery. Lateral UKA leaves the patient with proprioception in the remainder of the knee, as well as a postoperative knee that

more closely feels and functions like a "normal knee" due to ACL retention and resultant physiologic kinematics. However, because more host tissue remains, and has to function in harmony with an intracapsular prosthesis, there is greater potential for minor symptoms as compared to TKA. If the primary goal of the patient is the restoration of function and return to activity with a tolerance for minor symptoms, a lateral UKA is the best choice of treatment. If the patient is predominantly seeking a reduction in pain and leads a more sedentary lifestyle, then TKA may be more reliable option.

Radiographic Evaluation

Radiographic evaluation should demonstrate disease isolated to the lateral compartment. Much of the evaluation of the knee x-ray for consideration of lateral UKA is similar to that of medial unicompartmental arthroplasty. However, it is important to note that the location most common in lateral osteoarthritis is posterior-lateral or central-lateral rather than the classic anteromedial osteoarthritis described in medial disease. There is controversy about mild changes within the patellofemoral joint, with one camp demonstrating equivocal outcomes between those with mild and no patellofemoral arthritis, and another camp that recommends against any changes outside of the lateral compartment. These mild signs and symptoms may include small osteophytes and impingement from the tibia spine onto the contralateral condyle. Joint space narrowing of the medial compartment remains an absolute contraindication to lateral UKA even in the absence of medial symptoms, as this finding is suggestive of subclinical disease. Posterior subluxation of the femur on the tibia suggests that the ACL may not be intact and would thus be a contraindication to lateral UKA. This subluxation should be present both medially and laterally to the posterior aspect of the true tibia as a lateral only posterior subluxation of the femur is common in lateral osteoarthritis due to the physiologic screw home mechanism and increased translation about the degenerative lateral side of the knee. Also, significant bony defects in the tibia or significant valgus are a contraindication to lateral unicompartmental arthroplasty due to the tibial cut and thickness of the polyethylene required to restore the compartment; unicompartmental replacements only have limited polyethylene thicknesses. Finally, as in medial osteoarthritis, stress views can aid in further identifying a correctable knee as well as an overcorrectable knee that has bicompartmental disease.

Lastly, since most surgeons will perform a lateral unicompartmental arthroplasty through a lateral skin incision and arthrotomy, making it more difficult to intraoperatively change to a total knee replacement, it is important to be sure that a lateral unicompartmental arthroplasty is the correct choice. To that end, an MRI scan may be helpful in the decision process if the surgeon is not sure that lateral UKA is the definitive choice.

Representative Case

A 66-year-old active female presents with lateral sided knee pain when ambulating, gardening, as well as at night. She describes her pain as sharp intermittently and throbbing almost constantly. She received corticosteroids for several years until they no longer adequately alleviated her pain. The patient has a body mass index (BMI) of 33 and carries the diagnosis of hypertension. She is otherwise healthy.

On physical examination, the patient has tenderness to palpation on the lateral side of the knee at the joint line. She has full extension to 0 degrees and has flexion to 125 degrees. She presents with a mild effusion and has no crepitus or pain on testing of the patellofemoral joint. Clinically, the patient has slight genu valgus that is correctible to neutral but does not overcorrect. On ligamentous examination, the patient had an anterior and posterior drawer test negative for ACL or PCL insufficiency. Finally, she denies any hip or back pain on range of motion testing.

Radiographic imaging demonstrates (Fig. 9.1) lateral compartment osteoarthritis as evidenced by joint space narrowing, osteophyte formation, and subchondral sclerosis. The medial compartment

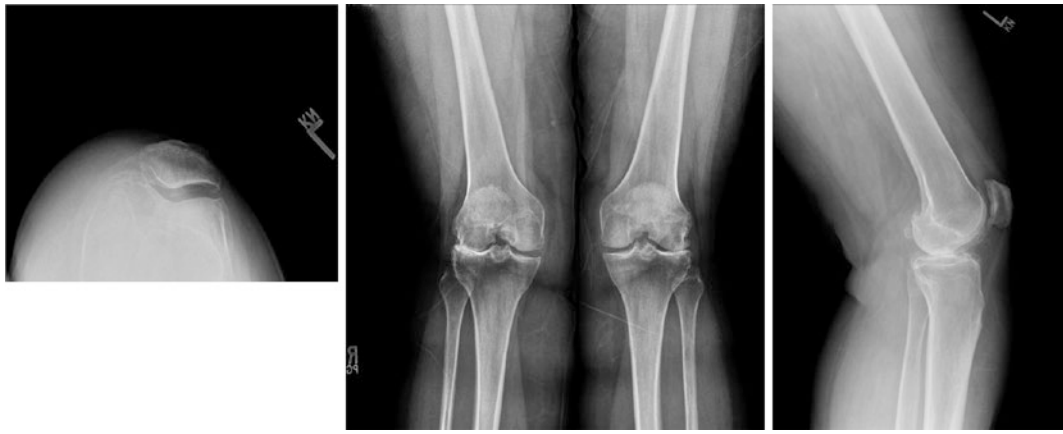

Fig. 9.1 Anteroposterior, lateral, and patellar view of a 66-year-old patient with left knee pain that is recalcitrant to nonoperative measures. There is lateral joint space narrowing, preserved medial compartment, and minimal disease in the patellofemoral compartment

of the knee has well-preserved joint space without radiographic signs of osteoarthritis. The patellofemoral joint also has well-preserved joint space with small osteophytes laterally and inferolaterally on the patella.

After a discussion about the risks and benefits of surgery, shared decision making with the patient led us to recommend a lateral unicompartmental arthroplasty. We reached this conclusion with this particular patient because she prioritized her active lifestyle and a quick recovery in our discussions. The patient was then scheduled for preoperative optimization, teaching, and finally outpatient surgery.

Technique

Preoperative Planning

In preparation for a lateral unicompartmental arthroplasty, the surgeon must plan the approach to the knee. A lateral arthrotomy allows for a smaller incision and less soft tissue disruption, but the surgeon should be comfortable performing a total knee arthroplasty through this approach should it be required. An alternative is to perform an arthroscopy prior to incision to determine whether lateral unicompartmental arthroplasty is an option. Lastly, if the surgeon is not comfortable with a lateral arthrotomy, a medial arthrotomy with a larger dissection may be chosen.

The lateral side of the knee has increased translation and overall laxity than the medial side. For this reason, it is universally accepted that a fixed bearing implant be used. Mobile bearing implants have a propensity to dissociate when used for lateral UKA [5]. Secondly, it is important to identify whether the chosen system has implants specific to the lateral side of the knee or if the system has "left lateral, right medial" implants. In addition, the surgeon should be sure that the bone loss on the lateral side can be managed with the available polyethylene thicknesses for the chosen system. Finally, should there be undiagnosed osteoarthritis within the medial or patellofemoral joints, or an incompetent ACL, a TKA system should be readily available as should the necessary retractors to perform the case for the chosen approach.

Exposure

Adequate exposure can be achieved from either a medial or lateral approach to the knee. The benefits of a medial approach include familiarity, ease of creating the vertical tibial cut adequately medial, and ease of conversion to a total knee arthroplasty. Lateral UKA from the lateral side

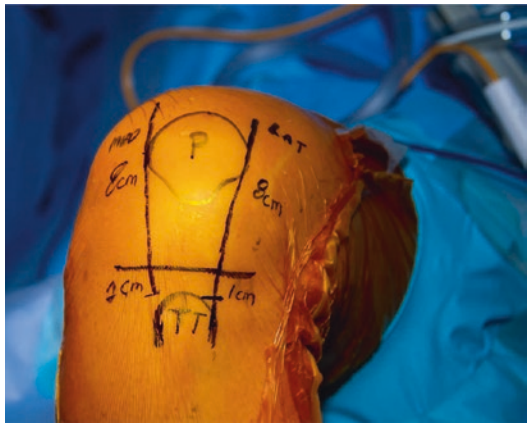

Fig. 9.2 Incision. This is a photograph of the left knee with landmarks including the patella (P), tibial tubercle (TT), as well as the medial and lateral sides noted. The Incision for a lateral UKA is performed either on the medial or lateral side based on surgeon preference and is about 8 cm proximal to the joint line (horizontal line in the photograph) and 1 cm distal to the joint line

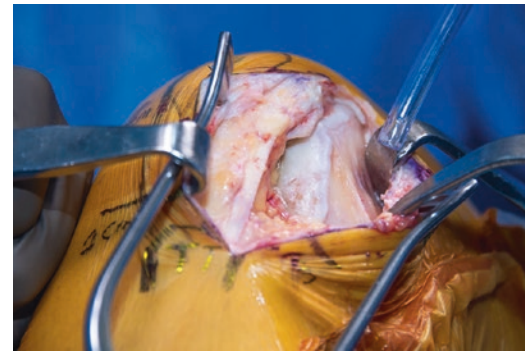

Fig. 9.3 Arthrotomy. This is the left knee with a lateral arthrotomy completed and minimal release of the coronary ligaments on the lateral side

minimizes incision length, soft tissue dissection, and allows for greater visualization.

The authors prefer the lateral approach for a lateral UKA. The skin incision begins at the superior-lateral pole of the patella and extends to the lateral edge of the tibial tubercle approximately 1 cm distal to the joint line (Fig. 9.2). This incision can be extended proximally should greater exposure be required. The skin incision is made with care as the subcutaneous tissue on the lateral side of the knee is thin between the skin and the lateral retinaculum.

The arthrotomy is made beginning 1 cm superior to the superolateral pole of the patella, unlike the medial side where the vastus medialis can be entered as part of the arthrotomy; on the lateral side, the arthrotomy is solely in the capsule as the vastus lateralis is not close the incision. The arthrotomy then extends distally parallel and just lateral to the patellar tendon. Care must be taken not to violate the patellar tendon with the arthrotomy as the patellar tendon may be more lateral than the surgeon expects if unfamiliar with a lateral arthrotomy. The arthrotomy is kept as medial as possible to achieve adequate exposure to perform the operation. The retinaculum and synovium are thinner on the lateral side of the knee, so care of these structures should be taken in order to have adequate tissue for arthrotomy closure. The fat pad is larger laterally than medially and will require some resection for exposure; resecting it just lateral to the lateral tibial spine is effective. After resection of the anterior horn of the lateral meniscus, the knee is placed in approximately 30–40 degrees of flexion and a retractor is placed in the intercondylar notch to inspect the patellofemoral joint and the medial compartment. Should the surgeon be uncomfortable performing a total knee arthroplasty from a lateral arthrotomy, an arthroscope may be used to inspect the medial side of the knee before the arthrotomy is performed. Finally, exposure to the lateral compartment is completed by releasing the coronary ligaments and lateral capsule from the lateral plateau in a subperiosteal fashion in order to place a retractor laterally to avoid damage to the lateral soft tissue structures (Fig. 9.3).

A medial arthrotomy to the knee is also a viable option for surgeons who prefer familiar anatomy and the ability to convert to a TKA. The trade-offs include larger incision and dissection, added difficulty of accessing the lateral aspect of the lateral compartment, and finally, the need to work around the patella and keep it protected throughout the case.

Osseous Preparation and Soft Tissue Balancing

The authors prefer first preparing the tibia in unicompartmental arthroplasty; this then allows

the flexion and extension gaps to be balanced as part of the femoral preparation. An extramedullary tibial cutting is placed perpendicular to the mechanical axis of the tibia. Care should be taken, based on implant system, to match the tibial slope, adjusting the slope of the guide in conjunction with the built-in slope of the cutting slot. Angulation of the cutting guide should be set by placing the distal aspect of the guide 5–10 mm lateral to the center of the ankle, allowing the guide to be parallel to the long axis of the tibia. Depth of resection should be approximately 1–2 mm off of the deepest aspect of the lateral plateau. Careful measurement of the depth of resection is important on the lateral side of the knee because lateral degeneration often creates more bone loss; overresection of the tibia can result in needing a large polyethylene insert, which may not be offered in the unicompartmental system.

After guide-pin placement, resection and slope is confirmed through the slot with a checking shim (angelwing). At this time, a lateral retractor placement is confirmed so that the lateral soft tissue structures are protected. The lateral tibial plateau is then resected, taking care not to undermine the tibial footprint of the ACL. A sagittal cut is then performed to complete the resection. The cut is parallel to the femoral condyle and the lateral tibial spine (Fig. 9.4).

Unlike the medial side, where the sagittal cut abuts the fibers of the ACL, the lateral tibial plateau is wider medial to lateral than the medial plateau and the implant will overhang in an anterior-posterior direction before it does in the medial-lateral direction. Therefore, it is not necessary to get all the way over to the fibers of the ACL and PCL, at the apex of the lateral tibial spine. In addition, on the medial side, the medial femoral osteophyte helps place the sagittal saw more lateral increasing the medial-lateral distance, which is helpful on the medial side. While on the lateral side, it is not necessary to have the sagittal saw more medial to increase the already large medial-lateral dimension; therefore, it is helpful to take out the lateral femoral osteophyte prior to making this sagittal cut (Fig. 9.5).

When performing the sagittal cut, care should also be taken not to past point through the resection into the remaining tibia as this may increase the risk of plateau fracture. If removed in one piece, the wafer of lateral tibia should be saved and used to approximate tibial component sizing (Fig. 9.6).

The knee is then balanced using spacer blocks. If it is found to be tight in extension, we recommend releasing the posterior capsule or taking removing some posterior slope in the tibia. Most commonly, we find the knee tight in flexion at which point the femoral component is distalized by removing less distal femur than is replaced with the femoral component to balance the gaps. Alternatively, the posterior condyle of the femur can be trimmed or additional slope is

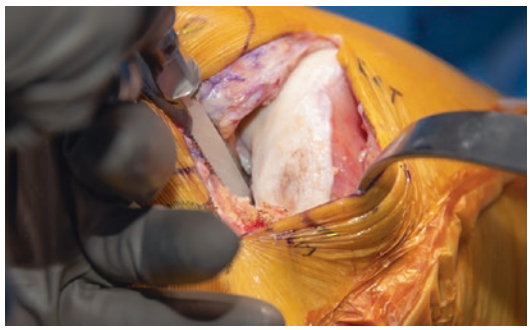

Fig. 9.4 Sagittal cut of tibia. This is a single-sided sagittal saw in proper position perpendicular to the tibial plateau and parallel to the lateral tibial spines

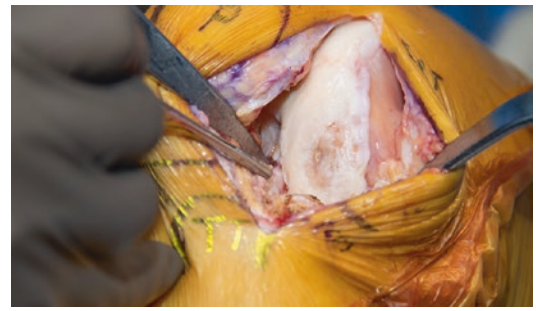

Fig. 9.5 Osteophyte. This is the surgeon pointing to the lateral femoral osteophyte that often blocks correct placement of the sagittal saw for the perpendicular cut. This should be removed with an osteotome prior to making this cut

cut into the tibia. An extramedullary distal femoral cutting guide is then placed, and the distal cut is made in extension. Unless the flexion gap is tight and the surgeon wishes to remove less bone than is replaced, the distal femoral cut should be the same as the distal thickness of the femoral component.

Next, the knee is flexed to 90 degrees and, with a retractor in the femoral notch, the patella is retracted medially. The level of the osteochondral junction is then marked anteriorly (Fig. 9.4). This step is crucial to sizing the femoral component. The appropriate size cutting block is placed just below the marked osteochondral junction. This ensures final component placement will not extend too far anterior to the trochlear surface and impinge on the patella (Fig. 9.7).

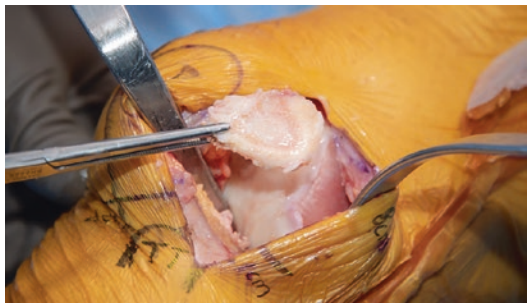

Fig. 9.6 Tibial cut. This is the lateral tibial plateau removed en-bloc from the knee after tibial resection. It is the minimal needed resection required to reach cancellous bone for cementation

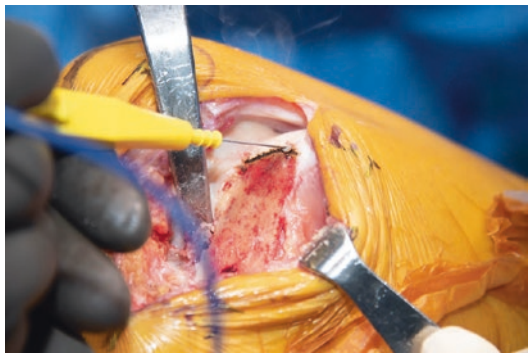

Fig. 9.7 Osteochondral junction. This image highlights the surgeon marking the osteochondral junction of the distal lateral femur. The femoral component, when placed, should not be anterior to this marking to avoid impingement with the patella

Once the appropriate guide is placed, a single screw pin holds the guide anteriorly and acts as an axis of rotation (Fig. 9.8a). In order to achieve appropriate rotation of the femoral component, and ultimately tracking on the polyethylene bearing, a spacer block is placed on the tibia and under the cutting block. This effectively derotates the femoral component from an internally rotated position to neutral (Fig. 9.8b). Failure to derotate the cutting block before making final cuts predisposes femoral component maltracking laterally on the bearing, which risks early bearing failure.

Once the block is in a satisfactory position, a second pin is placed and a lateral retractor is placed to protect the lateral structures of the knee. The posterior condyle and posterior chamfer cuts are then made and the lug holes are drilled. Although the system used does have an anterior chamfer slot, we prefer not to make this cut as it tends to remove excess anterior bone and cartilage. Rather, the implant has a small anterior flange that provides a smooth transition with the trochlear cartilage (Fig. 9.9). In sizing the femoral component, the osteochondral junction should be marked on the distal femoral cut. The proximal flange of the femoral component should be 2 mm below the osteochondral junction in order to avoid impingement. This is often one size smaller than would be chosen for a typical medial UKA.

After all the bone cuts are made, the tibia is then sized (Fig. 9.10). The lateral tibia is wider medial to lateral than the medial tibia. This allows the surgeon to place a larger tibial component on the lateral side, as lateral overhang is less commonly an issue when a tibial size that completely covers the anterior to posterior tibia is chosen. The tibia is then prepared with a lug hole and keel trough. Finally, the knee is checked for proper balance.

With the trial components in place, a "tongue-blade" spacer that has 2-mm and 3-mm ends is used to assess balance. With a lateral UKA, the proper knee balance allows for approximately 1.5–2 mm of laxity in extension and 2.5–3 mm of laxity in flexion (Fig. 9.11). Appropriate balance allows for kinematic rotation as well as translation on the lateral side of the knee, achieving maximum flexion and re-creating the anatomic screw home mechanism of the knee in extension.

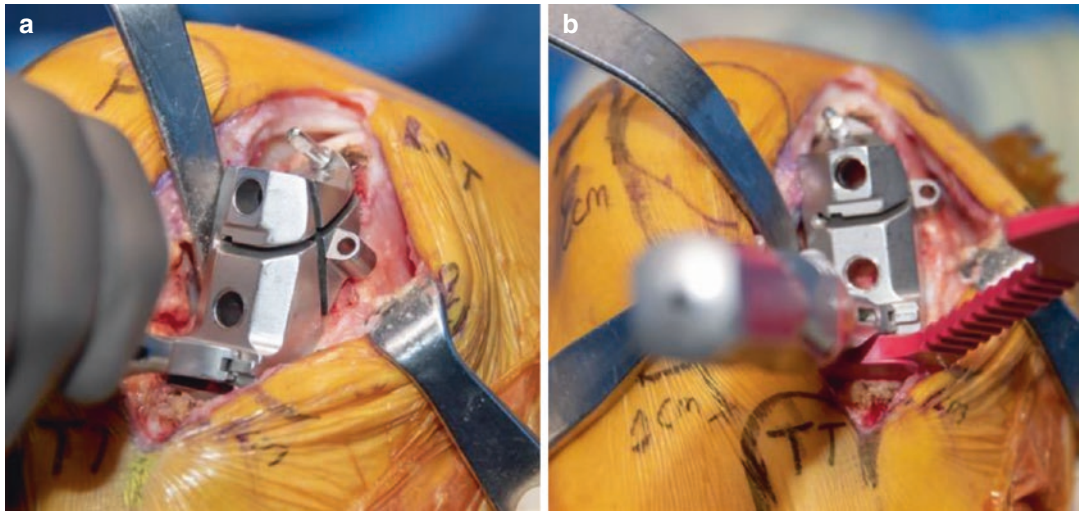

Fig. 9.8 (**a** [left], **b** [right]) Femoral cutting block. The femoral cutting block is placed with 1 screw pin anteriorly ensuring the sizing is below the osteochondral junction (left). Then, placement of the spacer (right) derotates the block, effectively externally rotating it, so that tracking is ensured to be in the middle of the tibial bearing

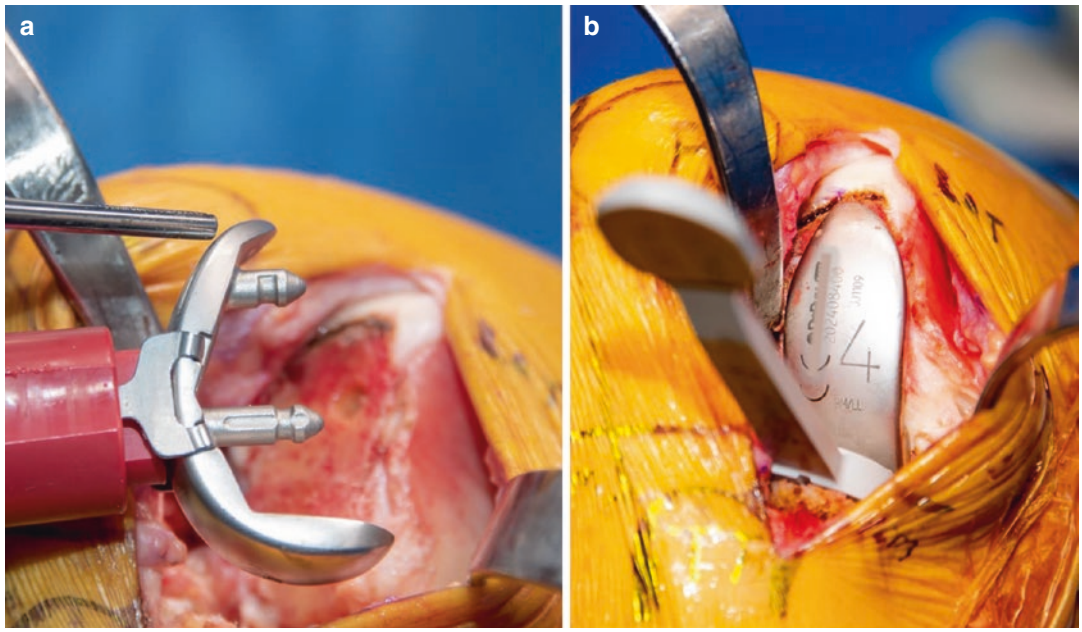

Fig. 9.9 (**a** [left], **b** [right]) Trial implant and sizing. The trial implant (left) has an anterior flange that should insert into the bone at the level of the osteochondral junction, providing a smooth transition from the final implant to the trochlear cartilage (right)

Component Insertion and Sizing

After osseous preparation, the knee is washed in the standard fashion and prepared for cementation of final components. The tibia is inserted first. The posterior aspect is seated first, then the anterior aspect, in an effort to force the cement anteriorly so that it can be removed easily.

Next, the femoral component is inserted. Due to the lateral position of the patella, exposure and instrumentation can be a challenge. Insertion of the femoral component can be a particular challenge. This is overcome in a lateral UKA by flexing the knee to approximately 60–90 degrees and applying a varus stress; the anterior lug is engaged first, under the patella, and then the femoral component can be rotated to engage the posterior lug. The trial polyethylene is placed and the knee is brought into full extension to allow the cement to cure. The cement is allowed time to dry. After hardening, excess cement is meticulously removed and the appropriate thicknesses polyethylene trial is chosen. It is important to reiterate that a lateral UKA should not be "overstuffed." Alignment, as well as 1.5–2 mm of laxity in extension and 2.5–3 mm in flexion are confirmed at this time to verify the appropriate bearing thickness. The final bearing is then inserted (Fig. 9.12).

Finally, the knee is irrigated once more and the capsule and any synovium are closed to achieve a watertight closure. The skin is then closed with absorbable suture. It is the authors' preference to

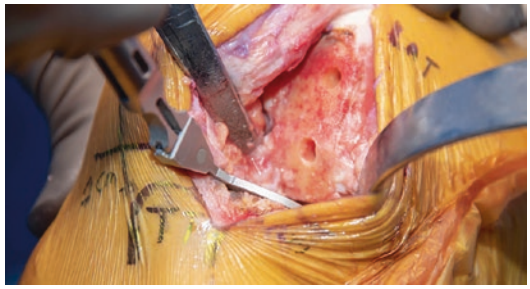

Fig. 9.10 Tibial sizing. This is the tibial sizing guide and guide for final tibia osseous preparation. Appropriate sizing should be assessed in the medial and lateral dimensions as well as the anterior-posterior dimension

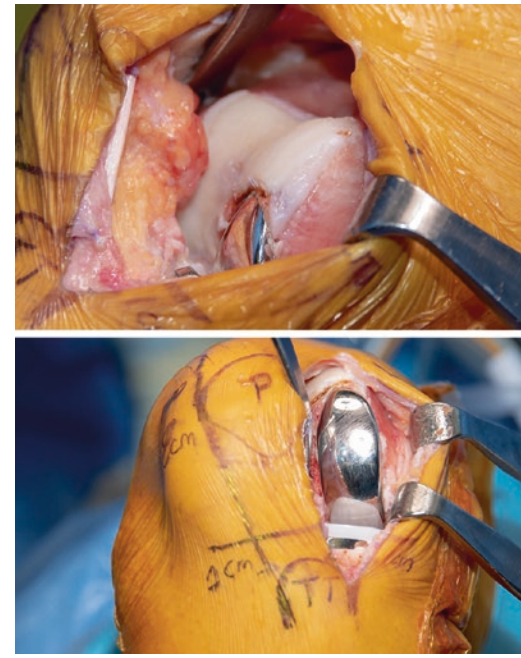

Fig. 9.12 Final components. The final component sits nicely at the trochlear junction anteriorly (top) and is seen here in flexion completed with cement dried (bottom)

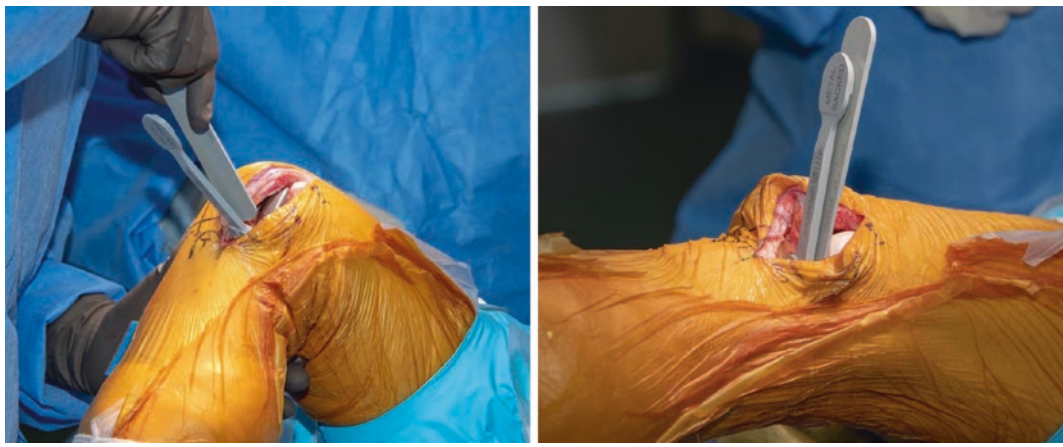

Fig. 9.11 Knee balance. With a tongue-blade spacer that is 3 mm on one side and 2 mm on the other, we ensure there is 2–3 mm of laxity in flexion (left) and 2 mm of laxity in extension (right) for proper balance of the knee

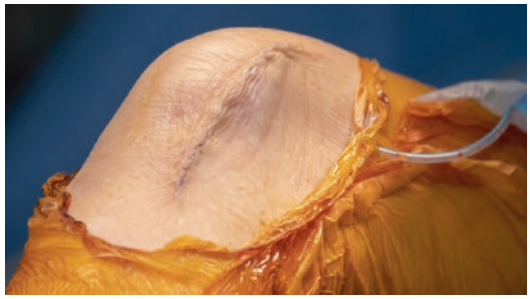

Fig. 9.13 Final closed incision. The arthrotomy, subcutaneous layer, and skin are closed in a layered fashion over a small drain that is removed prior to patient same day discharge

leave a small drain for approximately 1 hour, after the procedure to evacuate any immediate hemarthrosis postoperatively. This drain is removed in the PACU prior to patient discharge (Fig. 9.13).

Postoperative Care

After completing a physical therapy session, patients are routinely discharged home on the day of surgery and continue physical therapy for a few weeks postoperatively per standardized protocol. Patients are encouraged to resume their activities of daily living immediately postoperatively and are encouraged to return to their desired activity level within 2–3 weeks postoperatively.

Results

Results published on lateral UKA using modern implants and instrumentation with a fixed bearing yield similarly favorable result to medial UKA [2, 3, 5, 6, 13–15]. A recent systematic review of the literature, inclusive of both lateral and medial UKA, demonstrates no significant difference in survivorship at 5-, 10-, or 15-year follow-up (93%, 91%, and 89% respectively) [16]. This is combined data from cohort, as well as registry studies, inclusive of greater than 10 studies done between 2002 and 2015 [16]. To highlight a few, two independent authors published 15-year outcomes of lateral UKA and found 91% survivorship as defined by revision or conversion of components for any reason [3, 4]. The most common reason for reoperation at long-term follow-up was progression of arthritis in the medial compartment [3, 4].

A recent analysis of lateral UKA versus TKA for isolated lateral osteoarthritis by van der List and colleagues demonstrated superior outcomes of lateral UKA in the short term (mean 2.8-year follow-up) and further analyzed their data to conclude that, in particular, patients who were less than 75 years of age and female had particularly favorable outcomes with lateral UKA as opposed to TKA [10].

Outcomes of lateral UKA that raise concern are historical in nature. Scott, Cameron, and Argenson were of the first to publish on lateral UKA. These papers demonstrated relatively poor outcomes in the low 80% range for short-term survival [13, 17, 18]. On deeper examination of their results, it is evident that many of these failures were due to patient selection. Ashraf and Gunther also published on implant-specific failures. These historic lateral UKAs were performed using free hand cuts and implants that were found to be prone to fracture. Additionally, Gunther published a 21% failure rate with the use of a mobile bearing implant on the lateral side, with implant dissociation as the primary cause of failure [8]. With appropriate patient selection, instrumentation, and implant use, these suboptimal results are avoided.

Summary

In summary, lateral UKA is an excellent option for patients with primarily lateral compartment osteoarthritis seeking to continue an active lifestyle and enjoy a quick postoperative recovery. Proper planning, technique, and execution of the operation are paramount to success and achieving excellent long-term outcomes as reflected in modern literature.

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Treating Patellofemoral Arthritis with Patellofemoral Arthroplasty

10

Kevin J. Choo and Jess H. Lonner

Background

Epidemiological studies estimate the prevalence of isolated patellofemoral osteoarthritis (PF OA) in the range of 13–24% in women and 11–15% in men [1, 2]. A recent meta-analysis reported rates of isolated radiographic patellofemoral OA in a population-based cohort and symptom-based cohort to be 10% and 8%, respectively [3]. Women constitute the majority of patients presenting with patellofemoral OA, which may be related to higher incidence of dysplasia and malalignment in that group [4]. Other potential etiologies of isolated patellofemoral OA may be related to increased BMI or a history of trauma (patella fracture, chronic patellar dislocation/subluxation) [4, 5]. Overall, it appears that while isolated patellofemoral OA is a relatively uncommon problem when compared to tibiofemoral OA, it remains a source of pain and functional limitation [6].

Clinical Evaluation

Patients with isolated patellofemoral OA present differently than patients with tricompartmental or tibiofemoral OA. Perhaps, the most important distinguishing characteristic is the location of pain or discomfort, as these patients should present with pain localized to the peri- or retropatellar aspects of the knee joint. Localization of pain to these regions of the knee is crucial in the accurate diagnosis of symptomatic patellofemoral OA prior to PFA. Symptoms may be exacerbated by activities that preferentially load the patellofemoral joint, including stair or hill ambulation, rising from a seated position, squatting, or prolonged sitting with the knee in a flexed position. Conversely, prolonged ambulation on level surfaces (which is often difficult or painful in advanced tibiofemoral OA) should be relatively asymptomatic in patients with *isolated* patellofemoral OA. In addition, a history of anterior knee crepitus is common.

Other key elements of a patient's history include previous trauma to the knee, which may include patella fracture, patellar subluxation or dislocation, or blunt injury to the patella. A history of recurrent patellar dislocations may indicate the presence of malalignment or generalized ligamentous laxity. After the location and quality of pain have been established, the surgeon should ascertain whether previous interventions such as physical therapy, weight reduction, bracing, medications, injections, or nonarthroplasty surgery were undertaken. Last, a history of inflammatory or crystalline arthritis should be specifically addressed, as this would preclude the patient from consideration of PFA.

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Physical examination begins with observation of standing alignment and gait, which may provide clues regarding rotational or axial malalignment, coronal alignment, presence of more advanced arthritis or alternative sources of anterior knee pain, and/or muscular balance. Motion should not be particularly limited, and there should not be a flexion contracture, which would suggest more advanced disease. Check active patellar tracking with the limb dangling over the edge of the examination table. Typically, patellofemoral crepitus is felt and/or heard. Patellar maltracking may be observed with lateral deviation of the patella as the knee approaches full extension (J sign), indicating muscular imbalance or rotational deformity. For patients who have high Q angles, a tibial tubercle realignment procedure (antero-medialization) may be considered before or at the same time as PFA.

Provocative testing should identify the presence of tenderness with palpation around the patella, apprehension with attempted lateral subluxation, pain and crepitus with patellar compression, and recreation of patellofemoral crepitus and retropatellar knee pain with range of motion and squatting. Any associated medial or lateral tibiofemoral joint line tenderness should alert the surgeon to the possibility of meniscal pathology or tibiofemoral OA, even if radiographs are relatively normal. Other potential sources of anterior knee pain, such as pes anserine bursitis, patellar tendinitis, prepatellar bursitis, instability, or pain referred from the ipsilateral hip or back, must be ruled out. Cruciate and collateral ligament integrity should be carefully assessed, as tibiofemoral instability may predispose to early progressive tibiofemoral OA.

Imaging of the knee should include a standard plain film series, including standing anteroposterior (AP), standing midflexion posteroanterior (PA, Rosenberg), lateral, and axial (sunrise) views (Fig. 10.1a–d). AP and Rosenberg views should be notable for an absence of tibiofemoral joint degeneration, although small osteophytes and mild squaring of the femoral condyles may be acceptable in the context of normal tibiofemoral (TF) joint spaces and lack of clinical symptoms. The lateral view may demonstrate patellar osteophytes and patellofemoral joint space narrowing but is perhaps more helpful in the assessment of patellar height and exclusion of patella alta or baja deformity. The axial view is the best assessment for patellofemoral joint space and may also demonstrate other pertinent findings such as patellar tilt, subluxation, trochlear dysplasia, or osteophytes. If significant lower limb angular deformity is suspected, full-length standing plain films should be obtained.

Magnetic resonance imaging (MRI) is primarily used to confirm the findings of patellofemoral joint degeneration (chondral thinning, bony edema) and, perhaps as importantly, exclude the presence of substantial tibiofemoral compartment pathology such as meniscal injury, chondromalacia/arthritis or subchondral edema. The presence of more substantial tibiofemoral chondral disease or edema would exclude isolated PFA, although consideration may be given to BiKA, combined PFA and chondral grafting, or TKA. Previous arthroscopy photographs or video, if available, may be especially valuable in documenting the extent of patellofemoral joint disease as well as the absence of disease elsewhere.

Patient Selection/Indications

Proper patient selection is crucial for successful postoperative outcomes following PFA [5, 7, 8]. The ideal candidate for PFA has isolated, non-inflammatory arthritis of the patellofemoral joint, leading to pain and significant functional limitations. Patients with primary or post-traumatic osteoarthritis or other concurrent patellofemoral disorders such as trochlear dysplasia or mild patellar subluxation that have resulted in PF OA are also indicated for PFA. Our data on patients with less radiographic severity, but who nonetheless have appropriately painful and symptomatic Grade IV chondromalacia of the lateral patellar facet and/or lateral trochlea, show that they too

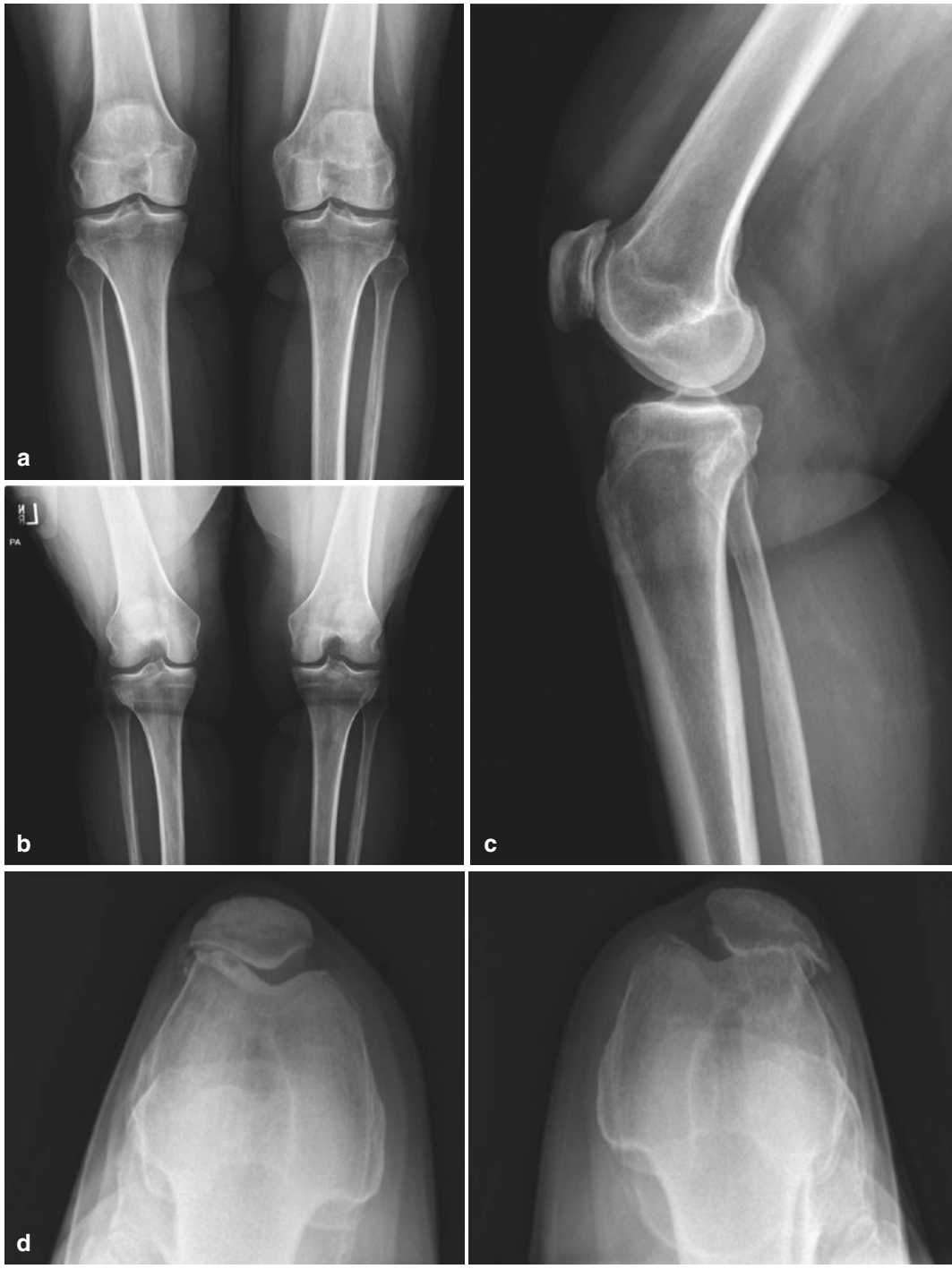

Fig. 10.1 (**a**–**d**) Standing anteroposterior (AP), midflexion posteroanterior (PA, Rosenberg), lateral and sunrise radiographs show arthritis localized to the patellofemoral compartment

may have substantial pain relief and symptomatic improvement with PFA. As mentioned above, patients should report localized retro-patellar or peripatellar pain, worsened with activities that load the patellofemoral joint. Conversely, they should have notable absence of signs and symptoms of tibiofemoral arthritis including limited pain with ambulation on level ground. Patients should also reasonably attempt some extent of nonoperative treatment prior to PFA, including physical therapy, weight loss, nonsteroidal anti-inflammatory medication, activity modification, injections, or bracing, which may or may not have much impact on symptoms.

There are a number of contraindications to PFA. PFA should not be considered in the presence of tibiofemoral cartilage loss (Grade III or more chondromalacia) or if the patient has tibiofemoral joint pain and tenderness that do not appear to be referred from the PF compartment. Similarly, PFA should not be performed in patients who have inflammatory arthritis or diffuse chondrocalcinosis, as they would be at a higher risk of ongoing pain, arthritis progression, and failure. While PFA is useful for some patients with Grade IV chondromalacia of the lateral patellar facet and/or lateral trochlea, we would not typically advise PFA in patients with isolated Grade IV chondromalacia of the medial patellar facet and/or medial trochlea, since medial-sided patellofemoral chondral wear should not typically be very painful; when it is, other sources of anterior pain should be sorted out and nonsurgical options pursued. Isolated PFA is contraindicated in the presence of flexion contractures, tibiofemoral malalignment, or uncorrectable patellar tracking.

Mild-to-moderate patellar maltracking or patellar tilt, on the other hand, is easily addressed at the time of PFA with lateral retinacular release or recession and appropriate positioning of the trochlear and patellar components. Alternatively, severe patellofemoral malalignment or rotational deformity, noted on clinical exam and confirmed with imaging, is a relative contraindication if not correctable prior to, or simultaneous with, PFA. Typically, the tibiofemoral alignment should be "neutral"; tibiofemoral malalignment suggests greater disease and would be a contraindication to isolated PFA [9].

Intuitively, due to the increased patellofemoral stresses associated with increased weight, obese patients are thought to be at increased risk of failure after PFA, but more of an issue is that obese patients are more likely to have subtle or overt TF disease, which can compromise the results of PFA. Indeed, this has been confirmed by previous studies demonstrating that obese patients (BMI >30 kg/m^2) are at a higher risk for revision for a variety of reasons [10, 11]. This mirrors the available data for TKA [12]. However, to date, there is no accepted BMI cutoff for PFA. Similarly, there is currently no consensus regarding optimal age for patients undergoing PFA, although authors have generally advocated for a younger patient population (30–60 years old) compared to that undergoing total knee arthroplasty (TKA). [13, 14] In one series, 50% of patients undergoing PFA were age 50 years or younger. Nonetheless, excellent outcomes are achievable even in octogenarians with isolated PF arthritis [15]. We would not typically recommend PFA in patients in their twenties.

Patients should also be evaluated for preoperative opioid use or dependence. Patients who require opioid medications for patellofemoral OA are generally considered poor candidates for PFA, and all attempts should be made to wean them from these medications prior to pursuing surgery. Last, previous studies have shown that coexisting psychological distress or psychiatric disease may be associated with poorer outcomes and/or poorer satisfaction postoperatively [15]. This has also been demonstrated repeatedly in the TKA literature. Accordingly, it is important for the practitioner to determine the mental status of patients prior to proceeding with PFA and set appropriate and realistic expectations for patients. Indications and contraindications are further summarized in Table 10.1.

History and Design Considerations

The first PFA design was introduced in 1955 by McKeever and comprised an isolated patellar resurfacing with a screw-on Vitallium shell. In the absence of trochlear resurfacing, this design was associated with early failure, particularly related to wear of the trochlear cartilage, and it was abandoned [16, 17].

Table 10.1 Indications and contraindications for PFA

Indications	Contraindications	Relative contraindications
Advanced primary isolated patellofemoral OA	Tibiofemoral OA or ≥ grade III TF chondromalacia	BMI > 40 kg/m^2
Post-traumatic patellofemoral OA	Inflammatory arthritis or chondrocalcinosis	Isolated grade IV chondromalacia of medial patellar facet and/or medial trochlea
PF OA secondary to patellar maltracking +/−trochlear dysplasia	Knee instability	Preoperative opioid dependence
Mild patellar subluxation or tilt	Limb malalignment (valgus >8°, varus >5°)	Disproportionate pain
Grade IV chondromalacia of lateral patellar facet and/or lateral trochlea	Flexion contracture	Equivalent anterior pain walking on level ground as descending stairs, kneeling, or squatting
Retropatellar/peripatellar pain worsened by descending stairs, kneeling, or squatting	Uncorrectable patellar malalignment	Age < 30 years
		Tibiofemoral tenderness

Subsequent PFA prostheses resurfaced both the patella and trochlea. "First-generation," or "inlay," design trochlear components were developed to position the prosthesis flush with the surrounding trochlear cartilage, with its rotation determined by native trochlear orientation [7, 18]. The design characteristics of inlay PFA trochlear components have proven to be problematic, when coupled with inherent anatomic variations of the native trochlea [18]. A previous MRI study demonstrated that trochlear inclination is nearly ~10° internally rotated relative to anatomic landmarks such as the transepicondylar axis (TEA) [19]. As a result, internal rotation of the trochlear component is common in inlay PFA, leading to higher rates of patellar tracking problems (Fig. 10.2a–d). Further, most inlay prostheses have narrow medial-lateral widths and do not extend proximal to the native trochlear surface; these design characteristics lead to an increased potential for patellar maltracking and catching/subluxation against the proximal trochlear flange with knee flexion, [7, 18, 19] and relatively high failure rates requiring re-operation for patellar instability as high as 29% at short- and mid-term follow-up [20–27].

"Second-generation," or "onlay," PFA trochlear components were developed to address the shortcomings of earlier designs, particularly the issues of geometric mismatch with the native trochlea and component positioning, which resulted in a relatively high incidence of secondary patellar maltracking and subluxation. Onlay-style trochlear prostheses replace the entire anterior trochlear surface, positioning the component flush with the anterior femoral cortical surface proximal to the trochlea, obviating some of the issues related to maintenance of the native anatomic rotation in earlier designs [7, 18]. The trochlear surface extends proximal to the native trochlea, which decreases the risk of catching/subluxation during the initial 10–20 degrees of knee flexion, and maintains the patella engaged in the trochlea in full extension. In addition, by routinely rotating the trochlear component perpendicular to the AP axis or parallel to the transepicondylar axis of the femur, the risk of maltracking and subluxation is reduced. In general, onlay-style prostheses have yielded better short- and medium-term results than inlay-style trochlear components owing to the elimination of patellar maltracking problems, which increase the need for secondary surgery or revision. Unlike inlay-style designs, which are more commonly revised early, onlay components are more durable and most likely revised late for progression of tibiofemoral arthritis, rather than early component failure [13, 18, 28, 29].

Surgical Technique

A standard para-median skin incision is utilized, extending just proximal to the proximal edge of the patella (in flexion) to the proximal medial aspect of the tibial tubercle (Fig. 10.3a).

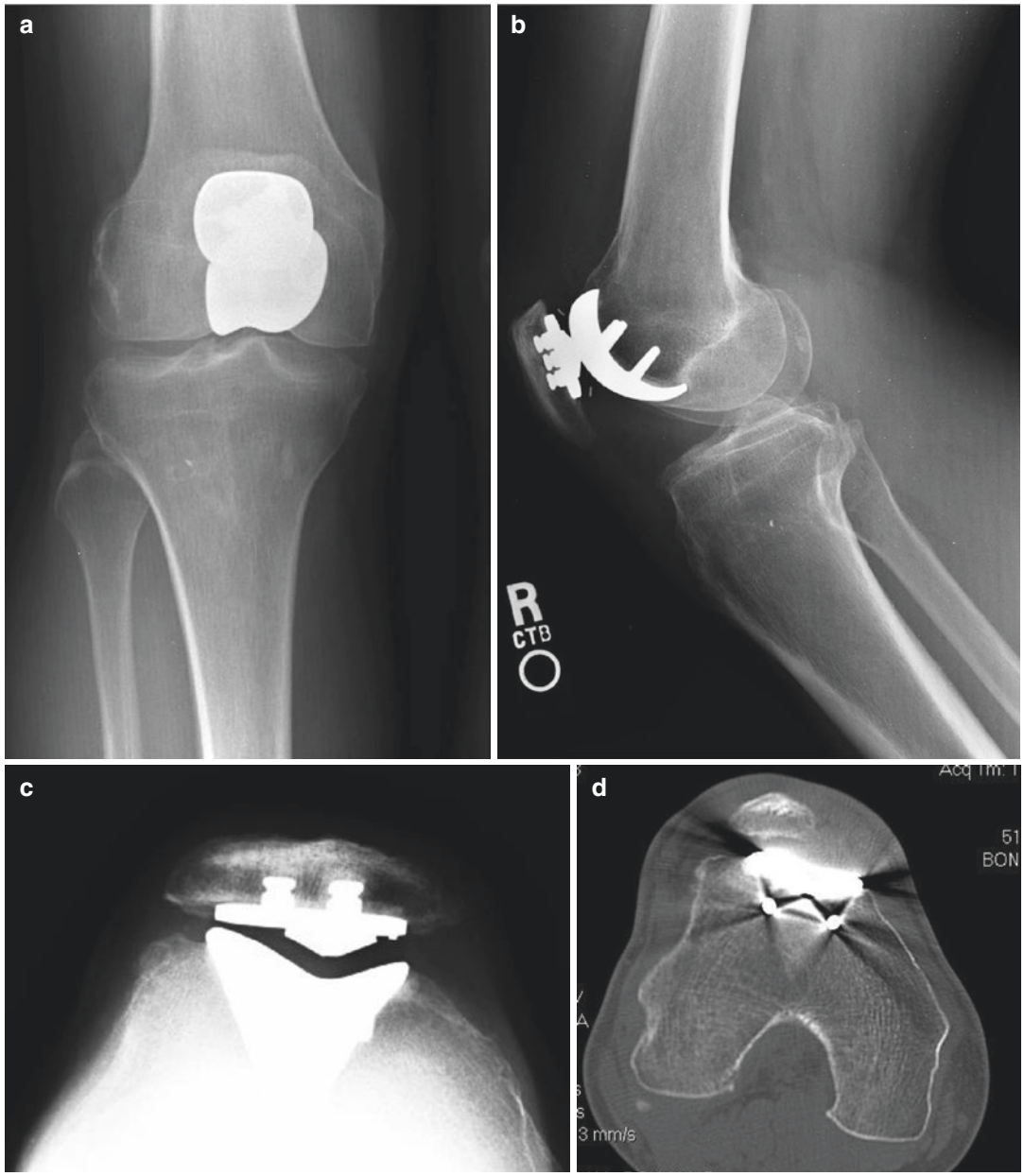

Fig. 10.2 (**a**–**d**) Postoperative AP, lateral, and sunrise radiographs and computed tomography scan after PFA with an inlay-style trochlear component show that it is internally rotated, causing lateral patellar subluxation and catching

The arthrotomy can be performed according to the surgeon's preference, as medial parapatellar, midvastus, and subvastus approaches will all provide adequate visualization of the patellofemoral joint space. In the author's experience, a medial parapatellar or midvastus approach is utilized in most cases. The surgeon should be cautious to avoid iatrogenic injury to the menisci, intermeniscal ligament, or articular cartilage of the femoral condyle or tibial plateau during the arthrotomy (Fig. 10.3b). Most often, the arthrotomy is thus made in limited flexion or full extension to slacken the capsule and keep it away from the medial femoral condyle. Before proceeding

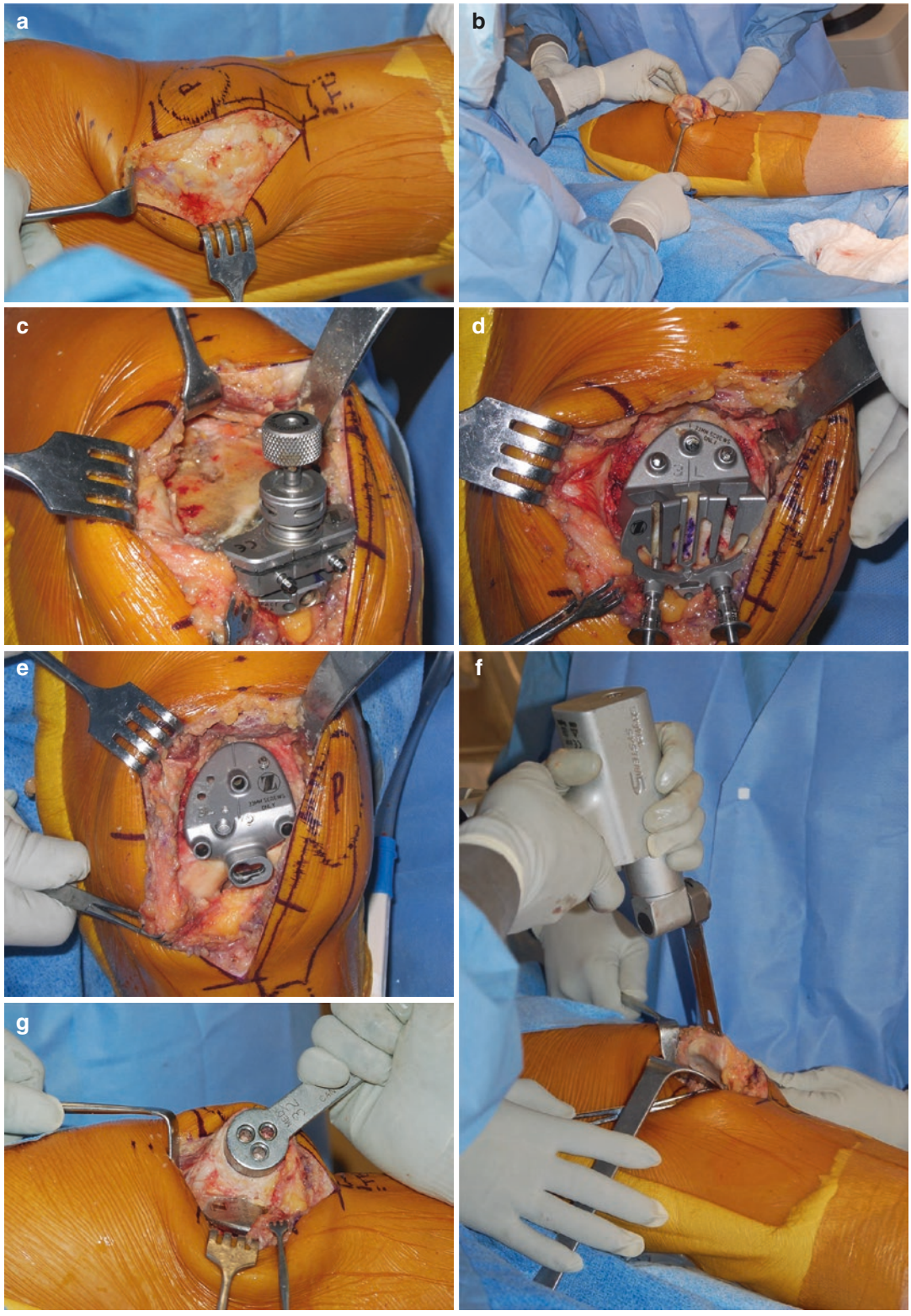

Fig. 10.3 (**a**–**j**) Intraoperative photographs demonstrate surgical technique of onlay-style PFA

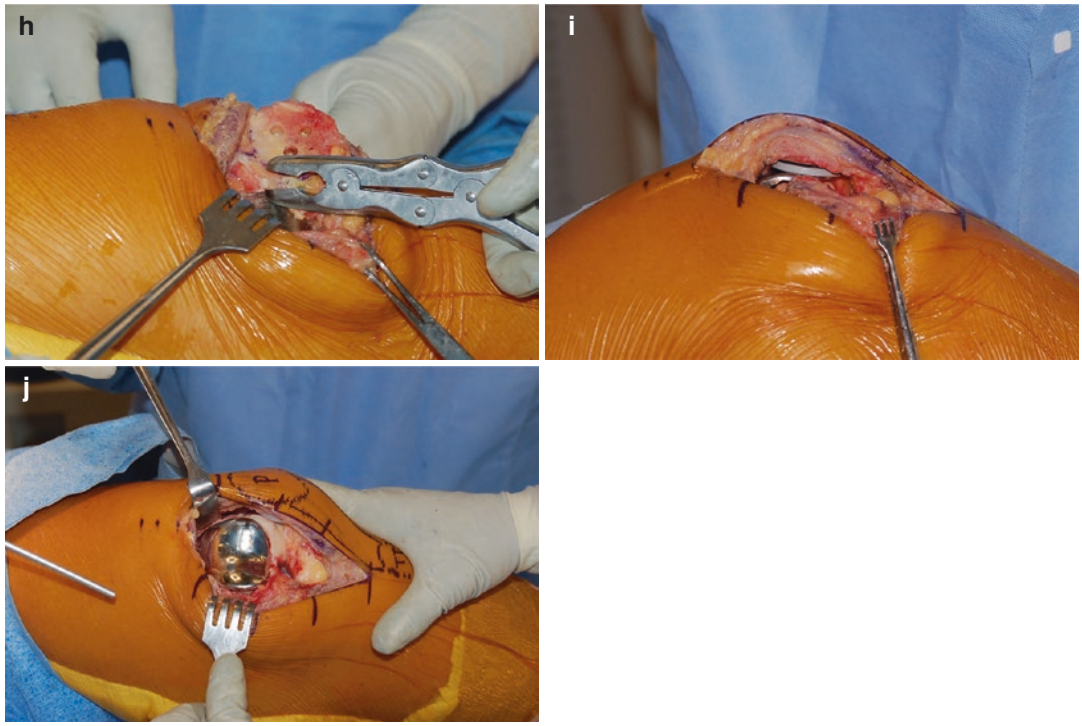

Fig. 10.3 (continued)

with the case, careful inspection of the entire joint is critical to ensure and confirm proper patient selection for PFA; the surgeon should inspect the tibiofemoral compartments for any sign of significant cartilage degeneration and be prepared to add a chondral resurfacing, BiKA, or proceed with a TKA if otherwise [30].

Although surgical techniques vary between systems, most protocols for onlay designs are centered on defining the anteroposterior axis of the knee joint (Whiteside's line). This is the landmark around which trochlear component rotation is set. The AP axis (Whiteside's line) is drawn with a marking pen. An intramedullary guide is utilized and the femoral canal accessed through a starting point anterior to the center of the intercondylar notch. The intramedullary guide is externally rotated so that its cutting slot is perpendicular to the anteroposterior axis of the femur (or parallel to the transepicondylar axis) and its vertical position secured to make a transverse resection flush with the anterior femoral cortex. An outrigger boom is applied to the cutting guide to determine the depth of the anterior resection. The guide is adjusted up or down to achieve an anterior resection that is flush with the anterior femoral cortex, leaving the classic "baby grand piano" sign (Fig. 10.3c). Anteriorization of the cut will result in overstuffing of the patellofemoral compartment; overly aggressive resection will cause notching of the anterior femur.

The next step involves sizing of the trochlear component and preparation of the intercondylar surface. We prefer to use a milling system, which can accurately prepare this area (Fig. 10.3d, e). The appropriately sized guide, corresponding to the implant size, is selected to maximize coverage of the resected anterior trochlear surface but leaving 1–3 mm of bone exposed on either side of the anterior surface of the trochlear component. This optimizes the surface for patellar tracking while also reducing the risk of mediolateral trochlear component overhang or synovial irritation. It is also important to check that the templated trochlear component does not encroach on the weight-bearing surfaces of the tibiofemoral

articulations or overhang into the intercondylar notch. The varus-valgus alignment of the trochlear component (and milling guide) is determined by the orientation of the femoral condylar surfaces, since in the region of transition onto the intercondylar, surfaces, the component edges must be flush with, or 1 mm recessed relative to the adjacent condylar articular cartilage. The trial trochlear component is then impacted into place.

Next, attention is turned to the preparation of the patella. The patella is resurfaced by the same principles followed in total knee arthroplasty. The resection should parallel the anterior patellar cortex, removing 8–10 mm, depending on the thickness of the patellar component selected and how much resection the native patella can accommodate (Fig. 10.3f). The remaining patella bone should be no thinner than 12–13 mm. The patellar component size is selected using a guide applied medially. The guide should rest on the medial edge of the patella and not overhang beyond the margins of the bone. Three lug holes are drilled, and the lateral edge of the guide or patellar prosthesis is traced with a methylene blue marker (Fig. 10.3g, h). The portion of the lateral patellar facet that is not covered by the patellar component should be removed to avoid a potential source of painful bone impingement that could occur if it were to articulate against either the trochlear implant or articular cartilage. Assessment of patellar tracking is performed with the trial components in place. If patellar tilt, subluxation, or catching of the components is noted, carefully ensure that component position and bone preparation are accurate and make corrections if necessary. Otherwise, patellar tilt and mild subluxation can usually be addressed successfully by a lateral retinacular recession or release. As stated earlier, more severe extensor mechanism malalignment would require a tibial tubercle realignment if there is an excessive Q angle, or a proximal realignment if the Q angle is normal.

After satisfactory trialing, the prepared recipient sites are irrigated with pulsatile lavage and dried. Methylmethacrylate is mixed and applied directly to the prepared bone surfaces in a doughy state. The cement is pressurized into the trabeculae and components implanted. Manual pressure is applied to the trochlear component, and a patellar clamp is used for the patellar component until the cement cures. Extruded cement is removed. Once again, patellar tracking is reassessed and the need for a lateral release or recession is determined (Fig. 10.3i, j). The wound is irrigated and sutured in layers. Postoperative radiographs are obtained (Fig. 10.4a–c).

Clinical Results of PFA

While inlay-style components have demonstrated high rates of secondary surgeries and early revisions to TKA due primarily to patellar maltracking problems, [11, 25] recent evidence shows routinely good clinical results and marked reduction of patellar maltracking when utilizing onlay-style trochlear components and surgical techniques that position the trochlear component perpendicular to the AP axis of the femur [28, 29, 31–33]. In fact, by revising inlay-style trochlear components that are experiencing patellar tracking and instability problems to an onlay device, patellar tracking and functional outcomes can be improved [34]. With those improvements in implant design and an understanding of the impact of trochlear component positioning, outcomes of PFA rival those of TKA [35]. Additionally, the majority of recent studies have demonstrated that the primary mode of failure after PFA is related to later progression of tibiofemoral arthritis, rather than early implant-related patellofemoral complications that have plagued inlay designs [28, 29, 31, 32].

The dichotomy in outcomes between inlay and onlay designs is highlighted in the Australian National Joint Registry, which shows that the 5-year cumulative revision rate was over 20% for inlay prostheses and under 10% for onlay designs. The most likely explanation for this has to do with trochlear component morphology and positioning relative to the femoral AP axis [36]. A single-surgeon series found that patients undergoing PFA with a first-generation inlay PFA had a 17% incidence of patellar maltracking, resulting in a relatively high need for second-

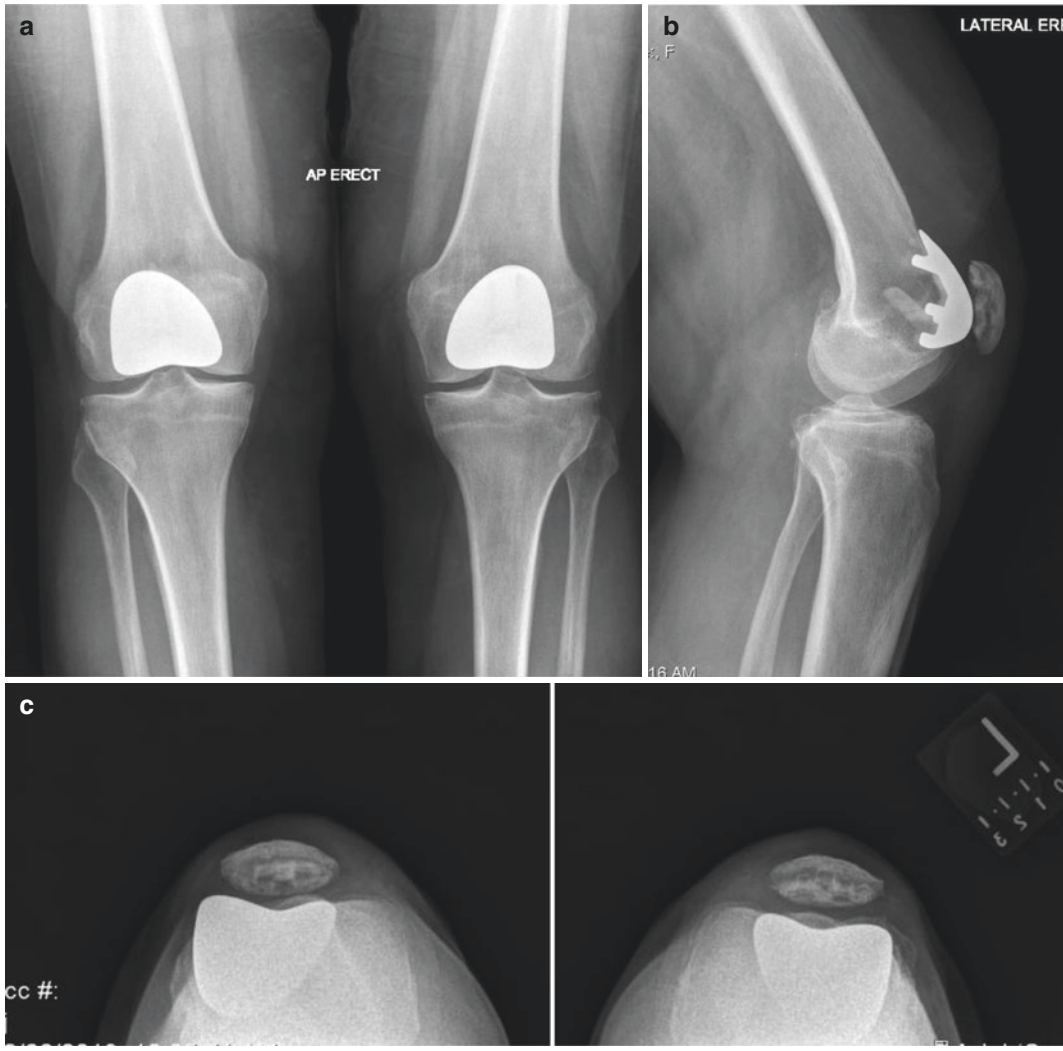

Fig. 10.4 (**a**–**c**) Postoperative AP, lateral, and sunrise radiographs after PFA with an onlay-style trochlear component positioned perpendicular to the AP axis of the femur, with good patellar tracking

ary surgery or revision, whereas those who had a second-generation implant, using an "onlay design," had an incidence of patellar maltracking of less than 1% [37]. Metcalfe et al., in the largest series to date, examined a total of 558 cases of PFA with an onlay-style prosthesis, using the United Kingdom National Joint Registry (NJR). The authors collected data from PFA performed over nearly two decades (1996–2014) and correspondingly had 2- to 18-year follow-up. They reported good functional outcomes by Oxford Knee Score and WOMAC. Their reported revision rate was 21.7% (105/483), of which the majority (58%) were for progression of tibiofemoral OA. The authors found that survivorship improved through the course of the study period, with 9-year survivorship of 91.8% for cases performed in the latter 9 years. They hypothesized that some of the observed effect may have been related to advances in instrumentation, surgeon experience, and refinement to surgical indications. Interestingly, the individual surgeon was found to have the most significant impact on revision rate. Again, this argues that technique and/or surgical indications may play a large role in improved survivorship in their registry data. Recent evidence regarding the outcomes of PFA is summarized in Table 10.2.

In the analysis of treatment strategies for PF OA, it is useful to consider the results of PFA compared to TKA. One retrospective study compared outcomes in 45 patients undergoing PFA or TKA at mean 2.5-year follow-up. They found similar Knee Society and pain scores, but the PFA group had significantly higher activity scores [38]. A recent meta-analysis of 28 studies compared complications with PFA and TKA performed for isolated patellofemoral arthritis. The authors found an eightfold higher likelihood of re-operation and revision for all PFA compared to TKA. However, when comparing second-generation onlay prostheses only, no significant differences in re-operation, revision, pain, or mechanical complications were found, indicating a significant effect of implant design and rotational positioning of the trochlear component.

Table 10.2 Results of patellofemoral arthroplasty (PFA)

Series	Implant utilized	Study size (No. of knees)	Average age (years)	Average follow-up (years)	Clinical outcome	Revision
Nicol et al. [28]	Avon (Stryker)	103	68 (46–84)	7.1 (5.5–8.5)	N/A	14% (14/103)
Ackroyd et al. [41]	Avon (Stryker)	109	68 (46–86)	5.2 (5–8)	Median Bristol pain score improved from 15 to 35 points at 2 years; mean Oxford score improved from 19 to 38 at 2 years and 40 at 5 years. 14 (4%) had residual anterior knee pain	3.6% (11/109), 5 patients required MUA
Mont et al. [29]	Avon (Stryker)	43	49 (27–67)	7 (4–8)	Significant improvement KSOS score from 64 to 87; KSFS score from 48 to 82	11.6% (5/43); all were revised to TKA for tibiofemoral progression
Dahm et al. [33]	Avon (Stryker)	59	56 ± 10.4	4 (2–6)	Significant improvement in KSFS from 56 to 78; KSPS 51–90. Significant improvement to Tegner activity level from 2 to 4; and UCLA activity score from 3.4 to 5.8	3% (2 of 59); both revised to TKA for tibiofemoral progression; re-operation with arthroscopic procedures in 2 additional patients
Liow et al. [10]	High-performance partial knee (DePuy)	51	52.7 ± 7.5	41. (2.2–6.1)	Significant improvement in Melbourne knee score, KSOS, KSFS, and PCS at 2 years. Overall, 76% excellent/good function at 2 years	7.3% (4/51); 3 for OA progression, 1 for patella maltracking
Kazarian et al. [15]	Gender solutions PJR (Zimmer)	70	50 (36–80)	4.9 (2.3–7.4)	57% satisfied or very satisfied by KSS Significantly improved original KSS knee (55–88) and function (39–85) scores	4% (2/70); 1 converted to TKA, 1 underwent additional UKA
Metcalfe et al. [31]	Avon (Stryker)	483	58.8 (25–92)	Minimum 2 years (2–18 years)	Median postoperative Oxford knee score was 35, WOMAC was 35 at 2 years	21.7% (105/483); 4 to revision PFA, 90 to TKA, 11 to unknown implant

Abbreviations: *KSOS* Knee Society Objective Score, *KSFS* Knee Society Functional Score, *KSPS* Knee Society Pain Score, *PCS* Physical Component Score, *KSS* Knee Society Score, *WOMAC* Western Ontario McMaster Universities Osteoarthritis Index

On subgroup analysis, first-generation inlay-style prostheses had over four times higher rates of significant complications than second-generation onlay prostheses, likely biasing the overall results. These data indicate that modern onlay-style PFA and TKA likely have similar rates of complications in this patient population [39].

To date, there are very little prospective data comparing PFA with TKA in patients with isolated patellofemoral OA. Recently, Odgaard et al. reported their results from a randomized controlled trial examining this issue. Patients with isolated patellofemoral OA were identified by clinical and radiographic assessment and randomized to receive either an onlay PFA or a TKA. The patients and clinical evaluators were blinded (for the first year), and various patient outcome measures were collected at regular follow-up visits up to 2 years postoperatively. The authors found significantly improved clinical outcomes (SF-36 body pain, KOOS symptoms, and Oxford Knee Score) in the PFA patients at 2 years. No patient-reported outcome (PRO) favored conventional TKA at 2 years, but KOOS scores and knee ROM were significantly more improved in the PFA group compared to the TKA group. Overall, there was no statistically significant difference between PFA and TKA in regard to risk of revision, although the authors reported that one patient had PFA revision and one patient had conversion to TKA [35].

Beyond implant design features, several studies have highlighted features that may lead to more durable results, on the one hand, or lead to failures or dissatisfaction, on the other hand. Several studies found that patients who undergo PFA for treatment of patellofemoral arthritis secondary to patellar malalignment, trochlear dysplasia, or prior patellar fracture have a diminished likelihood of failing due to progressive tibiofemoral arthritis compared to those with primary PF arthritis, as long as patella tracking is optimized prior to or during PFA surgery [40]. Nicol et al., for instance, reported a 14% revision rate, largely related to progressive tibiofemoral OA, in a consecutive series of 103 patients followed up for a mean of 7.1 years. They noted that the revision rate was significantly higher in patients with patellofemoral OA in the absence of trochlear dysplasia [28].

Obesity and elevated BMI have also been shown to be risk factors for poorer functional outcomes and increased risk of revision [10, 11]. These studies justify the inclusion of isolated trochlear dysplasia as an indication for PFA and obesity as a relative contraindication. Finally, patients with low mental health scores have now been shown to have suboptimal outcomes after PFA. Using the strict selection criteria and surgical technique outlined above, Kazarian et al. found significant improvements in the mean knee range of motion and Knee Society Knee and Function scores at an average 4.9 years of follow-up after PFA with a modern onlay-style design. Less than 4% of patients required revision arthroplasty, all for progressive tibiofemoral arthritis, and none for patellar maltracking. No components were loose or worn at most recent follow-up. Despite these improvements, while patients with high mental health scores were satisfied and had their expectations met, those with poor mental health scores tended to be dissatisfied with their outcomes and their expectations were not met, suggesting that patient mental health may be a valid selection criteria for PFA [15].

Summary

Patellofemoral arthroplasty (PFA) has been shown to be a durable and effective treatment in patients with isolated patellofemoral osteoarthritis (PF OA), with or without trochlear dysplasia. Historically, design limitations were associated with early failure related to patellar maltracking and subluxation. The development of onlay-style implants has significantly improved clinical outcomes and survivorship of PFA. As a result, with onlay-style implants, the most common etiology for failure after PFA is progression of tibiofemoral OA. In patients with medial or lateral tibiofemoral chondromalacia in addition to PF OA, performance of cartilage grafting or bicompartmental knee arthroplasty (BiKA) may be considered. Notably, with the use of modern implants, clinical performance and survivorship

now compares favorably to total knee arthroplasty (TKA) and may demonstrate superiority in certain clinical measures and patient-reported outcomes (PROs). As always, diligent patient selection is paramount to ensure successful outcomes after PFA; careful consideration should be given when discussing PFA with patients with elevated BMI, chronic opioid use, and comorbid mood disorders. With careful patient selection, meticulous technique, and modern onlay-style trochlear implants, excellent outcomes should be anticipated after PFA.

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11 Utilizing Unicompartmental Knee Arthroplasty for More than One Compartment

Brian Darrith, Jeffery H. DeClaire, and Nicholas B. Frisch

Introduction

Unicompartmental knee arthroplasty can involve any of the three knee compartments and is an excellent option for patients with relative preservation of the remaining two compartments. However, some surgeons have proposed that modular bicompartmental knee arthroplasty—replacing two compartments with two separate unicompartmental implants—can be as effective as total knee arthroplasty (TKA) for the treatment of bicompartmental arthritis with preservation of the third compartment. The purpose of the current discussion is to present the available evidence regarding bicompartmental knee arthroplasty, in the context of both staged unicompartmental arthroplasties and bicompartmental knee replacement undertaken in one surgical procedure, and to present a case of successful, staged unicompartmental arthroplasties.

Traditionally, total knee arthroplasty (TKA) has been the gold standard for the treatment of end-stage degenerative joint disease of the knee in elderly patients. There is a well-documented track record among patients with TKA, with high patient satisfaction and functional outcome [1–7]. With this success, there have been expanding indications for TKA in younger and more active patients [8]. The two most common implants utilized today are (posterior) cruciate-retaining and posterior-stabilized (sacrificing the posterior cruciate ligament) implants. Some reports have suggested suboptimal results utilizing these implants in younger patients and more active patients [9–11]. Implants designed to retain the anterior cruciate ligament (ACL) during TKA, also known as bicruciate-retaining TKA, might better preserve native knee mechanics and proprioception allowing for improved patient function and satisfaction [12–16]. With similar biomechanical arguments based on the preservation of both cruciate ligaments, the authors suggest that a bicompartmental knee arthroplasty more closely resembles native knee mechanics rather than TKA [17–19]. One level III study suggests that, because of the more anatomical biomechanics, bicompartmental knee arthroplasty results in superior functional measures and patient-reported outcomes [20]. Another proposed advantage of bicompartmental knee arthroplasty over TKA includes the preservation of bone stock and an associated reduction in intraoperative blood loss [21]. In pursuit of these biomechanical advantages, a monoblock bicompartmental component was developed for use about 10 years ago but was quickly taken off of the market for failure of the tibial component [22]. Because this device had a recognized,

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component-specific mechanism of failure and is no longer available for use, it will not be discussed; however, we acknowledge that there is ongoing research and developments in this area. Modular bicompartmental arthroplasty demonstrates promising short- and mid-term results [19–21] and will be the focus of the current discussion.

Case

Here we present a case of a 42-year-old male who presented to our office for evaluation of chronic left knee pain.[1] He described his pain as moderate, primarily medially based, constant, and getting progressively worse. He was status post left knee arthroscopy 2 years prior, which demonstrated grade 4 degenerative changes in the medial compartment. He had previously received corticosteroid and a series of viscosupplementation injections with only temporary relief of his symptoms and takes NSAIDs daily. He had undergone a period of weight loss and activity modification as well as a course of physical therapy.

On examination, there was no significant effusion and no evidence of infection. There was some medial joint line tenderness, full active and passive range of motion from 0 to 120 degrees, no laxity to varus or valgus stress at 0 or 30 degrees, and negative Lachman with no pivot shift. Patellar exam revealed minimal crepitus without apprehension or retinacular tenderness to palpation, passive patellar tilt was normal with no pain on quadriceps contraction. Radiographs included standing AP, standing flexion 45 PA, and lateral and sunrise views and demonstrated severe degenerative changes including medial compartment joint space narrowing, sclerosis, and osteophyte formation, with associated varus alignment and only moderate narrowing of the patellofemoral compartment (Fig. 11.1a–d).

Options were discussed with the patient, including conservative management, medial unicompartmental, and total knee arthroplasty. The patient elected to proceed with medial unicompartmental knee arthroplasty, and this was performed without complication. At the time of surgery, it was noted that there was a small 4 mm area of grade 4 change on the lateral trochlea of the patella, but the remainder of the patellofemoral and the lateral tibiofemoral compartments were completely normal. The implant used was a Biomet Oxford mobile-bearing unicompartmental knee, and postoperative radiographs showed appropriate component positioning with restoration of neutral joint alignment (Fig. 11.2a–c).

The patient did very well for 5 years, at which time he presented to clinic with worsening knee pain anteriorly in the patellofemoral compartment. He had no history of trauma or infection but complained of throbbing pain worse after sitting or standing for prolonged time, particularly under the knee cap. On examination, the patient had well-healed incision with no erythema or evidence of infection, active range of motion from 0 to 120 degrees, and stable to varus and valgus stress. He had maintained strength 5/5 in flexion and extension, with painless hip range of motion. All infectious markers were negative. We routinely draw an erythrocyte sedimentation rate (ESR) and a C-reactive protein (CRP) initially. We also perform an aspiration to assess cell count with differential stain, Gram stain, and cultures. Radiographs demonstrated well-fixed medial unicompartmental arthroplasty components, with no evidence of loosening with maintained component alignment. There was evidence of progressive degenerative changes in the patellofemoral compartment, with significant joint space narrowing (Fig. 11.3a–d). He was prescribed a period of activity modification, therapy, and prescription of NSAIDs without relief. Additionally, a corticosteroid injection was performed, which improved symptoms only temporarily.

Ultimately, the patient was offered the option of isolated patellofemoral arthroplasty versus revision of medial unicompartmental knee arthroplasty to total knee arthroplasty. We

[1]We would like to acknowledge Jeffery H DeClaire, MD, for contributing this case and thank him and his staff for their work in collecting the necessary materials to present.

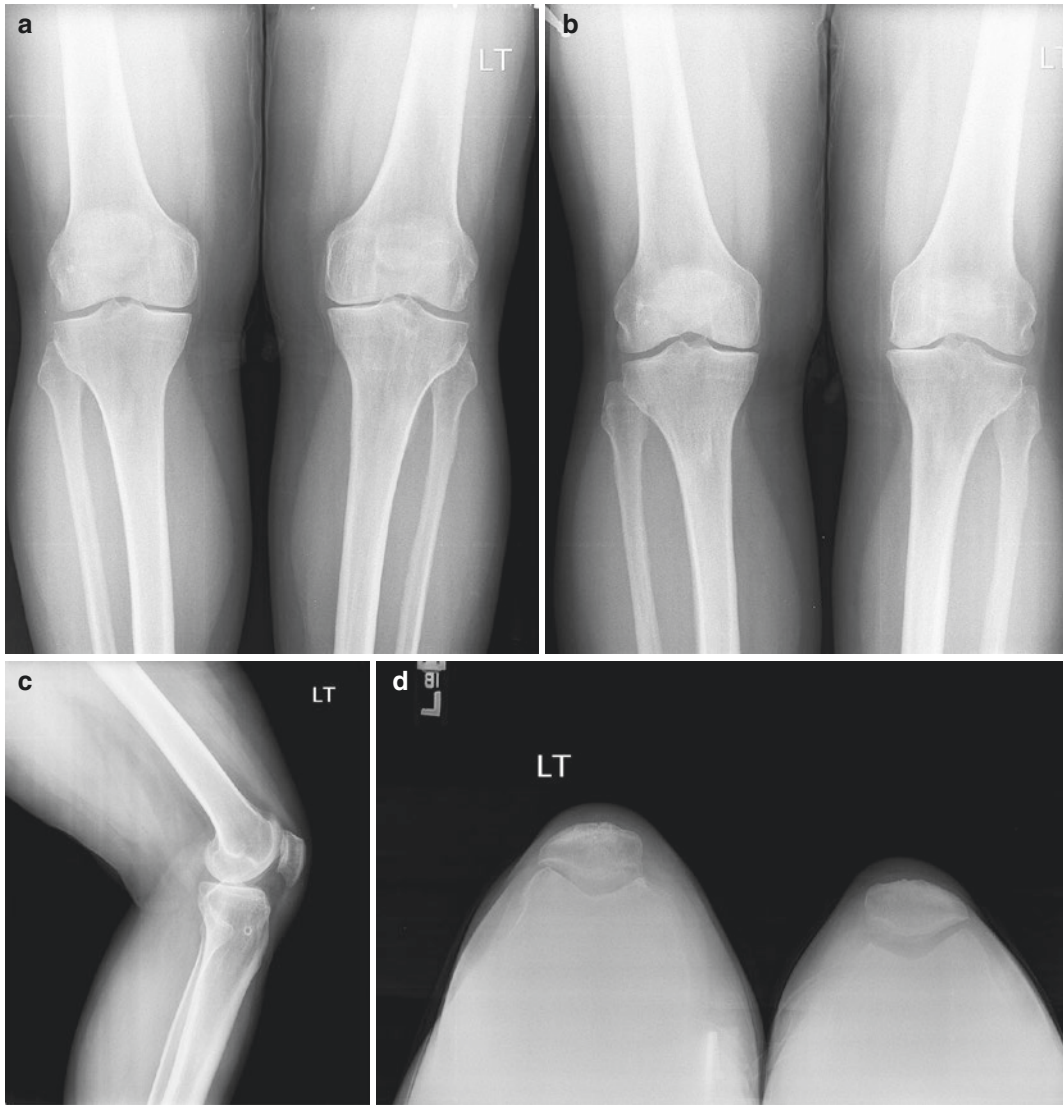


Fig. 11.1 Preoperative radiographs of the left knee including (**a**) standing AP, (**b**) standing flexion 45-degree PA, (**c**) lateral and (**d**) sunrise views. These radiographs demonstrate degenerative changes including medial compartment joint space narrowing, sclerosis, and osteophyte formation with an associated varus alignment and only moderate joint space narrowing of the patellofemoral compartment

explained that at the time of surgery, we would perform a thorough evaluation of the existing components in the medial compartment as well as the cartilage in the patellofemoral and lateral compartments. In the event that there were both lateral compartment and patellofemoral compartment degenerative changes, we would perform a conversion to a total knee arthroplasty. If the lateral compartment was spared, we were prepared to perform an isolated patellofemoral arthroplasty. After explaining all of the risks and benefits to the patient, he elected to proceed with patellofemoral arthroplasty.

An anteromedial incision was made using the previous surgical incision and a medial parapatellar approach utilized. Inspection of the joint at the time of surgery revealed severe degeneration of the patellofemoral joint with exposed bone-on-bone changes, present on both the patellar and trochlear side (Fig. 11.4a, b). The medial Oxford

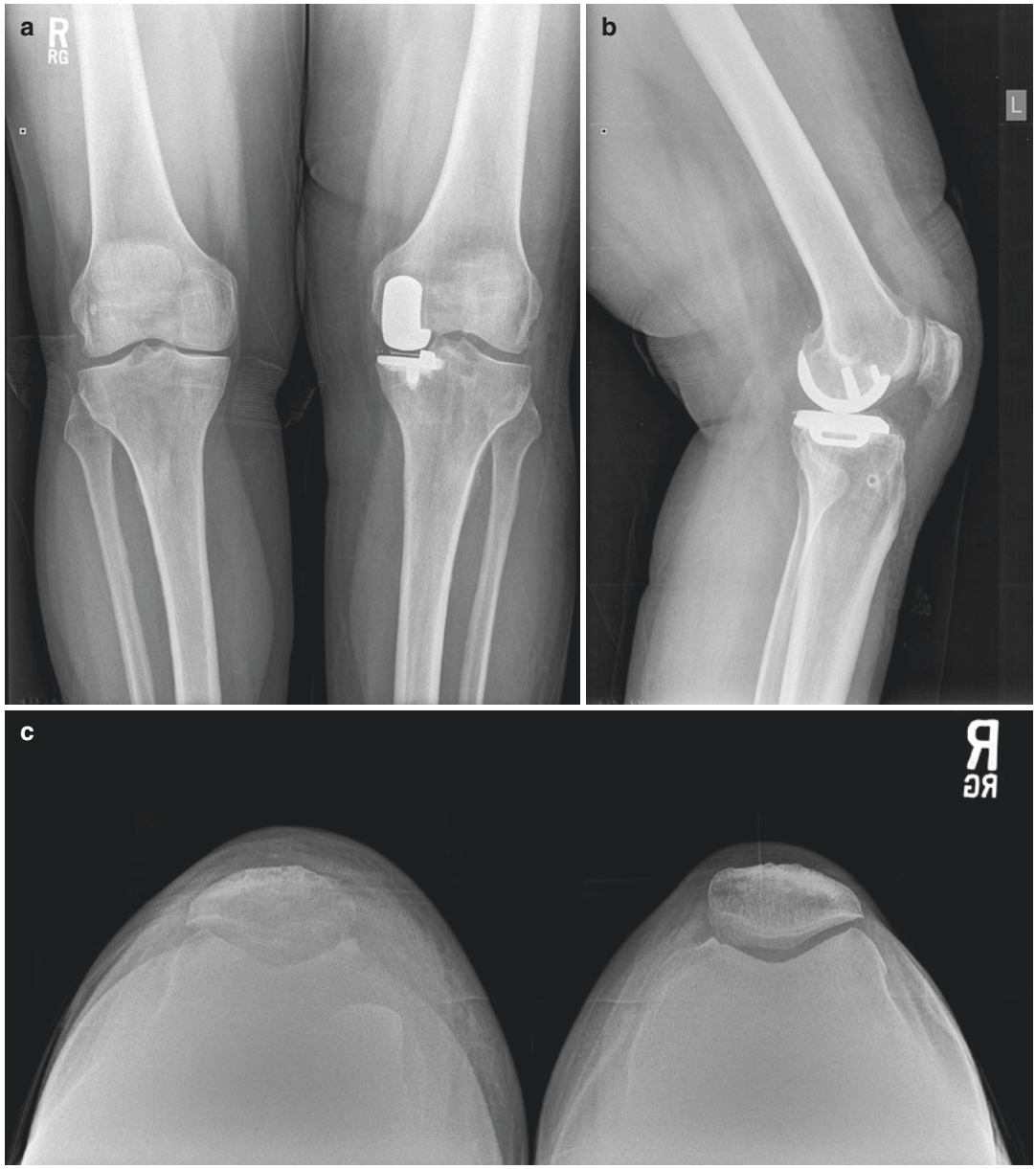


Fig. 11.2 Postoperative radiographs of the left knee status post-implantation of medial mobile-bearing unicompartmental knee implant, including (**a**) standing AP, (**b**) lateral and (**c**) sunrise views

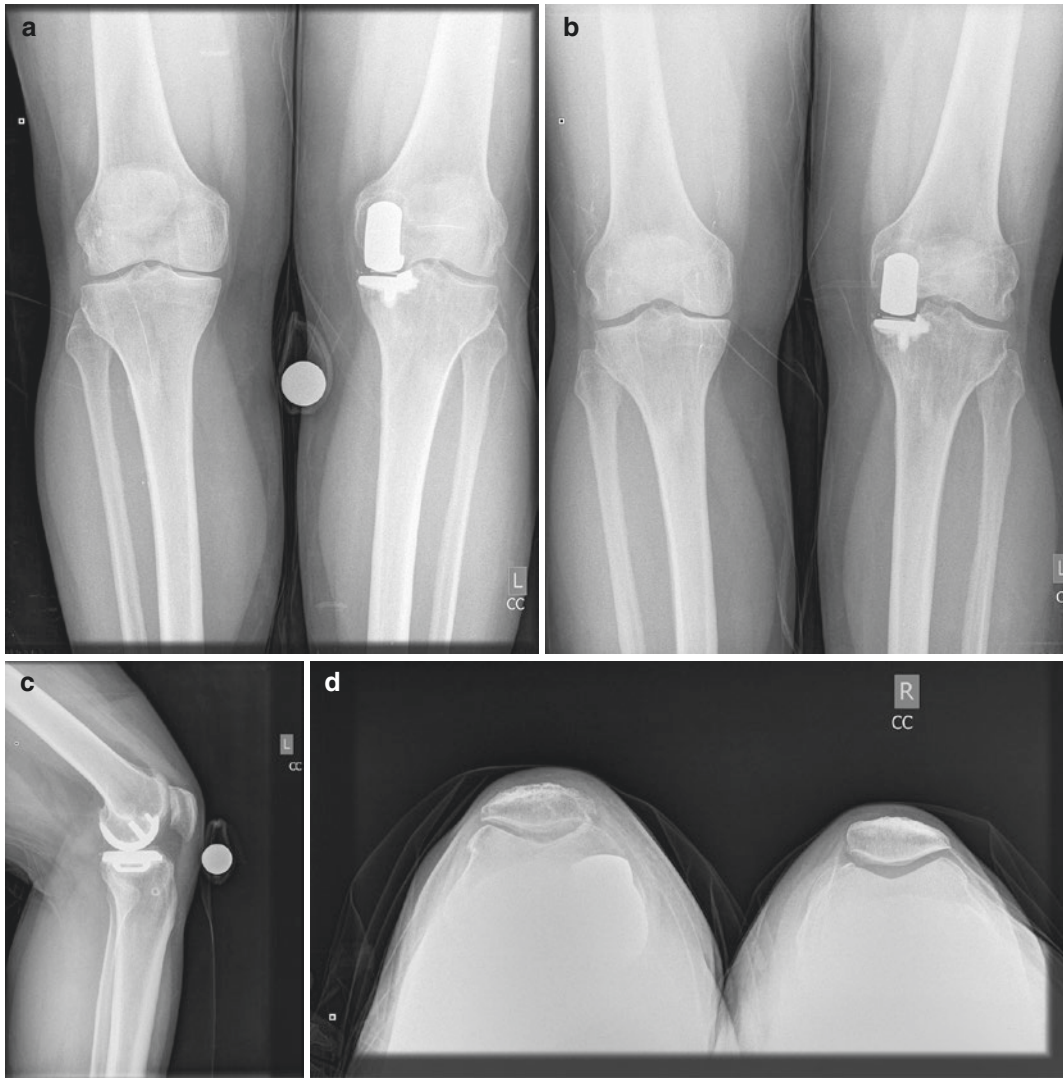


Fig. 11.3 Radiographs of the left knee at 5-year follow-up including (**a**) standing AP, (**b**) standing flexion 45-degree PA, (**c**) lateral and (**d**) sunrise views. There is evidence of well-fixed medial unicompartmental arthroplasty components in maintained alignment with no evidence of loosening. However, there is evidence of progressive degenerative changes in the patellofemoral compartment with significant joint space narrowing

components were well fixed and well maintained with no signs of loosening (Fig. 11.4c). The polyethylene was well maintained with no signs of wear. The polyethylene was removed, and a thorough lavage was carried out. A new polyethylene was inserted. The previous size was 4 mm, and after assessing balance throughout the arch of motion, a 4 mm polyethylene was used. Inspection of the lateral compartment revealed intact surfaces with no defects or significant changes. The meniscus was intact laterally, as were the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL). As such, it was determined to proceed with isolated patellofemoral arthroplasty using a Zimmer patellofemoral component.

We began with preparation of the patella. The patella was displaced laterally and the femoral canal entered. Using an intramedullary guide, the appropriate rotation was verified with the transepicondylar axis and the anterior cut was made. The femur was sized for a #4 femoral component with excellent coverage and no overhang. The femur was then prepared using the milling system with drill holes for peg fixation (Fig. 11.4d, e). Trial reduction was performed, and there was excellent tracking of the patellofemoral joint with no impingement and normal tracking with no lateral release required. The final implants were cemented in place using antibiotic cement (Fig. 11.4f). The wound was irrigated and closed with a layered closure.

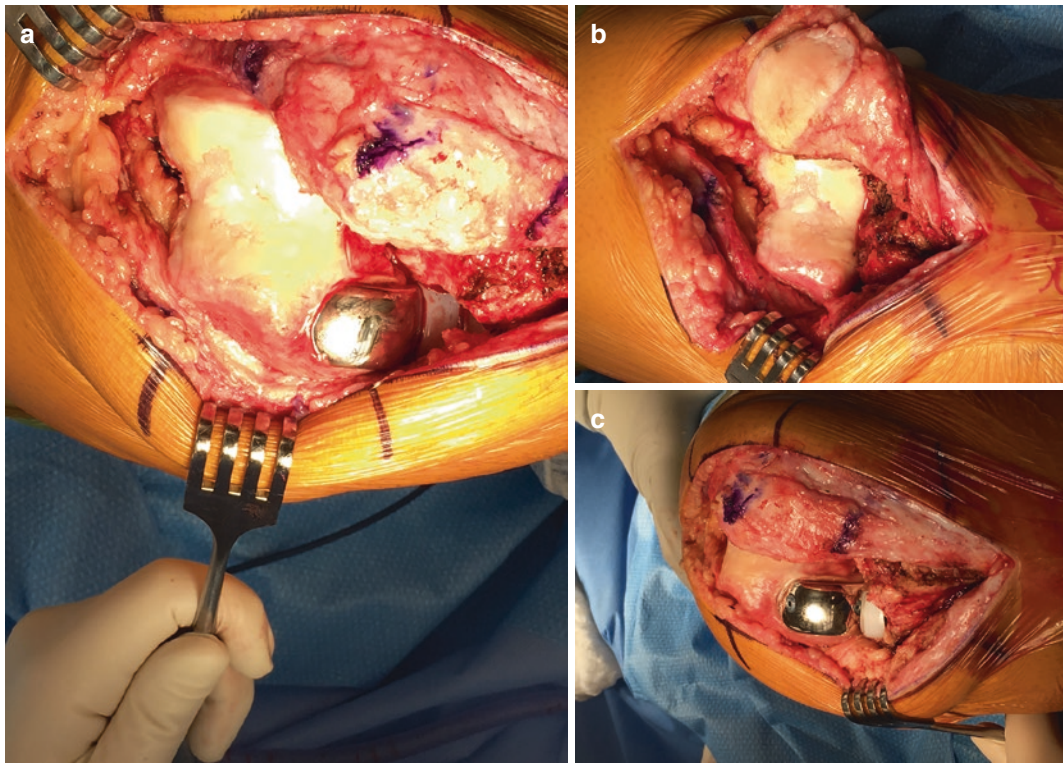
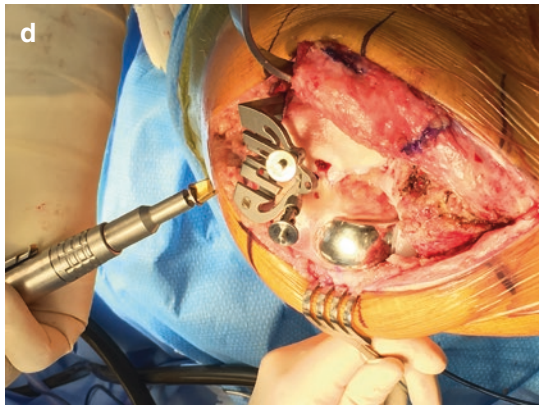
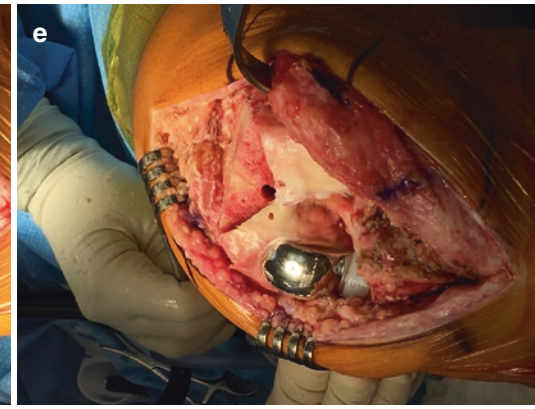


Fig. 11.4 Intraoperative images. (**a**, **b**) Inspection of the joint at the time of surgery revealed severe degenerative changes in the patellofemoral joint with exposed bone-on-bone changes present on both the patellar and the trochlear side. (**c**) Inspection of the existing medial unicompartmental components shows that they are well fixed and well maintained with no evidence of loosening or component failure. No significant polyethylene wear was noted. (**d**, **e**) Femoral preparation was performed using the milling system with drill holes for peg fixation. (**f**) The final implants were cemented in place, and this image demonstrates the relationship between the existing medial unicompartmental components and the newly placed patellofemoral components





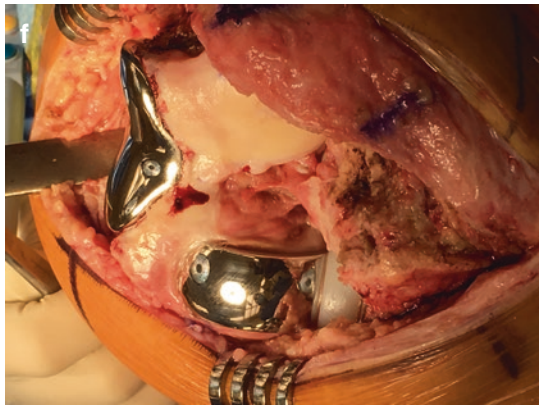


Fig. 11.4 (continued)

Postoperative radiographs demonstrate medial unicompartmental knee arthroplasty with patellofemoral knee arthroplasty (Fig. 11.5a–c). The patient did well in the immediate postoperative period with improvement in pain and function but did develop some laterally based pain concerning for soft tissue (lateral retinaculum) scarring over the lateral aspect of the patellofemoral implant consistent with impingement. He ultimately underwent an arthroscopic procedure, which revealed extensive scarring and adhesions with fibrotic bands over the superolateral area. These were removed arthroscopically, and further assessment of the joint demonstrated well-fixed components, no excessive wear of the medial polyethylene, or patellar polyethylene. Excellent alignment and tracking were demonstrated intraoperatively as well as maintained lateral cartilage, meniscus, and ligaments. The patient improved after this procedure, and we are continuing to follow his progress.

Discussion

The majority of the recent literature regarding bicompartmental knee replacement focuses on the combination of patellofemoral and unicondylar arthroplasty, with medial compartment arthroplasty being more common than lateral [19, 20, 23–29]. Of the nine studies and 255 cases included here, approximately seven-eighths involved medial compartment arthroplasty and two-thirds of patients were female (Table 11.1). At a mean follow-up of 3.4 years, only seven of 255 (2.7%) of the bicompartmental arthroplasties had been revised to TKA, and no UKAs were revised to another UKA. Complications requiring reoperation but not revision included a lateral retinacular release for patellar subluxation [23], two subsequent UKAs (one lateral and one medial) in the remaining compartment for progression of arthritis [28], two manipulations under anesthe-

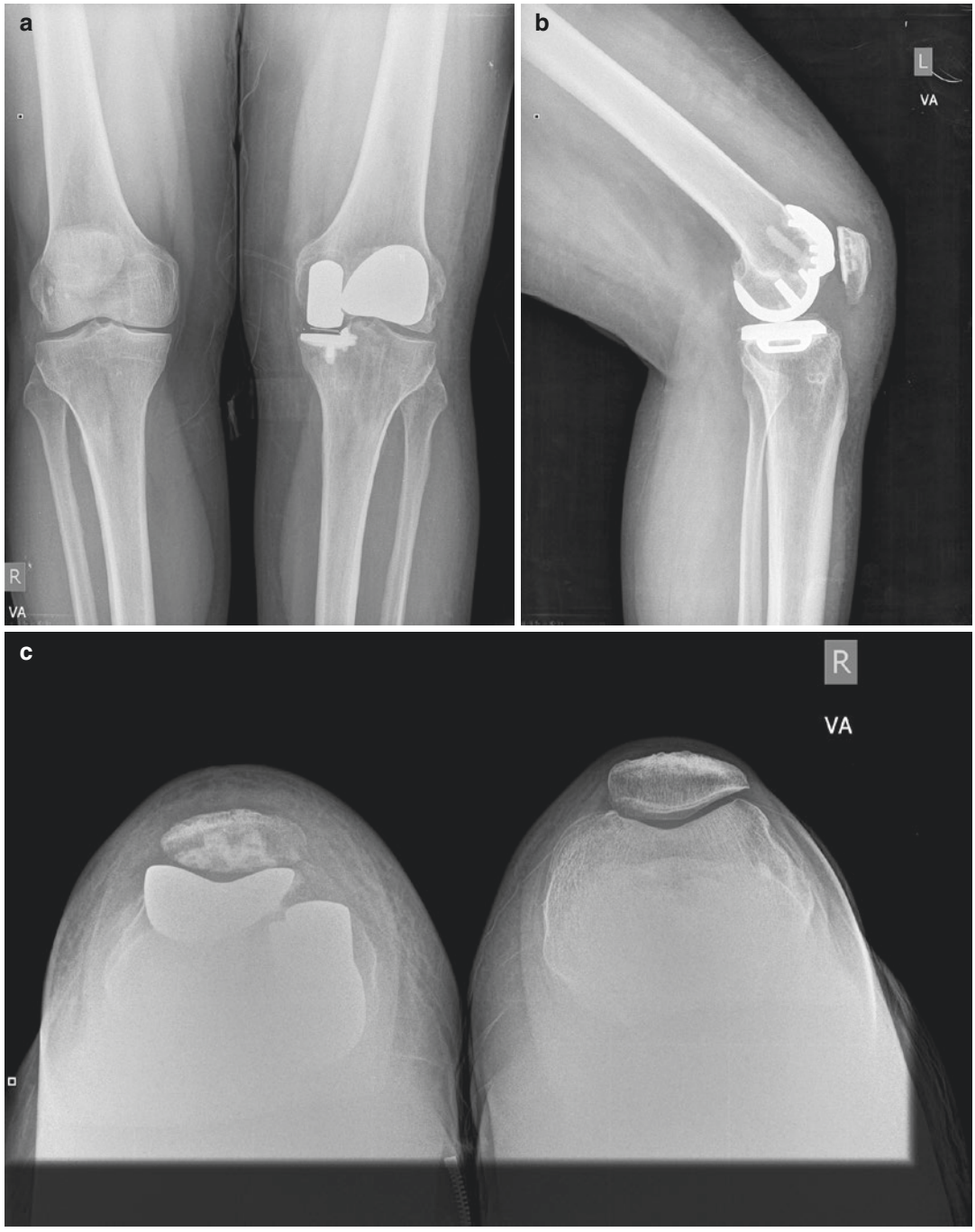


Fig. 11.5 Postoperative radiographs status post-patellofemoral arthroplasty, including (**a**) standing AP, (**b**) lateral, and (**c**) sunrise views

sia for arthrofibrosis, and one subsequent patellar resurfacing [27]. It is worth noting that both of the manipulations, and the one subsequent patellar resurfacing, occurred in patients who did not have the patellar resurfaced at the time of the index procedure [27], which is atypical for the included cases. Three of these seven revisions were secondary to aseptic loosening of the tibial component [26–28]. One revision was performed for each of the following indications: tibiofemo-

Table 11.1 Patellofemoral arthroplasty + medial or lateral unicompartmental arthroplasty

Primary author	Year	(n)	% Medial	% Female	Mean age	Mean BMI	Follow-up (years)	Revisions
Parratte [20]	2015	34	100%	62%	61	27.5	3.8	0
Yeo [23]	2015	22	100%	81%	64	27.3	5	1
Tan [34]	2013	15	100%	68%	52	26.0	2	0
Shah [25]	2013	16	100%	70%	52	27.6	2	0
Benazzo [26]	2014	30	90%	83%	67	–	4.9	1
Biazzo [27]	2018	20	60%	70%	67	–	2.8	1
Kamath [19]	2014	29	97%	62%	59	30.6	2.6	1
Ogura [28]	2018	59	69%	59%	51	28.3	3.8	3
Tamam [29]	2015	30	83%	62%	63.6	34.7	2.3	0
Totals		**255**	**86%**	**67%**	**59.1**	**29.1**	**3.4**	**7**

(*n*) number of cases, *BMI* body mass index

ral instability [19], traumatic fracture during an MVA [23], progression of the remaining compartment, and deep infection treated with two-stage exchange [28]. An additional two patients had degeneration of the remaining compartment (one lateral and one medial) treated with a subsequent unicondylar arthroplasty and resolution of symptoms [28]. Those authors did not consider this to be a revision or treatment failure, as the index components remained well fixed [28], and staged bicondylar knee arthroplasty has also been reported for the treatment of disease progression after medial UKA [30]. The proponents of bicompartmental arthroplasty would argue that this highlights an advantage of both unicompartmental and bicompartmental arthroplasty. Namely, replacing each arthritic compartment with a discrete unicompartmental prosthesis allows for subsequent unicompartmental replacement in the case of arthritic progression of a remaining native articulation despite appropriate functioning of the unicompartmental arthroplasty [19, 28]. This unicompartmental to bicompartmental "conversion" procedure has been described in as being successful in the variety of the possible iterations: an index unicondylar arthroplasty with later addition of a PFA [31], an index PFA with later unicondylar arthroplasty [26], and an index medial unicondylar arthroplasty with subsequent lateral unicondylar arthroplasty [32]. However, the numbers of such cases are quite limited and there is not sufficient evidence for any meaningful inferential meta-analysis.

Compared to staged bicompartmental unicondylar arthroplasties, there are relatively more data concerning bicompartmental unicondylar knee arthroplasties for the primary replacement of both tibiofemoral compartments in the same surgical procedure using two unlinked unicondylar prostheses [31, 33]. In a series of 22 cases with a mean patient-age of 60 years and mean follow-up of 4 years, no patients required revision or reoperation for any indication [33]. However, two of the procedures (9%) were complicated by intraoperative tibial spine fracture requiring intraoperative repair and protected weight-bearing for 4 months postoperatively [33]. In their larger series of 100 patients, Paratte et al. report a 4% rate of tibial spine fracture requiring intraoperative repair [31]. Considering that previous generations of unicondylar arthroplasty implants are known to be at a higher risk for complications and that their duration of follow-up is much longer than that in other studies, the relatively high revision rate is reasonable, with 16 of 100 knees being revised for aseptic loosening and one reoperation for progression of arthritis in patellofemoral compartment at 17 years of follow-up [31].

Conclusion

Despite the promising short- and mid-term results from modular bicompartmental arthroplasty, the evidence for bicompartmental arthroplasty is limited by a number of factors. First, the duration of available follow-up data is limited to less than 5 years, and longer term follow-up will be needed to appropriately weigh the risks and benefits. Second, additional high-quality studies are needed, as there is currently only one randomized trial comparing bicompartmental arthroplasty

with TKA [23]. Third, additional data regarding staged unicompartmental to bicompartmental arthroplasty are needed to inform the discussion regarding treatment of progression of arthritis and to compare the results of the simultaneous and staged bicompartmental procedures. Finally, as total joint arthroplasty continues to improve, especially with the increase in rapid recovery protocols and outpatient total knee procedures, we may need to start re-evaluating the benefits of bicompartmental knee arthroplasty.

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12 Unicompartmental Knee Arthroplasty and Anterior Cruciate Ligament Deficiency

Thomas W. Hamilton and Hemant Pandit

Introduction

While the anterior cruciate ligament (ACL) is intact in the majority of knees undergoing knee arthroplasty, the management of the arthritic ACL-deficient knee remains a significant challenge to surgeons. Often, patients with ACL deficiency and knee osteoarthritis (OA) are young, with high functional demands meaning unicompartmental knee arthroplasty (UKA) may represent the ideal treatment. Currently, however, there is a lack of consensus about whether UKA is indicated in the ACL-deficient knee and, if it is indicated, whether it should be performed concurrently with ACL reconstruction.

This chapter first reviews the role of the ACL, the incidence of ACL deficiency in OA and suitability for UKA in this population before focusing on how to determine ACL deficiency preoperatively and the treatment options in the ACL-deficient knee. The chapter concludes by reviewing the operative technique when performing UKA and concurrent ACL reconstruction before presenting a case study to illustrate relevant aspects of the management of the arthritic ACL-deficient knee.

Role of the Anterior Cruciate Ligament

In the native knee, the ACL is important for femoral rollback, the screw-home mechanism and maintenance of normal gait [1]. ACL deficiency is associated with instability, abnormal knee kinematics and a decline in activity [2, 3]. In addition, ACL deficiency is associated with loss of knee proprioception, provided in part by mechanoreceptors within the ACL, which is independently associated with poor knee function [4].

ACL deficiency in the setting of knee OA can be considered either primary or secondary. Primary ACL deficiency, where ACL deficiency typically occurs due to significant trauma, is an established risk factor for the development of secondary OA of the knee and following nonsurgical management of ACL rupture, the reported rates of OA range from 11% to 73% [5–18]. Conversely, secondary ACL deficiency occurs in the setting of established knee OA and is typically insidious in nature. Patients with a primary ACL deficiency are typically younger, and more

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active, with a more focal disease pattern, whereas in secondary ACL deficiency, patients are typically older and less active with a more extensive pattern of disease [19–24].

In an arthritic knee with functionally intact ligaments, the wear pattern on the tibial plateau is anteromedial. As the ACL degenerates, the wear pattern on the tibial plateau increases in size, but so long as the ACL remains intact, it rarely extends to the posterior quarter of the plateau and never to the posterior joint margin [20, 21, 25, 26]. With an intact ACL, posterior bone (and cartilage) within the medial compartment is preserved, as in flexion, the femur rolls back on the tibia ensuring that the medial collateral ligament (MCL) length is maintained and limb alignment restored (varus deformity disappears in flexion). Rupture of the ACL results in the wear pattern on the tibial plateau to extend posteromedially, which can be associated with posterior subluxation of the femur on the tibia, structural shortening of the MCL and structural damage to the lateral compartment [27].

Incidence of ACL Deficiency and Suitability for Unicompartmental Knee Arthroplasty

The ACL has been reported to be intact in around two-thirds of patients undergoing knee arthroplasty for OA (mean 69%, range 25–86%) [19, 28–34] (Table 12.1).

Thus, in one-third of knees with OA that are ACL deficient, it is important to establish which knees may be suitable for UKA, and have a focal disease pattern, and which knees have a more extensive disease pattern in which TKA would be the most appropriate treatment option [35].

In a series of 46 consecutive knees (42 patients) with ACL deficiency listed for medial UKA at the time of surgery, it was found that half had partial or focal full-thickness cartilage loss on the lateral femoral condyle, seven times higher than that seen in a matched control group with an intact ACL [36]. These data are supported by a radiographic cross-sectional study of almost 500 consecutive knees undergoing arthroplasty where of the 23% of knees (107 of 457 knees) that were identified as having radiographic evidence of ACL deficiency, based on a posterior wear pattern, half (51%; 55 of 107 knees) of these knees had evidence of lateral compartment disease, based on valgus stress radiograph [37] (Fig. 12.1).

In this radiographic cross-sectional study in knees with radiographic ACL deficiency, 53% (57 of 107 knees) were considered contraindicated for medial UKA based on radiographic assessment (medial partial-thickness cartilage loss seven knees (6.5%), lateral compartment disease 55 knees (51%), bone loss with grooving at the lateral patella facet 8 knees (7.5%) and functionally abnormal MCL one knee (1%)) [37].

Knees with radiographic ACL deficiency that retained suitability for UKA, based on the pathoanatomy of disease, had better preoperative Knee Society Functional Scores (mean 58.1 vs. 47.9, $p = 0.01$), Lower Extremity Activity Scores (mean 10.5 vs. 9.1, $p = 0.05$) and flexion (mean 113.5° v 107.7°, $p = 0.01$) compared tothose knees that had a more extensive disease pattern that did not meet criteria for UKA. Thus, those knees that retain suitability for UKA, based on the pathoanatomy of disease, may be more likely to benefit from UKA given their better level of preoperative function.

Table 12.1 Incidence of intact ACL at the time of total knee arthroplasty

Study	Year	Number of knees	% ACL intact
Cloutier [28]	1983	110	43
Jenny [32]	1998	125	25
Harman [19]	1998	143	75
Cloutier [29]	1999	204	80
Lee [33]	2005	107	71
Hill [31]	2005	360	77
Dodd [30]	2010	50	86
Johnson [34]	2013	200	78

Determining ACL Deficiency Preoperatively

As a third of knees undergoing arthroplasty are ACL deficient, and around half of these may be eligible for UKA (primary ACL deficiency with

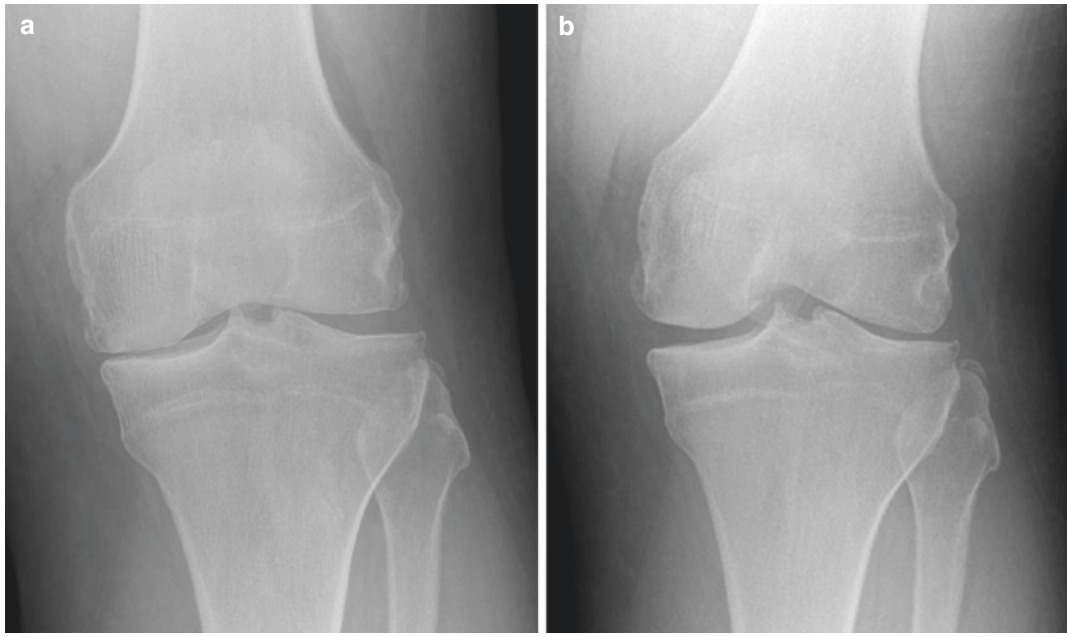

Fig. 12.1 Evidence of lateral compartment disease demonstrated on valgus stress radiograph in the ACL-deficient knee. (**a**) Standing AP radiograph; (**b**) valgus stress radiograph

secondary OA), it is important to consider, in the workup for UKA, how best to assess for ACL deficiency.

Based on patient history, it is often not possible to reliably identify ACL deficiency, as whilst a half of patients with knee OA and ACL deficiency recall a significant knee injury, around a quarter of patients with knee OA and an intact ACL also recall such an event [31]. Clinical examination using the Lachman test can be useful to screen for ACL deficiency; however, in the setting of osteoarthritis, findings can be misleading due to the presence of osteophytes and joint contracture [30, 34]. The ability of the Lachman test to exclude ACL deficiency (negative predictive value) is low (84%); however, its positive predictive value is high (94%; 95% CI 70–100%) [34]. As such, the presence of anterior tibial translation during Lachman test must alert the surgeon to high probability of ACL deficiency. The Pivot-Shift Test has not been found to be useful in the arthritic knee [30].

Arguably, the most useful preoperative test to assess for ACL deficiency is the true lateral radiograph of the knee. On the true lateral radiograph where the ACL is functionally abnormal or absent, the tibial erosion extends to the back of the tibial plateau and may be accompanied by posterior femoral subluxation. If the tibial erosion cannot be seen or does not extend to the back of the tibia, there is a 95% chance that the ACL is functionally normal [38, 39] (Fig. 12.2).

MRI has also been used to assess the status of the ACL. The sensitivity and specificity of MRI at detecting ACL tears has been reported as 87% (95% CI 77–94%) and 93% (95% CI 91–96%), respectively, although its performance is known to be lower in older patients, possibly due to the higher number of chronic, as opposed to acute ruptures in this group [40]. Whilst MRI has benefits in terms of providing morphological information about the status of the ACL, it has been demonstrated that provided the ACL is intact, the macroscopic status of the ACL does not influence outcomes after UKA. Based on this, it is the authors' practice to rely on a combination of clinical and radiographic findings to determine ACL integrity preoperatively with a final assessment being

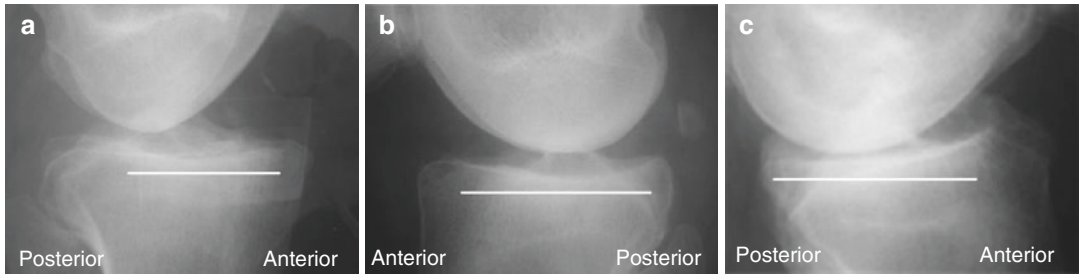

Fig. 12.2 Evaluation of the ACL on the true lateral radiograph. (**a**) Anteromedial wear with preserved posterior bone, indicating an intact ACL. (**b**) Posteromedial wear with loss of posterior bone indicating ACL deficiency. (**c**) Posteromedial wear with subluxation indicating ACL deficiency

made at the time of arthrotomy by passing a tendon hook around the native ACL and give a hard pull to assess its integrity [41].

Treatment Options in the ACL-Deficient Knee

For patients with ACL deficiency and bone-on-bone arthritis that does not respond to nonoperative treatment strategies, arthroplasty treatment options include the following:

- Total knee arthroplasty (TKA).
- Unicompartmental knee arthroplasty without ACL reconstruction.
- Unicompartmental knee arthroplasty with ACL reconstruction.

In those knees, around a half, with ACL deficiency and both medial and lateral tibiofemoral disease, best identified on stress radiographs, TKA is recommended [35, 37]. In knees with ACL deficiency that are suitable for UKA, as they tend to be younger with higher levels of function, UKA represents a good treatment option. Whether in this scenario the ACL should be reconstructed or not remains a significant debate [23, 24].

Reviewing the literature, there have been ten case series (308 knees) of UKA implanted in the setting of ACL deficiency (Table 12.2). Four of these series (169 knees) have included knees where UKA has been performed without ACL reconstruction and six series (139 knees) where UKA has been performed in conjunction with ACL reconstruction. The mean follow-up of these series is 5 years (range 1.7–16 years).

Little information is provided in included studies to indicate why UKA was performed with or without ACL reconstruction and significant differ-

Table 12.2 Case series of ACL-deficient knees managed with UKA with and without ACL reconstruction

Study	Country	Number of knees	Age	Age range	% Male
Unicompartmental knee arthroplasty without ACL reconstruction					
Fixed bearing					
Hernigou 2004 [42]	France	18	NS	NS	NS
Engh 2014 [43]	USA	68	65	39–91	52
Mobile bearing					
Goodfellow 1988 [44]	UK	37	NS	NS	NS
Boissonneault 2013 [36]	UK	46	65	SD 11	76
Unicompartmental knee arthroplasty with ACL reconstruction					
Fixed Bearing					
Krishnan 2009 [45]	Australia	9	56	50–64	56
Tinius 2012 [46]	Germany	27	44	38–53	41
Ventura 2017 [47]	Italy	14	55	45–59	64
Mobile bearing					
Dervin 2007 [48]	Canada	10	52	47–71	50
Weston-Simons 2012 [24]	UK	51	51	36–67	78
Tian 2016 [49]	China	28	51	41–61	36

ences in the mean age of cases where UKA has been performed alone (65 years) and in cases where UKA was performed in conjunction with ACL reconstruction (50 years), indicating that there is likely selection bias with regard to the choice of management (Table 12.2). In addition, the mean follow-up where UKA has been performed alone was 6 years (range 3–16 years), compared to that of 4 years (range 1.7–5 years) in series where UKA was performed in conjunction with ACL reconstruction, and as such, longer term data are required to fully evaluate outcomes in these cohorts.

Functional outcomes following UKA with and without ACL reconstruction are outlined in Table 12.3. Given the heterogeneity of treatment groups, and paucity of data, aside from acknowledging that UKA, regardless of whether it is implanted with or without concurrent ACL reconstruction, appears to improve function, it is not possible to determine whether outcomes are superior in one group over the other.

In the four series, 169 knees, where UKA was performed without ACL reconstruction, there were 19 revisions. In 12 cases (63%), there was aseptic loosening of the tibial plateau, four cases (21%) lateral compartment disease progression, one case (5%) unexplained pain, one case (5%) of bearing dislocation and one case (5%) the indication for revision was unknown. Ten of these cases were converted to TKA, one converted to bi-unicompartmental arthroplasty and one arthrodesis. In seven cases, the revision procedure was not specified. No other complications were reported (Table 12.4).

Table 12.3 Functional outcomes following UKA with and without ACL reconstruction

Study	Preoperative		Postoperative	
Unicompartmental knee arthroplasty without ACL reconstruction				
Fixed bearing				
Hernigou 2004 [42]	*Not reported*			
Engh 2014 [43]	*Not reported*			
Mobile Bearing				
Goodfellow 1988 [44]	*Not reported*			
Boissonneault 2013 [36]	OKS KSS F KSS O Tegner	27 (13–39) 70 (45–90) 42 (15–60) 3 (1–6)	OKS KSS F KSS O Tegner	43 (20–48) 100 (40–100) 88 (75–90) 2 (1–4)
Unicompartmental knee arthroplasty with ACL reconstruction				
Fixed bearing				
Krishnan 2009 [45]	OKS KSS Total WOMAC	36 (2–40) 135 (64–167) 45 (35–52)	OKS KSS T WOMAC	48 196 (170–200) 24 (21–27)
Tinius 2011 [46]	KSS F KSS O	39 38	KSS F KSS O	83 83
Ventura 2017 [47]	KOOS OKS WOMAC Tegner KSS O KSS F	63 (8.4) 29 (10.2) 72.1 (12.5) 2 (1–3) 45 (12.9) 80 (14.2)	KOOS OKS WOMAC Tegner KSS O KSS F	81.0 (10.2) 43.2 (9.5) 85.8 (8.7) 3 (2–4) 77 (13.0) 90 (15.0)
Mobile bearing				
Dervin 2007 [48]	*Not reported*			
Weston-Simons 2012 [24]	OKS KSS F KSS O Tegner	28 (16–46) 82 (45–100) 40 (25–80) 3 (1–5)	OKS KSS F KSS O Tegner	41 (17–48) 95 (45–100) 75 (25–95) 4 (1–5)
Tian 2016 [49]	OKS KSS F KSS O Tegner	31 (7.1) 64 (6.5) 60 (7.1) 4 (1.2)	OKS KSS F KSS O Tegner	43 (4.2) 87 (5.3) 85 (6.3) 5 (0.8)

Table 12.4 Revision of ACL-deficient knees managed with UKA with and without ACL reconstruction

Study	Number of knees	Number of patients	Mean follow-up (years)	Follow-up range (years)	Number of revisions
Unicompartmental knee arthroplasty without ACL reconstruction					
Fixed bearing					
Hernigou 2004 [42]	18	NS	17.0	15.0–24.0	7
Engh 2014 [43]	68	60	6.0	2.9–10.0	5
Fixed bearing					
Goodfellow 1988 [44]	37	NS	3.0	1.8–4.7.0	6
Boissonneault 2013 [36]	46	42	4.9	SD 2.7	1
Unicompartmental knee arthroplasty with ACL reconstruction					
Fixed bearing					
Krishnan 2009 [45]	9	9	2.0	1.0–5.0	0
Tinius 2011 [49]	27	27	4.2	0.8–5.9	0
Ventura 2017 [47]	14	14	2.2	2.0–3.3	0
Mobile bearing					
Dervin 2007 [48]	10	10	1.7	1.0–3.9	0
Weston-Simons 2012 [24]	51	51	5.0	1.0–10.0	3
Tian 2016 [49]	28	28	4.3	2.0–8.0	2

In the six series, 139 knees, where UKA was performed with ACL reconstruction, there were five revisions. In three cases where bearing dislocation occurred (60%), requiring open reduction, in one case (20%), there was lateral compartment disease progression with conversion to TKA, and in one case (20%) conversion to TKA following two-stage revision for infection. There were no cases of aseptic loosening. In addition to the revision procedures, there were three complications. One arthroscopy and loose body removal was performed, and there was one case of stiffness managed with arthroscopy and manipulation under anaesthetic.

Overall, the revision rate in the UKA without ACL reconstruction series was 1.81 per 100 observed component years (95% CI 0.54–3.69), equivalent to a 10-year survival of 82% (95% CI 63–95%), whereas the revision rate in the UKA with ACL reconstruction series was 0.19 per 100 observed component years (95% CI 0–1.06), equivalent to a 10-year survival of 98% (95% CI 89–100%) (Fig. 12.3).

While the differences in implant survival between UKA without and with concurrent ACL reconstruction do not differ significantly ($p = 0.17$), it is the authors' view that this is due to inadequate sample size and until further, longer term data are available, the authors would recommend that when UKA is performed, it should be done with concurrent ACL reconstruction.

If the two studies in which UKA were performed in an era where ACL was not recognised as a potential risk factor, Goodfellow et al. (1988) and Hernigou et al. (2004) are excluded, the failure rate in ACL-deficient knees decreases to 0.90 per 100 observed component years (95% CI 0.26–1.85; 10-year survival of 91% (95% CI 82–97%)), which is improved, but remains higher than that in those series in which the ACL had been reconstructed. This suggests that, during the period between these initial studies and more recent ones, there have been improvements in patient selection, surgical technique, implant design or perhaps changes to the revision threshold. Nonetheless, until such a time as clear selection criteria for performing UKA without ACL reconstruction are developed, based on long-term data, the current literature does not support performing isolated UKA in the ACL-deficient knee.

Conversely, where concurrent ACL reconstruction is performed, the revision rates of UKA are low and equivalent to a 10-year survival of 98% (95% CI 89–100%), which compared favourably to the rates in the literature, which reports a 10-year survival of 94% (95% CI

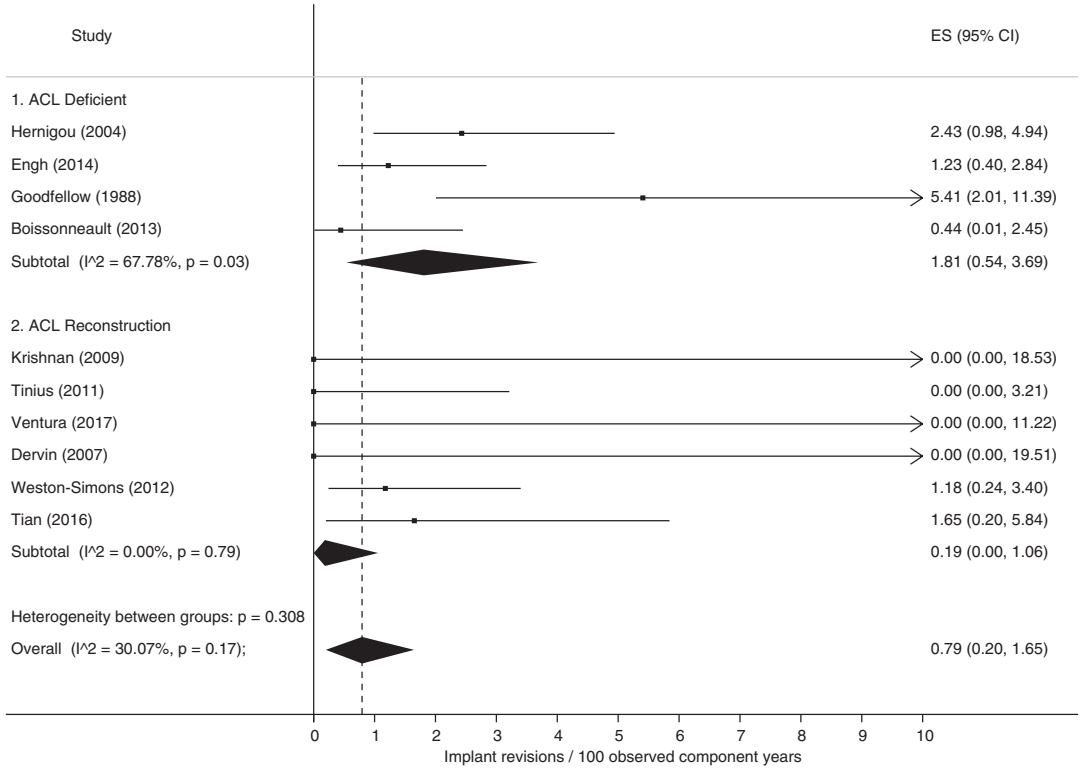

Fig. 12.3 Revision rate per 100 observed component years in ACL-deficient knees with and without concurrent ACL reconstruction

92–95%) in series of mobile-bearing UKA in the knee with an intact ACL and minimum 10-year follow-up [50]. Therefore, based on these data, the authors would conclude that in the ACL-deficient knee, UKA and ACL reconstruction represents good treatment, provided the patient meets indications for UKA.

Why there is a higher failure rate in UKA compared with UKA plus ACL reconstruction, with aseptic loosening of the tibial component being the predominant failure mechanism, may relate to the biomechanics of the knee following surgery. Kinematic assessment of the ACL-deficient knee has demonstrated that, compared to the ACL-intact knee, there is abnormal knee kinematics and bearing movement following mobile-bearing UKA [51, 52] (Fig. 12.4). This abnormal kinematics, and bearing movement, may increase shear forces on the tibial component and, consequently, result in aseptic loosening of the prosthesis.

In ACL-deficient knees undergoing osteotomy, it is known that tibial slope modification affects ACL strain and knee stability, and similarly, in cadaveric studies of fixed-bearing UKA, tibial tray slope modifications have been demonstrated to reduce anterior tibial translation in ACL-deficient knees [54]. In the case series by Hernigou, a tibial slope of more than 7° was associated with an increase in the rate of aseptic loosening, and thus in fixed-bearing UKA, it is not recommended to exceed this limit [42]. Whilst in mobile-bearing UKA, modification of tibial slope is not advised, overall, as outcomes of UKA are worse in the ACL-deficient knee without reconstruction, in both fixed and mobile-bearing designs, than in the reconstructed knee. Modification of the tibial slope without reconstruction of the ACL cannot be recommended.

Whether to use a fixed or mobile-bearing UKA remains an area of debate. Of the series in which UKA and ACL reconstructions were performed,

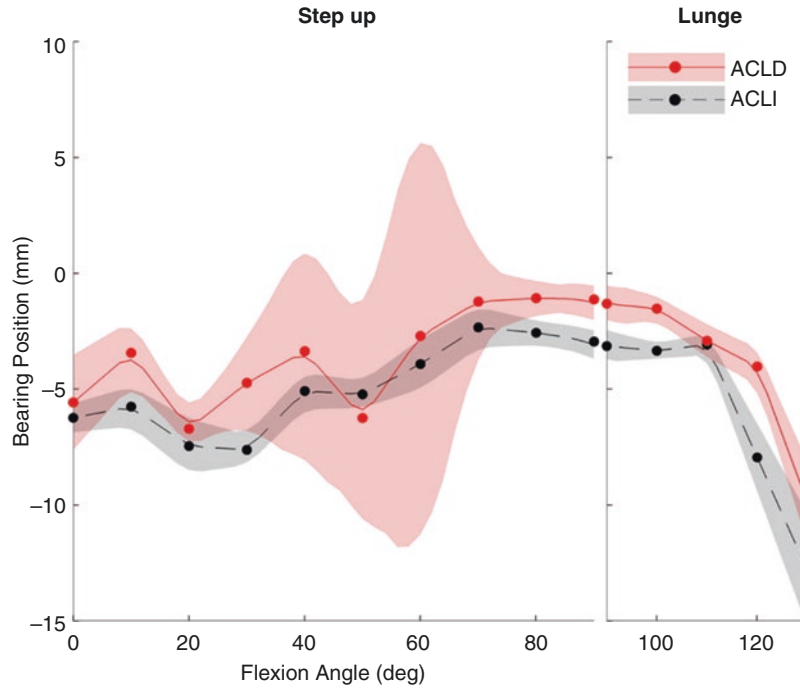

Fig. 12.4 Relationship between bearing position and knee flexion angle for the step-up and forward lunge exercises following mobile-bearing UKA; results for the ACLD and ACLI patient groups. The shaded areas indicate the 95% confidence intervals. Positive BP denotes anterior bearing position, and negative BP denotes posterior positioning. (From Pegg EC et al. [53])

three studies, 50 knees, assessed fixed-bearing designs and three studies, 89 knee, mobile-bearing designs. No failures were reported in the series reporting the outcomes of fixed-bearing designs at a mean of 3.2 years (range 2.0–4.2 years) compared to five failures in the series reporting the outcomes of mobile-bearing designs at a mean of 4.4 years (range 1.7–5.0 years). In the series reporting the outcomes of mobile-bearing design, there were three bearing dislocations, managed with bearing exchange, one lateral compartment disease progression managed with TKA and one infection managed with two-stage conversion to TKA.

No statistical difference was seen in implant survival between fixed and mobile-bearing UKA in ACL-reconstructed knees ($p = 0.79$), although the number of knees is too small to make an accurate comparison. The revision rate in fixed-bearing UKA with ACL reconstruction series was 0 per 100 observed component years (95% CI 0–0.70), equivalent to a 10-year survival of 100% (95% CI 93–100%). The revision rate in mobile-bearing UKA with ACL reconstruction series was 0.62 per 100 observed component years (95% CI 0–2.01), equivalent to a 10-year survival of 94% (95% CI 80–100%) (Fig. 12.5).

Whilst at medium-term follow-up no difference in outcomes between fixed- and mobile-bearing designs is seen, proponents of mobile-bearing designs argue that, in the longer term, mobile-bearings may be less susceptible to wear and offer superior outcomes. Blunn et al. have reported higher polyethylene wear with cyclic sliding, as seen in fixed-bearing designs, compared with compression or rolling, seen in mobile-bearing designs, and multiple studies have shown that the wear rate with mobile-bearing UKA is significantly less than that with fixed-bearing UKA [55–57]. Thus, mobile-bearing designs may be more forgiving in the setting of minor ligamentous laxity seen in ACL deficiency and subsequent reconstruction. This is particularly relevant, as typically, these patients are younger than the usual population undergoing TKA, and as such, long-term implant survival with low wear is crucial for this patient group. At present, the authors cannot recommend one design over another without further longer term data assisting in determining whether there is superiority of either fixed- or mobile-bearing design UKA in the ACL-reconstructed knee.

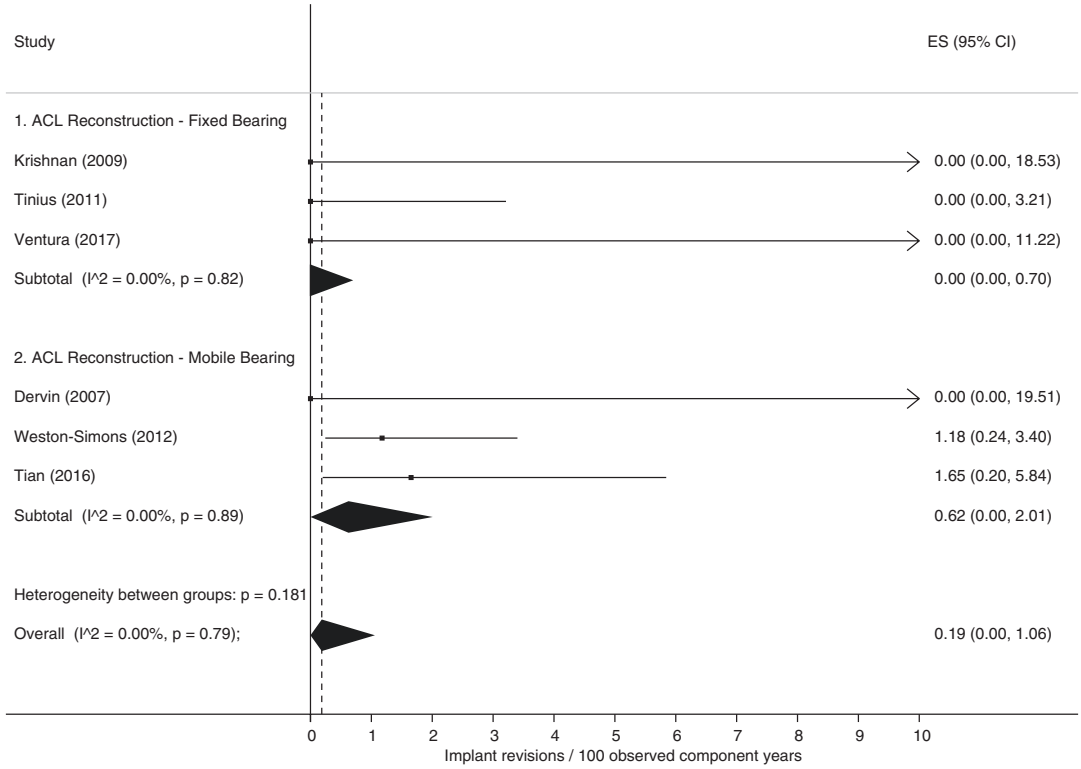

Fig. 12.5 Revision rate per 100 observed component years in fixed- and mobile-bearing UKA in knees with concurrent ACL reconstruction

Table 12.5 Pooled summary of outcomes in ACL-deficient knees

Study	Number of knees	Annual revision rate (%pa)	Annual revision rate 95% CI (%pa)	10-y survival (%)	10-y survival (%) 95% CI
All ACL deficient	169	1.81	0.54–3.69	82	63–95
Fixed	86	1.67	0.82–2.80	83	72–92
Mobile	83	1.48	0.36–3.17	85	69–96
All ACL reconstructions	139	0.19	0–1.06	98	93–100
Fixed	50	0	0–0.70	100	93–100
Mobile	89	0.62	0–2.01	94	80–100

Similarly, there is a paucity of evidence as to whether there is an optimum fixation type, cemented versus cementless prosthesis or ACL graft choice, with outcomes of hamstring and bone-patellar tendon-bone autograft both reported in the literature. Further work is required to identify whether there is any benefit of either type of fixation of the prosthesis or type of ligament reconstruction to inform future practice (Table 12.5).

Surgical Technique

ACL reconstruction can be performed simultaneously or in a staged procedure. In the authors' practice, patients whose primary symptoms relate to instability receive an ACL reconstruction initially, and if the patient subsequently presents with pain, then a mobile-bearing UKA is implanted if they meet indications for UKA. In patients who meet

indications for UKA and whose primary symptoms are pain, a simultaneous procedure is performed. In the published literature, three studies reported a staged procedure in some cases (total 46 knees), while a simultaneous UKA with ACL reconstruction was performed in all other cases.

Combined UKA and ACL reconstruction is a longer, more technically demanding procedure; however, it avoids the need for a protracted recovery due to reoperation. Performing UKA with concurrent ACL presents two technical challenges that are not encountered when the procedures are performed independent of each other. The first is avoiding impingement of the graft tunnel on the tibial component of the UKA, and the second is applying appropriate graft tension. To avoid impingement of the graft tunnel on the tibial component, which may also lead to tibial plateau fracture particularly with uncemented prosthesis, it is advised to place the tibial tunnel more vertically, with the entry point more lateral than normal (Fig. 12.6). In addition, if using cementless implants, the tibial tunnel should be drilled after positioning and impacting the tibial component to lower the risk of fracture during this manoeuvre. The graft tension should then be adjusted after implantation of the UKA and fixation of the femoral end of the ACL graft.

Whilst, as discussed above, there is a paucity of evidence as to the optimum ACL graft choice for simultaneous UKA with ACL reconstruction, the authors favour a bone–tendon–bone graft, as opposed to hamstring for three main reasons. First, we believe it provides stronger initial fixation (bone to bone rather than bone to tendon) permitting more aggressive early rehabilitation; second the tibial tunnel can be drilled through the donor site and is slightly lateralised, as previously mentioned. Third, the medial third of the patellar tendon may be harvested through the traditional UKA approach, thus reducing the operative morbidity.

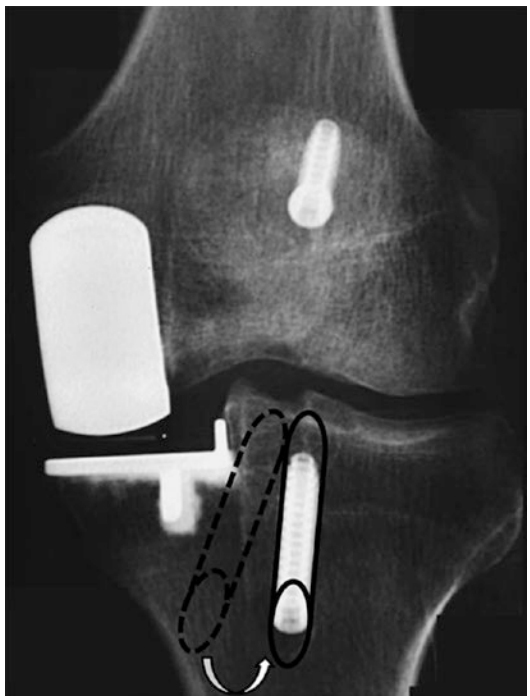

Fig. 12.6 Placement of the tibial tunnel, lateralised and verticalised, when performing simultaneous UKA with ACL reconstruction. (From Mancuso et al. [58])

Case Study

A 55-year-old teacher was referred to clinic with a two-year history of progressive, activity-related, right knee pain nonresponsive to nonsurgical management. His significant past medical history is that of ACL rupture, managed nonoperatively, which he sustained aged 45 playing soccer.

On clinical examination, he has a correctable 5° varus deformity of the right knee. Range of movement in the right knee is from 0° to 115° flexion. Lachman test is positive with no firm endpoint suggesting ACL deficiency.

An anteroposterior standing radiograph demonstrates bone-on-bone arthritis in the medial compartment (Fig. 12.7a), and a true lateral radiograph demonstrates a posterior wear pattern on the tibial plateau (Fig. 12.7b), suggesting ACL deficiency. A skyline radiograph excludes bone loss with grooving to the lateral facet of the patella, which, whilst rare, represents a contraindication to medial UKA (Fig. 12.7c). To assess the lateral compartment and integrity of the MCL, a valgus stress radiograph is performed, which demonstrates full-thickness preserved cartilage in the lateral compartment (Fig. 12.7d).

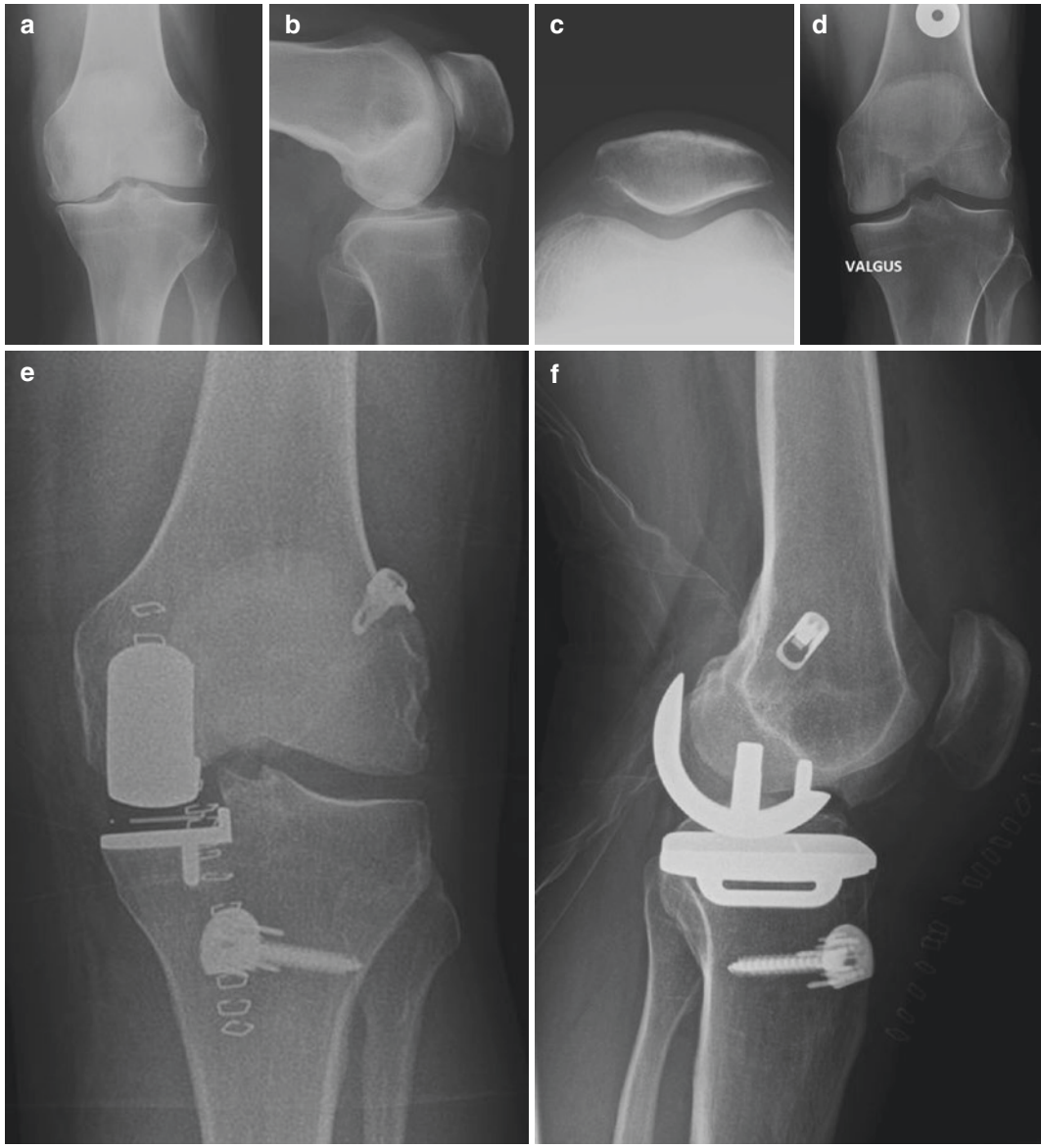

Fig. 12.7 Case Study. (**a**) Standing anteroposterior radiograph demonstrating bone-on-bone arthritis in the medial compartment, (**b**) Lateral radiograph demonstrating a posterior wear pattern, (**c**) Patellar view demonstrating preserved joint space, (**d**) Valgus stress radiograph demonstrating an intact lateral compartment, (**e**) AP postoperative radiograph demonstrating medial UKA with ACL reconstruction, (**f**) Lateral postoperative radiograph demonstrating medial UKA with ACL reconstruction

Based on clinical and radiographic assessment ACL deficiency is suspected. A structured radiographic assessment including valgus stress radiographs confirms suitability for medial UKA based on the pathoanatomy of disease. The decision is made to proceed with mobile-bearing UKA in conjunction with simultaneous ACL reconstruction. Following arthrotomy, ACL deficiency is confirmed and the joint is inspected to confirm suitability for medial UKA. ACL reconstruction is as describe above in the surgical technique using a lateralised and verticalised tibial tunnel placement (Fig. 12.7e, f).

Conclusion

- Around one-third of knees undergoing arthroplasty are ACL deficient.
- Around half of knees with ACL deficiency remain suitable for UKA based on the pathoanatomy of disease.
- The most common reason that ACL-deficient knees are not suitable for UKA is lateral compartment disease.
- A positive Lachman test is strongly associated with ACL deficiency; however, a negative Lachman test may be due to the presence of osteophytes and joint contracture.
- A posterior wear pattern on the true lateral radiograph, which may be associated with posterior femoral subluxation, suggests ACL deficiency.
- The results of UKA alone in ACL-deficient knees are inferior to UKA with ACL reconstruction.
- The results of UKA and concurrent ACL reconstruction in ACL-deficient knees are comparable to outcomes of UKA in the ACL-intact knee.
- While UKA with ACL reconstruction is a technically demanding operation both operations can be performed simultaneously and are associated with a low morbidity.
- When performing UKA with ACL reconstruction, care must be taken to avoid impingement of the graft on the tibial prosthesis and tensioning of the ACL graft, which should be performed after UKA implantation.

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13 Pain Management in Unicompartmental Knee Arthroplasty

Adam C. Young

Clinical Case

A 56-year-old woman presents for evaluation of left knee pain. She reports that her left knee pain has been prevsent for several years, worsening of late, does not radiate, and is a 9/10 on a visual analog scale, worse with ambulation and weight bearing. She has a medical history of obesity, fibromyalgia, depression, and hypertension. Surgical history is remarkable for tonsillectomy and lumbar microdiscectomy. Medications include hydrochlorothiazide 25 mg QD, duloxetine 30 mg QD, naproxen 500 mg BID, and oxycodone 10 mg TID for the past 6 months. Allergies include hydrocodone and iodinated contrast. Social history is negative for substance abuse, and review of systems is unremarkable. Examination is consistent with exquisite pain to palpation over the medial aspect of the left knee. There is no numbness, dysesthesias, or allodynia. Radiographs confirm findings of advanced osteoarthritis of the medial compartment of the left knee. She is consented for left UKA.

- What are the risk factors for this patient having poorly controlled postoperative pain?
- What can be done preoperatively to optimize this patient from a pain perspective?
- What would be an appropriate anesthetic plan?
- How does one successfully manage opioids prescribed after surgery?
- If this patient develops chronic pain, what is the next course of action?

Introduction

Pain remains a limiting factor in recovery from surgery despite numerous advances in surgical and anesthetic techniques. Unicompartmental knee arthroplasty (UKA) requires the development of an optimal pathway to allow patients to mobilize early and with as little pain as possible. In order to obtain long-term success rates, proper patient selection and application of anesthetic and analgesic techniques is prudent. This chapter is intended to enhance the reader's ability to recognize and optimize risk factors for the development of persistent pain after UKA, understand the anesthetic options for UKA, and appreciate the molecular basis of the pharmacologic agents to treat postoperative pain in these patients.

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The Mechanism of Sensing Pain

Our understanding of the pathway of pain transmission has improved over the past 20 years. As a result, our ability to develop and utilize targeted agents for the treatment of acute pain has been enhanced. Pain signal transmission begins in the periphery at the time of surgical incision. Direct damage to tissue results in the liberation of multiple substances including phospholipids from damaged cell walls. They are converted to arachidonic acid by phospholipase A_2, which in turn, is converted to a number of pro-inflammatory mediators, the most clinically significant being prostaglandins (PGs), which are produced by cyclooxygenase-2 (COX-2). Cells lack the ability to store PGs, which results in their immediate release, sensitizing peripheral nociceptors to mechanical and chemical stimuli. In addition, ion channels on these nerves are activated by ATP, which is released from epithelial cells. The combination of ion channel activation and nociceptor sensitization alters the resting membrane potential and influences the likelihood of depolarization and signal transmission along these neurons, primarily Aδ and C fibers. The process of *peripheral sensitization* occurs at this location when nociceptors that have a high threshold for depolarization are activated by the combination of these neurochemical events.

These fibers transmit signals to the spinal column where they enter the spine at a location determined by the dermatome, myotome, or sclerotome responsible that has received the nociceptive signal from the periphery. They synapse with second-order neurons that cross to the contralateral side of the spinal cord and ascend via the spinothalamic tract (STT). At this synapse, an interneuron modulates the ascending signal. Interneurons are part of a network of descending tracts that excrete both excitatory and inhibitory substances at the junction of the primary and secondary afferent neurons in the dorsal horn of the spinal cord. Additionally, this is a site where COX-2 is expressed, again producing the pro-inflammatory PGs, resulting in increased release of neurotransmitters from the primary afferent neurons, interference with glycine receptor (impairing the inhibitory actions of the neurotransmitter), and directly depolarizing the secondary afferent neurons in the STT. It is in the dorsal horn of the spinal cord where repetitive noxious stimulation results in a cumulative increase in signaling, with the end result being hyperalgesia. This process is known as *wind up*. The N-methyl-D-aspartate (NMDA) receptor also has a role at this level. When blocked, the summation of response is blunted and returns to normal.

Neurons of the STT project to higher structures after first synapsing in the thalamus. From there, neurons travel to the sensory cortex, the limbic system, and other subcortical areas. The limbic system connections mediate the autonomic and arousal responses seen with pain stimuli. *Central sensitization* is a state of hyperexcitability within the nociceptive reflexes pathway. Long-term exposure to nociceptive input can result in remodeling of the somatosensory cortex, with expansion of cutaneous receptive fields. Descending pathways from the brainstem are normally in a tonic state of inhibition. The neurotransmitters norepinephrine and serotonin are the main mediators of this signal. The descending pathway applies a signal on the interneurons located in the dorsal horn of the spinal cord. When there is release from this state of inhibition, there is, in turn, a state of excitability that leads to further ascending nociceptive signaling. The ability of this complex, interconnected signaling pathway to dramatically increase nociceptive activity should not be underestimated. This is clinically reflected by the variability between individual patient's pain perceptions even if undergoing the same surgical procedure.

Identifying Preoperative Risk Factors

Along with a greater understanding of the pathway of pain transmission, we are beginning to understand some of the characteristics that increase the risk for poorly controlled postoperative pain. A comprehensive review of these risk factors in the setting of total knee arthroplasty

(TKA) has yielded several significant outcomes: higher levels of catastrophizing, higher levels of preoperative pain, greater number of pain sites, depression and/or anxiety, and poorer levels of preoperative function. The strongest predictors are catastrophizing and presence of pain at sites other than the knee.

Catastrophizing has been described as the tendency to misinterpret and exaggerate situations that may be threatening. With regard to pain, the same aberrant response manifests with an exaggerated negative perception to a painful stimulus. At the time that it was first introduced as a concept, Sullivan and colleagues provided a questionnaire (see Fig. 13.1) that aids the physician in the diagnosis of catastrophizing. Higher scores equate to greater risk for persistent postoperative pain. It has been reported that a score above 30 equates to the 75th percentile in a group of injured workers; of these workers, 70% considered themselves disabled. It should be noted that the questionnaire can be divided into three domains: rumination, magnification, and helplessness. Previous studies regarding chronic pain following TKA have shown the rumination items (8, 9, 10, 11, highlighted in yellow in Fig. 13.1) to be the most predictive of persistent pain at 2 years. Patients with a score of 3.3 ± 2.1 on these items had no pain versus those with a score of 5.6 ± 3.7 experi-

	Not at All	To a Slight Degree	To a Moderate Degree	To a Great Degree	All the Time
I worry all the time about whether the pain will end	0	1	2	3	4
I feel I can't go on	0	1	2	3	4
It's terrible and I think it's never going to get any better	0	1	2	3	4
It's awful and I feel that it overwhelms me	0	1	2	3	4
I feel I can't stand it anymore	0	1	2	3	4
I become afraid that the pain will get worse	0	1	2	3	4
I keep thinking of other painful events	0	1	2	3	4
I anxiously want the pain to go away	0	1	2	3	4
I can't seem to keep it out of my mind	0	1	2	3	4
I keep thinking about how much it hurts	0	1	2	3	4
I keep thinking about how badly I want the pain to stop	0	1	2	3	4
There's nothing I can do to reduce the intensity of the pain	0	1	2	3	4
I wonder whether something serious may happen	0	1	2	3	4

Fig. 13.1 Pain catastrophizing questionnaire. (From Sullivan et al. [6])

enced chronic postoperative pain. Knowing this is helpful but more important is how to modify this risk factor. In the absence of intervention, catastrophizing remains stable. However, participation in targeted psychological therapy, such as cognitive behavioral therapy, has been shown to reduce scores associated with catastrophic thinking. Depression and anxiety will not be discussed in this section, but it should be noted that many symptoms of these illnesses overlap with items in the catastrophizing questionnaire.

Knee pain is the most common reason patients consider knee joint replacement. Reviewing the risk factors mentioned above, one could extrapolate that increased pain scores and pain at sites other than the knee may be seen as indicators that some degree of sensitization (peripheral and/or central) has occurred. Taking this into account, many patients presenting for evaluation for arthroplasty will be on some form of oral analgesics. While the use of acetaminophen and nonsteroidal anti-inflammatory drugs (NSAIDs) prior to surgery appears safe, the use of opioids prior to surgery has been correlated with worse patient-reported outcomes, including pain scores. Long-term use of opioids leads to the development of a phenomenon referred to as *opioid-induced hyperalgesia (OIH)*. OIH is an under-recognized state of nociceptor sensitization that results in a paradoxical response to opioid analgesics – escalating doses of opioids leads to more pain. The exact mechanism of this process is unknown. It is important to recognize and take into consideration that these patients, reporting significantly higher pain scores prior to surgery, are unlikely to achieve satisfactory pain relief following surgery. Determining the proper timing of operating on a patient with multiple risk factors requires careful consideration of the risk–benefit ratio. While surgical correction is the ultimate therapy in these settings, it should be noted that there are additional methods of reducing knee pain prior to arthroplasty to consider. These include physical therapy (PT), viscosupplementation, intra-articular steroids, and genicular nerve radiofrequency denervation.

Clinical Case Questions

- **What are the risk factors for this patient having poorly controlled postoperative pain?**
  - This patient has a high preoperative pain score (9/10), pain at multiple other sites (fibromyalgia), may have maladaptive thought processes (given history of depression), and is on preoperative opioids.
- **What can be done preoperatively to optimize this patient from a pain perspective?**
  - It would be prudent to administer a pain catastrophizing questionnaire. If she does score high, it would be worthwhile to address her fears associated with surgery and pain. It may be necessary to obtain the help of a mental health provider to administer cognitive behavioral therapy or graded exposure therapy. Her fibromyalgia pain symptoms should be under reasonable control and stable prior to proceeding with surgery. Lastly, it is ideal to wean opioids prior to surgery. To help facilitate this, one could perform an intra-articular steroid injection and she should be instructed to follow up with the prescriber of her opioids to have them weaned to the lowest dose possible.

Consequences of Poorly Controlled Postoperative Pain

Identifying and addressing risk factors for poorly controlled acute postoperative pain is essential in optimizing outcomes following UKA. The specter of poor postoperative pain control has many aspects: chronic pain, impaired function, delayed recovery from surgery, reduced quality of life, prolonged opioid use, and increased medical costs. Acute postoperative pain can affect other organ systems including cardiovascular (myocardial infarction), pulmonary (splinting, atelectasis, and pneumonia), gastrointestinal (nausea, vomiting, reduced motility, and ileus), and renal (urinary retention), leading to additional morbidity. Chronic pain also leads to impairments in sleep and mood, worsening preexisting anxiety or depression.

Chronic pain is the presence of pain beyond 3 months following the inciting event. Incidence of chronic pain across the spectrum of surgical procedures varies depending on the surgery in question. Although the incidence of chronic pain following UKA is unknown, the rate of chronic pain following TKA has been estimated as high as 20%. These patients are often unable to participate fully in PT, leading to poor functional outcomes.

Anesthesia for UKA and Techniques for Postoperative Pain Control

Anesthesia for UKA should routinely involve regional anesthesia techniques. This comes in many forms, each of which has pros and cons, which will be discussed in this section.

Neuraxial Blocks

Neuraxial blocks refer to the administration of local anesthetics that occur at sites within the spinal column. The two locations for blocks are the epidural space (between ligamentum flavum and dura mater) and the subarachnoid (also known as spinal) space. Administration of local anesthetics in the epidural space results in a slow-developing anesthetic. The dose required to achieve an adequate level of anesthesia is larger (compared to a subarachnoid block). A subarachnoid block results in rapid onset of an anesthetic, with a more complete motor blockade and faster developing hemodynamic effects compared to an epidural block. Neuraxial blocks can be a single dose (a.k.a. single shot) or continuous (via a temporarily-placed catheter). Adverse effects of neuraxial blocks are uncommon but can include pain at the site of injection, headache, bleeding, infection, and nerve damage. A review of more than 100,000 neuraxial anesthetics for total joint arthroplasty demonstrated no serious injuries from single-shot spinal anesthetics. Epidural hematomas were rare when an epidural catheter was placed, occurring at a rate of 1:7857; in these patients, there were several factors that contributed to the development of a hematoma, including altered coagulation parameters and use of antiplatelet/anticoagulant medications. The American Society of Regional Anesthesia (ASRA) has provided guidelines to minimize the risk of bleeding during neuraxial blocks and was not necessarily followed for these specific cases. Aside from adverse effects, there are many expected side effects from neuraxial blocks, which are related to the site of blockade and the pharmacological agent injected. Injection of local anesthetics results in reduced blood pressure, lower extremity numbness, lower extremity weakness, and urinary retention. All of these effects are limited, and their duration is directly related to the dose and specific local anesthetic administered. For example, spinal bupivacaine, administered in doses of up to 10 mg, generally produces these effects for up to 2–3 hours. Other medications used for neuraxial blocks include opioids and clonidine. Both of these can provide additional analgesia when local anesthetics alone fail to provide adequate pain relief; they augment the effects of local anesthetics but cannot be used alone for surgical anesthesia. The potential for prolonged weakness is something to take into account when choosing the dose of a spinal anesthetic and the setting in which the UKA is being performed (hospital versus ambulatory surgery center) and planned postoperative disposition. Of note, the benefits of neuraxial blocks far outweigh the use of general anesthesia; despite the potential for delayed weakness, patients receiving neuraxial blocks have fewer postoperative falls after knee replacement. The benefits of neuraxial blocks do not end there. Compared to general anesthesia, neuraxial blocks for knee arthroplasty reduce the incidence of 30-day mortality and morbidity such as pneumonia, pulmonary embolism, renal failure, and respiratory failure. There are also lower rates of blood loss, rates of blood transfusions, and surgical site infections.

Peripheral Nerve Blocks

Among the many ways of controlling postoperative pain, there are a variety of peripheral nerve

blocks. Depending on the dose and specific local anesthetic injected, these blocks can provide extended analgesia that allows patients to mobilize early and achieve early discharge following surgery. Targeting the correct nerves is critical, as a preference for sensory nerves is prioritized in order to prevent weakness associated with mixed motor/sensory nerves. The femoral, saphenous, sciatic, obturator, and lateral femoral cutaneous nerve blocks have all been studied for their use in providing analgesia knee arthroplasty. I should caution the reader that the evidence that supports use of these blocks is in *total* knee arthroplasty. However, the techniques described can be generalized to apply to the UKA patient.

Common approaches to UKA include mid-vastus and medial parapatellar. With these approaches, pain is transmitted along the saphenous nerve (infrapatellar branch), medial vastus muscle nerve (terminal branch), and femoral cutaneous nerve (anterior branch). Within the joint itself, distal elements from the obturator and tibial nerves combine to form the popliteal nerve plexus. This plexus innervates the menisci, perimeniscular joint capsule, posterior knee capsule, cruciate ligaments, and infrapatellar fat pad.

In the past 5 years, blockade of the saphenous nerve within the adductor canal of the thigh (AC block) has become an effective modality for both surgeons and anesthesiologists in aiding early ambulation and providing excellent analgesia. Given the ease with which the block can be performed with the low likelihood of motor blockade, the AC block has largely replaced the femoral nerve block in clinical practice. The adductor canal is an anatomical space in the thigh that is bordered by the sartorius muscle (superiorly), vastus medialis muscle (medially), and adductor longus/magnus muscles (medially). Within this musculoaponeurotic canal, the saphenous nerve travels with the superficial femoral artery and vein distally toward the adductor hiatus on the medial aspect of the lower thigh. An ideal location of the block has been postulated, and many authors agree that the medial thigh (approximately halfway between the anterior superior iliac spine and base of the patella) is that location. At this site, one can block the saphenous nerve only. Despite the close proximity of the medial vastus muscle nerve, it travels within a separate aponeurotic sheath and cannot be anesthetized simultaneously with an AC block. Ultrasound guidance facilitates recognition of the critical structure involved with an AC block, making it not only effective but also easily accomplished. A recent meta-analysis concluded that compared with femoral nerve blocks, AC blocks have been proven to preserve quadriceps strength without compromising analgesia. Small volumes are often effective and preferred. The borders of the adductor canal are dense, and higher injection volumes are associated with spread to less desirable sites. Proximal spread will lead to blockade of the femoral nerve, including the motor components, causing quadriceps weakness. Similarly, posterior spread of adductor canal injectate has been described, causing blockade of the sciatic nerve leading to foot drop.

The obturator nerve has historically been associated with variable success, as landmark-based techniques often lead to inaccurate sites of local anesthetic injection. However, with the routine use of ultrasound guidance, one can more reliably identify the intermuscular plane between the pectineus and external obturator muscles along the medial aspect of the inguinal ligament. A small volume of injection is all that is necessary to accomplish the block and avoid spread to adjacent neurological structures. Alone, an obturator nerve block (ONB) would not provide adequate analgesia following UKA. However, a recent randomized, controlled trial comparing the combination of ONB plus AC block to AC block alone resulted in superior pain relief in the combination group. The superior analgesia was offset by adductor weakness, the clinical significance of which is unknown, as the study did not document postoperative falls or time to discharge as endpoints.

The sciatic nerve divisions contain fibers that innervate the posterior aspect of the knee. There have been many studies in TKA patients comparing the addition of a sciatic nerve block (SNB) to femoral nerve block. A meta-analysis investigating the efficacy of such a combination of blocks has shown that the combination of blocks has

the ability to reduce pain early (12 and 24 hours) after surgery. The all-important question of promoting lower extremity weakness by performing SNB for these patients has unfortunately not been answered. In the published studies, there are no quantitative measures of dorsiflexion and plantar flexion strength, incidence of falls, and time to meet discharge criteria.

Given the need to address the posterior innervation of the central elements of the knee, many surgeons have made it routine practice to perform a periarticular injection (PAI) of local anesthetic alone or in combination with epinephrine, non-steroidal anti-inflammatory drugs (NSAIDs) and, in some cases, opioids. PAI is relatively safe, simple, and quick, as it is performed by the surgeon intraoperatively prior to closure. The use of PAI has been shown in some randomized, controlled trials to have similar analgesia to peripheral nerve blocks (femoral plus SNB) without the drawbacks of weakness that would impair early ambulation. These results are encouraging, but work remains to identify the ideal combination of local and regional anesthesia for these patients. There have not been investigations on blocks that avoid weakness (i.e., AC blocks) in combination with PAI that might accomplish superior analgesia and maintain motor strength allowing for early mobilization and expedited discharge. Another important aspect of PAI is what a surgeon injects – local anesthetics have been studied to a small degree and we do know that ropivacaine and bupivacaine have equianalgesic effects compared to liposomal bupivacaine.

Although rare, complications associated with nerve blocks include the possibility of nerve damage, bleeding, local anesthetic systemic toxicity (LAST), local anesthetic myotoxicity, and infection. The rate of long-term nerve damage following a peripheral nerve block has been estimated at 2–4 per 10,000 blocks. Unfortunately, the widespread adoption of ultrasound guidance has not altered this number, as incidence has remained stable over the past two decades. Bleeding at the site of injection remains rare; utilizing the ASRA guidelines for regional anesthesia has aided in minimizing this morbidity. LAST occurs when the injected local anesthetic solution reaches circulation via intravascular uptake or direct injection. This can result in seizures, arrhythmias, and cardiovascular collapse. In patients undergoing TKA, a meta-analysis concluded that LAST occurs at a rate of 0.68% with an overall decreasing trend. Treatment has been well described and involves administration of lipid emulsion. Local anesthetic myotoxicity is a complication of peripheral nerve blocks that has long been known, but for the sake of patients undergoing knee surgery, it was previously inconsequential. Myotoxicity manifests as necrosis of skeletal muscle with associated profound weakness. Although previously described with retrobulbar blocks, the problem seems to have resurfaced with the widespread adoption of the AC block. There are now multiple case reports of local anesthetic-induced myotoxicity following AC blocks in patients undergoing knee surgery. It is not completely understood why this block is associated with myotoxicity, but one should note the local anesthetic chosen for the block does have importance. In order of increasing toxicity, lidocaine, ropivacaine, and bupivacaine (including liposomal or microsphere formulations) have all been associated with myotoxicity. Higher concentrations and longer duration of exposure (i.e., continuous infusion) also correlate with this phenomenon. Recovery is possible but can take up to one year and aggressive physical therapy to achieve.

Clinical Case Question

- **What would be an appropriate anesthetic plan?**
  - This patient is an appropriate candidate for neuraxial anesthesia in the form of a single-shot spinal block with 10 mg isobaric bupivacaine. She is not on anticoagulants, and her prior spine surgery does not preclude this anesthetic approach. Prior to the spinal anesthetic, she should be given a single-shot AC block with 20 mL 0.5% ropivacaine with epinephrine 1:200,000 to provide for extended analgesia after her spinal anesthetic wears off (Table 13.1).

Table 13.1 Example of anesthetic plan for unicompartmental knee arthroplasty

	Preoperative (holding area)	Intraoperative (OR)	Postoperative (recovery room)
Medications	Pregabalin 100 mg PO Acetaminophen 1000 mg PO Celecoxib 400 mg PO	Dexamethasone 0.1 mg/kg IV (up to 10 mg) Ketamine 0.5 mg/kg IV (via bolus or divided doses) Ketorolac 15 mg IV Ondansetron 4 mg IV IV fluids titrated per hemodynamics Propofol infusion titrated for patient comfort	Oxycodone 5 mg every 4–6 hrs PRN
Regional anesthesia	Single-shot adductor canal block (20 mL 0.5% ropivacaine with epinephrine 1:200,000) Single-shot spinal anesthetic (10 mg isobaric 0.5% bupivacaine)		

Perioperative Medications Management of Acute Pain Following UKA

Medical management of acute pain is best accomplished by employing multimodal analgesia (MMA). MMA has been proven to provide superior analgesia and patient satisfaction compared to single-agent strategies. MMA is the method of combining analgesic medications with differing mechanisms of action with the intention of obtaining an additive or synergistic effect. While opioids are not excluded from this strategy, the addition of nonopioid medications (adjuvants) permits the use of lower dose necessary of opioids. These adjuvant medications enhance analgesia and minimize potential adverse effects.

Acetaminophen and Nonsteroidal Anti-Inflammatory Drugs (NSAIDs)

Although the exact mechanism by which acetaminophen produces its analgesic effect is unknown, it has been postulated that it inhibits central prostaglandin synthesis. Despite a likely similar mechanism of action, acetaminophen differs from traditional NSAIDs in that it has a relatively weak anti-inflammatory effect in the periphery, inhibits COX poorly at surgical sites, and has no effect on platelet function or the gastric mucosa. Systematic reviews have demonstrated that acetaminophen has similar effects in reducing postoperative pain after orthopedic procedures compared to traditional NSAIDs. But more importantly, the combination has demonstrated a synergistic effect.

Acetaminophen has gained popularity in the perioperative setting, as an intravenous (IV) formulation has become available. The major difference between IV and oral acetaminophen is that IV acetaminophen has a faster time to peak effect and higher peak serum and CSF concentrations. However, a superior clinical outcome with the use of the IV formulation has not been demonstrated at this time. The dramatic difference in cost may favor the use of the oral formulation. Oral acetaminophen has been used successfully in outpatients for acute pain. Of note, it is quite common for acetaminophen to be used in combination with short-acting opioids (e.g., hydrocodone/acetaminophen, oxycodone/acetaminophen), headache medications (e.g., aspirin/caffeine/acetaminophen), and common cold medications (dextromethorphan/phenylephrine/acetaminophen). There have been recommendations of a maximum daily dose to 3000 mg per day. A proposed dosing scheduled of 1000 mg every 8 hours appears safe as long as patients are not consuming acetaminophen from another source. The choice of 1000 mg does have signifi-

cance; compared to 650 mg, the 1000 mg dose confers superior analgesia.

Contraindications for acetaminophen include active liver disease or known allergy. Like NSAIDs, there is no need to taper or wean acetaminophen; it can be stopped abruptly without concerns of withdrawal.

NSAIDs are a very common analgesic medication and have a significant role in the perioperative setting. Surgical damage of tissue leads to the production of prostaglandins by the cyclooxygenase-2 (COX-2) enzyme. As mentioned previously, prostaglandins are important chemicals that initiate peripheral sensitization. NSAIDs acetylate the COX-2 enzyme and reduce prostaglandin formation and attenuate the hyperalgesic response.

Use of COX-2 inhibitors in the perioperative period has consistently demonstrated reduced postoperative opioid consumption, lower pain scores, and improved range of motion following total joint replacement. It is ideal to continue a COX-2 inhibitor after major surgery for a period of at least 2 weeks, as this timeframe coincides with the duration of the post-surgical inflammatory process. It is ideal to administer NSAIDs prior to surgery in order to obtain an effective blood level of the drug. A common practice is administering celecoxib 400 mg preoperatively on the day of surgery, followed by 200 mg every 12 hours postoperatively for a duration of 2 weeks. Alternatively, one could use one of many other NSAIDs. But it should be noted that the inhibition of COX-2 differs between individual NSAIDs. Meloxicam and celecoxib are on one end of the spectrum with the most COX-2 selectivity, while ketorolac and aspirin are the opposite (with a strong preference for COX-1).

It would be reasonable to continue both acetaminophen and NSAIDs until physical therapy has been completed. Like acetaminophen, celecoxib and other NSAIDs do not need to be weaned or tapered; they may be stopped without concern of precipitating withdrawal.

NSAIDs have demonstrated no increase in major bleeding events following TKA. Therefore, it is considered to be safe for patients on anticoagulation for deep venous thrombosis prophylaxis to continue NSAIDs. Contraindications to specific NSAIDs include allergy to aspirin and other NSAIDs as well as to sulfonamides. Avoid NSAIDs in patients with renal insufficiency or renal failure, and in patients older than 70 years, the dose should be reduced by half.

Neuropathic Medications (Anticonvulsants)

The anticonvulsant class of medications includes both gabapentin and pregabalin. These medications have been shown to be effective in treating acute postoperative pain. Both medications exert their effects by binding to and modulating $\alpha_2\delta$ voltage-dependent calcium channels. The end result is thought to be an inhibition of calcium influx via these channels, subsequently inhibiting the release of excitatory neurotransmitters. Additionally, these receptors may play an important role in the development of chronic pain; presynaptic voltage-gated calcium channels are upregulated in the dorsal root ganglion (DRG) playing a role in *wind up* following surgery; as mentioned previously, this is one of the processes by which chronic pain develops. In fact, animal models demonstrate the ability of pregabalin to reduce postoperative hyperalgesia.

The major advantages of pregabalin over gabapentin are greater bioavailability, increased lipid solubility (improving diffusion across the blood–brain barrier), and fewer drug interactions (due to absence of hepatic metabolism). The combined result is a more potent medication; pregabalin achieves efficacy at lower doses. The difference in bioavailability cannot be stressed enough. Gabapentin requires active transport across the gastrointestinal mucosa; doses of gabapentin 300 mg three times per day have approximately 60% oral bioavailability, whereas pregabalin has ≥90% oral bioavailability. Increasing doses of gabapentin do not necessarily translate to improved bioavailability; 1200 mg, 2400 mg, and 3600 mg dosages (divided three times per day) have 47%, 34%, and 33% bioavailability, respectively. It should come as no surprise that esca-

lating doses of gabapentin does not necessarily result in improved analgesia.

Perioperative use of pregabalin can decrease the incidence of chronic pain after TKA. Preoperatively, patients should be given a single dose of 100–150 mg pregabalin followed by 50–75 mg every 8–12 hours for 2 weeks postoperatively to achieve this. Studies of perioperative gabapentin use have been more heterogeneous, and there has been a lack of uniformity in dosing. Lack of clinical efficacy in the perioperative period is in all likelihood due to the aforementioned limitations of variable bioavailability and blood levels of the drug. Anticonvulsants may be continued, if the patient experiences continued pain following UKA. Contraindications for anticonvulsants include allergy to the compound itself or other medications in the same class. Doses should be reduced in patients with reduced renal function and in the elderly. Caution is advised when prescribing anticonvulsants to patients with mental illness, as these drugs have the potential to alter mood, worsening symptoms of depression.

Both gabapentin and pregabalin should be weaned, as abrupt cessation can lead to central nervous system hyperexcitability, causing irritability, restlessness, anxiety, and seizures. For example, a patient taking pregabalin 50 mg three times per day would reduce their dose to 50 mg twice per day, then to 50 mg once daily prior to stopping the drug altogether. That said, with such low doses of these drugs given for limited amounts of time, symptoms of withdrawal are unlikely to manifest.

Glucocorticoids

Administration of steroids in the perioperative period can modulate peripheral inflammatory pathways. As a component of MMA, steroids have been shown to reduce acute pain. Timing of administration appears to be most effective if steroids are administered prior to the surgical stimulus. While optimal doses have been debated, some have obtained a beneficial effect by administering dexamethasone 16 mg IV; one half of the dose has had mixed results. A recent meta-analysis has addressed this question and confirmed that a single dose of 10 mg dexamethasone IV prior to surgical incision will result in a reduction in acute pain for up to 48 hours without any adverse effects in patients undergoing TKA. The safety profile of a single dose of corticosteroids has been established by prior reviews and should reassure providers hesitant to administer steroids to a surgical patient. Caution is advised in diabetic patients, as steroids will certainly cause elevations in blood glucose.

Ketamine

Ketamine is a noncompetitive NMDA receptor antagonist. As mentioned previously, the NMDA receptor has an important role in the transmission of pain and the *wind up* process. As part of a multimodal regimen, ketamine has been shown to decrease opioid consumption and lower pain scores following surgery. This finding is part of a growing body of evidence that low-dose ketamine may play an important role when used as an adjunct to opioids, local anesthetics, and other analgesic agents.

One of the more impressive abilities of ketamine is its ability to reduce the incidence of chronic pain in patients undergoing a variety of procedures; a single dose of ketamine 0–0.5 mg/kg followed by an intraoperative and postoperative infusion of 0.7–4.2 mcg/kg/min was able to demonstrate fewer cases of persistent postsurgical pain at 6 months postoperatively in these cases. A meta-analysis of these data supported not only a pre-incisional bolus and intraoperative infusion but also an infusion for up to 24 hours. In a study of opioid-experienced patients undergoing spine surgery, ketamine at a dose of 0.5 mg/kg bolus followed by an intraoperative ketamine infusion of 10 mcg/kg/min resulted in reduced pain scores at 6 weeks. This is truly an impressive result, as the opioid-experienced patient often presents a challenge to both surgeons and anesthesiologists.

Side effects of ketamine are expected at doses ≥2 mg/kg, leading to psychomimetic effects that include hallucinations, nightmares, cogni-

tive dysfunction, or excessive sedation. Low-dose ketamine (<1 mg/kg total dose) appears to be associated with less adverse effects and may allow physicians to harness the benefits of perioperative ketamine without provoking its unwanted adverse effects.

Opioids

Opioid receptors are found at multiple sites within the central nervous system. Activation of the opioid receptors results in the reduction of excitatory neurotransmitter release from the presynaptic membrane secondary to the inhibition of voltage-gated calcium channels. Although use of opioids has been commonplace for postoperative pain management, the development of fast track and enhanced recovery protocols seeks to minimize their use.

Opioids come in two formulations, long-acting and short-acting versions. This is important to note as pharmacodynamics vary between the two and have the potential for causing respiratory depression and death. Short-acting opioids are the most commonly prescribed type of opioid for pain following UKA. Examples include tramadol and the combinations hydrocodone/acetaminophen and oxycodone/acetaminophen. One of the drawbacks to using combination products is the addition of acetaminophen to the opioid, which impacts the total daily dose of acetaminophen consumed. Only oxycodone comes in an immediate-release version without acetaminophen. Patients can be prescribed oxycodone immediate-release 5 mg or 10 mg every 4–6 hours on an as-needed basis for breakthrough pain. Patients should be encouraged to take this medication 1 hour prior to physical therapy. One hour seems an ample amount of time to allow patients to reach an effective blood level of the drug at the time of therapy. Short courses of opioids should be prescribed, and physicians should consult their state's prescription monitoring database to assure the patient has not received additional controlled substances that would put them at risk of over-sedation, respiratory depression, and death. Additionally, a prescriber should detail the patient's past experience with opioids including history of abuse or addiction. The potential for a recovering addict to relapse with a short course of postoperative opioids is real and can have devastating consequences. If concerned, a surgeon should consult a pain physician and possibly a psychiatrist preoperatively for assistance in managing the patient's acute postoperative pain and addiction.

Weaning opioids should be done in a systematic manner to avoid possible withdrawal. Short-acting opioids are prescribed to be taken on an intermittent, or "as-needed," basis. This requires the patient to consume the medication only when they have pain or prior to an activity that is anticipated to produce significant pain (i.e., physical therapy). After 2 weeks, weaning can begin on an individual basis. During the acute and subacute phases of postsurgical pain, patients should be weaned to the lowest effective dose of short-acting opioids. This means that patients are taking the lowest cumulative dose of opioids per day as is necessary to participate in physical therapy and to perform the same activities of daily living they were prior to surgery.

Withdrawal from opioids is an uncomfortable experience that occurs with abrupt cessation of opioids in patients consuming high doses or in cases of prolonged use. Early opioid withdrawal symptoms include agitation, anxiety, myalgias, insomnia, rhinorrhea, or diaphoresis. The symptoms of withdrawal can continue for weeks, although this is uncommon with opioid use for acute postoperative pain. Late symptoms include nausea, vomiting, abdominal pain, diarrhea, mydriasis, hypertension, tachycardia, and formication. Oral and transdermal clonidine have been used to combat the early effects of withdrawal, as it provides anxiolysis and blunts the increase in sympathetic activity; antidiarrheal and antinausea agents are often prescribed for patient comfort.

Metabolism of opioids is carried out in the liver. Opioids are converted to water-soluble metabolites, many of which remain biologically active, which are excreted by the kidneys. Any degree of renal insufficiency results in the accumulation of these metabolites and their unwanted effects such as myoclonus, respiratory depres-

sion, and seizures. Caution should also be exercised in patients with a history of obesity and obstructive sleep apnea (OSA).

The opioid epidemic has garnered much deserved attention. The scrutiny over prescribing of postoperative opioids should not come as a surprise. The Centers for Disease Control and Prevention recommend doses of no more than 50 mg morphine equivalent dose for acute postoperative pain. This statement should be taken with a grain of salt; the statement does not offer suggestions based on the surgical procedure performed or based on individual characteristics. It is prudent for the prescriber to take this into account, along with the known risk factors associated with adverse effects (including death) from opioids. These include concurrent use of benzodiazepines, marijuana, tobacco, alcohol, presence of psychiatric disorder (depression/anxiety), coronary artery disease, arrhythmia, history of substance abuse or aberrant medication taking behaviors, or impulse control problems (Table 13.2).

Table 13.2 Example of postoperative oral pain regimen following unicompartmental knee arthroplasty

Drug	AM	PM	QHS	AM	PM	QHS
	Day of surgery			**POD 1–8**		
Oxycodone IR 5–10 mg	PRN every 4–6 hours			PRN every 4–6 hours		
Acetaminophen 1000 mg		X	X	X	X	X
Celecoxib 200 mg	XX* (2 tabs)			X	X	
Pregabalin 50 mg	XX* (3 tabs)			X	X	X
	POD 9			**POD 10–13**		
Oxycodone IR 5–10 mg	PRN every 6 hours			PRN every 6 hours		
Acetaminophen 1000 mg	X	X	X	X	X	X
Celecoxib 200 mg	X	X		X	X	
Pregabalin 50 mg	X	X	X	X	X	X
	POD 14			**2–6 weeks postoperative**		
Oxycodone IR 5 mg	PRN every 8 hours			PRN QD with PT		
Acetaminophen 1000 mg	X	X	X	TID PRN		
Celecoxib 200 mg	X			Daily PRN		
Pregabalin 50 mg	X	X	X (stop on POD 15)			

*should be given preoperatively

Clinical Case Question

- **How does one successfully manage opioids prescribed after surgery?**
  - A prescription for opioids should begin with an agreement between patient and prescriber. At minimum, a verbal discussion of the risks and benefits of the drugs should take place; some practices utilize a formal document that is signed by both physician and patient. This document describes how the physician intends the medication to be used with warnings about the misuse and abuse of the drugs. It also sets expectations for the patient, knowing that opioids will not be continued if they fail to provide a meaningful benefit. A urine drug screen can be taken, with the intention to screen for unreported substances that could increase the risk for respiratory depression. Prior to writing a prescription for opioids, a physician should inspect their local controlled substance monitoring database. The database will offer insight as to what controlled substances the patient is receiving, from whom, and what dose/quantity. This will allow the surgeon to make an informed decision when providing any postoperative opioids. As stated above, the lowest effective dose of opioids should be utilized. This will likely vary from patient to patient; regular re-evaluations are necessary to ensure efficacy and allow for discussions of reducing postoperative opioids and potential barriers to weaning.

Postoperative Considerations

A successful UKA is one that ends with the restoration of function and reduction of pain. For many patients, this is in fact the case. For the unfortu-

nate few, with ongoing pain and failure to achieve adequate range of motion, further intervention is often needed. Aggressive and early intervention, in the form of medical management and physical therapy, can be helpful. The same can be said for knee manipulation. Without satisfactory management of pain symptoms, a full recovery may not be possible. Involvement of a pain specialist gives the opportunity for evaluation of a sympathetically-mediated processes, optimization of a medical regimen, and discussion for interventional therapies that may improve the outcome.

Unicompartmental knee osteoarthritis is a common problem with a proven and reliable treatment in the form of UKA. An understanding of the anatomical basis of pain and the pharmacologic agents used as part of MMA protocols to interrupt these pain pathways will assist the surgeon in creating a successful, expedited recovery for their patients. Anesthesia for UKA can be equally important in reducing morbidity and allowing for rapid recovery. Communication with the anesthesiology team is essential; a strong working relationship between anesthesiologist and surgeon can go a long way in producing a happy, functional patient following UKA.

Clinical Case Question

- **If this patient develops chronic pain, what is the next course of action?**
  - The presence of pain beyond 3 months following surgery is known as chronic pain. These patients require evaluation with a pain physician. Early referral is recommended.

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14 Blood Preservation Strategies in Total Knee and Unicompartmental Knee Arthroplasty

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Introduction

Total knee arthroplasties (TKA) are associated with significant blood loss, ranging up to 1.8 liters in some series [1–5]. This large degree of visible and hidden blood loss can result in various adverse effects including the development of symptomatic anemia requiring blood transfusion in up to 38% of patients [6–9]. Patients undergoing unicompartmental knee arthroplasty (UKA), however, have been shown to have decreased total blood loss and decreased risk of developing symptomatic anemia [10, 11]. This has been attributed primarily to smaller surgical exposures, minimal bony cuts, and the lack of need to access long bone intramedullary canals [11]. Despite these unique advantages, the incidence of postoperative blood transfusion occurs in up to 0.5% of patients undergoing UKA [12].

Current practice trends suggest a steady increase in the use of blood products in the health care system, increasing up to 6% per year [13]. This has resulted in multiple shortages of blood products and has increased the cost of both acquisition and use. Moreover, multiple studies have now demonstrated the potential adverse effects associated with the overuse of autologous and allogeneic blood transfusions including higher rates of postoperative infection, slower physical recovery, increased length of hospital stay, and increased morbidity and mortality [14]. As a result, the deployment of a patient blood management (PBM) protocol can potentially help mitigate these adverse effects and allow for appropriate use of patient, hospital, and healthcare system resources, thereby allowing for minimization of the consequences of postoperative blood loss anemia while also optimizing the patient's recovery process [13].

PBM has been defined as the "timely application of evidence-based medical and surgical concepts designed to maintain hemoglobin concentration, optimize hemostasis, and minimize blood loss, in an effort to improve patient outcome." [15] In this chapter, we present a concise overview of the preoperative, intraoperative, and postoperative blood preservation strategies available to patients undergoing elective total joint arthroplasty.

Preoperative Strategies

The influence of preoperative hemoglobin on the need for perioperative transfusion has been well established in the arthroplasty literature [16,

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17]. In one study, very few patients with preoperative hemoglobin levels greater than 15.0 g/dL required allogenic blood transfusion, whereas, patients with preoperative hemoglobin levels less than 13.0 g/dL were at 15.3 times greater risk to need a blood transfusion than those with a preoperative hemoglobin levels greater than 15.0 g/dL [17]. Similarly, other patient characteristics, including weight, age greater than 75 years, male gender, hypertension, and body mass index (BMI) less than 27 kg/m^2, have also been associated with increased risk of postoperative transfusion [6, 17]. These risk factors have been proposed to impart a synergistic increase in the risk of transfusion, when more than one risk factor is present [18]. As such, efforts targeted at preoperative optimization of these risk factors are integral in decreasing perioperative transfusion risk. Thus, in patients with multiple risk factors, all modifiable characteristics should be targeted for optimization in the preoperative period.

Subsequently, multiple guidelines have advocated for a detailed medical evaluation at least 3 weeks prior to an elective arthroplasty procedure in order to allow for sufficient time for the effects of any optimization intervention [13, 19, 20]. In general, preoperative optimization strategies have included iron, folate, vitamin B12 supplementation, erythropoietin (EPO), and preoperative autologous blood donation (PAD).

Erythropoietin

EPO is a glycoprotein that is normally produced in the kidneys in response to decreased oxygen tension. The latter typically occurs in various pathophysiological states including anemia or in the setting of pulmonary diseases (i.e., COPD). EPO functions by increasing the rate of red blood cell (RBC) maturation and differentiation in the bone marrow and thus functions to increase overall RBC mass. Commercially, EPO is available in the recombinant form and has been widely used in patients with anemia of chronic disease. In arthroplasty, EPO has been used either alone preoperatively, in conjunction with PAD preoperatively, or postoperatively [21]. Multiple different dosing strategies are available [22], but the use of preoperative EPO has been shown to be most effective in scenarios where large blood losses are expected [16].

Vitamin Supplementation

Multiple vitamins including folate, vitamin B12, and iron are integral to the production of RBCs. Deficiencies in these macronutrients have been associated with various macrocytic and microcytic anemias, respectively. As previously noted, multiple guidelines now suggest formal evaluation for the cause of anemia in patients scheduled to undergo elective arthroplasty. Preoperative supplementation with iron, vitamin C, and folate for 30–45 days before surgery has been associated with lower transfusion rates in at least one series [23]. On the other hand, other studies have demonstrated no benefit of iron supplementation with respect to minimizing postoperative hemoglobin levels [24]. Further, iron supplementation has also been associated with medication side effects including constipation, reflux symptoms, and abdominal pain. Thus, current evidence seems to at least weakly support maximizing supplementation of anemia-associated vitamins. Iron supplementation, on the other hand, is not recommended for routine use.

Preoperative Autologous Donation of Blood (PAD)

PAD is defined as the procurement of a patient's blood prior to surgery. Typically, the patient donates 1–2 units of blood, at least 3 weeks prior to the planned elective procedure to allow for preoperative hemoglobin levels to recover. The patient's autologous blood is then used as a substitute for transfusion of allogenic units either during surgery or postoperatively.

The routine use of PAD in elective arthroplasty surgery has mostly fallen out of favor. Initial studies comparing PAD with preoperative EPO administration demonstrated lower transfusion rates in the PAD group (28% vs. 8%)

[25]. Yet others have reported lower allogenic transfusion rates in patients receiving EPO than those undergoing PAD [20]. PAD decreases preoperative hemoglobin stores and also requires advanced planning, preparation, and storage of the donated units of blood, which could potentiate issues with bacterial contamination, infection, and clerical errors [20, 21, 26–28]. Moreover and somewhat surprisingly, some studies have demonstrated an increased risk of postoperative autologous and/or allogenic transfusions with the use of PAD [28]. Thus, in modern practice, PAD may play a role only in procedures with high expected blood loss, such as bilateral or revision procedures, and its routine use is no longer recommended [29].

Intraoperative Strategies

Intraoperative strategies, like the name implies, refer to approaches to reduce blood loss both during and immediately after surgery. Multiple intraoperative options are available and are discussed further below.

Acute Normovolemic Hemodilution (ANH)

ANH is a similar concept to PAD discussed above. ANH differs, however, in the timeframe in which autologous blood is harvested from the patient. In ANH, blood donation occurs just prior to or at the time of surgery. The donated blood can then be transfused back to the patient postoperatively. The main advantage of ANH over PAD relates to the decreased potential for transfusion clerical errors, bacterial contamination, and wasted units, since blood harvest occurs just before or at the time of surgery [13]. However, the main disadvantages include higher cost and potential for greater blood loss, although the latter has not approached statistical significance [30]. In general, the current literature on ANH is conflicting, partly due to difference in outcome measures and comparators [29–31]. Thus, the role for ANH remains limited in current practice and is often reserved only for select patients including those with religious or personal beliefs against receiving allogeneic blood transfusions.

Tourniquet

Pneumatic tourniquets have long been used in knee arthroplasty due to their potential to offer a "bloodless" surgical field, improved cement interdigitation, and decreased surgical time [32]. Multiple studies have demonstrated shorter surgical times with tourniquet use in TKA [32, 33]. Decreased surgical time, in turn, offers the potential for minimization of hidden blood loss, and by corollary, transfusion rates; however, most studies have failed to demonstrate a significant difference in blood loss, change in hemoglobin levels, or transfusion requirements with tourniquet use [34, 35]. Further, tourniquet use is potentially associated with increases risk of venous thromboembolic events [33], arterial thrombosis [36], and postoperative wound complications [37]. Thus, orthopedic surgeons should balance these risks with the potential benefits of tourniquet use and tailor their decision making to individual patients.

Bipolar Sealants and Argon-Beam Coagulation (ABC)

Bipolar electrocautery sealant devices couple continuous flow of saline with electrocautery. These devices offer the theoretical advantage of being able to minimize thermal damage to soft tissues by maintaining a cool electrocautery tip, while still allowing cauterization of blood vessels. In general, bipolar electrocautery has not shown any significant difference in terms of blood loss, postoperative hemoglobin, transfusion rate, or drain output when compared to traditional monopolar electrocautery, in multiple randomized controlled trials [28, 38, 39].

ABC, on the other hand, works by using ionized argon gas to deliver radiofrequency cauterization. The argon gas theoretically improves visualization and decreases the zone of tissue

necrosis, thereby decreasing soft tissue injury. Overall, data are still limited on the use of both of these devices. While they offer theoretical advantages, they are potentially associated with increased costs and lack of clear benefit.

Antifibrinolytic Agents

Antifibrinolytic agents including tranexamic acid (TXA) are competitive inhibitors of plasminogen, thereby preventing its conversion to plasmin and its further conversion to fibrin. These agents work to stabilize fibrin clots and decrease fibrinolysis, thus helping achieve hemostasis. TXA is by far the most widely studied antifibrinolytic agent in total joint arthroplasty and can be administered in intravenous, oral, and topical formulations. The efficacy of TXA in decreasing blood loss and transfusion rates has been demonstrated in multiple randomized controlled trials and meta-analyses [40–44]. Recent clinical practice guidelines endorsed by the American Association of Hip and Knee Surgeons (AAHKS), American Society of Regional Anesthesia and Pain Medicine (ASRA), American Academy of Orthopaedic Surgeons (AAOS), the Hip Society, and the Knee Society have advocated for the administration of TXA (irrespective of formulation or dosage) in patients undergoing primary joint arthroplasty due to its well-established safety and efficacy profile [45].

Topical Hemostatic Agents

Topical hemostatic agents include a wide array of therapeutics including fibrin sealants, platelet-rich plasma (PRP), platelet-poor plasma, collagen agents, and cellulose. Of these agents, fibrin sealants are the most closely studied agents in the orthopedic literature. Fibrin sealants typically have two separate mixtures of coagulation proteins including fibrinogen, factor XIII, thrombin, and calcium. When the two mixtures are combined, a fibrin seal is formed. In one randomized controlled trial, a statistically significant difference in the mean reduction of hemoglobin concentrations was found on the first postoperative day in patients treated with a fibrin sealant when compared to the nontreated controls [46]. While these initial results were encouraging, several other studies have noted no clinically significant differences between postoperative drain outputs, hemoglobin concentrations, transfusion rates, or postoperative complications between treated and control groups [47]. As such, the routine use of these agents must again be considered carefully.

Postoperative Strategies

Transfusion Triggers

Stringent transfusion algorithms have become one of the most effective means to reduce the rate of allogenic blood transfusion. Newer, more restrictive transfusion protocols have decreased the rate of allogenic blood transfusion while imparting no change in cardiovascular morbidity or mortality or length of hospital stay [48]. Thus, the American Association of Blood Banks' clinical practice guideline on transfusion now recommends the restriction of allogenic blood transfusion to patients whose hemoglobin is less than or equal to 8 g/dL and exhibit symptoms of anemia [49]. This recommendation has been supported in the orthopedic literature in several studies [50–52]. Current guidelines now recommend that patients with hemoglobin levels less than 6 g/dL receive red blood cell transfusions and patients with hemoglobin levels greater than 10 g/dL not receive a transfusion, regardless of their physiological reserve [49]. For patients with hemoglobin levels between 6 and 10 g/dL, the decision to transfuse should be based on expectation of continued blood loss, intravascular volume status, cardiovascular reserve, and symptoms of anemia [49].

Reinfusion Drains/Systems

Reinfusion systems rely on the acquisition of shed blood either intraoperatively through red

cell salvage suction systems or postoperatively through reinfusion drains. The shed blood, once collected, is then filtered, lavaged, and reinfused back into the patient. Thus, these systems can serve as alternatives to allogenic transfusions. The published literature on their efficacy still remains controversial. In one randomized controlled trial, the use of a postoperative reinfusion systems was found to produce a notable decrease in allogenic transfusion requirement [53], whereas in other studies, use of these devices resulted in no difference in transfusion requirement and came at the expense of significantly higher postoperative blood loss [54]. The latter has been thought to be secondary to the characteristics of the shed blood, which contains increased concentrations of tissue plasminogen activator (tPA) and lower levels of fibrin compared with normal blood. This has been proposed to produce a net effect of fibrinolysis and thus increased postoperative drainage [55, 56].

Conclusion

The deployment of a patient blood management protocol can potentially help minimize perioperative blood loss associated with many arthroplasty procedures. From the discussion presented above, it is clear that there are multiple different blood conservation strategies available to the modern orthopedic surgeon. Some of these strategies are supported by robust clinical evidence, establishing both safety and efficacy for their use. Others offer theoretical and/or plausible benefits, but their clinical efficacy remains equivocal. This discordance highlights the importance of tailoring blood management protocols to the individual patient, based on the preoperative evaluation of the patient's comorbidities, estimated blood loss of the surgical procedure, and potential patient response to anemia. Ultimately, these preoperative, intraoperative, and postoperative blood preservation strategies are all tools in the armamentarium of the orthopedic surgeon to aid in optimizing patient recovery and minimize overutilization of otherwise constrained resources.

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15 Outpatient Unicompartmental Knee Arthroplasty

Robert A. Sershon and Kevin B. Fricka

Introduction

Surgeon and patient interest in outpatient joint replacement has grown in recent years [1–3]. This paradigm shift can largely be attributed to advancements in perioperative management and growing efforts to increase value provided by joint arthroplasty through diminishing the economic burden [3–5]. With the Centers for Medicare and Medicaid Services' decision to remove total knee arthroplasty from the Medicare inpatient-only list, a growing demand for outpatient arthroplasty is anticipated. This is especially true in the setting of unicompartmental knee arthroplasty (UKA), which has been on the outpatient list for many years.

Multiple investigations have reported outpatient hip and knee arthroplasty as a safe, reproducible, and cost-effective means of delivering patient care in appropriately selected patients [3–22]. With over five million individuals projected to undergo a hip or knee replacement on a yearly basis by 2050, further investigation of appropriate patient selection, prevention of complications, and economic benefits associated with outpatient joint arthroplasty are imperative [4, 17, 18, 23–27].

Unicompartmental knee arthroplasty has grown in the outpatient setting due to its joint-preserving nature, relatively low morbidity, and recent pressures to curtail hospital stays and associated costs [28–30]. In this chapter, we will discuss essential elements of outpatient UKA, including: patient selection and safety, preoperative education, unique elements of preoperative planning, surgical technique, perioperative management, and prevention of complications.

Institutional Readiness

Prior to launching an outpatient joint replacement program, an established system for quality and performance measurement must be in place. Quality metrics, such as length of stay, surgical time, blood loss, readmission rates, and complication rates, should be readily available for a comparative analysis following the introduction of outpatient UKA.

We support the position statement released by the American Association of Hip and Knee Surgeons (AAHKS) requiring optimization of the following elements prior to participation in outpatient program [31]:

- Appropriate patient selection (on medical grounds)
- Patient education and expectation management (e.g., preoperative "joint school")

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- Social support and environmental factors (family or professional outpatient support)
- Clinical and surgical team expertise
- Institution facility or surgery center factors (history of successful teamwork and an environment conducive to optimizing surgical outcomes)
- Evidence-based protocols and pathways for pain management, blood conservation, wound management, mobilization, and VTE prophylaxis.

Patient Selection

Patient Selection

Appropriate patient selection is a key element in outpatient joint replacement. Multiple authors have shown that outpatient UKA results in high satisfaction with no clinically significant increased risk of complications when patient selection is appropriately performed [1, 7, 14, 15]. Because UKA has been on the outpatient list for many years, many surgeons plan for the majority of patients undergoing UKA to be discharged the same day or within 24 hours.

Following surgical indication for a partial knee replacement, each individual must be effectively counseled to ascertain the feasibility of undergoing an outpatient procedure. It is essential to have a strong social support system in place, regardless of a patient's physical capability to undergo the intervention. Those without a reliable support system are best treated with an overnight hospital stay.

Traditionally, candidates for outpatient surgery have been identified as younger, healthier individuals with low American Society of Anesthesiologists (ASA) and Charlson Comorbidity Index (CCI) scores [3, 8–12, 32]. This method of patient selection is subject to significant physician discretion, and literature regarding patient safety is largely limited to single-physician retrospective case series [3, 8–12, 20, 22, 33].

Recent attempts have been made to objectively identify candidates for outpatient joint replacement surgery [17, 24, 25, 34–36]. Courtney et al. demonstrated higher risk for readmission and complications following outpatient joint replacement in patients aged more than 70 years and those with malnutrition, cardiac history, COPD, smoking history, cirrhosis, or diabetes mellitus [24, 25]. In an attempt to appropriately risk-stratify patients for successful outpatient surgery, Meneghini et al. generated the Outpatient Arthroplasty Risk Assessment (OARA) score. [17] The algorithm is based on the presence of nine comorbidity categories, namely, general medical, hematological, cardiac, endocrine, gastrointestinal, neurological and/or psychological, renal and/or urology, pulmonary, and infectious disease. In a review of over 1100 early discharge patients, the authors report the OARA score to be more predictive of successful same-day or next-day discharge for primary joint arthroplasty than ASA and CCI scores. Although early results are promising, further prospective investigations to validate the utility of the OARA are needed before widespread acceptance of the scoring tool is adopted [17, 36].

It is the authors' belief that the vast majority of patients undergoing UKA can be safely treated as outpatients. At our institution, over 95% of partial knee replacement are done as outpatient surgery. In our series comparing 569 UKAs performed in the hospital setting versus the surgery center setting, the only patients excluded were those with a significant cardiac history or a lack of social support. Currently, it is the senior author's policy to plan all UKAs as outpatient surgery.

Preoperative Education and Support System

Preoperative counseling and the presence of a reliable support system are pillars of outpatient arthroplasty surgery. Despite the growing popularity of outpatient surgery among surgeons, less than 50% of patients are aware that same-day discharge is an option and over 50% of patients expect a minimum 2-day stay following a joint replacement [37]. Further barriers to rapid recovery protocols are present when patients or

their relatives have previously experienced an extended hospital or rehabilitation stay, making such practice their standard of care. Nevertheless, thorough preoperative education regarding the safety, patient satisfaction, and benefits associated with outpatient UKA can aid in eliminating fears or preconceived notions about same-day discharge.

The surgeon and team members should present a detailed and easily understandable program focusing on the perioperative period, setting clear expectations for both patient and support system. All members of the surgical team and clinical staff should convey the same message to each patient. Details of the operation, preferred mode of anesthesia, multimodal pain management protocol, physical therapy requirements for discharge, common barriers to discharge, and home care following surgery should be highlighted. The preferred method of postoperative communication with the surgeon's office should be clearly delineated. A comprehensive preoperative teaching class is an option, but not mandatory. In our institution's experience, confident detailing of the postoperative recovery plan and a concise handout highlighting the aforementioned points by the surgeon and perioperative team have proven invaluable in educating our patients.

Perioperative Management

Multimodal pain protocols reduce the total opioid consumption with the goals of decreasing the incidence of postoperative delirium, respiratory depression, ileus, urinary retention, and nausea.

Preoperative analgesia protocols are essential elements to multimodal pain pathways [15, 33, 38]. Administration of select medications prior to incision aids in decreasing the local inflammatory response and reducing the pain signaling to the central nervous system [15, 33, 38]. Nonsteroidal anti-inflammatory drugs (NSAIDs), including cyclooxygenase (COX)-2 inhibitors, gabapentinoids, and acetaminophen, have gained popularity for their narcotic-sparing effect. The use of narcotics can be further diminished through the utilization of preoperative motor–sparing peripheral nerve blocks, non-narcotic spinal anesthesia, intravenous ketorolac, perioperative glucocorticoids, and intraoperative wound infiltration with long-acting local anesthetics.

In this section, we will highlight evidenced-based protocols for preoperative anesthesia, multimodal analgesia, blood management, surgical techniques, and postoperative management.

Preoperative Medication

Pre-emptive pain and nausea management should begin in the preoperative holding area. Our current regimen is as follows: oral acetaminophen 1 g, oxycodone hydrochloride 10 mg, celecoxib 400 mg, pregabalin 75 mg, and a scopolamine patch placed behind the ear. Selective withholding of medications may be considered in cases of advanced age, allergies, or a documented history of prior drug intolerance.

Neuraxial Anesthesia

In the rapid recovery setting, spinal-epidural anesthesia with an additional motor-sparing regional block is preferred over general anesthesia. This bias is due to higher rates of pulmonary complications, infections, acute renal failure, 30-day mortality, and prolonged hospital stay associated with general anesthesia in the setting of knee arthroplasty [39, 40].

Spinal anesthesia utilizing sodium-channel blocking local anesthetics (e.g., lidocaine or mepivicaine) with elimination or minimization of opioids has dual benefits. Minimizing narcotic medication in the spinal injection reduces opioid-related side effects, while the short-acting local anesthetic agents allow patients to more rapidly participate in postoperative physical therapy. We prefer the use of 2% lidocaine for neuraxial anesthesia due to lidocaine's significantly shorter onset of action and overall duration (2 hours) when compared to bupivacaine (4–8 hours) [15, 38]. Recent literature has shown lidocaine spinals are safe and effective in the outpatient joint replacement setting, with low urinary retention rates and no episodes

of transient radiculitis, possible rare side effect of lidocaine [41]. Recent literature has also shown clinically significant benefits of utilizing mepivicaine over bupivacaine spinals, demonstrating fewer urologic complications and shorter length of stay in patients receiving mepivicaine [42]. Our recommended regimen for planned outpatient partial knee replacement is a single-shot spinal consisting of 2% lidocaine or 2% mepivicaine.

Regional Blocks

Regional nerve blocks have become an increasingly important element of rapid recovery programs. Femoral nerve blocks have traditionally been the gold standard. However, due to mixed motor and sensory involvement, persistent quadriceps weakness can result and lead to delayed discharge due to a prolonged time until ambulation. Additionally, motor blocks serve as a potential fall risk during the early recovery period [26, 43, 44]. Because of its motor-sparing capabilities, the adductor canal block has gained popularity over femoral blocks and continuous spinal anesthesia in recent years [4, 7, 15, 26, 45, 46]. The adductor canal block provides a selective sensory blockade with minimal decrease in quadriceps strength, enabling early ambulation and decreasing early fall risk [26, 45, 46]. Recent literature has shown a single-shot adductor canal block with bupivacaine and multiple adjuvants provide equivalent analgesic benefit for up to 30 hours when compared to a continuous adductor canal block [46]. At our institution, we routinely utilize ultrasound-guided single-shot adductor canal blocks (0.5% ropivacaine, 25 mL).

Intraoperative Medication

Multimodal pain and nausea control continue intraoperatively with the administration of ondansetron 4–8 mg for nausea, dexamethasone 4–10 mg for nausea and anti-inflammatory purposes, and propofol for procedural sedation. The authors find propofol particularly useful in the rapid recovery setting due to its quick onset of action, short half-life, and hypotensive effects. However, diligent and continuous airway monitoring is required, as propofol is a known respiratory depressant. Ketamine (0.5 mg/kg) has also proven effective and provides additional pain control [26]. Standard preoperative antibiotics should always be administered.

Blood Management

Blood transfusion in the setting of partial knee arthroplasty is rare; however, blood conservation remains a critical element of outpatient UKA. The process beings with maintaining normothermia preoperatively and employing appropriate fluid hydration during the perioperative period. Meticulous hemostasis with the use of electrocautery is recommended during surgery. Extensive data and AAOS recommendations now support the routine use of tranexamic acid (TXA) to decrease transfusions in hip and knee arthroplasty [47, 48]. The dosage and route of administration do not appear to substantially differ in their effectiveness, leaving these elements up to surgeon's discretion [47, 48]. Our current regimen includes 1 g IV TXA prior to tourniquet inflation and 1 g IV TXA in the recovery room. Placement of a tourniquet is recommended, although recent literature has questioned its efficacy in the era of tranexamic acid [49]. Watertight arthrotomy closure and tissue glue have been reported to reduce external drainage when combined with the current generation of dressing materials [4].

Surgical Technique

Surgeons should employ their preferred surgical technique in the outpatient setting. Although the current authors employ a minimally invasive surgical (MIS) midvastus or lateral arthrotomy technique in an effort to minimize soft tissue trauma at the time of surgery, debate continues to exist over clinically meaningful differences in early recovery for MIS vs. traditional techniques [50–52]. Similarly, no universally accepted clinically important differences have been reported

between traditional instrumentation versus patient-specific instrumentation or traditional operative technique versus computer-assisted [53–55].

Local tissue infiltration with a periarticular injection (PAI) "cocktail" has gained traction over the past decade [26, 33, 38]. Various combinations of a long-acting anesthetic, NSAID, steroid, and epinephrine introduced into the soft tissues surrounding the knee have been described [26, 33, 38]. Substantial debate exists over the efficacy of liposomal bupivacaine, with a recent randomized controlled trial showing no superiority over standard bupivacaine [56]. It is the author's opinion that the method in which the cocktail is administered is more important than the medications contained with the cocktail itself. We recommend targeted infiltration of a bupivacaine-only injection into the posterior capsule, proceeding anteriorly, and always aspirating to ensure no vascular structure is injected. Following diffuse capsular infiltration, 20 mL is injected into the periosteum of the femur and tibia, followed by 10 mL into the anterior suprapatellar synovium and extensor mechanism. Residual bupivacaine is infused in the subcutaneous tissues [38].

Postoperative Management

Two clearly defined phases of care comprise the immediate postoperative period: acute phase and step-down phase. During these phases, attention should focus on medical optimization and the prevention of complications that can occur in the first 24 hours after a procedure, such as: falls, over-sedation, urinary retention, nausea, pain, dehydration, and hypotension [3, 23, 26, 57].

The acute phase begins with transfer of the patient from the operating room to the post-anesthesia recovery unit. Continued monitoring and medical stabilization by anesthesia and nursing are performed, while pain, nausea, and dehydration are concurrently managed [15, 26, 38]. The multimodal regimen continues with IV ketorolac 15–30 mg (once), tramadol 50 mg (q 6 scheduled), and hydrocodone-acetaminophen 10–325 mg (q4 PRN). Intravenous rehydration is performed to diminish nausea and optimize a steady-state fluid balance. Overzealous rehydration must be avoided to mitigate the risk of iatrogenic urinary retention, with a goal of less than 1500 mL total fluids administered [58, 59]. Routine laboratory draws are not necessary following routine partial knee arthroplasty, and we do not routinely employ this practice at our institution [60]. Early straight leg raise is encouraged as soon as the patient gets to the recovery room to instill confidence and alleviate fears of early mobilization.

The step-down phase begins after the patient is medically stable, weaned from oxygen, pain is controlled, and transfer to a private recovery area is deemed appropriate by experienced nursing and anesthesia staff. The patient is encouraged to sit up in bed and is given oral liquids and a light snack. With the assist of a nurse or physical therapist, the patient is directed to sit on the side of the bed with feet dangling and is then allowed to stand. The physical therapy staff subsequently coaches the patient on how to properly utilize an ambulatory aid, followed by a short walk to the restroom for a voiding trial.

Postoperative urinary retention (POUR) is a common barrier to discharge and has been reported to occur in up to 46% of arthroplasty patients scheduled to undergo a rapid-recovery joint replacement [58, 61]. Patients over 60 years with a history of urinary retention, those receiving high volumes of perioperative intravenous fluids, and patients receiving opioid-containing spinals are at higher risk for POUR [58, 59, 61, 62]. To mitigate the risk of POUR, we advocate opioid-free spinal analgesic consisting of lidocaine or mepivicaine only, total fluid administration goal of less than 1500 mL, minimization of narcotic medication where feasible, and early ambulation.

Physical therapy goals for discharge include safe ambulation with either crutches or a walker and management of activities of daily living following discharge. Specific protocols may be individualized to each institution and should be developed with the input of the physical therapy department [3, 10]. At our institution, we require patients to independently stand from a chair,

ambulate with the use of crutches or a walker, and void prior to discharge.

Once the goals of discharge have been met, the previously provided discharge materials are again reviewed with the patient and family members. The nursing staff will highlight the medication regimen, local wound care, contact information for the surgeon's office, how to schedule outpatient physical therapy, and when to return to the office for a follow-up appointment. Following discharge, patients are contacted within 24 hours to assess their progress and to answer questions. In our experience, the use of a mobile application that provides daily surgeon-specific updates, permits two-way communication, and provides home-directed exercises has proven beneficial in guiding patients through their postoperative recovery.

Thromboprophylaxis

Deep vein thrombosis (DVT) prophylaxis is required for all patients undergoing joint arthroplasty, and the appropriate regimen should be based on a patient's risk [23, 63]. In our experience, most patients undergoing rapid recovery UKA are lower risk for thromboembolic events and can be safely treated with compression stockings and aspirin [15, 64, 65]. In higher risk patients, we prefer the use of oral factor Xa inhibitors, which do not have to be monitored [63].

Results of Outpatient Surgery

Rapid recovery protocols and tools for safe selection of outpatient joint replacement surgery patients continue to evolve. Multiple authors have shown outpatient joint replacement surgery is safe, cost-effective, and leads to higher patient satisfaction scores [1, 3, 5, 7–17, 20, 21, 36, 37]. Excellent outcomes with low complication rates have been achieved in both hospital and outpatient ambulatory surgery center settings [8, 15, 21, 66]. Further, AAHKS has released a position statement supporting outpatient joint arthroplasty in appropriately selected patients at aptly prepared centers, highlighting specific, critical areas for continued focus and development [31].

Summary

The success of an outpatient joint replacement surgery program relies on the development, integration, and implementation of multiple elements, including: well-defined criteria for patient selection, patient education, social support system, perioperative medical optimization and management, multimodal pain control, consistent and dependable perioperative teams, and coordinated postoperative care by surgeons and other providers. If the above recommendations are implemented, it is our opinion that UKA can be appropriately performed in the outpatient setting on most patients (> 95%) in a safe, effective manner with high patient satisfaction.

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16 Therapy for Unicompartmental Knee Arthroplasty: Pre-op, Day of, and Post-op

Peter F. Helvie and Linda I. Suleiman

Introduction

Rehabilitation after unicompartmental knee arthroplasty (UKA) is a vital part of a successful outcome. Patients with degenerative joint disease of the knee have often undergone physical therapy prior to presenting to a surgeon, as therapy continues to be a mainstay of nonoperative treatment of degenerative joint disease. Patients who ultimately undergo a UKA will typically have a physical therapist work with them preoperatively, in the hospital or ambulatory surgery center (ASC) immediately after surgery, and may continue to do so in the weeks to months following surgery. The role of these three phases of therapy continues to evolve. As cost-saving measures continue to be implemented, and technology and telemedicine further develops, the role of formal physical therapy has been called into question in UKA patients.

In this chapter, we will review the three phases of physical therapy: preoperative, day of surgery, and postoperative. A standard physical therapy regimen will be outlined for patients undergoing UKA, which is often similar/identical to that implemented for patients undergoing total knee arthroplasty (TKA). In addition to detailing typical physical therapy protocols, we will review therapy adjuncts, technologies being utilized to replace formal therapy, and recent literature that calls into the question the utility of formal physical therapy in patients undergoing UKA.

Preoperative Physical Therapy

Physical therapy prior to arthroplasty is a routine part of the treatment of symptomatic degenerative joint disease of the knee. Therapy is often a mainstay of treatment in these patients, and many will have worked with a physical therapist, at the direction of their primary care provider, prior to being referred to a surgeon. There are many adjuncts and modalities utilized by physical therapists, some of which will be discussed here. The utility of preoperative therapy has been questioned, and recent studies have called into question whether therapy prior to knee replacement surgery improves outcomes in patients who undergo either unicompartmental or total knee arthroplasty.

Osteoarthritis (OA) is a common diagnosis treated with physical therapy, and there exists a number of exercises that can be beneficial to, and are typically included in the treatment of, patients with OA [1]. Exercise has been shown to

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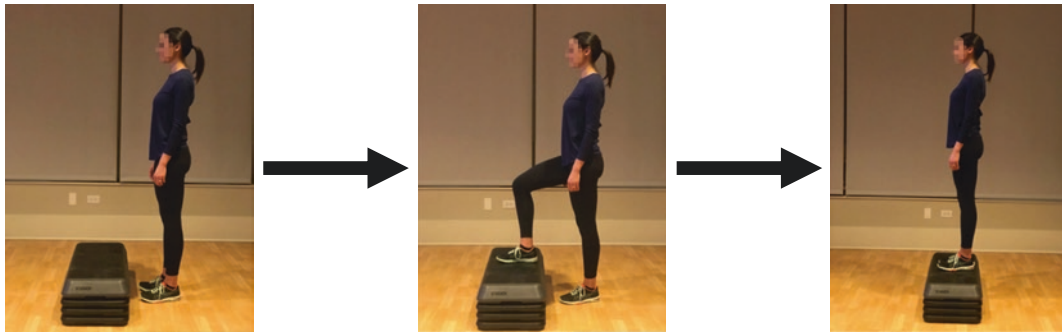

Fig. 16.1 Step-ups. The patient stands upright in front of an elevated platform and steps reciprocally up and then back to ground level to gain strength and endurance

be effective across multiple studies; some of the common and evidence-based exercises include the following:

- Step-ups (Fig. 16.1)
- Quadriceps sets
- Seated leg press
- Partial squats
- Range of motion exercises (passive and active)
- Flexibility and stretching of calves, hamstrings, quadriceps
- Stationary biking

Exercise has been shown to increase function and decrease pain in the short term; however, the effect seems to diminish with time [2]. This is likely due to the progression of the degenerative changes within the knee. The mainstay of physical therapy, as demonstrated by the above list of exercises, is quadriceps strengthening. Quadriceps weakness can lead to functional deficits, and its function is important for proper knee kinematics. Difficulty with standard quadriceps strengthening exercises may be encountered due to pain, and techniques may need to be modified. Deep flexion, in particular, is frequently challenging and painful for those with degenerative joint disease, and modifications are frequently made to allow patients to perform partial exercises to avoid deep flexion and maintain the benefits of strengthening their quadriceps. This is especially true in patients who have multicompartmental degenerative changes, and patellofemoral disease is present. In patients with pure unicompartmental symptoms, deep flexion should theoretically be less difficult than someone with multicompartmental disease and may suggest that the physician should more closely evaluate the patellofemoral joint.

Aerobic exercise has many benefits including cardiovascular endurance, weight control, improved balance, and improvements in stiffness. Land-based aerobic exercises can be difficult for patients with knee arthritis due to the repetitive impact it has on the knee joint. Aquatic exercise has the benefit of added buoyancy and reducing the forces across the knee, while maintaining the benefits of aerobic exercise. Aquatic exercise has been shown to improve joint mobility, pain, physical function, and quality of life [3].

Therapeutic modalities are sometimes utilized by physiotherapists in the treatment of knee arthritis. Transcutaneous electrical nerve stimulation (TENS) is the application of an electrical current through the skin, with the aim of pain modulation [4]. Relief provided by TENS varies, and in most cases, it is a temporary solution and does not have any significant lasting effect for patients. In a systematic review, there was found to be no proven effect on outcomes with use of TENS; however, it is still a commonly employed modality by physiotherapists. Other therapeutic modalities include various forms of electrical stimulation, massage, proprioceptive training, acupuncture, and sleep behavioral training [4].

Much of the above-described therapy, and many of the modalities, can generally be applied to patients with knee arthritis. In patients with

unicompartmental arthritis, the use of bracing and footwear can theoretically provide more directed therapeutic benefits by unloading the affected compartment. For patients with medial compartmental disease, for example, a lateral wedge in the shoe can reduce the varus moment on the knee, thus unloading the force across the medial knee [5]. The reduction in medial force can reduce the pain from loading across the arthritic portion of the knee; however, there are conflicting studies, many of which show no benefit in lateral wedging [6, 7].

Knee unloading braces are used with similar philosophy in mind. A 2017 study in the United Kingdom looking at the cost-effectiveness of knee offloading braces found them to be cost-effective after 4 months of use, with the most beneficial duration being 7–12 months. The average length of use was 26 months, with a resulting increase in 0.44 quality-adjusted life year gains. The average cost saved was $822 (£625) per patient [8]. A 2006 study in the *Journal of Arthroplasty* confirmed that most knee offloading braces perform as advertised and do in fact increase condylar space on the offloaded side, with the majority of patients (>75%) experiencing pain relief with the use of the brace. They compared multiple different braces in a second arm of the study and found that not all braces achieve the same results; the Bledsoe brace (Breg, Inc.) produced the best results, followed by the Don Joy Ortho brace [9].

Although physical therapy is a standard part of patient care prior to UKA, and certainly may provide benefit to patients prior to surgery, there may not be benefit in the measured outcomes of UKA in patients who had preoperative physical therapy. In a small study of 39 patients, preoperative and postoperative measures of strength, self-selected walking speed, and oxygen cost of walking were measured. The group receiving therapy improved in the preoperative time period; however, at 3 months postoperatively, there was no difference in the groups [10]. Data for patients undergoing TKA showed that preoperative therapy do not seem to confer improved outcomes either. A 2015 systematic review in the *Journal of Arthroplasty* found no difference in the Western Ontario and McMasters Universities Arthritis Index (WOMAC) and SF-36 scores, no to slight improvement in strength, no difference in pain scores, no change in range of motion (one study found that preoperative therapy patients reached 90 degrees 1 day sooner), and no to slightly shorter hospital stay. One study did show less likelihood of discharge to a rehab facility [11].

Physical therapy is not without cost. Bradley et al. took a comprehensive look at the medical costs in the two years preceding UKA. They found that physical therapy had a per-patient average cost of $256 for Medicare patients [12]. In patients with degenerative changes severe enough to warrant a UKA, the efficacy of nonoperative treatments should be carefully analyzed.

Physical therapy for the arthritic knee certainly has an important role in the conservative management of knee pain. However, the role of therapy in patients with arthritis severe enough to warrant a UKA has not firmly been established. There is peaking interest in the various educational models used to instruct patients on exercise and therapy that may be performed without the use of formal physical therapy. The use of smartphones and tablets with clear, video-based instruction may be the new direction of preoperative therapy for patients who are on track for a UKA.

Day of Surgery

As knee arthroplasty, particularly unicompartmental, has moved toward shortened in-hospital stay and has even become a procedure commonly performed as an outpatient, the extent of in-house physical therapy has decreased. The role of physical therapy while inpatient is to primarily ensure patients are safe to discharge home and able to recover with rehabilitation performed outside the hospital. Although published physical therapy protocols in the literature and textbooks for UKA are sparse, established protocols and discharge goals for total knee arthroplasty are available. In Giangarra's Clinical Orthopaedic Rehabilitation textbook [1], a standard outline of in-hospital

postoperative therapy and discharged goals is outlined. The goals are as follows:

- Range of motion: minimum of 60–90 degrees of flexion
- Ambulation: 150 ft. with a rolling walker assist
- Transfer: Independence with transfers alone or with caregiver, and minimally assisted to modified independence with stairs as needed for home environment, using assisted device and/or caregiver

Day of surgery discharge has become more common and often a goal of both patient and provider. Clearance by therapy at the surgical facility is an important landmark for a patient to reach prior to safe discharge home. Gondusky, et al. [13] published their perioperative pathway for safe and effective same-day discharge in UKA patients. Along with a comprehensive preoperative screening methodology and patient education, perioperative multimodal pain control regimen, and social support, a brief physical therapy session was included for all patients. In their protocol, the therapists assessed all patients for safety and mobility with crutches or a walker and provided in-home exercises. All patients were made weight bearing as tolerated after surgery and were given a knee immobilizer to wear until they were able to perform five normal straight leg raises. A regimented postoperative, at-home and outpatient, therapy protocol was initiated as well, which will be discussed in more depth later in this chapter.

Continuous passive motion (CPM) has been studied as a part of the immediate postoperative rehabilitation in arthroplasty. While literature on CPM in UKA is sparse, the effectiveness of it in total knee arthroplasty has not been well supported in recent literature. Joshi et al. [14], in a randomized prospective trial, looked at the use of CPM for their patients undergoing TKA and a standard physical therapy regimen. They found no difference in range of motion (at 6 weeks and 3 months), no clinically relevant benefits with respect to clinical outcomes, or discharge disposition. Interestingly, length of stay was longer for patients who received CPM, and as expected, there was an increased cost per patient of $235.50. A 2014 Cochrane review by Harvey et al. found no conclusive evidence to support CPM in TKA [15]. Whether or not this holds true after UKA remains unanswered, but due to the more invasive nature of TKA, it seems unlikely that UKA patients would see a benefit from CPM use.

Postoperative Therapy

Therapy once discharged from the hospital or surgery center tends to follow a standard and routine pathway. Most patients have a physical therapist visit their home and engage them in at-home therapy for the first few weeks after surgery, although immediate outpatient therapy is becoming more common. Once able to safely leave home, most patients continue to have formal physical therapy at an outpatient rehabilitation center. Again, specific protocols and literature on therapy after UKA are sparse when compared to the available published literature on TKA. A standard TKA rehabilitation protocol focuses on much of the same exercises and modalities as those of preoperative therapy. Home therapy focuses on restoring and regaining range of motion, strength, and functional movement. Strengthening exercises used include the following, in addition to any modalities therapists see fit for a given individual patient [1]:

- Quadriceps sets (Fig. 16.2)
- Heel slides (Fig. 16.3)
- Straight leg raises
- Gluteal sets
- Low-load, long-duration strengthening exercises
- Recumbent biking
- Band exercises including standing terminal knee extension
- Hip abductor/adductor and external rotator strengthening (e.g., clamshell exercises)
- Ankle pumps

Knee range of motion is stressed with the final goal of restoring full extension and 120 degrees of flexion. Both active and passive range of motion

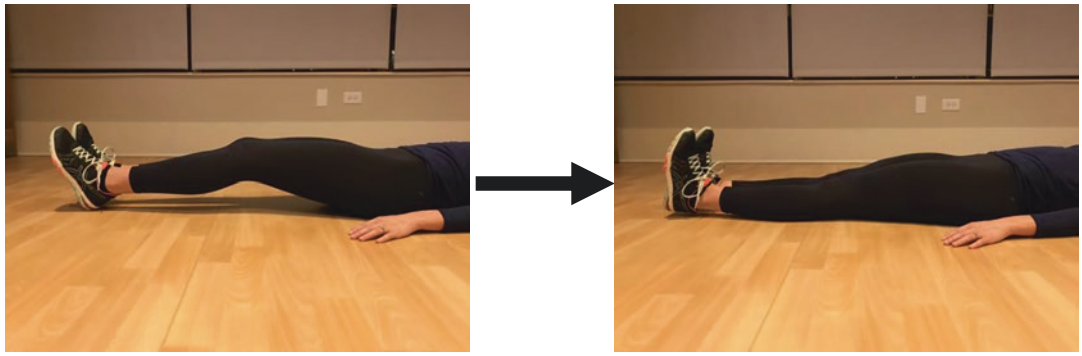

Fig. 16.2 Quad sets. The patient lays supine with legs relaxed (flexion in left image exaggerated to demonstrate motion), and flexes their quadriceps, extending their leg and pushing their knee into the ground to improve terminal extension and regain quadriceps strength

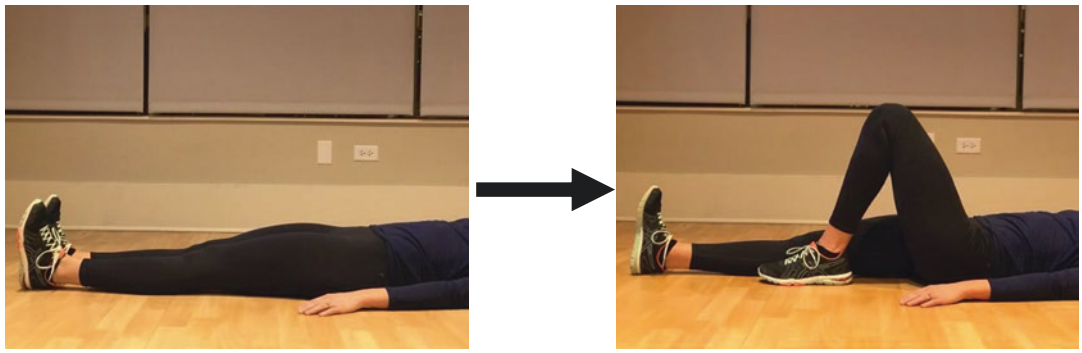

Fig. 16.3 Heel slides. The patient lays supine and flex their knee, pulling their heel toward their body to improve knee flexion

are stressed. Stretching of the entire lower extremity is included and not solely focused on knee range of motion, but includes IT band stretching, hamstrings, gastroc-soleus, etc. Functional and proprioceptive work begins during this time period as well and includes the following:

- Progression to independence in activities of daily living
- Eliminating the need for assisted devices and restoring normal gait pattern
- Balance exercises
- Progressing ambulation distance and tolerance
- Functional practice for activities such as sit-to-stand, toilet transfers, bed mobility

The Gondusky pathway [13] for same-day discharge enrolls the patients in at-home physical therapy for the first 2–3 weeks. The therapist visits the patient's home on postoperative day 1, and, thereafter, three times per week for 1-hour visits. Once the initial at-home therapy is concluded, the patients are enrolled in outpatient physical therapy if transition to a home exercise program is not possible at that point. In their study, outpatient therapy lasted up to 3 months, but many patients were discharged from outpatient therapy sooner, and some progressed well enough in at-home therapy that they did not require outpatient therapy. The progression of ambulation without assistance was left up to the expertise of the therapists.

The standardized nature of postoperative therapy in total knee arthroplasty, costs associated with physical therapy, and the advent of more advanced smartphones and tablets with higher quality app design, video interfacing,

and advanced patient-physician communication tools, have led to the development of programs, which can both supplement and replace formal physical therapy. Chughtai et al. [16] studied 157 patients undergoing either TKA or UKA, using a tele-rehabilitation program. The program used an instructional avatar, three-dimensional motion measurement and analysis software, and a real-time tele-visit function. The patients undergoing UKA had an average of 3.2 office visits with a therapist. They found patients were very satisfied with the program, spent an average of 29.5 days partaking in therapy at an average of 26.5 minutes per day. Knee Society Score for pain improved by 350% and 27% improvement was seen for function in patients undergoing UKA compared to their preoperative values. WOMAC scores improved by 57% for UKA patients. Of note, they did not report objective measurements in range of motion, or data on return to activities, use of assisted devices, or complications associated with stiffness.

Jorgensen et al. [17] performed a randomized, prospective trial, evaluating two groups of patients undergoing UKA, those randomized to supervised progressive resistance, and those scheduled for unsupervised therapy. Their primary outcome was leg extension power at 10 weeks postsurgery. Patients in the unsupervised group were offered instruction in a home-based exercise program that consisted of 12 exercises, focusing mainly on knee range of motion, and blood and lymph circulation. Six weeks after surgery, they saw a therapist who gave them instruction for a new at-home program that was made up of six low-intensity strength exercises to be done three times per week. Patients in the supervised cohort were seen twice per week in combination with the at-home program given to the unsupervised group. At 10 weeks, there was a significant increase in leg power in the supervised group as compared to the unsupervised group. However, this difference did not reach significance, and at 1 year, leg extension power was equal in the two groups. The only statistically significant difference between the two groups at 10 weeks was an increased walking speed in the supervised group; however, this significance was lost at 1-year follow-up. The authors concluded that supervised therapy was not superior to an unsupervised home program.

The results of Jorgensen's study beg the question of whether formal therapy is necessary following UKA. Fillingham, et al. [18] performed a randomized clinical trial in patients undergoing UKA, randomizing them to 6 weeks of outpatient physical therapy or to an unsupervised home exercise program. Their primary outcome was range of motion, and they found that the unsupervised group gained 6.6 degrees of motion, while the formal physical therapy group gained 5.0 degrees. This difference did not reach statistical significance. Of note, the patients randomized to the unsupervised home-therapy group did have statistically significant greater preoperative knee range of motion. The differences in the other secondary outcome measurements failed to reach statistical significance. They also demonstrated a cost savings of over $1000 per patient in the unsupervised home-therapy program.

Conclusion

Physical therapy continues to be a standard treatment modality in patients suffering from knee osteoarthritis. In patients who ultimately undergo UKA, the role of therapy is not clearly defined and may be unnecessary. Preoperative therapy has been shown to help in the short term, and there are benefits associated with use of therapy adjuncts such as off-loading braces. However, preoperative therapy has not reliably been shown to improve outcomes in patients undergoing UKA and TKA. A theoretical benefit of preoperative therapy is that introducing patients to exercises and rehabilitation techniques may reduce anxiety and help them recover from surgery.

As arthroplasty continues to move toward an outpatient procedure and in-hospital time decreases, the role of therapy in the immediate postoperative period may need to evolve. The primary role of day of surgery therapy at the hospital and ASC is to ensure patient safety for discharge home. Another important responsibility of

the immediately postoperative therapist is to provide education to the patient that reinforces their expected postoperative course. As reviewed in the postoperative therapy section above, instruction covering an at-home therapy program may be a vital part of preparing patients for a successful postoperative pathway.

The role of therapy after hospital discharge continues to evolve as well. As technological improvements have allowed for alternative delivery methods and cost-saving measures become more and more important, the role of formal physical therapy after UKA has come into question. There are data supportive of unsupervised, at-home therapy, which could replace formal physical therapy visits. Virtual therapy apps and detailed instructions on home-therapy exercises have shown similar outcomes as formal physical therapy. Rehabilitation after surgery is vital to a successful outcome, and the nature of this rehabilitation may involve more patient-directed, unsupervised therapy in the future.

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Part III

Complications of Unicompartmental Knee Arthroplasty

17

Disease Progression and Component Failure in Unicompartmental Knee Arthroplasty

Matthew J. Hall, Peter J. Ostergaard, and Christopher M. Melnic

Introduction

Outcomes of unicompartmental knee arthroplasty (UKA) have improved significantly since it was first introduced. Multiple studies have reported 10-year survival rates of 95–98% [1–4]. Survivorship at 15 and 20 years has also been reported to exceed 90% in multiple studies [3, 5]. Despite these improvements, UKA is still susceptible to complications and failures. While numbers vary between studies, aseptic loosening and progression of osteoarthritis are among the most common modes of failure. The rates of mobile-bearing dislocation have decreased significantly with the introduction of fixed-bearing UKA. Other less common modes of failure include polyethylene (PE) wear, infection, periprosthetic fracture/tibial collapse, and unexplained pain. Of failures, 19% occur in the first year postoperatively, while 48.5% occur in the first 5 years postoperatively [6]. Of these, aseptic loosening is the most common mode of early failure accounting for 26%, while progression of osteoarthritis is more common in midterm (38%) and late (40%) failures [7].

Patient selection plays an important role in outcomes following UKA. The initial indications for this procedure were isolated medial or lateral compartment osteoarthritis, post-traumatic arthritis, or osteonecrosis, with functional integrity of the anterior cruciate ligament, coronal plane deformity <15° (deg), flexion contracture <5°., in a patient >60 years old, weight <82 kilograms, and limited physical activity in the absence of inflammatory arthritis [8–10]. Limits due to age, activity level, body mass index (BMI), and patellofemoral disease are now considered controversial [6]. Specifically, recent evidence has shown that patients with concomitant patellofemoral arthritis have similar outcomes to those without patellofemoral joint disease [11].

Implant design and surgical technique also play an important role in UKA survival. Factors associated with decreased survivorship include a change in joint space height of more than 2 millimeters (mm), change in tibial component obliquity >3°, tibial slope >5°, change in slope >2°, and >6° of divergence between the tibial and femoral components [12] (Fig. 17.1). Overcorrection of a varus deformity with medial UKA is associated with the development/progression of osteoarthritis of the lateral compartment, while under-correction may be associated with increased polyethylene wear [13]. Lower position of the joint line is associated with asep-

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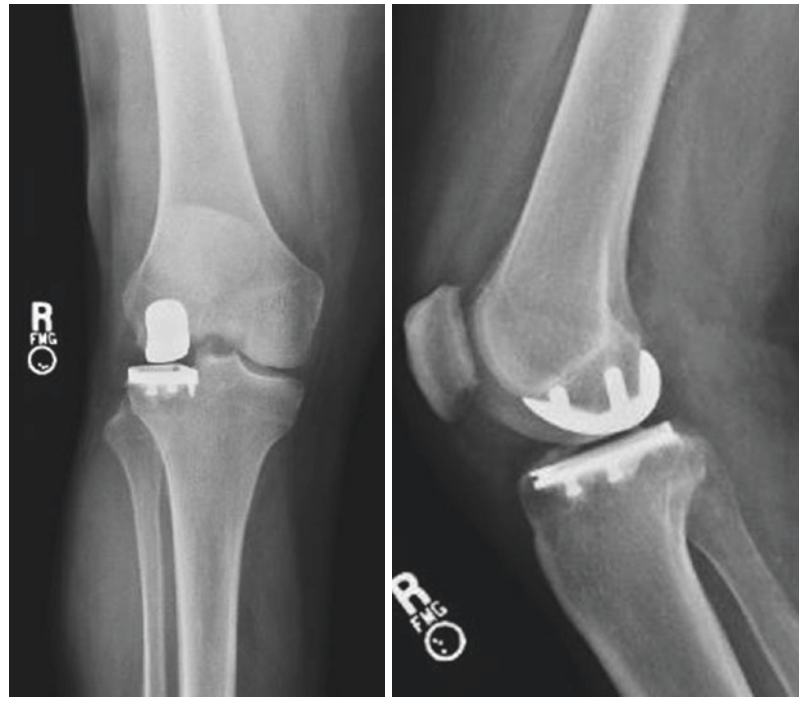

Fig. 17.1 Well-positioned lateral unicompartmental arthroplasty

tic loosening, while higher position is associated with early polyethylene wear and progression of degenerative changes in the other compartment [12]. Overall, revision surgery is more common with a tibiofemoral angle of >7° valgus or >3° varus [14]. The importance of technical factors is further supported by registry data showing that low-volume surgeons (<10 UKA/year) have worse outcomes, while high-volume surgeons (>30 UKA/year) have outcomes similar to total knee arthroplasty [15].

Given the relative prevalence of isolated medial versus lateral compartment osteoarthritis, medial UKA is much more common than lateral UKA [8, 16, 17]. Overall, the most common causes for medial UKA failure are aseptic loosening (36%) and progression of osteoarthritis in the lateral compartment (20%), while the most common causes for lateral UKA failure are progression of osteoarthritis (29%), aseptic loosening (23%), and bearing dislocation (10%) [7, 18]. Despite the discrepancy in the prevalence of medial vs. lateral UKA, there are no significant differences in survival at 5, 10, or 15 years [8]. Many studies analyze both medial and lateral UKA together, but the anatomic and biomechanical differences between compartments contribute to different failure modes, particularly in regard to mobile-bearing dislocations [7, 8, 19–23]. Differences including the convexity of the lateral condyle, the relative laxity of the lateral collateral ligament, and the medial pivot of the knee during flexion make mobile-bearing implants more prone to dislocation in lateral UKA, especially in the early postoperative timeframe [7, 19–25]. For this reason, some authors recommend using only fixed-bearing implants when considering a lateral UKA [24–26].

Overall, there is no difference in reoperation rates between fixed and mobile-bearing UKA [27, 28]. In a meta-analysis by Ko et al., progression of osteoarthritis and aseptic loosening were the most common causes of reoperation in mobile-bearing UKA, while polyethylene wear was the predominant cause of reoperation in the fixed-bearing group. The overall time to reoperation was shorter for mobile bearings, compared to fixed bearings, but the timing of this between groups depended on cause. Aseptic loosening and tibial component subsidence caused earlier

revision in the fixed-bearing group. Progression of arthritis and unexplained pain led to similar timing of reoperation between mobile-bearing and fixed-bearing groups. Progression of arthritis may be more common in mobile-bearing groups due to surgeons' desire to avoid mobile-bearing dislocation by putting in a "tight" knee and risk a slight overcorrection in alignment [29]. In contrast, fixed-bearing implants may better tolerate under-correction to offload the other compartment [27].

Conversion rates for both lateral and medial UKA are low, with an approximately 1% annual revision rate [30]. Conversion procedures can be technically demanding and often require the use of bone graft or augmentation to supplement bony deficits [31–34]. Most studies have found that the posterior cruciate ligament (PCL) can still be retained in converting to a total knee arthroplasty (TKA) [31–34]. Outcomes for revision of failed UKA have been shown to be equivalent if not superior to revision of failed primary TKA and are similar in long-term outcomes to primary TKAs [34, 35].

Modes of Failure

Progression of Arthritis

Progression of osteoarthritis in the remaining compartments is one of the most common modes of failure. Multiple studies cite the rate of UKA failure due to progression of arthritis between 1% and 9% [3, 36]. However, among UKA failures, progression of arthritis accounts for 15–50% of failures and is the most common mid- to late-term mode of failure [3, 5–7]. Patient selection and failure to follow specific indications may contribute, as patients with inflammatory arthritis, higher American Society of Anesthesiologists (ASA) score, and obesity are at a higher risk of developing adjacent compartment disease [37–39].

Technical aspects that contribute to progression of arthritis include overcorrection of the mechanical axis [13, 40] (Fig. 17.2). Hernigou et al. reported in their series of 58 medial UKAs that a hip-knee-ankle angle over 180° was associated with a higher and more rapidly occurring degeneration of the lateral compartment. Putting in a tight knee to avoid mobile-bearing dislocation can increase the contact stress in the adjacent compartment and contribute to degenerative wear [29, 40]. In contrast to total knee arthroplasty, component placement also affects femorotibial contact independent of the mechanical axis of the limb. Implant placement can reduce contact area and thereby increase local stress [41].

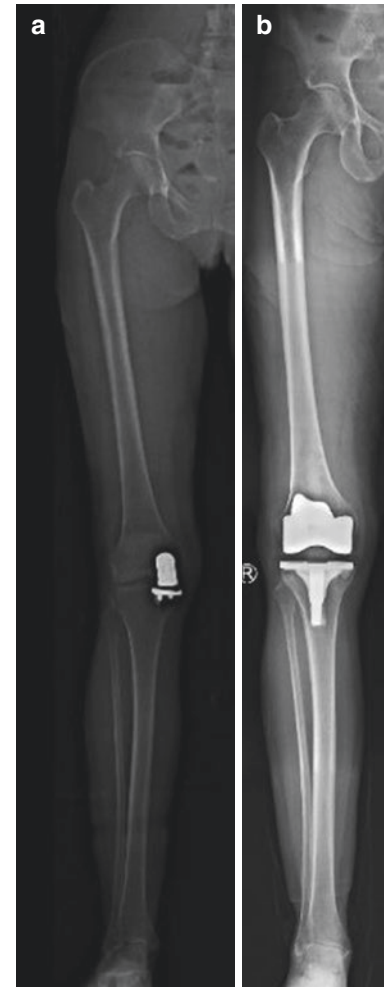

Fig. 17.2 (**a**) A medial unicondylar arthroplasty that overcorrected the deformity and created a valgus mechanical axis. The patient presented with laterally based pain. (**b**) The revision procedure radiographs correcting the mechanical axis

The clinical significance of patellofemoral joint degeneration is controversial. While it was initially thought that patellofemoral arthritis could contribute to anterior knee pain and patient dissatisfaction, recent literature has shown no difference in functional outcomes or reoperation rates in patients with patellofemoral arthritis documented at the time of surgery [11]. An oversized femoral component can also lead to patellofemoral impingement, which may be more symptomatic than patellofemoral arthritis [3]. This is more common with lateral UKA [42]. Interestingly, recent studies have demonstrated improved patellofemoral joint congruence following UKA [43]. The recommended management of symptomatic adjacent compartment degeneration is revision to total knee arthroplasty [37].

Aseptic Loosening

Another major cause of UKA failure is aseptic mechanical loosening of the components. Overall rates of aseptic loosening in UKA have been cited between 0.5% and 18% [3]. Of UKA failures, aseptic loosening accounts for 31–45% of failures and is the major mode of failure in the first several years following UKA [5–7]. Patients at a higher risk for aseptic loosening include young, overweight patients with significant varus deformity [37, 44]. Aseptic loosening is more common with the tibial component than in the femoral component [6] (Fig. 17.3). Mechanical factors that increase stress on the tibial component and can contribute to loosening include malalignment, overcorrection of deformity, excessive tibial slope, and anterior cruciate ligament (ACL) deficiency [45]. Mechanically, lowering the joint line corresponds to increased stress on the UKA components and aseptic loosening, while raising the joint line leads to early polyethylene wear and progressive degenerative changes in the other compartment [12]. Initial data suggested that fixed-bearing implants have a higher rate of aseptic loosening due to lower conformity than mobile-bearing components, but recent data have shown that mobile-bearing components may paradoxically demonstrate higher rates of aseptic loosening [27, 28, 46]. All-polyethylene tibial components have a higher rate of loosening than metal-backed components [7, 39, 44]. Aseptic loosening is best addressed by conversion to total knee arthroplasty, although revision UKA may be considered for select patients.

Polyethylene Wear

Polyethylene wear is a less common mode of UKA failure but still accounts for 12–25% of UKA failures [7]. It usually presents as a late mode of failure, after 8 years, but early cases of catastrophic failure have also been reported [47, 48]. Technical factors that contribute to polyethylene wear include component malposition and under-correction of deformity [13, 47, 49]. Implant-specific factors associated with polyethylene wear include thickness less than 6 mm, lack of design conformity, and flaws in the manufacturing and sterilization of PE [47, 49]. Debris from polyethylene causes an osteolytic reaction at the bone-implant interface and can affect alignment and stability of the implant. Uneven load distribution from component malalignment/instability can accelerate aseptic loosening [47]. Increased ligamentous laxity and subluxation of the tibiofemoral implant surface can also contribute to increased polyethylene wear [48]. In addition, progression of osteoarthritis may also cause attenuation of the anterior cruciate ligament, leading to increased subluxation as well [48]. Subluxation of the implants concentrates force over the peripheral aspect of the tibial component, which is also where the polyethylene layer is the thinnest [48]. Improvements in wear-characteristics of polyethylene may decrease the prevalence of UKA failure from polyethylene wear. Management options of polyethylene wear include polyethylene exchange or revision to total knee arthroplasty.

Bearing Dislocation

Mobile-bearing dislocation accounts for 1.5–4.6% of UKA failures [5]. These dislocations

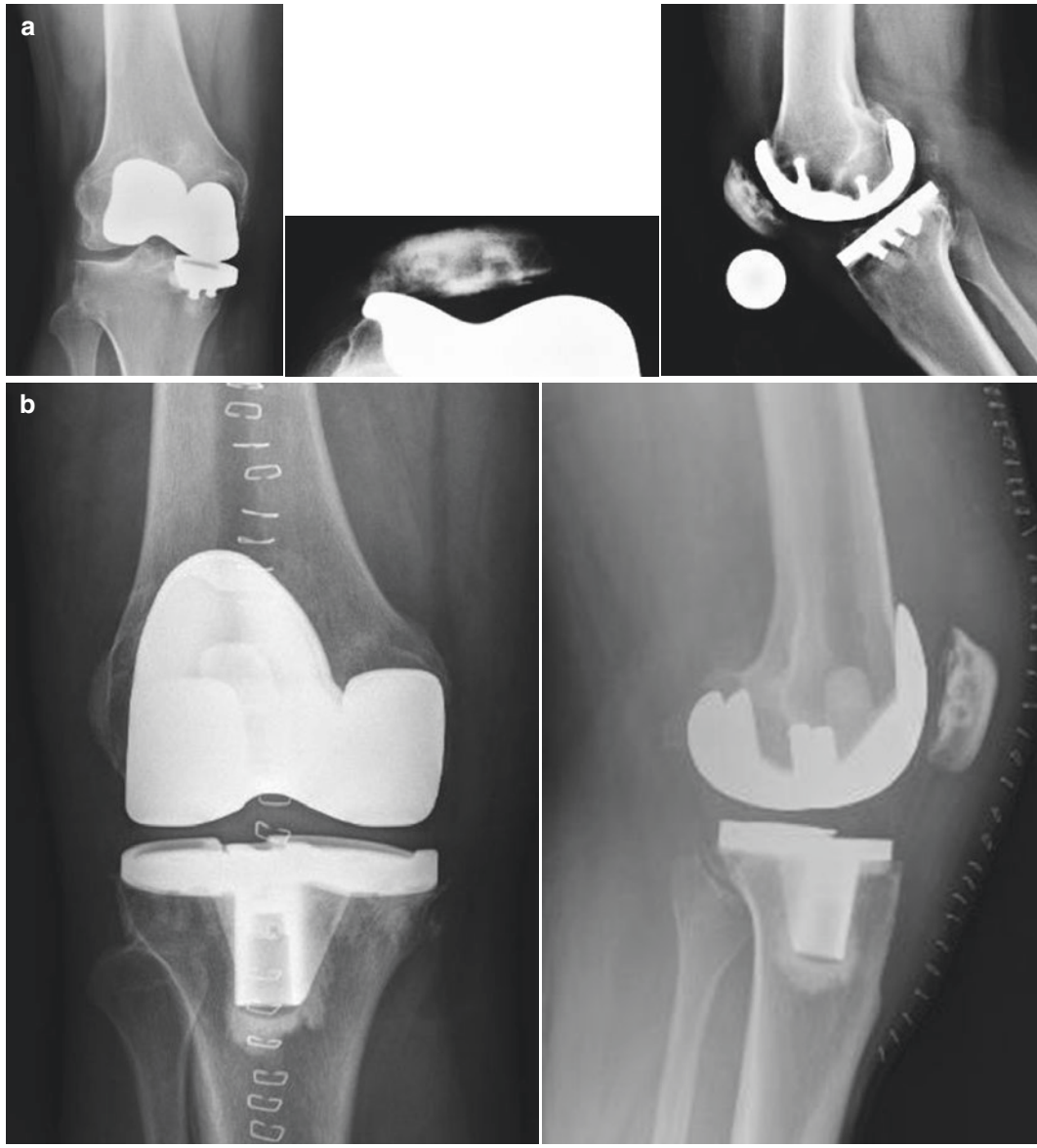

Fig. 17.3 (**a**) A failed bicondylar replacement with tibial subsidence and loosening. (**b**) Revision to a cruciate-retaining total knee arthroplasty

more commonly affect the lateral compartment secondary to the increased laxity of the lateral collateral ligament (LCL), the convexity of the lateral tibial condyle, and the medial femoral rollback during flexion [5, 7, 19–22, 49]. Medial mobile-bearing dislocations can occur in the setting of unbalanced flexion/extension gaps, instability due to medial collateral ligament (MCL) injury, or component malposition with impingement of the insert on the adjacent bone [46, 50]. In contrast to total knee arthroplasty, soft tissue releases are not recommended in UKA due to risk of instability and bearing dislocation, as the goal of UKA is to restore ligament tension to normal, thereby restoring knee kinematics [40]. Joint instability following UKA can also contribute to early polyethylene wear and aseptic loosening, which can, in turn, increase the risk of

mobile-bearing dislocation [47]. Management for bearing dislocation includes revision UKA with a fixed bearing or conversion to total knee arthroplasty [37].

Tibial Collapse

Tibial subsidence is the most common cause of periprosthetic fracture following UKA and accounts for 3.6–10.4% of UKA failures [6, 51]. Tibial collapse commonly presents as a late complication and is more common in elderly patients, suggesting osteoporosis as a contributing factor [51, 52]. It most commonly affects the medial tibial plateau due to increased pressure and load [37]. Technical factors, which may contribute to tibial subsidence, include excessive posterior tibial slope [52, 53]. Surface area of the tibial component and depth of the tibial resection may also play a role, but this has not been demonstrated in the literature [52]. Tibial collapse is also more commonly associated with fixed-bearing all-polyethylene implants. These implants have higher contact stresses at localized points in the anterior and medial tibia, leading to localized edge loading and tibial collapse [54]. Management options for tibial collapse include percutaneous screw fixation and revision to TKA and may require cement, augments, cones, and stems depending on the degree of bone loss, status of the other knee compartments, and degree of deformity [31–34, 46, 52, 55].

Infection

Infection following UKA occurs at a rate of 0.2–1% [56]. While this rate is slightly lower than that of total knee arthroplasty, UKA infections are unique in that they involve both the prosthesis and native cartilage [56]. The diagnostic workup of infection in UKA is based on that of total knee arthroplasty with preoperative laboratory studies used to guide potential aspiration [57, 58]. Given the involvement of both native cartilage and prosthesis, slightly different thresholds for the diagnosis of infection have been proposed. In a study of 259 patients undergoing revision UKA, Schwartz et al. [59] found a 10.8% infection rate and proposed cutoff values of the following: ESR: 27 mm/h, CRP: 14 mg/L, synovial fluid WBC count of 6200 cells/μL, and 60% neutrophils. The proposed cutoff for aspirate leukocyte count is higher than that of total knee arthroplasty. This may be attributable to the involvement of more of the native cartilage but requires further investigation and validation [59]. The causative organisms in UKA infections are similar to those in total knee arthroplasty infection with coagulase-negative *Staphylococcus*, *S. aureus*, group B *Streptococcus*, *E. coli*, and *P. acnes* among the most common organisms [56, 59]. Management of UKA infection is similar to that of total knee arthroplasty. Acute infections can be managed with irrigation, debridement, polyethylene liner exchange, and antibiotics, while chronic infections require irrigation and debridement with antibiotic spacer, antibiotics, and conversion to total knee arthroplasty [37]. Labruyere et al. proposed synovectomy with one-stage conversion to total knee arthroplasty and 3 months of antibiotics as a reasonable alternative to two-stage conversion to total knee arthroplasty, with no infection recurrence and good functional outcomes at early follow-up [56].

Unexplained Pain

Unexplained pain is an important cause for revision after UKA. While etiology is unknown, it accounts for up to 23% of revision surgery according to registry data from England and Wales [60]. This is significantly higher than the rates of revision for total knee arthroplasty for unexplained pain, which is estimated to be about 9% [60]. Overall, the rates of the unexplained pain following UKA vary from 5% to 15% [5–7]. While the etiologies may differ on a patient-by-patient basis, proposed etiologies include loose bodies, cement extrusion, meniscal tears in the native compartment, and chronic regional pain syndrome or reflex sympathetic dystrophy [37]. Due to the limited exposure and single-piece implants used in some systems, it can be

technically challenging to remove extruded cement from the posterior aspect of a UKA. Given the hybrid of native cartilage and prosthesis, failure to restore normal joint alignment and mechanics can contribute to pain generators such as meniscal tears and loose bodies. Furthermore, all-polyethylene tibial components have been associated with higher rates of unexplained pain [61]. This may be related to the higher rates of tibial collapse seen with fixed-bearing all-polyethylene tibial component due to higher load transfer to the tibia resulting in persistent bone remodeling [61]. The threshold for revision due to unexplained pain may also differ based on surgeon experience and familiarity with UKA [62]. In an examination of the New Zealand Joints Registry, Goodfellow et al. showed that in knees that had very poor outcome (Oxford Knee Score <20), 63% of UKAs went onto revision surgery, while only 12% of TKAs were revised [62]. Management of the unexplained pain following UKA is surgeon-specific, but the conversion of a UKA to a total knee arthroplasty is less technically demanding than revision of a total knee arthroplasty. Thus, surgeons may have a lower threshold to offer revision to total knee arthroplasty as an option for patients with unclear pain generators following UKA [60, 62].

Patellofemoral Arthroplasty

Patellofemoral arthroplasty (PFA) has seen an increase in popularity owing in large part to the development of second-generation PFA design and technique [63]. First generation of complete PFA (replacement of both patella and trochlea) was performed using the inlay technique – replacing only the trochlear cartilage and leaving subchondral bone intact. As a result, position of the trochlear component was dictated based on the anatomy of the native trochlea and free-hand technique proved technically challenging [64–66]. While early 1- to 2-year outcomes were encouraging, first-generation PFA showed high rates of excessive wear in the trochlear groove and patellar maltracking [65–68]. Long-term follow-up, ranging from 5 to 20 years, showed revision rates of 25–60%, with failure secondary to patella maltracking, trochlear wear, and progression of tibiofemoral joint arthritis [67–70].

Second-generation PFA was developed as a result of the high percentage of failures seen with the inlay technique. With the second-generation onlay design, anterior femoral cuts are made and the trochlear prosthesis is seated within the anterior compartment of the knee. In addition, modifications to the trochlear implant design and shape allowed for decreased catching, better tracking angle, and congruity throughout range of motion [71]. As a result of these changes, as well as careful patient selection, revision rates with second-generation techniques have been reported to be as low as 3–10% at 5- to 10-year follow-up [72–74]. With the onlay technique, revision due to patellar maltracking has been shown to be approximately 1–2% [73, 74]. The most common modes of failure for modern PFA are progression of tibiofemoral arthritis (38%), persistent anterior knee pain (16%), aseptic loosening (14%), and patellar maltracking (10%). Persistent anterior knee pain is the most common complaint among those with an early need for revision, while progression of tibiofemoral arthritis is the most common late mode of failure [64, 73, 75]. When comparing second-generation PFA and TKR, some studies have shown no difference in revision rates or pain while also reporting quicker recovery and higher activity scores in patients who underwent PFA [75, 76]. Treatment for failure of PFA is conversion to TKA, with multiple studies showing equivalent outcomes to primary TKA [77, 78].

Summary

UKA has developed over the years into a successful and predictable procedure, with survival rates greater than 90% at 10, 15, and 20 years. Aseptic loosening and adjacent compartment arthritis account for the majority of UKA revisions. Mobile-bearing dislocation, tibial collapse, and infection account for the remaining implant failures. Patellofemoral arthroplasty is most often revised due to persistent anterior knee pain or

progression of tibiofemoral arthritis. Unexplained pain following UKA is another common cause of revision but may be biased by the relative ease of converting a UKA to a total knee arthroplasty. Conversion to total knee arthroplasty is generally recommended for implant failure; however, less invasive management such as irrigation and debridement with polyethylene liner exchange may be appropriate in select circumstances such as acute infection or polyethylene wear.

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18

Periprosthetic Fracture in Unicompartmental Knee Arthroplasty

Anthony J. Boniello, Craig J. Della Valle, and P. Maxwell Courtney

Introduction

Periprosthetic fracture following unicompartmental knee arthroplasty (UKA) is a rare but important complication that orthopedic surgeons must be prepared to treat. Fortunately, periprosthetic fractures following UKA are uncommon, with reports in the literature limited to case studies [1–7] and small case series [8–11]. The overall incidence of periprosthetic fracture following UKA has been reported in several studies as between 0.1% and 1.2% [12–14]. While the incidence of fracture is small, the rate at which UKA is being performed has increased 6.2-fold from 2000 to 2009 [15]. Despite this increase in the popularity of UKA, the rate of revisions resulting from periprosthetic fractures decreased nearly 70% during 2005–2015 relative to 1994–2004 [16]. This decrease may be a result of improved implant designs and operative techniques as well as surgeon awareness of techniques to avoid this complication.

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Etiology

There is a paucity of literature analyzing risk factors for periprosthetic fracture following UKA. Patients with metabolic bone conditions leading to poor bone quality are at risk for periprosthetic fracture in general [17]. Fractures have also been associated with stress risers associated with the pinholes used to affix the tibial cutting guide, the vertical tibial cut itself, and tibial component size and position [8, 9, 12]. Low-volume hospitals also appear to have a higher risk of revision due to fracture than high-volume hospitals [18].

The vast majority of UKAs are performed on the medial compartment, accounting for 90–95% of the total amount of the UKA procedures [19]. Not surprisingly, periprosthetic fractures most often occur in the medial tibial plateau, with periprosthetic femoral fractures occurring less frequently [14] One study of 246 UKAs found a 0.4% incidence of medial plateau periprosthetic fracture [12]. Another study of 1576 UKAs reported 0 periprosthetic fractures in 24 lateral UKAs, versus 6 in 1552 medial UKAs. The same study also reported periprosthetic fractures occur most frequently on the tibial (five cases) versus the femoral side (1 case) [14]. With lateral UKA being performed at a much lower rate, lateral periprosthetic fracture following UKA is rare, with only one such case report in the orthopedic literature [1].

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One proposed etiology of a stress riser, which may lead to periprosthetic fracture, involves the vertical tibial cut [3, 20]. Seeger et al. analyzed six cadaveric specimens and found extended sagittal cuts of 10 degrees reduce the loading capacity of the tibial plateau (3.9 vs 2.6 kN, $p < 0.05$) and therefore may increase the risk of periprosthetic fracture [20]. (Fig. 18.1).

Stress risers related to component size and position have also been reported as a potential source of periprosthetic fracture. A large tibial component may increase the force being exerted on the nonsupported portion of the tibial tray in weight-bearing flexion, which may result in a periprosthetic tibial plateau fracture [9]. Alternatively, a small tibial component results in increased pressure transmission between the component and the proximal tibial plateau. The stress will be concentrated on a small and eccentric region of the tibial plateau potentially leading to tibial plateau fractures as well [9]. Peripheral placement of the tibial component is often necessary to avoid impingement on the anterior cruciate ligament. However, this practice could lead to a metaphyseal fracture of the tibia due to decreased bone support beneath the tibial components [12].

Fig. 18.1 An extended sagittal cut increases the risk of periprosthetic fracture following UKA. ([Clarius et al. 2010, Knee, Elsevier, reprinted with permission] [20])

Periprosthetic fractures may also be related to stress risers resulting from the pinholes, which are required to position the extramedullary guide on the proximal tibia [8]. Similarly, preparation of the tibia with a tibial gouge, which is used in some systems, may also create a stress riser if the posterior tibial cortex is breached, through which a fracture line can propagate [4] (Fig. 18.2).

Femoral periprosthetic femoral fractures may occur as well, although with less frequency than tibial plateau fractures [3–6, 8, 9, 12, 20]. Impaction trajectory during femoral component placement may result in a periprosthetic fracture. Figure 18.3 shows the effect of the direction of the impaction force relative to the femoral condyle. Although dorsally directed impaction facilitates sliding of the pegs into the bone, this could also create a shear force on the medial condyle. A vertical shear force to a flexed knee is known as the usual mechanism of injury of coronal plane fractures of the femoral condyle in high-energy trauma [5].

Case Examples

Case 1

A 72-year-old female underwent right medial UKA for isolated medial compartment osteoarthritis. Four pins were placed to hold the extramedullary tibial cutting guide, one of which violated the medial cortex. The patient developed medial knee pain postoperatively and was managed with protected weight bearing (Fig. 18.4). Unfortunately, on serial radiographs (Fig. 18.5a

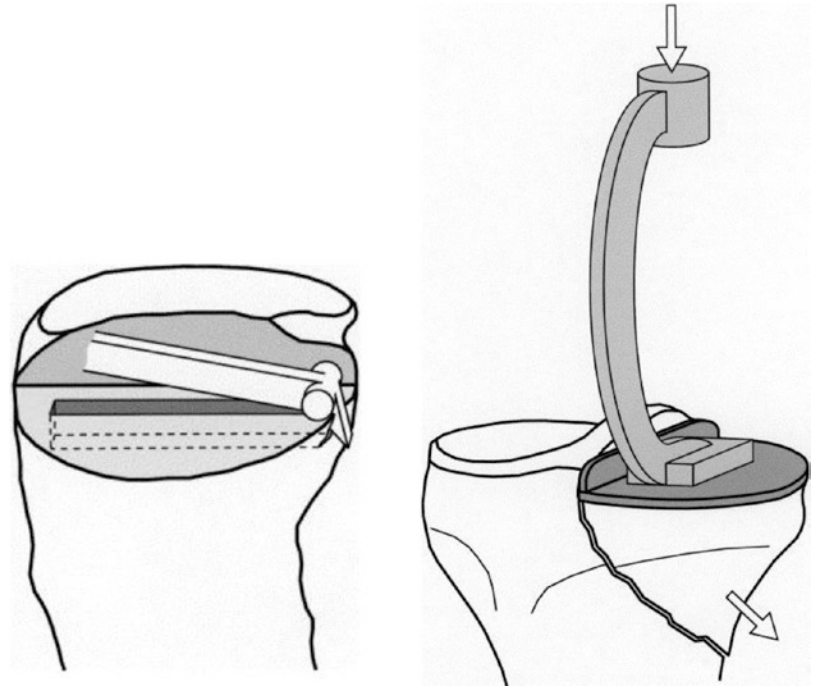

Fig. 18.2 Stress riser as a result of breaching of the posterior cortex by the tibial gouge. ([Sloper et al. Knee, 2003, Elsevier, reprinted with permission] [4])

Fig. 18.3 Diagrams demonstrating the effect of the direction of the impaction force relative to the femoral condyle. Left: slightly anteriorly directed impaction angle resulting in an impaction force in line with the medial condyle. Right: posteriorly directed impaction angle resulting in a shear force on the medial condyle. ([Brinke et al. Sport Traumatol Arthrosc. 2016, Springer, reprinted with permission] [5])

and b), her components subsided and she was managed with revision TKA 6 months following her index procedure [8].

Case 2

A 68-year-old female with isolated medial compartmental degenerative joint disease of her knee underwent an uncomplicated left medial UKA. She was recovering well until she sustained a mechanical fall 2 weeks postoperatively where she developed a varus deformity, pain, and inability to bear weight (Fig. 18.6). Her components were found to be stable, and she underwent open reduction and internal fixation with a medial proximal tibial locking plate. At 1 year, she was doing well with a radiographically healed periprosthetic tibial plateau fracture and a well-functioning, well-fixed medial UKA (Fig. 18.7).

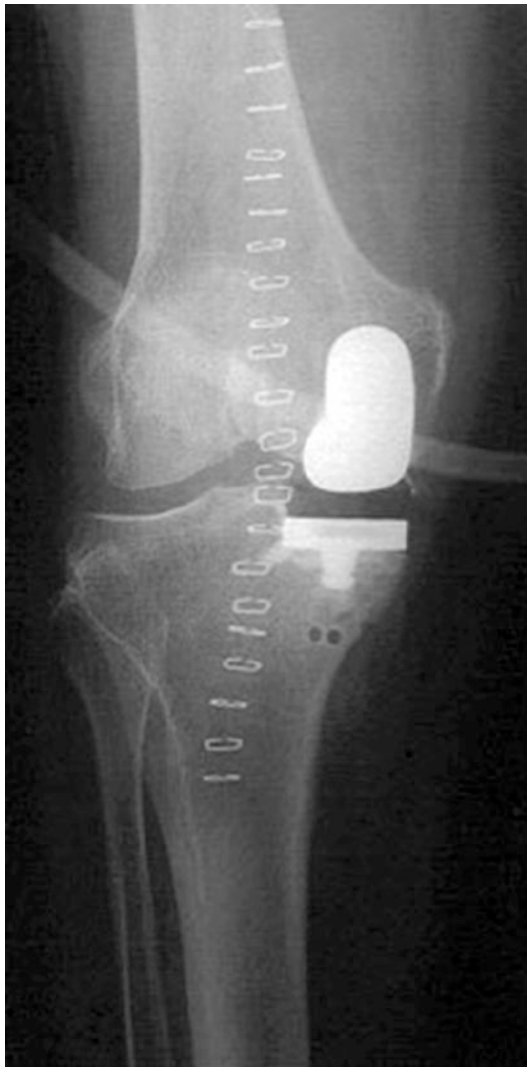

Fig. 18.4 Initial postoperative radiographs demonstrating a stress riser from multiple pins in the tibial plateau, one of which violated the medial cortex. ([Brumby et al. Journal of Arthroplasty, 2003, Elsevier, reprinted with permission] [8])

Treatment

Optimal treatment for periprosthetic fractures following UKA varies based on the timing of fracture, timing of diagnoses, patient functional status, fracture displacement and morphology, and, most importantly, implant stability.

Nonoperative Treatment

Nonoperative treatment has been proposed for nondisplaced fractures with stable components or for lower demand, elderly patients. Some data show success with nonoperative management in a long leg cast with no weight bearing for at least 6 weeks [5, 10]. Pandit et al. recommended conservative treatment if a nondisplaced fracture is diagnosed early [11]. One study by Woo et al. found that five out of five patients treated nonoperatively went on to union. However, due to component migration and poor patient-reported health and function scores, the authors ultimately recommend surgical treatment [10]. For nondisplaced tibial plateau fractures with stable implants, we recommend a period of protected weight bearing with a hinged knee brace of at least 6 weeks. Careful, frequent, clinical, and radiographic follow-up is necessary in these patients to recognize early fracture displacement.

Surgical Treatment

Surgical management varies based on fracture location, displacement, and stability of the components. Typically, surgical intervention is recommended if the fracture is displaced, but it is paramount that the treating surgeon determine the stability of the UKA prosthesis. Any amount of subsidence or migration of the femoral or tibial components on serial radiographs is indicative of a loose prosthesis. With stable components and a displaced fracture, such as Case 2, we recommend open reduction and internal fixation with a buttress plate. Open reduction and internal fixation of a large medial proximal tibial component with 6.5 mm cannulated screws has been described [21]; however, a medial buttress plate provides more stability and is strongly preferred [3, 21]. One cadaveric study compared angle-stable T-plates (manufacture and size not reported) versus two 6.5-mm cannulated screws [21]. The authors reported the median fracture load for the plate versus screw groups were 2.64

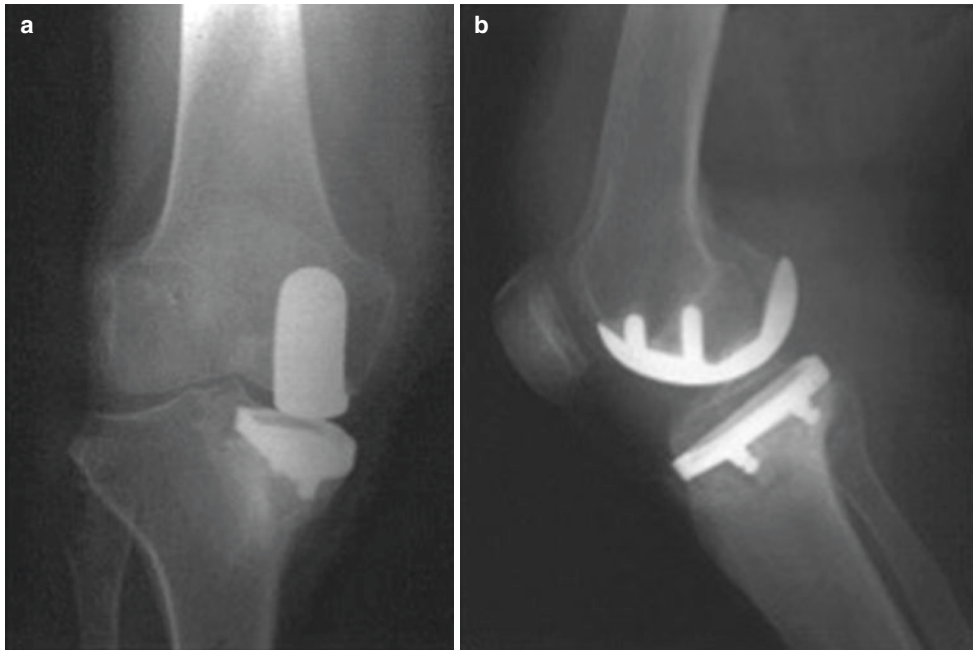

Fig. 18.5 (**a** and **b**) Radiographs at 6 months of follow-up demonstrating subsidence of the implant. ([Brumby et al. Journal of Arthroplasty, 2003, Elsevier, reprinted with permission] [8])

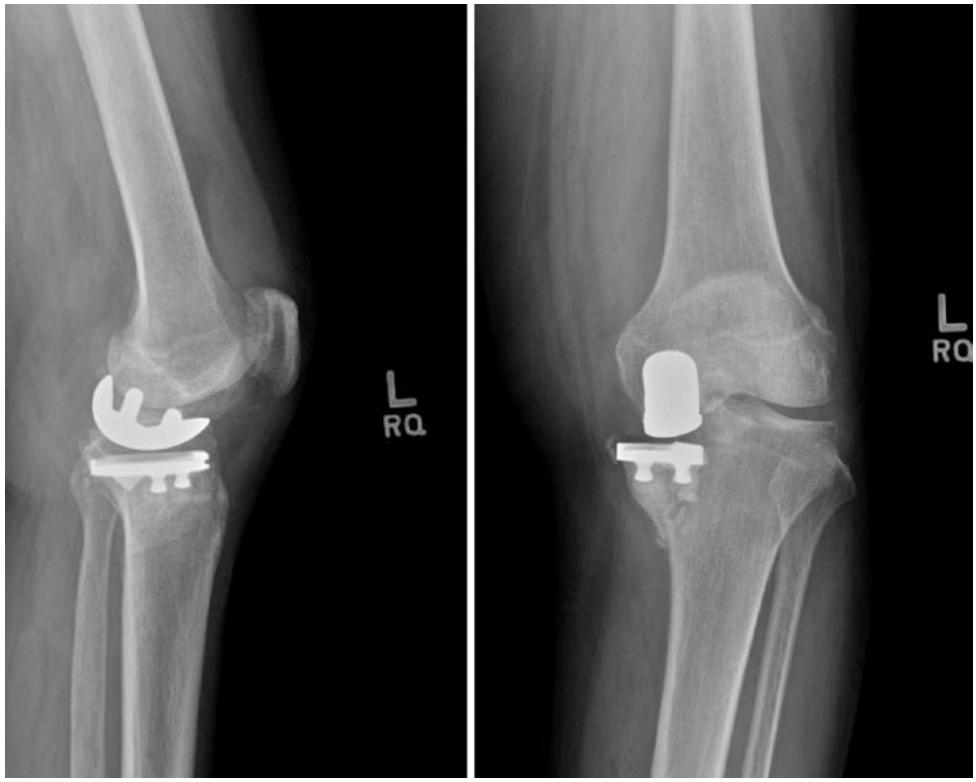

Fig. 18.6 AP and lateral views demonstrating a medial tibial plateau periprosthetic fracture around a well-fixed UKA implant

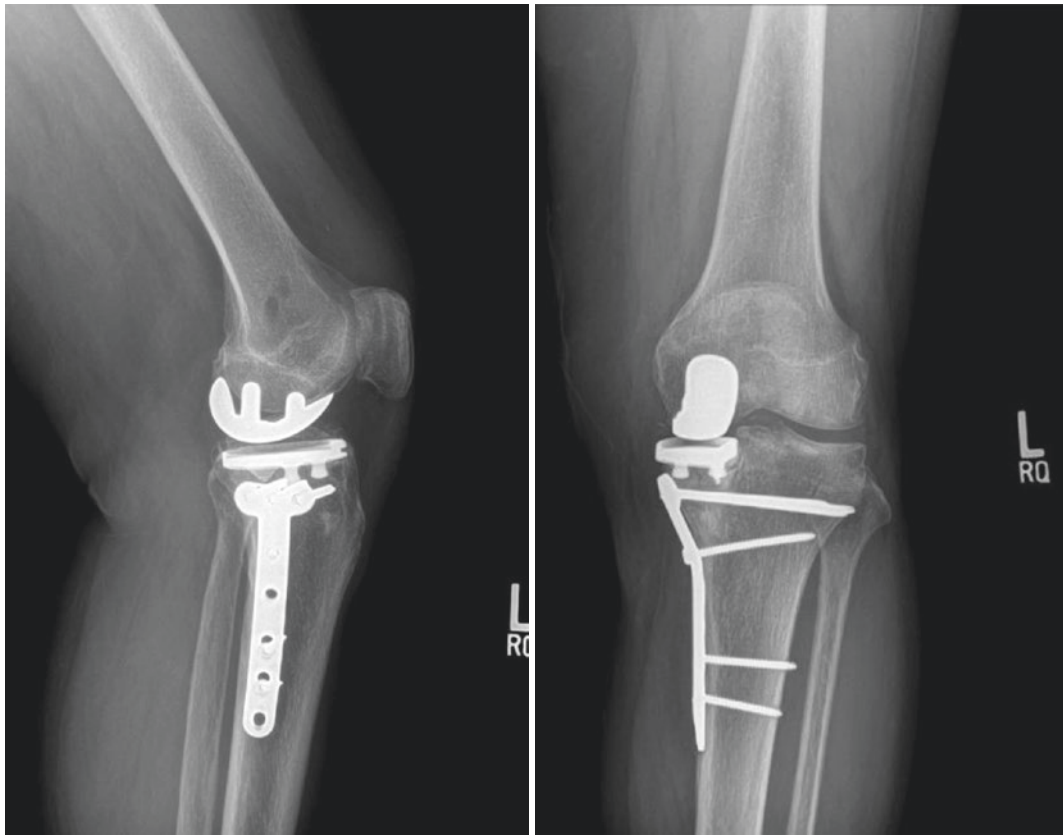

Fig. 18.7 Postoperative radiographs at 1 year demonstrating a well-healed periprosthetic tibial plateau fracture treated with plate osteosynthesis

versus 1.50 kN, respectively (p = 0.028). We recommend a period of at least 6 weeks of protected weight bearing in an unlocked hinged brace following ORIF of a periprosthetic fracture around a well-fixed UKA prosthesis.

As in periprosthetic fractures around THA or TKA, patients with a fracture around a UKA with a loose prosthesis must be revised. Conversion of UKA to TKA for a periprosthetic fracture can be a technically complex operation requiring stems, bone graft, augments, and revision components [5, 8]. Our recommended treatment algorithm is shown in Fig. 18.8.

Summary

Periprosthetic fracture following UKA is a rare but important complication. The reported incidence of periprosthetic fracture ranges from 0.1% to 1.2% and most common in the medial tibial plateau. Nonoperative treatment with protected weight bearing and bracing can be successful for non- or minimally displaced fractures with stable components. Surgical treatment options for tibial periprosthetic fractures following UKA include open reduction and internal fixation with a buttress plate for displaced frac-

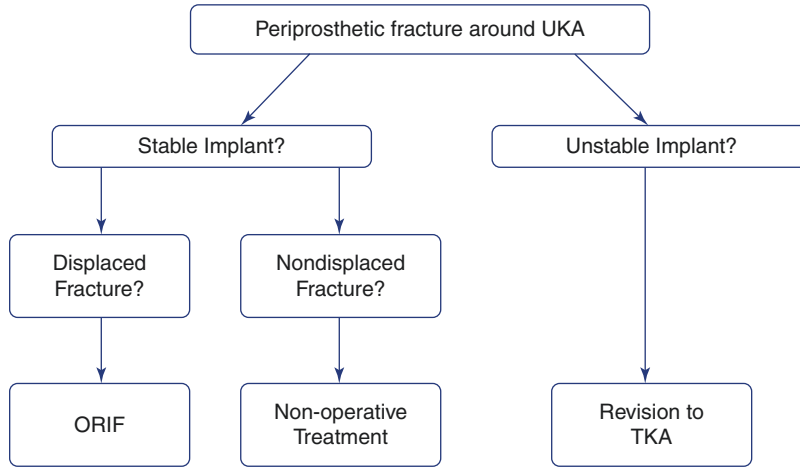

Fig. 18.8 Recommended treatment algorithm for management of periprosthetic fractures around a UKA

tures around a stable component and conversion to TKA for unstable implants, which can be technically challenging.

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19 Preventing Infections in Unicompartmental Knee Arthroplasty

Charles P. Hannon and Craig J. Della Valle

Introduction

Periprosthetic joint infection (PJI) is a devastating complication after total joint arthroplasty (TJA). While rates of PJI are lower after unicompartmental knee arthroplasty (UKA) compared to total knee arthroplasty (TKA), PJI still leads to a substantial increase in morbidity and mortality after UKA [1]. Unfortunately, despite significant research into infection after total joint arthroplasty (TJA), rates of PJI have not significantly changed over the past several years with PJI rates of up to 2% encountered after primary TKA and up to 1% after primary UKA [2]. One of the most effective strategies in combating PJI is prevention. Much of the literature on prevention of PJI is focused on TKA; however, the same principles apply to UKA. This chapter focuses on the three major areas of PJI and SSI prevention in UKA: (1) preoperative strategies, (2) intraoperative strategies, and (3) postoperative strategies (Table 19.1).

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Preoperative Strategies for Preventing PJI

Preoperative strategies for preventing PJI after UKA are primarily focused on identifying and modifying or eliminating known risk factors including obesity, malnutrition, hyperglycemia, active infection, immunosuppressive medications, skin problems, chronic medical conditions, intravenous drug abuse, tobacco use, alcohol consumption, preoperative opioid use, methicillin-resistant *Staphylococcus aureus* colonization, and depression [3]. We recommend reading Chap. 4, optimizing the host, which goes into great detail about many of these modifiable risk factors and how to address them prior to surgery.

Preoperative Skin Cleanse

The skin is a natural protective barrier of microbes but also serves as a large host of bacteria that can cause PJI. Preoperative skin cleansing has been shown to be an effective method to decrease bacterial load and decrease rates of surgical site infections (SSI) [4]. The Centers for Disease Control and Prevention recommend a full body wash the night before surgery [5]. The type of cleansing agent that should be used remains controversial [5]. While historically, soap and water was the recommended cleansing agent, recent literature suggests that the antiseptic chlorhexi-

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Table 19.1 Strategies for reducing UKA prosthetic joint infection

Preoperative	Intraoperative	Postoperative
Medical optimization with modifying medical risk factors Preoperative skin cleanse Preoperative infection screening	Preoperative antibiotic prophylaxis Hair removal with clippers Surgical site preparation with antiseptic Minimizing operating room traffic and operative time Antibiotic-impregnated cement for high-risk patients Maintenance of normothermia	Aspirin for venous thromboembolic prophylaxis when clinically Limiting allogeneic blood transfusion Minimize length of stay Antibiotic prophylaxis prior to invasive gastrointestinal, genitourinary, or dental procedures

dine gluconate may be more effective in reducing PJI. Kapadia et al. demonstrated in their series of 3717 patients that preoperative chlorhexidine gluconate reduces PJI after TKA by 6.3-fold [6]. A prospective randomized controlled trial conducted by the same group found that preoperative cleansing with chlorhexidine gluconate, both the night before and morning of surgery, led to a 2.5% reduction in PJI incidence [7]. At our institution, we recommend that all patients wash the area of the incision with chlorhexidine gluconate wipes the night before and the morning of any lower extremity arthroplasty procedure including UKA.

Infection Screening

The presence of local or systemic infection is considered to be a contraindication prior to any elective arthroplasty procedure [8]. Patients may be colonized, but remain asymptomatic, in several areas including the urinary tract, skin, nails, and anterior nares [9]. Dental screening has been studied, but no evidence has been found that routine dental screening reduces the incidence of PJI [10, 11]. Similarly, there is limited evidence supporting routine urine screening to reduce PJI.

There is substantial evidence that nasal carriage of methicillin-resistant *Staphylococcus aureus* (MRSA) is a risk factor for subsequent surgical site infection (SSI) [12]. Several risk factors for *S. aureus* carriage include male gender, obesity, history of multiple hospital admissions, cerebrovascular accident, and presence of pets at home [13]. Controversy exists regarding the cost-effectiveness of routine nasal screening and treatment, but some reports suggest that this can reduce SSI by up to 3.5-fold [14]. Empirical use of mupirocin without screening has also been studied and shown to be effective in reducing SSI incidence, but there remain concerns regarding the development of mupirocin resistance with widespread use [15, 16]. Preoperative nasal povidone iodine solution has also been studied and may be more efficacious than nasal mupirocin in preventing PJI [17]. Universally applied, preoperative nasal povidone iodine may also be more cost-effective than MRSA screening and treatment in preventing SSI [18].

Intraoperative Strategies for Preventing PJI

Preoperative Antibiotic Prophylaxis

The administration of appropriate prophylactic antibiotics prior to incision may be the most effective measure of reducing PJI and SSI prior to UKA. The use of prophylactic antibiotics has been shown to markedly decrease the risk for PJI and SSI by eliminating possible infecting organisms that may reach the incision by contamination [19]. Typically, a first- or a second-generation cephalosporin is recommended, as it is bactericidal and has good distribution in varying tissue types [20]. In addition, it provides broad bacteria pathogen coverage and is cost-effective [21, 22]. For most patients in North America, cefazolin is utilized with 1 g being used for patients who

weigh less than 80 kg, 2 g for patients between 80 kg and 120 kg and 3 g for patients who weigh more than 120 kg. For patients who are allergic to penicillin, clindamycin may be used as an alternative. Vancomycin has been studied as an adjunct for patients who are at high risk for MRSA infection, such as institutionalized patients, health care workers, and patients with a history of MRSA infection [23]. It is important to note, though, that vancomycin should not be used alone for prophylaxis, as it has poor gram-negative coverage and can increase rates of PJI and SSI [24]. Vancomycin dosing should be weight based, and the drug should be infused slowly, generally over 1 hour prior to incision.

Prophylactic antibiotics should be administered within 1 hour prior to incision [25]. If the surgery lasts longer than the half-life of the prophylactic agent (e.g., 4 hours for cefazolin) the antibiotic should be re-dosed and a second dose should be given to the patient intraoperatively. Similarly, if intraoperative blood loss is high, redosing of antibiotics should also be considered [25]. Postoperatively, many surgeons continue prophylactic antibiotics for 24 hours. However, recent evidence suggests that a single postoperative dose may be as effective, less toxic, cheaper, and prevent long-term development of antibiotic resistance [26].

Hair Removal

While there is no evidence on the influence of hair removal on PJI and SSI rates after TKA or UKA, most surgeons remove hair prior to surgery. Removing hair allows for better wound visualization and subsequent closure and additionally may reduce the bacterial burden at the incision [5]. When hair is removed, clippers should be used instead of razors [27].

In our practice, we routinely remove hair over the surgical incision prior to the procedure using clippers. Hair removal should occur as close to the surgical procedure as possible yet outside of the operating room.

Surgical Site Preparation

Prior to incision, an antiseptic skin preparation agent should be utilized to rapidly clear the surgical site of any residual bacteria and suppress growth of any potential contaminants [28]. The most commonly used intraoperative surgical site preparation agents are chlorhexidine gluconate based or povidone iodine based. A recent Cochrane review found that there is weak evidence that chlorhexidine is superior to iodine in reducing SSI [29]. The addition of alcohol to either a chlorhexidine gluconate or povidone iodine solution has been shown to increase the antibacterial efficacy of the antiseptic solution, reduce bacterial load, and increase the length of efficacy [30, 31]. Iodine-impregnated drapes are also commonly used for arthroplasty procedures; however, limited evidence is available regarding their influence on SSI rates [32].

Operating Room Traffic

Airborne bacteria are known to be present in the operating room, but their role in SSI and PJI is controversial. Airborne bacteria are present due to many factors, but a major carrier of these bacteria is operating room staff [33]. Increased operating room (OR) traffic increases the number of bacteria that are brought into the operating room and that may be displaced airborne [34]. OR traffic has been shown to increase air particle counts, bacterial count, disrupt airflow, and may lead to increased contamination of the surgical site [35, 36]. There are no specific guidelines to reduce operating room traffic, but at our institution, we make several efforts to limit OR traffic during UKA procedures. To reduce traffic, we have all implants inside the OR prior to the procedure. Second, we attempt to limit the number of persons in the room during the surgery and limit the number of door openings, which both have been found to increase the density of air particles [34]. Additionally, we attempt to limit staff changes, such as the scrubbed technicians or anesthesia, during the procedure.

Body Exhaust Suits and Surgical Helmet Systems

Body exhaust suits or surgical helmet systems are commonly used during arthroplasty procedures; however, their role in reducing SSI and PJI is controversial. A systematic review by Young et al. found that negative-pressure Charnley-type body exhaust suits led to less air contamination, less wound contamination, and fewer deep infections when compared to positive-pressure surgical helmet systems [37]. A review of the New Zealand Joint Registry database also found that surgical helmet systems did not reduce SSI and may in fact increase PJI [38]. At our institution, all scrubbed staff use surgical helmet system. Future level I studies are warranted to determine whether body exhaust suits and surgical helmet systems influence SSI or PJI.

Laminar Airflow

The impact of laminar airflow ventilation compared with conventional ventilation has been studied for decades. Early studies in the 1970s and 1980s suggested that laminar airflow reduced infections [37, 38]. Recent systematic reviews and registry data suggests\ that laminar airflow may in fact increase the rate of PJI, particularly if it is horizontal laminar flow (as opposed to vertical) [38–40]. The New Zealand Joint Registry found that laminar airflow increased PJI by an odds ratio of 1.6 [38]. The efficacy of laminar airflow in reducing PJI is thus still debated. While laminar airflow may not be necessary, any efforts to modify the air quality and number of air particles with a positive ventilation system likely decrease the bacterial count in the operating room and ultimately the risk for SSI and PJI.

Body Temperature Management

There is no literature to our knowledge on the influence of maintenance of normothermia on PJI and SSI after UKA; however, there are several theoretical advantages. Maintaining adequate oxygenation of tissues is essential for an effective immune system. Hypothermia is known to cause vasoconstriction and subsequently limits oxygen delivery to tissues [5]. Several studies in nonorthopedic literature have found that intraoperative warming with forced air warming systems have led to a significant reduction in SSI [41]. As a result, the Center for Disease Control and Prevention and the World Health Organization have strongly recommended that all intubated patients receive supplemental oxygen and have normothermia maintained intraoperatively. Concerns have been raised that forced warming systems may paradoxically increase SSI by disrupting airflow, yet this remains debated [42, 43]. Further studies of forced warming systems in TJA are required to determine the true influence on SSI and PJI.

Antibiotic-Impregnated Cement

The routine use of antibiotic-impregnated cement in knee arthroplasty remains controversial, and differences in use are mainly geographic. In Europe, antibiotic-impregnated polymethylmethacrylate cement is widely utilized. However, registry data on its influence on PJI and SSI are mixed. A Nordic registry study demonstrated that antibiotic-impregnated cement reduced infections in THA patients [44]. Both the Australian registry and the Canadian registry found no difference in infection rates between plain cement and antibiotic cement in TKA patients [45]. As a result of this inconclusive evidence and the increased cost, widespread use of antibiotic-impregnated cement has not been adopted in the United States. At our institution, we utilize antibiotic cement for high-risk patients, such as patients with a history of MRSA infection, diabetes, and/or on immunosuppressive medications.

Wound Closure and Dressing

Many studies have compared different sutures and closure techniques in TKA and evaluated wound dehiscence, SSI, and PJI [46, 47]. Currently, there is no consensus on what suture or closure

technique should be utilized. Barbed monofilament suture has been shown to be cost-effective, decrease operative time, decrease biofilm formation, and bacterial adherence and lead to fewer wound complications compared with traditional suture (Fig. 19.1) [48, 49]. Recent interest in antimicrobial-coated sutures has been investigated, but current literature is inconclusive. A meta-analysis of 29 studies of nonorthopedic literature found that triclosan-containing sutures may reduce the risk of SSI compared with plain suture [50]. However, a recent randomized controlled trial of 2546 hip and knee arthroplasty patients found no difference between triclosan-containing sutures and normal sutures in rates of PJI and SSI [51]. Staples may also be used, but concerns have been raised regarding increased superficial infection and wound dehiscence. At our institution, we utilize barbed suture for closure of all layers including the subcuticular layer, as this has been shown to least disrupt normal blood flow [52].

There are many options when dressing the surgical wound, all with varying risks and benefits. Regardless of the type of dressing utilized, it should be placed under sterile conditions and monitored for drainage postoperatively. Some research suggests that hydrocolloid dressings or hydrofiber dressings may decrease the rate of SSI and PJI compared with a gauze dressing [53, 54]. Silver-impregnated dressings have also been studied and been shown to reduce rates of PJI by over 3- to 4.5-fold compared to gauze dressings [55, 56]. For patients who are at increased risk of postoperative wound infections (e.g., obese patients, poor skin quality), negative-pressure wound therapy may be beneficial [57, 58]. At our institution, we utilize a hydrocolloid dressing with ionic silver (Aquacel®) that can be left on for up to 7 days after surgery (Fig. 19.2). This dressing also allows patients to shower immediately postoperatively. For patients at high risk for infection or who have concern for wound breakdown, we utilize an incisional negative-pressure wound vac system (Prevena™ Incision Management System).

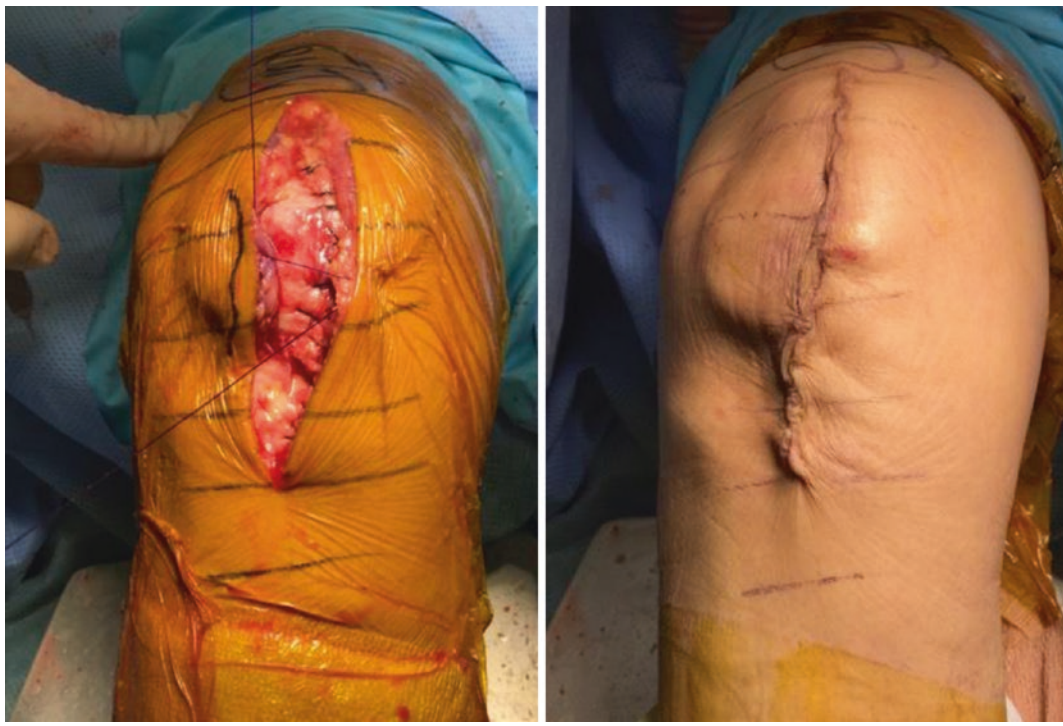

Fig. 19.1 Three-layer barbed suture closure of UKA

Operative Time

Multiple studies have demonstrated that longer operative time increases the risk of PJI and SSI after primary TJA [59–61]. A database review of 165,474 patients by Bohl et al. found that an operative time greater than 107 minutes was correlated with a 9% increased risk of SSI [59]. While the etiology of this increased risk is multifactorial, all efforts should be made to reduce the operative time as much as possible.

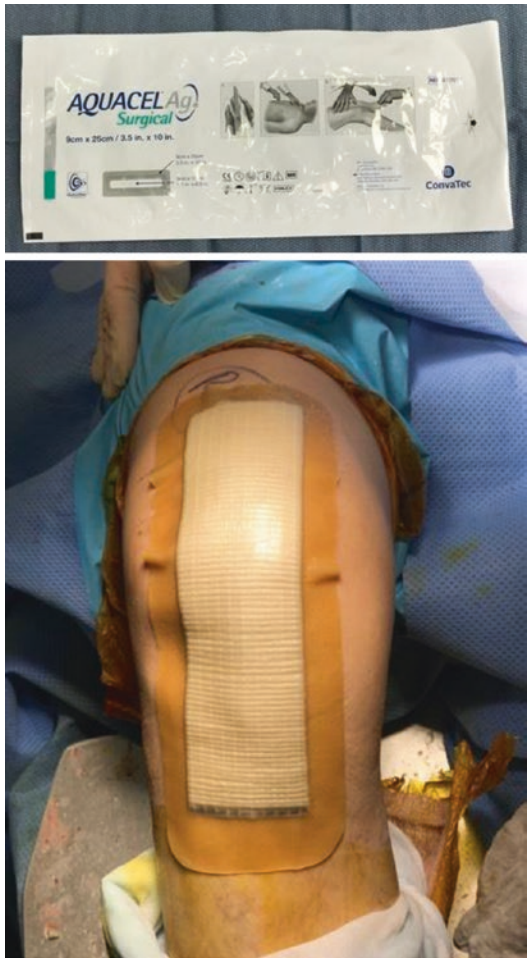

Fig. 19.2 Silver-impregnated waterproof dressing (AQUACEL® Ag Surgical, ConvaTec)

Postoperative Strategies for Preventing PJI

Venous Thromboembolic Prophylaxis

Chemoprophylaxis is recommended after TJA by the Academy College of Chest Physicians and the American Academy of Orthopaedic Surgeons [62]. Several agents may be utilized, including aspirin, low-molecular-weight heparin, heparin, direct oral anticoagulants, vitamin K antagonists, and direct thrombin inhibitors. Aspirin has been shown to be as efficacious as the previously listed agents and been shown to result in a lower risk of wound complications, SSI, and PJI [63, 64]. At our institution, most UKA patients are placed on aspirin for VTE prophylaxis postoperatively unless they are felt to be at a high risk for VTE or if they are chronically anticoagulated preoperatively.

Limiting Allogeneic Blood Transfusion

Perioperative allogeneic red blood cell transfusions have been shown in multiple studies to be an independent significant risk factor for SSI after TJA [65]. A recent review of 6788 primary and revision TKA and THA patients at a single institution found that there was a dose-dependent association between allogeneic red blood cell transfusion and SSI with the risk increasing by almost twofold with transfusion of 1 unit and 7.4-fold increase with transfusion of greater than 3 units [66]. As a result, at our institution, we greatly limit the number of perioperative allogeneic red blood cell transfusions in the perioperative period. Typically, we reserve blood transfusions for patients with a hemoglobin <7 g/dL who are symptomatic (e.g., shortness of breath). With the routine use of tranexamic acid, the risk of transfusion in general is low, with transfusion after UKA being quite rare.

Limiting Length of Stay

After primary TJA, longer length of stay is correlated with increased risk for SSI and PJI [67, 68]. The etiology of this is also likely multifactorial, but limiting exposure to possible nosocomial infections is crucial for preventing PJI and SSI. At our institution, for healthy patients with few medical comorbidities, we offer UKA as an outpatient. For patients who prefer to stay in the hospital after surgery or are not candidates for outpatient surgery, we strongly encourage early discharge after UKA. This encouragement for early discharge begins with preoperative education and continues during the hospital stay with early mobilization and ambulation after surgery. A majority of patients are able to go home the day after surgery. In addition, we strongly discourage patients from going to a skilled nursing or rehabilitation facility after surgery.

Antibiotic Prophylaxis

Routine antibiotic prophylaxis prior to dental, gastrointestinal, or genitourinary procedures is controversial [63]. At the 2018 International Consensus on Orthopedic Infections meeting, 64% of surgeons agreed that there is no role for routine prophylactic antibiotic administration prior to dental or genitourinary procedures [63]. However, many surgeons remain concerned about the transient bacteremia that occurs after a dental, genitourinary, and gastrointestinal procedure and the risk for PJI and SSI. At our institution, we recommend lifelong antibiotic prophylaxis prior to dental procedures, genitourinary and gastrointestinal procedures but recognize that this remains controversial.

Conclusion

Prevention is the key to reducing rates of PJI after UKA. Prevention measures may be categorized as preoperative, intraoperative, or postoperative. Developing and implementing a comprehensive and standardized prevention protocol incorporating preoperative, intraoperative, and postoperative measures is most effective in combating PJI. Future research and innovation will hopefully help provide additional strategies to prevent PJI.

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20 Infection Remediation in Unicompartmental Knee Arthroplasty

Kevin C. Bigart and Denis Nam

Introduction

Unicompartmental knee arthroplasty (UKA) has increased in popularity, yet utilization by surgeons varies based on training, experience, or comfort level with the procedure. A recent analysis by Campi et al. estimated that, worldwide, only 10% of orthopedic surgeons perform UKA despite the operation growing in popularity and published 10-year survival rates above 90% for both mobile- and fixed-bearing systems [1–3]. With that said, joint replacement registries still show relatively high rates of revision and failure of partial knee replacements [4]. The most commonly reported modes of UKA failure are aseptic loosening, polyethylene dislocation with mobile-bearing systems, progression of adjacent compartment disease, and less commonly polyethylene wear and prosthetic joint infection (PJI) [5, 6].

The frequency of periprosthetic infection following unicompartmental knee arthroplasty is relatively low. Kim et al. reported on 1576 UKAs performed at their institution from January 2002 to December 2014. They reported a total of 89 complications, of which only five were infections (0.3%) [5]. Foran et al. reported on a single-institution series of 51 patients and 62 cemented, fixed-bearing UKAs. They reported a 10-year survivorship of 98%, 15-year survivorship of 93%, and 20-year survivorship of 90%. None of the failures or revisions were for a diagnosis of periprosthetic infection [7]. Hernandez et al. retrospectively reviewed 22 years of Mayo Clinic data and noted only 15 UKA infections out of a total of 1440 UKAs (1.0%) [8]. Lastly, Bergesen et al. published on 1000 consecutive medial UKAs, in which there was one stated infection (0.1%) [6]. Overall, the reported rate of UKA infection is estimated to be between 0.1% and 1.0% [8–11].

Patient Presentation and Diagnosis

A typical patient presentation is similar to that for a prosthetic total knee infection and should follow the same diagnostic algorithm. Hernandez et al. noted approximately one-third of their 15 infected UKA patients to present acutely post operation, one-third acutely with hematogenous seeding, and one-third as chronic infections [8]. Workup should include a thorough history and physical examination. Laboratory evaluation should include an ESR and a CRP. Of note, these baseline labs should be performed in all patients undergoing revision of their UKA to rule out infection as the potential etiology of failure. If either of these markers is elevated, or clinical suspicion is high,

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a synovial fluid aspiration should be performed and analyzed for white blood cell count, polymorphonuclear percentage with differential, and culture. To aid in the diagnosis of UKA PJI, the Society of Unicondylar Research and Continuing Education published a study with the optimal cutoff values for these tests. After evaluating 259 patients undergoing revision of failed UKA, they found the best test was synovial WBC of 6200 WBC/μL with 60% PMNs, followed by CRP of 14 mg/L and finally an ESR of 27 mm/hr. [12] Finally, a routine series of knee radiographs should also be obtained and carefully reviewed.

Management

Once the diagnosis of UKA infection is confirmed, the best method of management remains unclear. Unfortunately, given the limited data available, the best treatment option remains an area of debate. Options for management include debridement and implant retention (DAIR), one-stage exchange of UKA to TKA and two-stage exchange involving antibiotic spacer placement. Issues are apparent with each method and the risks and benefits are similar to those discussed during management of an infected TKA. However, unique to an infected UKA is the presence of native cartilage. With a UKA infection, the native cartilage surfaces are compromised, which may provide a nidus for continued infection, leading to subsequent chondrocyte necrosis and the potential for accelerated arthrosis of the contralateral compartments. Thus, given the potential for accelerated adjacent compartment disease, the utility of DAIR may be limited. However, this remains a potential treatment option in the setting of an acute infection. One-stage exchange to a TKA has reportedly been successful. In a small cohort of nine infected UKA cases, Labruyere et al. demonstrated success in all cases with a one-stage exchange to TKA, five of which occurred after a previous DAIR [9]. With only one case, Bohm et al. published success with a one-stage exchange to TKA [13]. One-stage exchange, much like DAIR, would involve a complete synovectomy, debridement of all infected tissue, resection of the UKA implant, and placement of a total knee replacement with a course of intravenous antibiotics. If a one-stage exchange is performed, it is the preference of the authors to perform the initial debridement and explantation, then remove all drapes and instruments, and use a second set of sterile drapes and equipment to perform the re-implantation. Surgeons should always have a revision knee system available with stems and augmentation in case of significant tibial or femoral bone loss is encountered.

Although difficult to define a gold standard in the treatment of UKA infection (given the limited data available), two-stage exchange comprising implant resection, bone cuts for a future TKA and removal of remaining cartilage, and placement of an antibiotic spacer (articulating or static) potentially has the highest likelihood of infection eradication. Hernandez et al. published a 100% infection-free survivorship at 5 years for UKA infections treated with two-stage exchange. They did, however, comment that one case had aseptic femoral component loosening at 5-year post re-implantation that required revision to stemmed components. In the same study, they reported a success rate of only 71% for infection-free survivorship at 5 years when the initial treatment was DAIR [8].

Regardless of the intervention chosen, UKA infection requires surgical intervention unless patient medical comorbidities are too significant to undergo anesthesia. All of these situations require a multidisciplinary team approach with medical optimization and consultation with an infectious disease specialist. There does not appear to be a recommended postoperative antibiotic protocol specifically for UKA infections. Currently, most providers are adapting their TKA PJI antibiotic protocols which we feel is the most reasonable approach. All of the above operative interventions should be followed by a tailored course of antibiotics directed by preoperative aspiration cultures, intraoperative tissue cultures, and sensitivity testing.

Conclusion

In conclusion, UKA infection is a relatively uncommon problem, and there is a paucity of cases and recommendations in the literature. Patients can present in any stage of the postoperative period, and it is important to perform a complete workup to assist in the diagnosis of infection. Once diagnosed, patient comorbidities as well as surgeon comfort and experience will undoubtedly and understandably play an influential role in the decision to proceed with DAIR vs. one-stage vs. two-stage intervention. It is important to recognize that although data are limited, DAIR does appear to have a higher rate of failure than one- and two-stage revision procedures. Both one- and two-stage procedures have shown success even in the setting of chronic UKA infection. Regardless, periprosthetic infection requires some method of surgical intervention and a multidisciplinary team approach including medicine and infectious disease specialists for perioperative management. The orthopedic surgeon will need to rely on their team to collaborate and determine the duration and type of postoperative antibiotics, as there is not a strong body of evidence to support any particular protocol.

Patient Case Report

Initial Presentation

A 73-year-old male presents to clinic 5.5 years from right lateral unicompartmental knee arthroplasty due to 3 days of right knee pain and swelling that started on vacation in Europe. The patient reported antecedent subjective fevers and chills prior to the onset of knee pain. He has a history of chronic sinus infections and had started to develop congestion, which he correlated with fevers and chills and started his "usual" treatment of azithromycin. When his knee pain began, he attributed this to increased activity while walking in Europe; however, they flew home the day before presentation and he began having difficulty weight bearing on the knee. He denied other injuries to the knee. He denied wound healing complications after surgery and had no antecedent knee pain prior to 3 days ago.

His medical history is significant for hypertension, gastroesophageal reflux disease, peptic ulcer disease, benign prostatic hyperplasia, hyperlipidemia, deep vein thrombosis in 2001 after being bedridden for spinal infection which was successfully treated with Eliquis, left renal cell cancer with subsequent nephrectomy in 2004 with subsequent chronic renal insufficiency, low-grade intra-abdominal lymphoma diagnosed in 2004 with current surveillance protocol per oncologist, descending aortic aneurysm diagnosed in 2007 that is currently stable, and he was told by a physician in Europe that his heart rate was irregular on examination the previous week, but he had no EKG confirmation or further workup and he has no history of irregular heart rhythm.

Physical Examination

He is alert and oriented with no acute distress. Upon inspection, his right knee appears swollen, with mild warmth and erythema circumferentially around his knee with an erythematous rash over the right lower leg, which he states has developed in the past 3 days correlating with his pain. A significant effusion is present, and ROM was restricted to 0–80 degrees and more painful at terminal flexion. He was otherwise neurovascularly intact with palpable pulses.

- Laboratory Evaluation
- Serum WBC 12.56 cells
- Serum ESR 36 (0–17 mm/hr)
- Serum CRP 110.6 (0.0–8.0 mg/L)

Imaging

Radiographs revealed a well-positioned lateral unicompartmental arthroplasty without radiolucent lines to suggest component loosening or migration (Fig. 20.1).

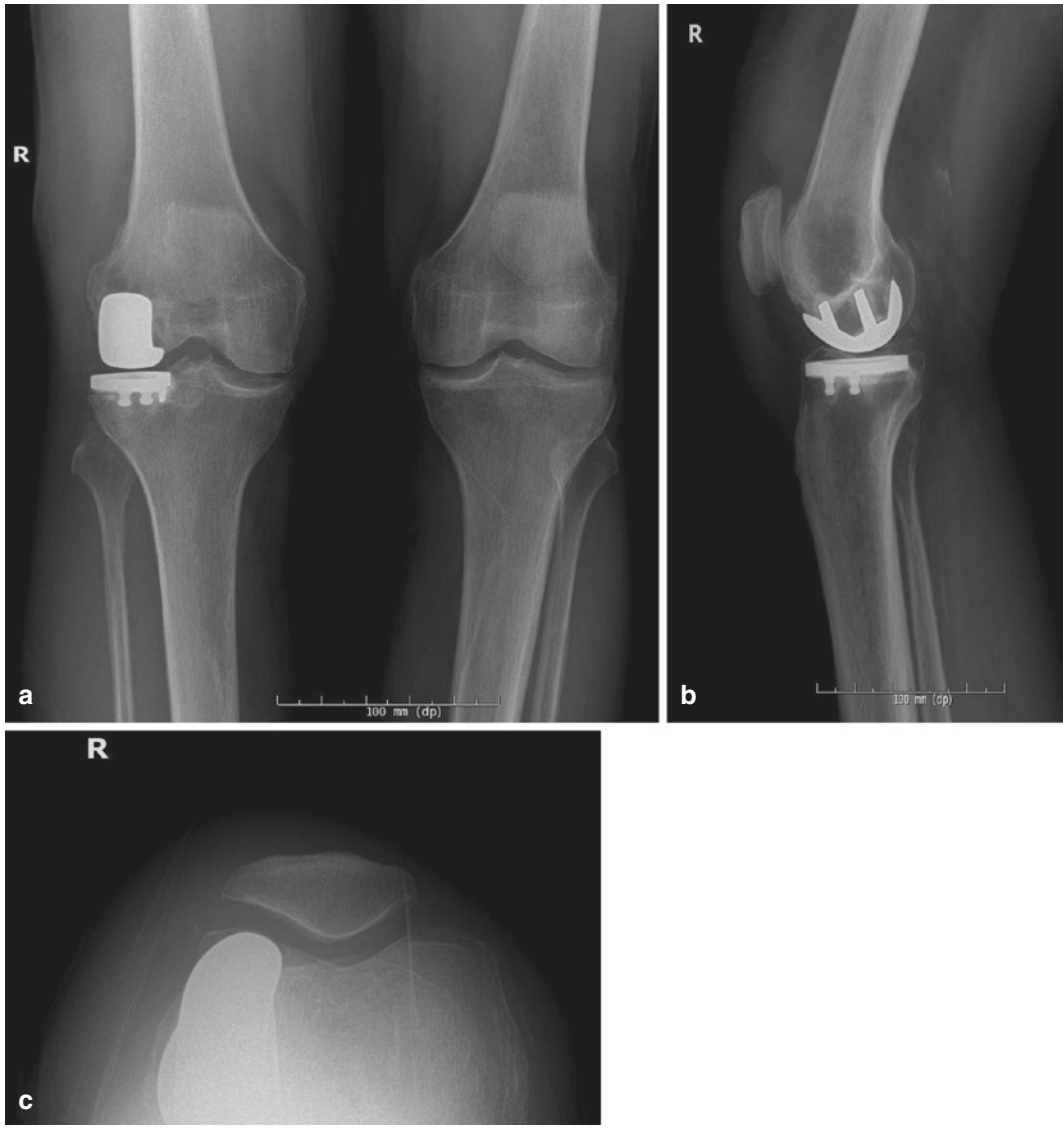

Fig. 20.1 (**a**–**c**) Preoperative radiographs (**a**) AP of bilateral knees, standing (**b**) Lateral view of right knee, and (**c**) Merchant view of right knee

Assessment

With his history, physical examination, and elevated inflammatory markers, we were concerned for possible prosthetic joint infection. An aspiration of his knee was performed, which showed the following:

- Synovial WBC: 63,320 cells with 95.5% PMN
- Synovial RBC: <1000 cells

We felt this was consistent with an acute infection and after discussion of the risks and benefits and surgical options with the patient we chose to perform and DAIR (debridement with implant retention) with polyethylene insert exchange. Patient was admitted to the hospital and surgery was performed the next day to allow for medical evaluation and optimization.

Intraoperatively, the patient was found to have a completely intact retinaculum. A small initial

arthrotomy was made to suction out the joint as much as possible and prevent infected fluid from spreading into the surrounding tissues. This was followed by a complete arthrotomy to allow for complete irrigation and debridement. The polyethylene liner was removed, and the components were irrigated and scrubbed with a brush to attempt to eradicate any bacterial glycocalyx. The contralateral compartments did not show any evidence of softening or cartilage loss. After copious irrigation, we placed the same thickness polyethylene insert back into the knee and closed.

Follow-Up

The infectious disease service directed intravenous antibiotic treatment. The patient ultimately had no growth on cultures from both the aspiration and intraoperative tissue, and it is possible that the azithromycin may have compromised the cultures. Culture-negative infections are not ideal, and in this case, the patient was treated with 6 weeks of IV vancomycin. This antibiotic was chosen due to concomitant lower extremity cellulitis, which led the infectious disease physician to believe this is more than likely a gram-positive infection. His cellulitis improved quickly with treatment as well, which was reassuring. After his IV vancomycin course was completed, the patient was kept on a 6-month history of doxycycline. Apart from antibiotics, the patient was monitored with postoperative visits and laboratory evaluation. He is feeling well, wound healed well, and his ROM is now 5–120. His ESR and CRP normalized by 2 weeks postoperatively and have remained within normal limits on subsequent evaluation.

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Index

A
Acetaminophen, 154, 155
Ackroyd C.E., 117
Acrylic prosthesis, 5
Acute normovolemic hemodilution (ANH), 163
Advantages of UKA, 13
Aglietti, P., 57
Akan, B., 47
Albumin, 29
Aleto, T.J., 48
All polyethylene (AP) tibia, 47–49
  components, 45, 69
  designs, 43, 49, 62
Ambulatory surgery centers (ASC), 58
American Academy of Orthopaedic Surgeons (AAOS), 164
American Association of Hip and Knee Surgeons (AAHKS), 164, 169
American Joint Replacement Registry (AJRR), 3
American Knee Society Objective Scores, 15
American Knee Society Scores, 16
American Society of Anesthesiologists (ASA), 170, 191
American Society of Regional Anesthesia (ASRA), 151, 164
Angiotensin-converting enzyme (ACE) inhibitors, 30
Anterior cruciate ligament (ACL), 9, 19, 70, 73, 96, 100, 121, 126
  bone on bone arthritis, 142, 143
  deficiency, 17, 21, 22, 192
  incidence of, 134
  lateral compartment disease, 135
  lateralised and verticalised tibial tunnel placement, 143
  MRI, 135
  non-responsive to non-surgical management, 142
  pathoanatomy of disease, 143
  posterior bone indicating, 136
  radiographic ACL deficiency, 134
  reconstruction surgery, 21
  role of, 133, 134
  subluxation indicating, 136
  surgical technique, 141, 142
  tibial erosion, 135
  tibial plateau, 142
  treatment options
    abnormal kinematics, 139
    ACL reconstruction, 136
    bi-unicompartmental arthroplasty, 137
    bone-on-bone arthritis, 136
    cemented *vs*. cementless prosthesis, 141
    failure rate, 138, 139
    fixed bearing designs, 139–141
    functional outcomes, 137
    mobile-bearing designs, 139–141
    outcomes in, 141
    revision of, 138
    tibial plateau, 137
    tibial slope, 139
Anteromedial incision, 123
Anteromedial osteoarthritis (AMOA), 15, 70, 73–75, 77, 86, 91
Anticonvulsants, 155, 156
Aquacel®, 211
Argenson, J-N. A., 45, 48, 104
Argon-beam coagulation (ABC), 163
Arthritic progression in lateral compartment, 86
Arthrotomy, 99, 112
Aseptic loosening, 86, 87
Ashraf, T., 104
Aspirin, 29, 30, 32
Atherosclerosis
  angiographic management, 30
  diagnosis, 29
  internists in preoperative clinic, 30
  medical management, 29, 30
  scope of problem, 29

B
Baker, P., 14
Bariatric surgery, 27
Bearing dislocations, 84, 86
Berend, K.R., 16, 69–75, 77, 78, 80, 84, 86–90
Berger, R.A., 7, 17, 45, 48, 57, 95–104
Bergesen, 217
Beta-blocker, 30

T. L. Gerlinger (ed.), *Unicompartmental Knee Arthroplasty*,
https://doi.org/10.1007/978-3-030-27411-5

Bicompartmental knee arthroplasty (BiKA), 57, 108, 114, 118, 121
Biocompatibility, 5
Biomaterials, 5
Biometallic biconvex femoral component, 8
Biomet Oxford mobile-bearing unicompartmental knee, 122
Bi-unicompartmental arthroplasty, 137
Blevins, J.L., 13–17
Blood preservation strategies
  intra-operative strategies
    ANH, 163
    antifibrinolytic agents, 164
    bipolar electrocautery sealant devices, 163
    pneumatic tourniquets, 163
    topical hemostatic agents, 164
    TXA, 164
  post-operative strategies
    reinfusion systems, 164, 165
    stringent transfusion algorithms, 164
  pre-operative strategies
    EPO, 162
    PAD, 162, 163
    risk factor, 162
    vitamin supplementation, 162
Bloom, K.J., 49
Blunn, G.W., 140
Bohl, D.D., 25–32, 212
Bohm, E., 218
Boissonneault, A., 17, 21, 136–138
Bone-on-bone medial compartment arthritis, 58
Bonutti, P.M., 16, 50
Bovie electrocautery, 60
Bradley, A.T., 181
Brinke, B., 201
Brown, N.M., 38
Brumby, S.A., 202, 203
Bucholz, 8
Burton, A., 50

C
Callaghan, J.J., 7
Cameron, H., 104
Campi, S., 4, 217
Cardiovascular disease, 29
Cavaignac, E., 16
Cemented UKA, 45–47
Cementless components, 80
Cementless flat metal Vitallium baseplate, 43
Cementless implants, 62
Cementless UKA, 44–47
Centers for Medicare and Medicaid Services, 58
Central sensitization, 148
Charlson Comorbidity Index (CCI), 170
Chemoprophylaxis, 212
Chondrocalcinosis, 59, 72
Choo, K.J., 107, 108, 110–112, 114–118
Chughtai, M., 184
Clarius, M., 200
Cloutier, J.M., 134
Computer assisted surgery systems, 10
Continuous passive motion (CPM), 182
Coronal plane deformity, 96
Correctable valgus deformity, 96
Corticosteroids, 97
C-reactive protein (CRP), 122
Croley, J.S., 43–50
Cross, M.B., 40
Cruciate and collateral ligament integrity, 108
Cruciate ligament tension, 80
Cyclooxygenase-2 (COX-2) enzyme, 155

D
Dahm, D.L., 117
Debridement and implant retention (DAIR), 218
Deep vein thrombosis (DVT) prophylaxis, 174
Dervin, G.F., 136–138
Deshmukh, R.V., 14
Diabetes
  epidemic, 28
  HbA1c, 28
  hyperglycemia, 28
Dichotomy, 115
Dodd, C.A.F., 134
Dorsal root ganglion (DRG), 155
Duloxetine, 147

E
Edmondson, M., 8
Emerson, R.H., 49
Engh, G.A., 21, 136–138
Erythrocyte sedimentation rate (ESR), 122
Erythropoietin (EPO), 162
Estrogen replacement therapy, 32
Exclusion criterion for UKA, 21
Extramedullary tibial cutting guide, 60

F
Faisal, A., 3–11
Faour, M.O., 8, 20
Femoral articulation, 69
Femoral cutting block, 102
Fillingham, Y.A., 184
Finite element analysis model, 47
Fischer, M., 38
Fixed bearing (FB), 49, 50
  designs, 9
  implants, 62
  UKA model, 11
Flat metallic tibial component, 69
Flat polyethylene tibial components, 8
Flexion contracture, 74
Focal anteromedial arthritis, 59
Folate, 162
Foley catheter, 59
Foran, J.R., 217

Fuller, B.C., 57–63
Full-thickness skin flaps, 60

G
Geller, J.A., 19–23
Gerlinger, T.L., 25–32, 57–63
Ghomrawi, H.M., 4
Gleeson, R.E., 49
Glimepiride, 25
Glucocorticoids, 156
Gondusky, J.S., 182
Gondusky pathway, 183
Goodfellow, J.W., 8, 43, 69, 70, 73, 90, 136, 138, 195
Grade II/III Kellgren-Lawrence changes without patellofemoral joint (PFJ) symptoms, 14
Grade IV chondromalacia, 110
Greco, N.J., 39, 69–75, 77, 78, 80, 84, 86–90
Grosso, M.J., 19–23
Gunston, 8
Gunther, T.V., 104

H
Hamilton, T.W., 14, 16, 17
Harman, M.K., 134
Harrysson, O.L.A., 16
Harvey, L.A., 182
Haughom, B.D., 16
Heel slides, 183
Heinert, 8
Hemiarthroplasty, 43
Hernandez, N.M., 217, 218
Hernigou, P., 136–138, 191
High tibial osteotomy (HTO), 40
Hill, J., 134
History
  all-polyethylene tibia version, 6
  classic indications for UKA, 7
  early, 4–7
  fixed bearing UKA model, 11
  high rates of success and survivorship, 7, 10
  historical advancements and innovation, 8–10
  MacIntosh tibial insert thicknesses, 6
  Marmor Modular knee system, 9
  Oxford knee UKA survivorship, 8
  patient optimization and multimodal clinical pathways, 10
  robotic assisted surgery, 10
  tibial/femoral realignment osteotomies, 3
  total knee arthroplasty, early history comparison
    less surgery, 4
    postoperative complications, 4
    recovery after surgery, 4
    varus/valgus deformity, 4
  unicompartmental arthritic changes, 3
Hopper, G.P., 4
Hutt, J.R.B., 48
Hydrochlorothiazide, 147
Hypercoagulability
  aspirin, 32
  early physical therapy and ambulation, 32
  etiology, 32
  prophylaxis, 32
  risk stratification, 32
Hyperglycemia, 28
Hypoalbuminemia, 29
Hypothermia, 210

I
Impingement, 71
Implant choices
  AP tibia and a MB tibial component, 47–49
  cemented *vs*. cementless, 45–47
  cementless fixation, 44
  designs concept, 44, 45
  MB design, 43
  mobile *vs*. fixed bearings, 49, 50
  Oxford mobile-bearing prosthesis, 44
  stainless steel femoral component with an AP tibia, 43
Inclusion criteria, 19
Indications, 13, 14, 16, 17
  ACL deficiency, 17
  cost-effectiveness analyses, 14
  Kozinn and Scott criteria, 14, 16
  Oxford medial UKA, 15
  Oxford mobile bearing UKA, 16
  PFJ disease, 17
  radiographic criteria, 14
  return to activity rate, 14
  weight/BMI, 16
Infection remediation
  assessment, 220–221
  follow-up, 221
  imaging, 219–220
  initial presentation, 219
  management, 218
  patient presentation & diagnosis, 217–218
  physical examination, 219
  polyethylene wear, 217
Inflammatory arthritis, 19, 22
Inlay' design, 111
Inlay-style designs, 111
Inlay-style trochlear component, 112
Insall, J., 57
Intra-articular injections, 31, 57
Ipsilateral knee, 31
Isaac, S.M., 38
Isolated lateral gonarthrosis, 95

J
Jenny, J.Y., 134
Johnson, A.J., 134
Joint arthroplasty, 43–44
Jorgensen, P.B., 184
Joseph, S.M., 37–40
Joshi, R.N., 182

K
Kandil, A., 16, 20
Kapadia, B.H., 208
Kaplan-Meier analysis, 45, 89
Karas, V., 95–104
Kazarian, G.S., 117, 118
Kendrick, B.J., 71
Ketamine, 156
Keys, G.W., 88
Kim, K.T., 217
Kleebald, 21
Knapke, D.M., 43–50
Knee balance, 103
Knee Society functional scores, 47
Knee Society objective score, 73
Knee Society Scores (KSS), 14, 39
Ko, Y.B., 190
Koh, I.J., 48
Konan, S., 23
Kozinn, S.C., 7, 14, 20–22, 58, 72, 73, 90
Kozinn and Scott criteria, 16, 20
Krishnan, S.R., 136–138
Kwon, O-R., 50

L
Labruyere, C., 194, 218
Lachman test, 135
Laskin, R.S., 57
Lateral arthrotomy, 98
Lateral compartment arthritis, 62
Lateral compartment osteoarthritis, 97
Lateral joint compartment, 5
Lateral sided knee pain, 97
Lateral unicompartmental arthroplasty, 38, 129
  component insertion and sizing, 102–104
  exposure, 98, 99
  indications
    history, 96
    patient, 96, 97
    physical examination, 96
    radiographic evaluation, 97
  osseous preparation and soft tissue balancing, 99–101
    extramedullary tibial cutting, 100
    femoral cutting block, 102
    knee balance, 103
    osteochondral junction, 101
    osteophyte, 100
    sagittal cut of tibia, 100
    tibial cut, 101
    tibial sizing, 103
    tongue-blade spacer, 101
    trial implant and sizing, 101, 102
  outcomes of, 104
  postoperative care, 104
  preoperative planning, 98
  TKA for, 104
Lee, G.C., 134
Leta, T.H., 40
Levine, B.R., 3–11
Levine, W.N., 40
Liddle, A.D., 4, 46
Lim, C.T., 23
Liow, M.H.L., 117
Lisowski, L.A., 88
Local anesthetic systemic toxicity (LAST), 153
Lombardi, A.V., 40
Lonner, J.H., 107, 108, 110–112, 114–118
Low-dose ketamine, 157
Lyons, M.C., 13

M
MacIntosh, D.L., 5–7
MacIntosh Vitallium prosthesis, 5
Mackinnon, J., 7
MAKO® robot assisted versus traditional Oxford instrumentation UKA, 14
Malnutrition, 28
Mamor, 7
Mancuso, F., 142
Manzotti, A., 48
Marfo, K.A., 69–75, 77, 78, 80, 84, 86–90
Marginal osteophytes, 60
Mariani, E.M., 47
Marmor, L., 8, 43, 47, 57, 69
Marmor Modular Knee System, 8, 9
Mayman, D.J., 13–17
McKeever, D.C., 4–6, 43, 110
McMasters Universities Arthritis Index (WOMAC), 181
Medial arthrotomy, 98, 99
Medial collateral ligament (MCL), 73, 75, 77, 80, 193
Medial compartment OA, 14
Medial osteoarthritis, 97
Medial Oxford mobile bearing UKA, 17
Medial parapatellar arthrotomy, 70
Medial unicompartmental knee arthroplasty (mUKA), 25, 38, 97, 129
  complications, 63
  implant options, 61, 62
  indications/contraindications, 58, 59
  outcome and survival, 62
  revision, 63
  technique, 59–61
  technology, 62
Medicare, 27
Mesko D.R., 37–40
Metal-backed (MB) design, 43, 45, 47–49, 62
Metcalfe A.J., 117
Metformin, 25
Methicillin resistant *Staphylococcus aureus* (MRSA), 208
Methylmethacrylate, 115
Meticulous surgical technique, 84
Microplasty instrumentation, 72, 87
Mild-to-moderate patellar maltracking, 110
Miller-Galante UKA, 45
Miller-Gallante prosthesis, 48
Miller-Gallante/Zimmer Unicompartmental High Flex Knee System, 49

Minimally invasive approach, 88
Minimally invasive surgery (MIS), 44
Mini-midvastus arthrotomy, 60
Mobile bearing implants, 49, 50, 69, 98
  complications
    arthritic progression in lateral compartment, 86
    aseptic loosening, 86, 87
    bearing dislocations, 84, 86
    unexplained pain, 87, 88
  design rationale, 62, 71, 72
  dislocation, 192, 193
  history, 70, 71
  indications, 72–74
    osteonecrosis, 74, 75
  long-term outcomes, 88, 89
  microplasty instrumentation, 72
  surgeon volume, 90
  surgical pearls, 80, 84
  surgical principles and technique, 75, 77, 78, 80
  TKA, compatison to, 89, 90
Moderate lateral facet disease, 74
Modern implant designs, 19
Modular bicompartmental knee arthroplasty, 121
Molloy, J., 20
Monoblock all-polyethylene tibial implants, 62
Mont, M.A., 117
Multimodal analgesia (MMA), 154
Murray, D.W., 7, 8, 16, 70
Myocardial infarction, 29
Myocardial perfusion imaging, 29

N
Naal, F.D., 14, 38
Naproxen, 147
Native knee kinematics, 21
Neufeld, M.E., 49
Neuraxial anesthesia, 171–172
Neuraxial blocks, 151
Neuwirth, A.L., 19–23
Newman, J., 14
Nicol, S.G., 117, 118
N-methyl-D-aspartate (NMDA) receptor, 148
Non-constrained polyethylene modular tibial component, 8
Non-inflammatory arthritis, 14, 17
Nonsteroidal anti-inflammatory drugs (NSAIDs), 150, 153–155, 171
Nutritional interventions, 29
Nutritional status
  albumin, 29
  impacts short-term outcomes, 28, 29
  markers of, 28
  nutritional interventions, 29

O
Obesity, 20
  epidemic, 26
  impact on long-term outcomes, 27
  impact on short-term outcomes, 26, 27
  nutritional information, 27
  surgery, 27
Obstructive sleep apnea (OSA), 158
Obturator nerve block (ONB), 152
O'Connor, J.J., 8, 43, 69, 70
Onlay design, 44, 116
Onlay-style prostheses, 111
Onlay-style trochlear component, 115, 116
Onlay technique, 45
Opioid-induced hyperalgesia (OIH), 150
Opioid receptors, 157, 158
Osteoarthritis (OA), 13, 39, 95, 179
Osteochondral junction, 101
Osteonecrosis, 74, 75
Osteonecrosis in the postoperative knee (ONPK), 75
Osteophytes, 76, 86, 100
Outpatient Arthroplasty Risk Assessment (OARA) score, 170
Outpatient unicompartmental knee arthroplasty
  multiple investigations, 169
  patient selection, 170
  perioperative management
    blood transfusion, 172
    intra-operative medication, 172
    neuraxial anesthesia, 171–172
    post-operative management, 173–174
    regional nerve blocks, 172
    surgical technique, 172–173
    thromboprophylaxis, 174
  preoperative counseling, 170, 171
  quality metrics, 169
Oxford knee score, 15, 16, 47, 69, 73, 118
Oxford medial UKA, 15, 46
Oxford mobile-bearing prosthesis, 44
Oxford mobile bearing UKA, 16
Oxford Partial Knee System, 71, 75, 76
Oxford Twin Peg, 70
Oxford UKA, 8–10, 14, 15, 21
Oxycodone, 147

P
Pain management
  acetaminophen, 154, 155
  anesthetic plan, 154
  anticonvulsants, 155, 156
  cells lack, 148
  central sensitization, 148
  COX-2 enzyme, 155
  COX-2 inhibitors, 155
  glucocorticoids, 156
  ketamine, 156
  low-dose ketamine, 157
  medical management and physical therapy, 159
  MMA, 154
  neurotransmitters norepinephrine, 148
  NSAIDs, 154, 155
  opioid receptors, 157, 158
  pain signal transmission, 148

Pain management (*cont.*)
peripheral sensitization, 148
poorly controlled postoperative pain, 150–151
post-operative oral pain, 158
post-operative pain control
neuraxial anesthesia, 153
neuraxial blocks, 151
peripheral nerve blocks, 152, 153
preoperative risk factors, 148–150
questionnaire, 149
serotonin, 148
Pandit, H., 7, 46, 57, 73, 88, 202
Parratte, S., 39
Partial knee replacements, 57
Partial medial meniscectomy, 60
Patella, 126
Patellar grind test, 96
Patellar maltracking, 108, 111, 115
Patellar tilt, 110
Patellofemoral arthritis, 7
Patellofemoral arthroplasty (PFA), 19, 126, 195
clinical results, 115–118
history and design considerations, 110–112
indications and contraindications for, 111
patient selection and indications, 108, 110
surgical technique, 111, 112, 114, 115
Patellofemoral arthrosis, 59
Patellofemoral compartment, 14
Patellofemoral joint, 17, 98
Patellofemoral joint osteoarthritis, 17
Patellofemoral knee arthroplasty, 127
Patellofemoral osteoarthritis (PF OA), 17
clinical evaluation, 107–109
etiologies, 107
PFA (*see* Patellofemoral arthroplasty (PFA))
Patient blood management (PBM), 161
Patient criteria, 19, 20
ACL integrity, 21, 22
age, 19, 20
deformity, 20, 21
inflammatory type arthritis, 22
pre-existing patellofemoral disease, 22, 23
weight, 20
Patient expectations
activities of daily living, 38
age cut-offs for UKA, 39
benefits, 38
failure modes of UKA, 39
primary TKA, 40
temporary solution, unicompartmental knee, 37
Patient outcomes, 37
Patient-specific instrumentation (PSI), 62
PearlDiver database, 16
Pearle, A.D., 16
Peersman, G., 49
Pegg, E.C, 140
Peri-articular erosions, 22
Peripheral nerve blocks, 151–153
Peripheral sensitization, 148
Periprosthetic fractures
etiology, 199–201
initial postoperative radiographs, 202
isolated medial compartmental degenerative joint disease, 201
medial tibial plateau periprosthetic fracture, 203
non-operative treatment, 202
orthopaedic surgeons, 199
periprosthetic tibial plateau fracture, 201
surgical treatment, 202, 204
treatment algorithm for, 205
well-healed periprosthetic tibial plateau fracture, 204
Periprosthetic joint infection (PJI), 31
intraoperative strategies
antibiotic cement, 210
antibiotic prophylaxis, 208–209
body exhaust suits/surgical helmet systems, 210
body temperature management, 210
hair removal, 209
laminar airflow ventilation, 210
operating room traffic, 209
operative time, 212
surgical site preparation, 209
wound closure & dressing, 211
postoperative strategies
allogeneic blood transfusion limitting, 212
length of stay, 213
routine antibiotic prophylaxis, 213
venous thromboembolic prophylaxis, 212
preoperative strategies
infection screening, 208
risk factors, 207
skin cleanse, 207, 208
TJA, 207
PF arthritis, 23
Phase 3 model, 10
Physical therapy
day of surgery, 181, 182
postoperative therapy, 182–184
preoperative physical therapy
aerobic exercise, 180
educational models, 181
exercise, 180
knee unloading braces, 181
osteoarthritis, 179
oxygen cost of walking, 181
self-selected walking speed, 181
therapeutic modalities, 180
Pivot-Shift Test, 135
Plate, J.F., 4, 20
Pneumatic tourniquets, 163
Polycentric knee replacement implants, 8
Polyethylene thicknesses, 98
Polyethylene wear, 192
Polymethylmethacrylate (PMMA), 60
Porous coated anatomic knee (PCA), 45
Posterior cruciate ligament (PCL), 96, 100, 126, 191
Post-operative urinary retention (POUR), 173
Pre-existing patellofemoral disease, 22, 23

Preoperative autologous donation of blood (PAD), 162, 163
Pre-operative hemoglobin, 162
Prevena™, 211
Price, A.J., 13, 39, 89
Propofol, 172
Prosthetic joint infection (PJI), 217
Proximal tibial osteotomy, 3
Pulmonary embolism, 32

Q
Quad sets, 183
Quality-adjusted life year (QALY), 4

R
Regional nerve blocks, 172
Reinfusion systems, 164, 165
Repicci prosthesis, 45
Revised Cardiac Risk Index (RCRI), 29
Rheumatoid arthritis, 22, 74
Right knee pain, 25, 57
Risk mitigation
  atherosclerosis
    angiographic management, 30
    diagnosis, 29
    internists in preoperative clinic, 30
    medical management, 29, 30
    scope of problem, 29
  diabetes
    epidemic, 28
    HbA1c, 28
    hyperglycemia, 28
  early postoperative adverse events, 26
  hypercoagulability
    aspirin, 32
    early physical therapy and ambulation, 32
    etiology, 32
    prophylaxis, 32
    risk stratification, 32
  intra-articular injections, 31
  nutritional status
    albumin, 29
    impacts short-term outcomes, 28, 29
    markers of, 28
    nutritional interventions, 29
  obesity
    epidemic, 26
    impact on long-term outcomes, 27
    impact on short-term outcomes, 26, 27
    nutritional information, 27
    surgery, 27
  smoking
    cessation, 31
    epidemiology, 30
    extensive counseling, 31
    surgical site infection and other postoperative events, risk for, 31
Ritter, M.A., 7
Robertsson, O., 8
Robotic assisted surgery, 10
Robotic assisted UKA, 14, 20

S
Saenz, C.L., 48
SCDs, 32
Schlueter-Brust, K., 47
Schwartz, A.J., 194
Sciatic nerve blocks (SNB), 152
Scott, C.E.H., 48
Scott, R., 7, 14, 20, 58, 72, 73, 90
Scott, R.D., 104
Seeger, J.B., 200
Siljander, M.P., 43–50
Siman, H., 14
Sloper, P.J.H., 201
Smoking
  cessation, 31
  epidemiology, 30
  extensive counseling, 31
  surgical site infection and other postoperative events, risk for, 31
Song, E-K, 23
Spinal anesthesia, 171
Spinothalamic tract (STT), 148
Spontaneous osteonecrosis, 15
Spontaneous osteonecrosis of the knee (SPONK), 74
Squire, M.W., 7
Stainless steel femoral component with an AP tibia, 43
Staphylococcus aureus, 207
Stasis and intimal injury, 32
St. Georg modular prosthesis, 44
St. Georg sled, 44
Streit, M.R., 20
Stress echocardiography, 29
Stryker, 45
Surgical site infection, 28, 29, 31
Svard, U.C., 70, 89
Swedish Knee Arthroplasty Registry, 16
Symptomatic arthritis, 20

T
Teflon, 5
Tegner activity scale, 73
Tegner Activity scores, 16
Thein, R., 23
Thromboprophylaxis, 174
Tian, S., 136–138
Tibial/femoral realignment osteotomies, 3
Tibial inlay cementation technique, 43
Tibial osteotomy, 3
Tibial plateau fractures, 80
Tibial polyethylene insert thickness, 8
Tibial sizing, 103
Tibial subsidence, 194
Tibial tubercle realignment procedure (antero-medialization), 108

Tibiofemoral arthritis, 110
Tibiofemoral (TF) joint spaces, 108
Tinius, M., 136–138
Titanium implants, 5
Topical hemostatic agents, 164
Total joint arthroplasty (TJA), 28, 32, 207
Total knee arthroplasty (TKA), 3, 13, 17, 19, 25, 38, 110, 117, 121, 148–149, 161, 179, 181, 191
  benefits, 38
  mobile-bearing implant, compatison to, 89, 90
  patient expectation, 40
  postoperative complications, 4
  recovery after surgery, 4
  UKA to TKA revision, 40, 63
  varus/valgus deformity, 4
Traditionally total knee arthroplasty (TKA), 121
Tranexamic acid (TXA), 164
Transcutaneous electrical nerve stimulation (TENS), 180
Transepicondylar axis (TEA), 111
Trial implant and sizing, 102
Tricompartmental arthritis, 95
Tri-compartmental arthroplasty, 57
Tricompartmental joint replacement, 4
Tricompartmental total knee arthroplasty (TKA), 3

U
Uncemented implants, 46
Unexplained pain, 87, 88, 194, 195
Unicompartmental knee arthroplasty (UKA)
  aseptic loosening, 190, 192
  bearing dislocation, 190
  compartment
    anteromedial incision, 123
    bicompartmental "conversion" procedure, 129
    bicompartmental knee arthroplasty, 121
    bicruciate-retaining TKA, 121
    lateral compartments, 123
    intraoperative images, 126
    medial joint line tenderness, 122
    medial unicompartmental knee arthroplasty, 122
    monoblock bicompartmental component, 121
    patella, 126
    patellofemoral arthroplasty, 127
    patellofemoral compartment, 122, 123
    postoperative radiographs, 124, 127
    preoperative radiographs, 123
    tibial component, 121, 128
    tibial spine fracture, 129
    TKA, 121
    unicondylar arthroplasty implants, 127, 129
    viscosupplementation injections, 122
  implant design and surgical technique, 189
  infections, 194
  isolated medial/lateral compartment osteoarthritis, 189
  mobile bearing dislocation, 192, 193
  osteonecrosis, 189
  periprosthetic fracture/tibial collapse, 189
  PFA, 195
  polyethylene wear, 189, 192
  positioned lateral, 190
  post-operative timeframe, 190
  post-traumatic arthritis, 189
  progression of osteoarthritis, 190–192
  tibial component subsidence, 190
  tibial subsidence, 194
  total knee arthroplasty, 190, 193
  unexplained pain, 194, 195
  valgus mechanical axis, 191
Unicondylar arthroplasty, 19
Unindicated revision arthroplasty, 88

V
Valgus deformity, 4, 5, 21
van der List, J.P., 16, 17, 20, 46
Varus deformity, 4, 21, 63, 73, 86
Venous thromboembolism (VTE), 27, 32
Venous thrombosis, 32
Ventura, A., 136–138
Vitallium, 5
Vitamin B12, 162
Von Keudell, A., 39
Vorlat, P., 70

W
Waldstein, W., 14
Walker, T., 20, 38
Walton, N.P., 14
Warfarin, 32
Wear-induced periprosthetic osteolysis, 63
Western Ontario, 181
Weston-Simons, J.S., 136–138
Woo, Y.L., 202

Y
Yang, K.Y., 14
Yoshida, K., 8
Young, S.W., 210

Z
Zimmer patellofemoral component, 126