Lateral Unicompartmental Knee Arthroplasty

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Abstract

» Lateral unicompartmental knee arthroplasty affords excellent functional results and implant survivorship for properly selected patients. More high-quality studies are necessary to determine whether expanded indications for medial unicompartmental knee arthroplasty also apply to lateral unicompartmental knee arthroplasty.

» Operative adjuncts such as robotics, custom implants, and navigation technology hold promise in minimizing the technical burden and unfamiliarity of lateral unicompartmental knee arthroplasty.

» Improvements in lateral-specific implants may translate to operational efficiency and improved outcomes, but few lateral-specific implants currently exist.

» Mobile-bearing devices have increased rates of failure due to bearing dislocation, and further studies are warranted to evaluate this complication with newer designs.

» Future registry and cohort studies should show medial unicompartmental knee arthroplasty and lateral unicompartmental knee arthroplasty separately to allow for better understanding of the nuances and technical differences between these uniquely different procedures.

For patients with isolated lateral compartment arthritis, lateral unicompartmental knee arthroplasty (UKA) is an appealing alternative to total knee arthroplasty. The advantages of UKA compared with total knee arthroplasty include improved postoperative range of motion, preservation of the cruciate ligaments and bone stock, improved proprioception, increased patient satisfaction, earlier return to activities, shorter hospital stay, and fewer complications[1-6]. Although most of the large series on UKAs have been on medial UKA, modern published reports on lateral UKA have shown similar clinical advantages with excellent survivorship[7-10].

Despite potential clinical benefits, lateral UKA continues to be rarely performed. Although isolated lateral compartment arthritis has a prevalence of 5% to 10% in those with knee arthritis[11,12], lateral UKA represents <1% of knee arthroplasties. Modest results reported in early series as well as the technical demands and unfamiliarity of lateral UKA among surgeons and patients may contribute to lateral UKA underutilization. Modern lateral UKA outcomes have compared favorably with medial unicompartmental arthroplasty and total knee arthroplasty at short-term and intermediate-term follow-up with improved understanding of the lateral compartment anatomy and kinematics and advancing techniques and implants.

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Anatomy and Knee Kinematics

The medial and lateral compartments are anatomically unique. The medial plateau is concave and is larger in both length and width than the lateral plateau. The lateral plateau has a convex shape and sits 2 to 3 mm proximal to the medial plateau. The medial meniscus is oval-shaped, thicker, and less mobile and has stouter capsular attachments than the lateral meniscus[13]. The lateral meniscus covers a larger percentage of the plateau than the medial meniscus (approximately 50%). It is more mobile during knee flexion because of its C-shape and less robust capsular attachments[13].

The differences in medial and lateral compartment anatomy accommodate the complex motion of the knee. During knee flexion, the femoral condyles both roll and translate on the tibia. This motion facilitates deep flexion by clearing the tibia from the femur and avoiding osseous or soft-tissue impingement. In addition, during flexion, the medial femoral condyle pivots on the medial plateau, translating only 1.5 mm posteriorly on average. In contrast, the lateral side translates posteriorly by as much as 15 mm[14]. A lack of medial translation is the result of a more congruent medial tibiofemoral articulation, a relatively static medial meniscus with stout capsular attachments, and tighter medial soft tissues. In contrast, laxity and decreased congruity on the lateral side are responsible for increased mobility in this compartment[13,15]. This increased lateral laxity allows for increased lateral condylar lift-off of up to 7 mm during flexion compared with 2 mm on the medial side[16]. The differential translation of the medial and lateral compartments accounts for the external rotation profile of the femur on the tibia during knee flexion[15]. When the knee goes from flexion to extension, this profile is reversed, leading to relative external rotation of the tibia. This phenomenon has been called the "screw-home" mechanism[15].

Indications

The success of UKA is often dependent on proper patient selection. After analyzing early failures, Kozinn and Scott proposed several indications to identify the ideal candidate for UKA[12,17]. These included unicompartmental noninflammatory arthritis, age of >60 years, weight of <80 kg (<180 lb), avoidance of heavy labor or heavy activity, flexion of ≥90° with correctable angular deformity of <15°, and an intact anterior cruciate ligament (ACL)[12,17] (Table I). Of note, these indications were not specific to medial or lateral UKAs. After following these strict criteria, Sah and Scott and Scott et al. reported improved survivorship[11,18]. However, these indications have become too restrictive with improvements in clinical knowledge, surgical techniques, and implants[16]. Specifically, surgeons have challenged limitations based on patellofemoral arthritis, obesity, age, activity level, and ACL competency (Table I). Hamilton et al. retrospectively reported that 68% of their patients undergoing medial UKA would have been considered contraindicated by these initial standards. However, at 10 years, they reported no differences in implant failure or revision rate between the ideal and contraindicated cohorts, with better functional scores in the contraindicated group[19].

Unfortunately, no comparable study exists evaluating these surgical indications specifically in lateral UKA. It is generally considered that lateral UKA is indicated in patients who have non-inflammatory, symptomatic, isolated lateral compartment arthritis with a correctable deformity. The passive range of motion of ≥90° is necessary for proper implant positioning. Consideration should be given to avoiding lateral UKA in patients with a flexion contracture of >10°, as this has been correlated with poorer functional scores in some medial UKA studies[19,20]. However, to our knowledge, no studies have evaluated flexion contracture and lateral UKA.

Additionally, it remains unclear whether asymptomatic partial-thickness cartilage damage in either the patellofemoral or medial compartment affects lateral UKA outcomes and survivorship. Preoperative stress radiographs can be helpful by confirming a correctable deformity and maintenance of cartilage height in the medial compartment with a varus force[21,22]. Although comparable studies in lateral UKA are lacking, several recent studies have shown excellent outcomes in patients undergoing medial

TABLE I Comparison of Classic Indications for Lateral UKA as Defined by Kozinn and Scott[12,17] and Emerging Indications

Classic Indications	Emerging Indications
Age of >60 years	No age restriction
Weight of <80 kg (<180 lb)	No weight restriction
Non-heavy laborers, low activity	No limitation based on labor, activity
Preoperative range of motion ≥90°	Preoperative range of motion ≥90°
Correctable deformity <15°	Correctable deformity
Asymptomatic patellofemoral joint arthritis	Asymptomatic patellofemoral joint arthritis even with subchondral bone exposed*
No eburnated bone in medial compartment, patellofemoral joint	No eburnated bone in medial compartment
Intact cruciate ligaments	Intact ACL not requisite*

*There is evidence in medial UKA literature, but limited investigations for lateral UKA.

UKA with asymptomatic exposed bone in the patellofemoral joint[19].

The effect of age on lateral UKA remains poorly understood. Traditional indications have limited UKA to patients who were >60 years of age. Registry data have suggested a higher risk of revision for patients undergoing UKA at a younger age[19,23-26]. In contrast, Baker et al. reported no difference in time to failure, mechanism of failure, or 15-year survival in 1,000 consecutive patients undergoing mobile-bearing UKA[27]. Additionally, Von Keudell et al. noted that younger patients who underwent medial UKA had higher satisfaction rates compared with those who underwent total knee arthroplasty[28]. Although high-quality series evaluating the effect of age on lateral UKA have been limited, there are a few mixed cohort studies that offer insight. Heyse et al. retrospectively evaluated active patients who were <60 years of age and had undergone UKA and reported comparable functional scores between medial and lateral UKA cohorts and excellent survivorship of 94% in the lateral UKA cohort (mean, 10.8 years)[29]. These clinical scores were comparable with other lateral UKA series (Table II). At a 6-year follow-up, Liebs and Herzberg found no association between age and failure in medial and lateral UKA cases with patients ranging from 44 to 91 years of age[30]. Currently, the effect of age on implant survival and clinical outcomes is poorly understood. Although limited studies have evaluated age and lateral UKA specifically, we do not consider age as a strict contraindication.

Similarly, the effects of obesity on lateral UKA are not clear. In a systematic review of medial and lateral UKAs, van der List et al.[31] reported no effect of body mass index (BMI) on revision rate with a BMI cutoff of 30 kg/m^2. Several cohorts with higher cutoffs have reported increased revision rates in medial UKA[32-34]. However, this increased risk is comparable with that seen in total knee arthroplasty[35]. With regard to lateral UKA, Xing et al. followed a cohort of 31 lateral UKA cases for 3 years on average and reported no increased rate of failure in obese patients; the authors noted a trend toward improved outcomes compared with obese patients having undergone medial UKA[36]. Liebs and Herzberg evaluated a mixed cohort of patients undergoing medial or lateral UKA and reported no correlation between revision and BMI at a mean 6-year follow-up[30].

Although limited evidence exists with respect to ACL deficiency in lateral UKA, ACL deficiency as a contraindication to medial UKA has been challenged. Recent studies have suggested that an intact ACL is not a prerequisite for medial unicompartmental arthroplasty success[37,38]. One group reported slightly improved functional outcomes comparing ACL-intact and ACL-deficient knees at a 5-year follow-up[37]. Although there has been limited research on lateral UKA with regard to ACL deficiency, a meta-analysis in UKA failed to identify ACL status as a risk factor for early revision[39]. Biomechanical studies have shown ACL-deficient knees in young patients to have increased lateral compartment mobility[40-42]. However, the kinematic profile in young, ACL-deficient knees may be different from arthritic, ACL-deficient knees[43]. Furthermore, Goodfellow et al. noted no failures in 9 patients with deficient ACLs who underwent mobile-bearing lateral UKA[44]. Nevertheless, lateral unicompartmental knee arthroplasty in the ACL-deficient knee, especially with a mobile-bearing component, should be approached with caution until further studies are available to inform management.

Approach

Although most surgeons perform lateral UKA through a lateral approach, success has been reported with either a medial approach or a lateral approach. Both approaches offer advantages and disadvantages.

Medial Approach

Lateral UKA can be performed effectively through a medial parapatellar arthrotomy similar to that utilized traditionally for total knee arthroplasty. The medial approach has the advantage of near-universal familiarity to knee surgeons, increased extensibility, and, most importantly, the ability to convert easily to total knee arthroplasty intraoperatively and postoperatively (Fig. 1). A revision is often performed through a medial parapatellar incision if a revision from lateral UKA to total knee arthroplasty is required in the future. Thus, a primary medial approach for lateral UKA avoids future concerns over patellar blood supply when converting from lateral UKA to total knee arthroplasty. Lastly, the medial approach facilitates tibial component placement in the slight internal rotation required to recreate lateral knee kinematics. Excellent outcomes have been reported for lateral UKA using a medial parapatellar approach, with no revisions at a mean of 5.2 years[11]. Of note, this group reported a conversion rate of 50% to total knee arthroplasty intraoperatively in candidates for lateral UKA[11].

Lateral Approach

The benefits of the lateral approach include a direct window to the lateral compartment, smaller incisions, lower likelihood of damage to medial structures, and lack of the patellar eversion requirement. The drawbacks to the lateral approach include more difficult conversion to total knee arthroplasty and potential compromise to the patellar blood supply if a future surgical procedure requires a medial parapatellar arthrotomy. However, Berend et al. reported no intraoperative conversions to total knee arthroplasty using the lateral approach after preoperative stress radiographs or preoperative arthroscopy[21]. To our knowledge, no reports exist on the outcomes of revision to total knee arthroplasty after the lateral approach. Establishing correct tibial rotation is another limitation as the patellar tendon tends to force the cut into external rotation. Taking this into account, a trans-patellar tendon vertical tibial cut to achieve proper internal rotation has been described[21] (Fig. 2). Edmiston et al. noted similar functional

TABLE II Summary of Published Clinical Series Reporting Outcomes in Mobile-Bearing Lateral UKA*

Study	Notable Characteristics†	Implant	No. of Knees	Outcomes†	Survival†
Walker[7] (2018)	Age 65 yr (36 to 99 yr)	Oxford Domed (Biomet)	363	OKS 40.3; Tegner score 3.2 (95% confidence interval, 3.1 to 3.3); UCLA 40.3 at final follow-up	90.5% at 3 yr, 85% at 5 yr (1 to 7.75 yr); 20 bearing dislocations at 5 yr (8.5%)
Newman[97] (2017)	Included patients with exposed bone in the patellofemoral joint without symptoms; age 71 yr (44 to 92 yr)	Oxford Domed (Biomet)	64	OKS preop. 26 (9 to 36), to 42 (10 to 48) at final follow-up	87% at 6.7 yr (2 to 10 yr); 1 patient had multiple bearing dislocations
Weston-Simons[69] (2014)	Age 64 yr (32 to 90 yr)	Oxford Domed (Biomet)	265	From preop. to postop.: OKS 24.1 to 40.3, American KSS-objective 47.8 to 85.6, American KSS-function 68.2 to 83	92% at 8 yr; 4 bearing dislocations
Marson[68] (2014)	Age 57.7 yr (41 to 77 yr)	Oxford Domed (Biomet)	15	OKS 36.6 at final follow-up	92% at 2.9 yr (1.3 to 4 yr); 1 bearing dislocation
Altuntas[67] (2013)	Included patients with exposed bone in the patellofemoral joint without symptoms; age 71 yr (44 to 92 yr)	Oxford Domed (Biomet)	64	OKS preop. 24 to 42 at final follow-up	97% at 3.1 yr (2 to 5 yr); no bearing dislocations, 4 revisions
Schelfaut[98] (2013)	Age 60 yr (31 to 86 yr); BMI 26.4 kg/m^2 (20.7 to 36.6 kg/m^2)	Oxford Domed (Biomet)	25	OKS improved 23.3 preop. to 42.1 postop., patient satisfaction excellent in 84%	92% at 1.67 yr (1 to 2.8 yr); 1 bearing dislocation, 2 revisions
Liebs[30] (2013)	Age 73.6 yr (44 to 91 yr); weight 79.4 kg (40 to 166 kg)	Preservation (DePuy)	128	WOMAC physical function 34, pain 34, and SF-36 PCS 38	82.8% at 9 yr; similar survival to medial UKA; no association between revision and age, weight‡
Streit[53] (2012)	Age 60 yr (36 to 81 yr); BMI 28 kg/m^2 (21 to 42 kg/m^2)	Oxford Domed (Biomet)	50	Scores at final follow-up: OKS 43, American KSS-objective 91, American KSS-function 90	94% at 3 yr; 3 bearing dislocations (6.2%)
Pandit[10] (2010)	Age 63 yr (42 to 85 yr)	Oxford Domed (Biomet)	69	OKS preop. 22.1 to 40.6 at final follow-up	98% at 2.3 yr (1 to 4 yr); 1 bearing dislocation
Gunther[65] (1996)	Age 68 yr (40 to 88 yr)	Oxford Mobile Bearing Phase I, II (Biomet)	53	None	79% at 5 yr; 6 bearing dislocations
Goodfellow[44] (1988)	Included ACL-deficient knees	Oxford Mobile Bearing Phase I (Biomet)	27	Improvement in walking distance, pain relief‡	2 failures due to bearing dislocation at 3 yr (1.8 to 4.8 yr); no failures in ACL-deficient knees

*OKS = Oxford knee score, UCLA = University of California Los Angeles knee score, KSS = Knee Society score, WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index, and SF-36 PCS = Short Form-36 Physical Component Summary. †The values (other than percentages) are given as the mean, with or without the range in parentheses. ‡Cases of medial UKA and lateral UKA are included in the outcome.

scores between the medial and lateral approaches in 65 patients with fixed-bearing implants at 2 years postoperatively. The marginally improved range-of-motion scores in the lateral-approach cohort were attributed to a potential increase in postoperative scarring of the more extensile medial approach[45].

Technical Considerations

Proper tibial component positioning is vital to UKA success and should match the native tibial joint line. The tibial component should be placed along the lateral tibial spine with a slight internal rotation to accommodate the screw-home mechanism of the femur. When using a lateral parapatellar approach, there is a tendency to externally rotate the tibial component to avoid the patellar tendon[46]. Therefore, a proper tibial cut can be facilitated by either bluntly retracting the patellar tendon or making a vertical incision in the patellar tendon and passing the blade through

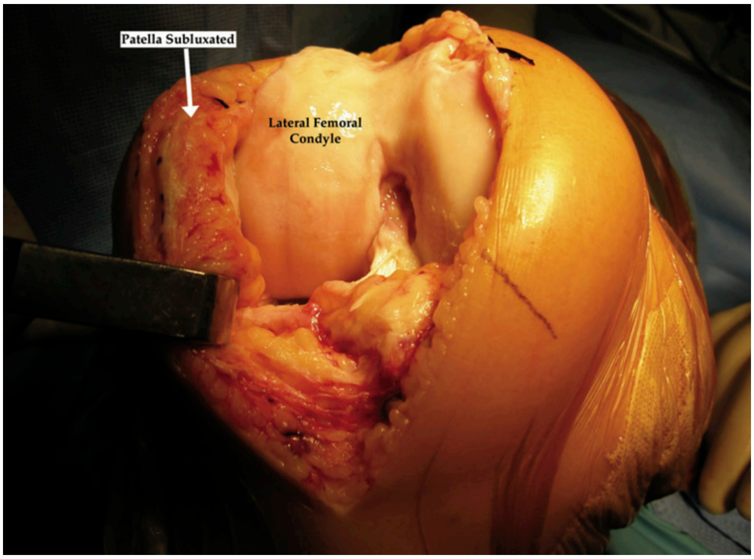


Fig. 1

Intraoperative photograph demonstrating a medial parapatellar approach with patellar subluxation to visualize the lateral compartment. (Reproduced from: Sah AP, Scott RD. Lateral unicompartmental knee arthroplasty through a medial approach. Study with an average five-year follow-up. J Bone Joint Surg Am. 2007 Sep;89[9]:1948-54.)

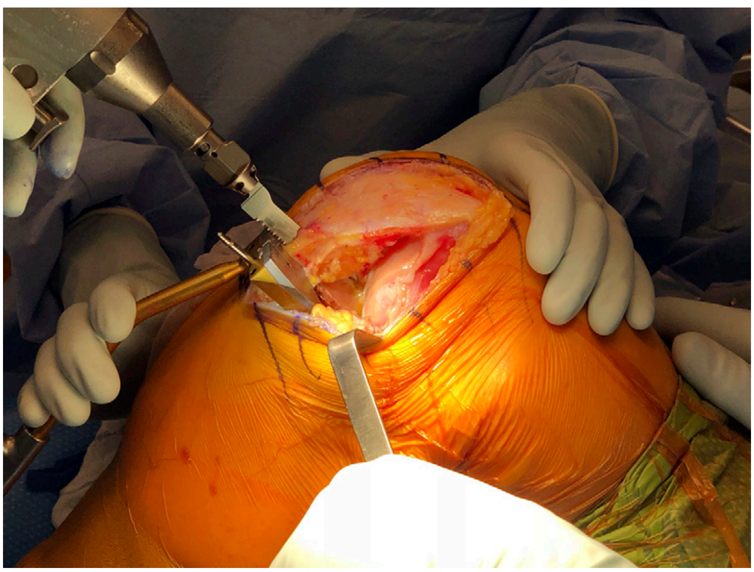
this window[21]. Resection depth should always be minimized to maximize the contact area between the implant and strong subchondral bone because deeper resections risk implant subsidence into the weaker metaphyseal bone.

Although a wide range of normal values for the native lateral slope exists, minimizing asymmetric forces on the subchondral bone by matching the native slope may improve implant longevity. The lateral tibial plateau has an average (depending on sex and race) of 4.8° to 5.8° of posterior slope, with a wide range of variability (−1.8° to 15°)[47]. Although there is a lack of clinical studies examining the tibial component slope in lateral UKA, a biomechanical study has shown that increased anterior strain is imparted to the subchondral bone with decreased slope and increased posterior strain is imparted to the subchondral bone with increased slope[48]. Gulati et al. found that a tibial slope of <2° or >12° led to increased early failures in medial UKA[49]. Similarly, Chatellard et al. reported higher failure rates when the tibial slope was >2° from the native slope[50].

The tibial component should match the plateau dimensions, avoiding either overcoverage or undercoverage. Proper implant sizing can be a challenge when using medial UKA implants for lateral UKA. These medial implants frequently do not fit the lateral plateau precisely and can overcover or undercover portions of the resected tibia. Regardless, tibial overhang should be minimized to avoid impingement on surrounding tissues. Chau et al. found that an overhang of ≥3 mm resulted in poorer clinical outcomes on the medial side[51]. Although the popliteus tendon may be less tolerant to overhang, the clinical importance of overhang in lateral

Fig. 2

Intraoperative photograph demonstrating a lateral parapatellar approach with a transpatellar tendon portal used to make the vertical tibial cut. This technique avoids the potential for external rotation of the tibial component.



UKA has not been investigated, to our knowledge. Improved fit from newer lateral-specific and patient-specific implants may mitigate this problem. Undercoverage should be avoided to minimize the potential for implant subsidence into the weaker cancellous bone[52]. Additionally, during flexion, undercoverage may facilitate subluxation or edge-loading of the tibial implant.

Recreating the joint line is paramount, as elevation of the joint line can lead to instability, particularly when mobile-bearing implants are utilized[53]. The joint is elevated either by overmilling the distal part of the femur in an attempt to match the flexion and extension gaps or by overstuffing the lateral compartment by sizing the insert during flexion rather than extension[53,54]. Lateral UKA should be balanced in extension only as the natural flexion laxity of the lateral compartment will allow for a thicker tibial insert.

The femoral component must accommodate the screw-home mechanism. Placing the femoral component in slight external rotation will accommodate the relative internal rotation of the femur when moving from flexion to extension. Therefore, the femoral component will be centered on the tibia in both flexion and extension[55] (Fig. 3). The implant should be checked in flexion and extension to confirm that the positioning of the implant recapitulates the natural rotational profile of the knee. Utilizing this technique has been shown to decrease the rate of implant failures: Pennington et al.[56] reported a 100% survival rate at 12.4 years in fixed-bearing implants, whereas Pandit et al. saw a 50% decrease in failure rate with mobile-bearing implants, with no primary dislocations[10].

The optimal alignment after lateral UKA should result in a slight undercorrection of the deformity. Overcorrecting valgus alignment and overstuffing the lateral compartment lead to early failures via the progression of medial compartment arthritis[9,57-59]. Choosing the appropriate polyethylene thickness on the lateral side can be particularly challenging, as the natural laxity lacks the same restraint present on the medial side. The insert thickness should always be judged in extension, and a slight gapping in flexion should be accepted. In contrast, not performing alignment correction may lead to elevated stress across the prosthesis and early implant failure[50,60]. The optimal limb alignment should result in force being transferred through both the resurfaced and nonresurfaced compartments. In medial UKA, Vasso et al. reported that residual undercorrection of 1° to 4° of varus led to the best functional scores[61]. On the lateral side, van der List et al. reported improved functional scores in cases in which 3° to 7° of valgus was maintained compared with neutral alignment[62].

Fixed Compared with Mobile Bearing

Because of the substantial sagittal motion in the lateral compartment during knee flexion, there is a theoretical benefit of implanting a mobile polyethylene insert to decrease the complex force vectors, point loading, and polyethylene wear. Mobile-bearing clinical and laboratory studies have demonstrated unidirectional forces at both the femur and tibia in addition to abrasive-adhesive wear similarly observed in hip implants[63,64].

Despite promising laboratory data, series on mobile-bearing lateral UKA have been plagued by high rates of bearing dislocation. Gunther et al. reported an 82% survival at 5 years with an 11% dislocation rate. The authors attributed this high rate of dislocations to a lack of appreciation of the laxity that exists in the lateral compartment[65]. This laxity leads to an increased condylar liftoff in flexion (7 mm compared with 2 mm on the medial side)[16]. Specific technical factors have also contributed to these failures including malrotation of the femoral and tibial components and joint-line elevation[10,53,66]. By addressing these technical challenges, Pandit et al. reported a decrease in bearing dis-

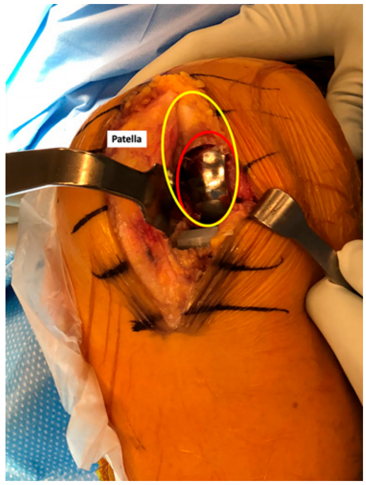


Fig. 3

Intraoperative photograph from a lateral parapatellar approach demonstrating external rotation of the femoral component (red oval) with respect to the orientation of the lateral femoral condyle (yellow oval). As the knee moves from flexion to extension, the femur will undergo relative internal rotation, maintaining congruence with the tibial component and avoiding impingement on the tibial spines.

location from 10% to 5%[10]. This same design group reported no primary dislocations and 98% survivorship at 2.3 years with the development of a domed tibial tray: a biconcave mobile-bearing implant to increase the jump distance required for bearing dislocation[10]. Using this same implant, several other authors have reported poorer short-term and intermediate-term results with dislocation rates ranging from 0% to 8.5% from 1.7 to 8 years with survivorship of 85% to 97% over that same time frame[7,53,67,68] (Table II). Despite these technical challenges, clinical outcomes have been comparable with those reported in series performed using fixed-bearing lateral UKA, with high patient satisfaction[4,7,69].

Fixed-bearing lateral UKA implants have shown longevity comparable with medial UKA. Several contemporary series have reported intermediate-term survivorship rates ranging from 92% to 100%[9,12,22,56,70]. In older series, O'Rourke et al.[71] reported a 72% survival rate at 24 years, whereas Ashraf et al. reported a 74% survival rate at 15 years using all-polyethylene tibial components[72]. Clinical scores have been comparable with series on medial UKA, with consistently good to excellent intermediate-term and long-term results[2,8,56] (Table III).

Outcomes: Registry Studies Compared with Cohort Studies

Registry studies have traditionally shown poorer UKA survivorship compared with cohort studies. A systematic review comparing registry and cohort studies in UKA showed continued divergence of outcomes, with cohort studies showing 94% survival at 5 years, 91% survival at 10 years, and 87% survival at 15 years and registry data showing 92% survival at 5 years, 84% survival at 10 years, and 70% survival at 15 years[31]. Unfortunately, many registries combine medial and lateral UKAs in revision data or do not report survivorship altogether. The analysis of registry data from the National Joint Registry for England, Wales, Northern Ireland and the Isle of Man revealed 93% survival of 2,052 lateral UKAs at 5 years, without a discrepancy between fixed and mobile-bearing implants[27]. These results are similar to results seen in contemporary cohort studies, which have excellent lateral UKA survivorship. Fixed-bearing implant survival has been reported to range from 92% to 98% at 10 years[8,9,22,70] and even 100% at a mean of 5.2 and 12.4 years[11,56]. Mobile-bearing studies have shown 90% to 98% survival at 2 years[10,67], 90% to 94% survival at 3 years[7,53], and 92% survival at 8 years[69]. Liebs and Herzberg reported a more sobering 83% survival in a mixed cohort[30]. Interestingly, this group reported relatively poor survivorship in their medial UKA cases as well.

The interpretation of the discrepancy between registry and cohort data can be challenging. As a high proportion of prosthesis developers publish cohort series, some have questioned the validity of these cohort outcomes[73,74]. Others have claimed that these superior outcomes are indicative of high-volume surgeons who are experienced with the unique anatomy and challenges of the lateral aspect of the knee. The analysis of registry data identified low-volume surgeons and centers as having an increased risk of revision in medial UKA[75].

Failure

The primary modes of failure of lateral UKA also differ between cohort and registry data. Cohort studies have shown higher rates of progression of osteoarthritis (32%) compared with rates of aseptic loosening (16%) as the primary cause for failure[76]. In contrast, pooled registry data have shown similar rates of failure due to progression of osteoarthritis (24%) and aseptic loosening (28%)[76]. In a systematic review utilizing both registry and cohort studies, the progression of osteoarthritis was the most frequently cited cause of failure, in 22% of early failures, 59% of intermediate-term failures, and 78% of late failures[77]. Unique to mobile-bearing implants, bearing dislocation was the most common reason for early failures in these patients. The vast majority of these bearing dislocations occurred within the first year[10].

Emerging Technology

UKA, especially lateral UKA, can be a technically challenging procedure with the potential for implant malalignment. Technologies aimed at improving the accuracy and precision of component positioning, balance, and alignment through advanced preoperative imaging techniques, 3-dimensional navigation, robotics, and 3-dimensional printing are being explored.

Navigation

Although the overall clinical outcomes of navigation-assisted lateral UKA have proven to be similar to manual techniques, navigation assistance improves the consistency of implant positioning. There is a lack of studies comparing navigation-assisted techniques and conventional techniques in lateral UKA. However, several studies have shown short-term and intermediate-term outcomes for medial UKA. Navigation appears to afford more precise implant positioning, particularly in the coronal alignment. It also avoids the alignment outliers reported with manual implantation[78,79]. The majority of studies have small sample sizes and show only short-term results. Song et al. reported improved clinical scores at 9 years with comparable survival[79]. However, most studies have not demonstrated clinical benefits to navigation in medial UKA[80-84]. It remains to be seen if these results in medial UKA will translate to lateral UKA.

Robotics

In clinical studies, robotic UKA improves the precision of implant positioning, rotation, depth of resection, recreation of the joint line, and overall limb alignment when compared with manual implant positioning[85-89]. Thein et al. evaluated robotic implant positioning in lateral UKA specifically and noted that, although the robot was more precise in all facets of implant positioning, the technology struggled with adequate alignment correction and tended to overstuff the joint 11% of the time[90]. This overcorrection was attributed to the residual laxity on the lateral side. Batailler et al. compared 23 lateral UKAs performed using either robotic or manual techniques and reported no revisions in the robotic group. The 2 revisions required in the manual group were attributed to improper implant positioning[91]. Although more long-term studies are warranted, initial intermediate-term clinical studies have shown comparable functional scores and lower revision rates in robotic lateral UKA[90].

Patient-Specific Instrumentation

Patient-specific instrumentation provides custom anatomic cutting jigs derived from preoperative computed tomography or magnetic resonance imaging and aims to improve implant positioning. In medial UKA, others have also reported improved implant positioning precision compared with conventional techniques[92,93]. However, Ollivier et al. reported no improvements in alignment with patient-specific instrumentation compared with conventional implants for medial UKA. Additionally, this group reported no

TABLE III Summary of Published Clinical Series Reporting Outcomes in Fixed-Bearing Lateral Unicompartmental Knee Arthroplasty*

Study	Notable Characteristics†	Implant	No. of Knees	Outcomes†	Survival†
Batailler[91] (2019)	Age 69 yr (49 to 87 yr); BMI 26 kg/m^2 (18 to 32 kg/m^2)	HLS Uni Evolution (Tornier)	23	KSS-knee 90 and KSS-function 93 at final follow-up (combined medial and lateral UKAs)‡	100% at 1.7 yr (1 to 3.8 yr)
Edmiston[45] (2018)	Age 61.3 yr; BMI 28.2 kg/m^2	Miller Galante (Zimmer)	65	Combined preop. KSS 125 to 146 at final follow-up	94% at mean (and std. dev.) 6.8 ± 3 yr
Kim[99] (2016)	Age 63.3 yr (48 to 80 yr)	ZUK (Zimmer)	30	Preop. to final follow-up: KSS-knee: 63 to 86; KSS-function: 69 to 92	97% at 3.2 yr (2 to 4 yr)
Demange[96] (2015)	Age 59 yr (44 to 88 yr); BMI 28.7 kg/m^2	iUni G1 (Conformis)	33	Preop. to final follow-up: KSS: 48 to 94	97% at 3 yr (2 to 4.4)
Lustig[100] (2014)	Age 73 yr (25 to 85 yr); weight 66.7 kg (40 to 85 kg); BMI 25 kg/m^2 (19 to 33 kg/m^2)	HLS Uni Evolution (Tornier)	46	Preop. to final follow-up: KSS-knee: 68 to 95; KSS-function: 69 to 82	94.4% at 10 yr, 91.4% at 15 yr; mean follow-up 14.2 yr (10.2 to 18 yr)
Smith[9] (2014)	Age 65 yr (36 to 91 yr)	AMC Uniglide (Corin)	101	Preop. to 5 yr: KSS-knee: 44 to 81.7; KSS-function: 56 to 76.6; OKS: 19.9 to 37.2	98.7% at 2 yr, 95.5% at 5 yr
Berend[8] (2012)	Age 68 yr; weight 184 lb (83.5 kg); BMI 30 kg/m^2	Repicci II (Biomet), Vanguard M (Biomet)	100	Preop. to final follow-up: KSS-pain 49 to 94; KSS-function: 47 to 89	97% at 3.3 yr (2 to 6.8)
Heyse[29] (2012)	Patients <60 yr, mean age 54 yr (30 to 60 yr); 22% had athletic lifestyle	Accuris (Smith & Nephew)	50	Preop. to final follow-up: KSS-knee: 90.4 to 97; KSS-function: 91.2 to 98.8‡	94% at 10.8 yr (5 to 16 yr); 71% able to perform sport of choice at final follow-up‡
Xing[36] (2012)	Age 67 yr (36 to 90 yr); BMI 28.8 kg/m^2	Preservation (DePuy)	31	Median postop. WOMAC of 6	100% at 4.5 yr (2 to 6.4 yr)
Argenson[22] (2008)	High activity level in 77%; age 61 yr (34 to 79 yr); BMI 26 kg/m^2 (18 to 43 kg/m^2)	Marmor (Zimmer), Alpina (Biomet), ZUK (Zimmer), Miller Galante (Zimmer)	40	63% returned to previous activity; preop. to final follow-up: KSS-knee: 57 to 88; KSS-function: 46 to 78	92% at 10 yr; 84% at 16 yr; mean follow-up 12.6 yr (3 to 23 yr)
Sah[11] (2007)	Age 61 yr (37 to 84 yr)	Brigham Unicondylar (DePuy), Preservation (DePuy), PFC (Press-Fit Condylar; DePuy)	48	Preop. to final follow-up: KSS-knee: 39 to 89; KSS-function: 45 to 80	100% at 5.2 yr (2 to 15 yr)
Forster[63] (2007)	Age 75 yr (55 to 93 yr)	Preservation (DePuy)	17	Median KSS-knee: 41 preop., 95 at 2 yr; median KSS-function: 50 preop., 95 at final follow-up	100% at 2 yr
Pennington[56] (2006)	Age 68 yr (52 to 86 yr); weight 171 lb (77.6 kg) (106 to 263 lb [48.1 to 119.3 kg]); BMI 28 kg/m^2 (21 to 39 kg/m^2)	Miller Galante (Zimmer)	29	HSS: 60 (42 to 79) preop., 93 (82 to 100) postop.	100% at 12.4 yr (3.1 to 15.6 yr)
Ashraf[72] (2002)	Age 69 yr (35 to 81 yr)	St. Georg Sled (Waldemar Link)	83	BKS: 53.2 preop., 90.1 at 2 yr, 86 at 5 yr, 83 at 10 yr	74.5% at 15 yr, 83% at 10 yr
Ohdera[57] (2001)	Age 65 yr (52 to 77 yr)	Omnifit B (Stryker), PCA (Howmedica), Marmor (Zimmer)	18	Preop. to final follow-up: JOAKS 64 to 85.3	89% at 8.25 yr (5 to 15.75 yr)

*KSS = Knee Society score, ZUK = Zimmer Unicompartmental High Flex Knee, OKS = Oxford Knee score, HSS = Hospital for Special Surgery, BKS = Bristol Knee Score, PCA = porous-coated anatomic, WOMAC = Western Ontario and McMasters Universities Osteoarthritis Index, and JOAKS = Japanese Orthopaedic Association Knee Score. †The values (other than percentages) are given as the mean, with or without the range in parentheses. ‡These cases include medial UKA and lateral UKA in the outcomes.

improvements in gait or functional scores at 1 year[94]. Patient-specific instrumentation appears to minimize alignment outliers compared with conventional techniques and may benefit the low-volume surgeon[93,95]. Further investigation is necessary to determine if patient-specific instrumentation improves functional outcomes or alignment in lateral UKA.

Lateral-Specific Implants and Custom Implants

The theoretical advantage of a lateral-specific implant is clear as a more congruent fit should translate to less risk of implant subsidence and overhang. Medial-designed implants utilized on the lateral plateau can be imprecise and can lead to mismatch in anterior-posterior or medial-lateral profiles and subsequent overhang or undercoverage[51,52]. Although off-the-shelf lateral UKA-specific implants exist, reports comparing outcomes with medial-designed implants utilized in lateral UKA do not exist, to our knowledge. However, Demange et al. recently reported on custom 3-dimensional-printed lateral-specific implants compared with medial UKA implants utilized on the lateral side. They compared patients who received a custom implant (iUni; Conformis) with those who underwent conventional lateral UKA with medial components (Miller Galante Uni; Zimmer). They reported improved survival rates at 3 years in the patient-specific instrumentation group, with comparable functional scores. Although they did not report on component alignment, they noted improved tibial component fit to the lateral side compared with the nonanatomic, medial-sided implants[96]. Nevertheless, many surgeons routinely perform lateral UKA using medial-designed implants. It remains to be seen if custom or off-the-shelf, lateral compartment-specific implants will improve outcomes.

Summary

Lateral UKA affords excellent functional results and implant survivorship for properly selected patients. Although traditional indications have been expanded for medial unicompartmental arthroplasty, more high-quality studies are necessary to determine whether all of these expanded indications apply to lateral UKA. Additionally, although lateral UKA is technically demanding and may be unfamiliar to many surgeons, operative adjuncts such as robotics, custom implants, and navigation technology hold promise in minimizing the technical burden of this operation. Moreover, there remain few implant options specifically designed for lateral UKA, and improvements in lateral-specific implants may translate to operational efficiency and improved outcomes as well. However, it is clear that mobile-bearing devices have increased rates of failure due to bearing dislocation, and further studies are warranted to evaluate this complication with newer designs. Future studies, both registry and cohort, should show medial and lateral UKAs separately to allow for better understanding of the nuances and technical differences between these uniquely different procedures.

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