■ KNEE

Patient-acceptable symptom state for reporting outcomes following unicompartmental knee arthroplasty

A MATCHED PAIR ANALYSIS COMPARING UKA IN ACL-DEFICIENT VERSUS ACL-INTACT KNEES

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Aims

The patient-acceptable symptom state (PASS) is a level of wellbeing, which is measured by the patient. The aim of this study was to determine if the proportion of patients who achieved an acceptable level of function (PASS) after medial unicompartmental knee arthroplasty (UKA) was different based on the status of the anterior cruciate ligament (ACL) at the time of surgery.

Methods

A total of 114 patients who underwent UKA for isolated medial osteoarthritis (OA) of the knee were included in the study. Their mean age was 65 years (SD 10). No patient underwent a bilateral procedure. Those who had undergone ACL reconstruction during the previous five years were excluded. The Knee injury Osteoarthritis Outcome Score Activities of Daily Living (KOOS ADL) function score was used as the primary outcome measure with a PASS of 87.5, as described for total knee arthroplasty (TKA). Patients completed all other KOOS subscales, Lysholm score, the Western Ontario and McMaster Universities Osteoarthritis Index, and the Veterans Rand 12-item health survey score. Failure was defined as conversion to TKA.

Results

Survivorship at ten years was 97% in both the ACL-deficient and ACL-intact groups. The mean survival was 16.1 years (95% confidence interval (CI) 15.3 to 16.8) for the ACL-deficient group and 15.6 years (95% CI 14.8 to 16.361) for the ACL-intact group (p = 0.878). At a mean of nine years (SD 3.5) in the ACL-deficient group, 32 patients (87%) reached the PASS for the KOOS ADL. In the ACL-intact group, at a mean of 8.6 years (SD 3) follow-up, 63 patients (85%) reached PASS for the KOOS ADL. There was no significant difference in the percentage of patients who reached PASS for all KOOS subscales and Lysholm between the two groups.

Conclusion

PASS was achieved in 85% of all UKAs for KOOS ADL, similar to reports for TKA. Fixed-bearing, medial, non-robotically-assisted UKA resulted in 97% survival at ten years in both the ACL-deficient and ACL-intact groups. There was no significant difference in all outcomes between the two groups. Understanding PASS will allow better communication between surgeons and patients to improve the surgical management of patients with single compartment OA of the knee. This study provides mid- to long-term data supporting the use of PASS to document outcomes following UKA. PASS was met in more than 85% of patients with no differences between ACL-deficient and ACL-intact knees at a mean follow-up of nine years.

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Introduction

Patient-reported outcome measures (PROMs) have become the routine method of assessing health-related quality of life and satisfaction in musculoskeletal research.[1] PROMs are often expressed as continuous variables with p-values to compare differences between forms of treatment, making it difficult to evaluate an individual patient's response and improvement in clinical practice.[2] The concept of a patient-acceptable symptom state (PASS) has been developed to address this constraint and allow the evaluation of an individual patient's clinical status at a given time. PASS has been introduced in the literature, including total knee arthroplasty (TKA), as a scale to infer satisfaction. However, to our knowledge, this concept has not been reported in patients after unicompartmental knee arthroplasty (UKA).[3-5]

PASS is defined as the highest level of symptoms beyond which the patient considers themselves well, implying satisfaction with treatment.[5] As an indication of wellbeing, PASS can be used as a target in the management of chronic conditions such as osteoarthritis (OA) and its treatment with an arthroplasty.[5] PASS focuses on the success of operative treatment at a particular time and is not related to the success at short-term follow-up. PASS thresholds for the Knee injury and Osteoarthritis Outcome Score (KOOS) have been shown to be highly predictive of satisfaction after TKA.[4]

The number of patients undergoing UKA continues to rise, with an annual increase of 5.8% in older patients (≥ 65 years) and 25.6% in younger patients (< 65 years).[6] Potential advantages of UKA include rapid recovery, improved gait, shorter hospital stay, less postoperative morbidity, lower cost, and preservation of bone stock in middle-aged active patients.[7-12] While other alternatives, such as TKA, high tibial osteotomy (HTO), and cartilage procedures, eliminate pain and improve function, more recent studies have shown that UKA results in superior improvement in function and greater likelihood in meeting patient expectations.[7-12]

The single compartment, osteoarthritic anterior cruciate ligament (ACL)-deficient knee is a challenging condition to treat, particularly in active middle-aged patients who wish to maintain a high level of activity. It has been reported that up to 80% of untreated ACL-deficient knees and up to 50% of ACL-reconstructed knees have radiological evidence of OA at five- to 15-year follow-up.[13,14] Historically, however, ACL deficiency has been a contraindication to UKA due to high rates of aseptic loosening of the tibial component and greater eccentric prosthetic wear in early series with a mobile-bearing implant.[15,16] Recent reports with fixed-bearing implants have challenged this contraindication, reporting success without instability or excessive wear in the non-reconstructed ACL-deficient knee with medial compartment OA.[17-19]

Several registries that have included mobile- and fixed-bearing implants have reported high revision rates of UKA.[20-23] The difficulty with comparing registry data is that there are many confounding factors such as different designs of components, surgeons with differing lengths of experience, and patient demographics, which make the data difficult to apply to a surgeon's clinical practice. While these registries provide unequalled safety data, studies of UKAs carried out by an individual surgeon can describe in detail failures and outcomes, using the PASS, similar to those reported after TKA.[4] With an increased focus on patient satisfaction and subjective outcomes, PASS may provide an excellent way to determine the success of UKA in the treatment of OA. The aim of this study was to determine if the proportion of patients who achieved an acceptable level of function (PASS) at mid- to long-term follow-up after medial UKA was different based on the status of the ACL at the time of surgery.

Methods

Following institutional review board approval by Quorum (Quorum Protocol #33949), patients who underwent medial UKA by the senior author (KDP) between 2002 and 2015 were identified from a prospectively collected database. Patients who had undergone ACL reconstruction during the previous five years, those with incomplete data, and those who declined to participate were excluded.

Patients were candidates for UKA if they had isolated medial compartment OA, pain in the medial tibiofemoral compartment with restriction of activities of daily living, and a medical history, symptoms, physical examination, and radiological findings consistent with this diagnosis. Contraindications for UKA were a varus deformity of > 15°, a range of active flexion of < 105°, gross anteroposterior instability, evidence of tibial pseudosubluxation on anteroposterior radiographs, and excursion on varus and valgus testing at 0° and 30° of knee flexion of > 8 mm.

The patients underwent arthroscopy to inspect and record the grade of OA of the patella and lateral compartment prior to UKA. Patients with an absent, torn, or non-functioning (e.g. no restraint on probing) ACL at arthroscopy were defined as ACL-deficient and were matched (1:2) by age (standard deviation (SD) 3 years) and sex with patients who with an ACL-intact knee who underwent UKA. No patients were excluded due to comorbidities, including diabetes, hypertension, and heart disease. Outerbridge[24] OA grade I to IV in any patellar facet was not an exclusion criterion, nor was Outerbridge grade I or II OA in the lateral compartment.

A total of 114 medial UKAs in 114 patients were included in the study (Figure 1). Of the 40 ACL-deficient knees, two patients (5%) died, leaving 38 ACL-deficient knees (95%) which were matched with 76 ACL-intact knees. The mean age in both groups was 65 years (SD 10), with 19 females and 19 males in the ACL-deficient group, and 38 females and 38 males in the ACL-intact group. The mean BMI was 28 kg/m^2 (SD 5) in the ACL-deficient group, and 29 kg/m^2 (SD 5) in the ACL-intact group ($p = 0.200$, independent-samples *t*-test).

All patients underwent fixed-bearing medial UKA (ZUK Uni Knee System; Smith & Nephew, USA) using an intramedullary technique as previously reported, with a patelloplasty.[25] In ACL-deficient knees, the tibia was cut with 0° of posterior tibial slope to minimize anterior tibial translation.[26]

Pre- and postoperative physical examination of the knee included a record of the range of motion, of varus or valgus deformity, and ligamentous assessment. Failure was defined by conversion to TKA. Pre- and postoperative radiological evaluation included anteroposterior, Rosenberg,[27] Merchant,[28]

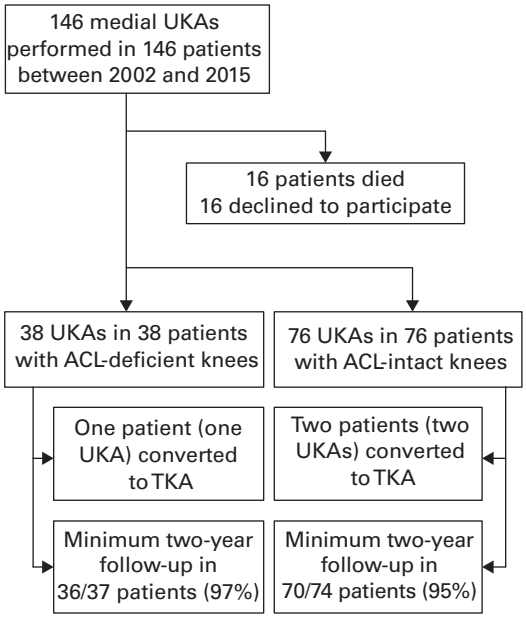

Fig. 1

Diagram showing the selection of patients. ACL, anterior cruciate ligament; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty.

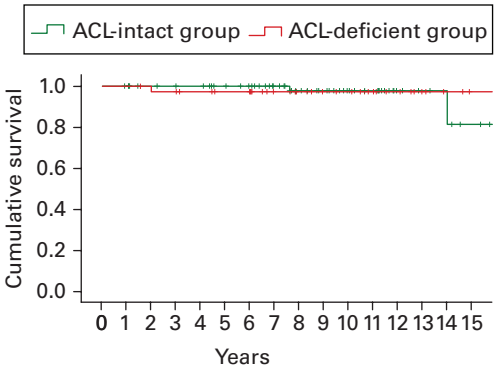

Fig. 2

Kaplan-Meier survivorship comparing anterior cruciate ligament (ACL)-deficient to ACL-intact knees.

and Hughston views,[29] and a three-foot (full limb, standing) radiograph,[30] which were used to assess limb alignment and the status of the joint line and prosthesis.

The KOOS Activities of Daily Living (KOOS ADL)[31] was used as the primary outcome measure with a PASS of 87.5, as previously defined in patients with TKA.[4] Other patient-reported outcomes included the Veterans Rand 12-item (VR-12) health survey physical component (PCS) and mental component (MCS) scores,[32] KOOS, Lysholm,[33] Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC),[34] and Tegner activity level.[35] The PASS thresholds for the other KOOS subscales were as follows: KOOS Pain = 87, KOOS Symptoms = 84, KOOS Quality of Life = 66, and KOOS Sport = 43.8.[3] The PASS threshold value for the Lysholm score was 70.[3]

Statistical analysis. Statistical analysis was performed using SPSS (version 27.0; IBM, USA). Data are presented as mean (SD). Fisher's exact test was used for comparison of categorical data. For data with significant departure from normal distribution, nonparametric univariate analysis was performed with the Mann-Whitney U test for two-group comparisons and Wilcoxon signed rank test for paired samples. For normally distributed data, the independent-samples *t*-test was used for two group comparisons. Survivorship was evaluated using a Kaplan-Meier curve. Significance was set at $p < 0.05$.

Results

There were no complications, deep-vein thromboses, or need for revision due to infection during the study period.

Survival at ten-year follow-up was 97% in both the ACL-deficient and ACL-intact group (Figure 2). The mean survival following UKA for the ACL-deficient group was 16.1 years (95% confidence interval (CI) 15.3 to 16.8) and 15.6 years (95% CI 14.8 to 16.361) for the ACL-intact group ($p = 0.878$, log-rank Mantel-Cox). The failure rate (conversion to TKA) was 2.6% (1/38) in the ACL-deficient group and 2.6% (2/76) in the ACL-intact group ($p = 1.000$, chi-squared test).

Follow-up was obtained for 36 of the 37 patients (97%) with ACL-deficient knees (38 minus one failure) and 70 (95%) of the 74 ACL-intact knees (76 minus two failures) (Figure 1). At a mean of nine years (SD 3.5; 3 to 14.9) in the ACL-deficient group, 32 patients (87%) reached the PASS for KOOS ADL. In the ACL-intact group, at a mean of nine years follow-up (SD 3; 3 to 15.7), 63 patients (85%) reached PASS for KOOS ADL. There was no significant difference in the percentage of patients who reached PASS for all KOOS subscales and Lysholm between the two groups (all p-values > 0.05) (Table I). There were no significant differences between the groups for any outcome measure (KOOS ADL, $p = 0.113$; KOOS Pain, $p = 0.491$; KOOS Symptoms, $p = 0.553$; KOOS Sport, $p = 0.896$; KOOS Quality of Life, $p = 0.562$; Lysholm, $p = 0.789$; WOMAC, $p = 0.98$; VR-12 PCS, $p = 0.910$; VR-12 MCS, $p = 0.970$; all independent-samples *t*-test) including KOOS, Lysholm, WOMAC, and VR-12. The median Tegner activity score at follow-up in the ACL-deficient group and ACL-intact group was 4 (interquartile range 3 to 5.5), which is similar to what has been reported in normal knees in patients aged > 60 years.[25] There was no significant difference in the range of flexion or extension of the knee between groups, pre- or post-operatively (Table II).

Discussion

In this series of non-robotically assisted, fixed-bearing medial UKAs, PASS was used to analyze outcomes, as has been done for TKA.[4] Over 85% achieved PASS at a mean follow-up of nine years, with no significant differences between ACL-deficient and ACL-intact knees. Survival at ten years was 97%, regardless of the status of the ACL.

We used PASS thresholds for KOOS determined on three-year outcomes reported in the literature to define success following UKA in the ACL-deficient and ACL-intact knee, allowing patients to describe their own success and outcomes.[4] We found continued acceptable symptom states

Table I. Postoperative patient-reported outcome scores in anterior cruciate ligament (ACL)-deficient and ACL-intact groups with percentage of patients reaching the patient-acceptable symptom state (PASS).

Score	ACL-deficient UKA		ACL-intact UKA		
	Mean postoperative score (SD)	PASS, %*	Mean postoperative score (SD)	PASS, %*	p-value†‡
KOOS ADL	94 (7)	87	90 (15)	85	0.392
KOOS Pain	90 (10)	77	88 (17)	72	0.797
KOOS Symptoms	80 (14)	60	82 (15)	67	0.674
KOOS Sport	71 (27)	87	72 (29)	81	0.479
KOOS Quality of Life	78 (15)	84	80 (22)	89	0.507
Lysholm	87 (17)	85	86 (18)	90	0.675
WOMAC	9.3 (6)	N/A	13.6 (13)	N/A	N/A
VR-12 PCS	57 (8)	N/A	53 (7)	N/A	N/A
VR-12 MCS	54 (4)	N/A	54 (5)	N/A	N/A

*Patient-acceptable symptom state was defined as Knee injury and Osteoarthritis Outcome Score (KOOS) Pain = 87; KOOS ADL = 87.5; KOOS Symptoms = 84; KOOS Quality of Life = 66;[3] KOOS Sport = 43.8; Lysholm = 70.[2]
†Chi-squared test.
‡p-value for comparisons of proportions of patients meeting PASS between ACL-deficient and ACL-intact groups.
KOOS-ADL, Knee injury Osteoarthritis Outcome Score Activities of Daily Living; MCS, mental component; N/A, not applicable; PCS, physical component; SD, standard deviation; UKA, unicompartmental knee arthroplasty; VR-12, Veterans Rand 12-item health survey; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

Table II. Preoperative and postoperative (mean nine years' follow-up) knee flexion and extension angle for the anterior cruciate ligament (ACL)-deficient and the ACL-intact groups.

Variable	ACL-deficient UKA	ACL-intact UKA	p-value*
Mean extension, ° (SD)			
Preoperative	3 (5)	2 (4)	0.619
Postoperative	1 (2)	0 (2)	0.140
Mean flexion, ° (SD)			
Preoperative	121 (14)	120 (11)	0.761
Postoperative	129 (10)	130 (8)	0.769

*Independent-samples *t*-test.
SD, standard deviation; UKA, unicompartmental knee arthroplasty.

in patients with UKA for up to 15 years postoperatively. We also found similar results using PASS threshold values for the Lysholm score previously established in patients after cartilage repair in the knee.[3] PASS scores focused on the current state (mid- to long-term follow-up) of the success at the time of the investigation which is not dependent on the short-term success, such as at two-year follow-up. These data suggest that most patients continue to "feel well", despite increasing age and potential age-related decreases in activity. The number of patients reaching PASS in this study was equivalent to or higher than that in similar cohorts of patients with TKA.[4] Further research is needed to identify if the level of PASS decreases with follow-up of more than ten years in an ageing population.

The patients in the ACL-deficient group had postoperative Tegner scores between 4 and 7, indicating participation in sporting activities, such as skiing, jogging, running, and tennis, which involve impact loading, twisting, and high flexion, without adverse effect on the survival of the prosthesis. Hamilton et al[36] reported that the level of activity undertaken by a patient did not alter the long-term outcome of UKA. Yim et al[37] reported at three-year follow-up a mean Lysholm score of 90, compared with 87 in this series at our mean follow-up of nine years, which is within the reported minimal clinically important difference (MCID) for the Lysholm score. Similar comparisons can be made to other outcomes using KOOS and WOMAC scores.[38,39]

Higher failure rates in ACL-deficient knees have been noted when using a mobile-bearing UKA.[15,39] Historically, in a series of 103 patients, Goodfellow et al[15] demonstrated a ten-fold increase in failure rates in ACL-deficient knees. The primary mode of failure was aseptic loosening, as well as medial bearing instability, not seen in their ACL-intact cohort. We did not find any evidence of aseptic loosening, infection, or high failure rate in our series of fixed-bearing UKAs placed with a posterior slope of 0° in the ACL-deficient knee.

Some authors have challenged the need for an intact ACL when undergoing a medial UKA.[17,18,40] In a series of 81 knees, Engh et al[40] reported a 94% survivorship at six years in ACL-deficient, fixed-bearing UKA and 93% survivorship in fixed-bearing UKA in ACL-intact knees, although ten-year outcomes were not reported. Our results are similar with a mean follow-up of nine years and a maximum of 15 years.

Adaptive changes of the capsule of the knee are the result of chronic OA, often including contracture, and the development of osteophytes and scar tissue, which provide some stability in the absence of an ACL.[41–43] Marshall et al[43] showed the development of osteophytes along the borders of the femoral condyles in dogs with ACL deficiency, increased OA, and thickening of the joint capsule, concluding that knees became less unstable in the anteroposterior plane as the thickness of the capsule increased. In the classic article by Brage et al,[44] loss of anteroposterior laxity in knees with single compartment OA was described. They hypothesized that the resultant osteophyte production and soft-tissue contracture may be a compensatory mechanism and responsible for the decrease in laxity.[44] Dayal et al[41] continued support for this theory when showing that knees with OA of Kellgren-Lawrence grade IV have less anteroposterior laxity than those with less severe OA. These studies confirm our observations on examination and described by patients with an osteoarthritic, ACL-deficient knee, with limited signs of anteroposterior laxity. In the senior author's (KDP's)

experience, these patients complain of their knee 'falling into a pothole' with mediolateral instability, rather than anteroposterior giving way. Confirmation on standing lateral radiographs shows no evidence of tibial subluxation or fixed anterior tibial translation.

The maintenance of stability and restoration of joint mechanics is required for a high level of function in a UKA. Careful debridement and removal of intercondylar osteophytes should be performed to allow for mobility of the fixed-bearing prothesis. It has been shown that an increase in posterior tibial slope decreases the tension in the collateral ligaments, whereas a decrease in posterior tibial slope increases this tension to achieve stability.[43,45–49] We attempted to maintain a 0° posterior tibial slope for the ACL-deficient knees and selected our tibial cut at 0°. Posterior tibial slope and proper tensioning of the collateral ligaments will limit anterior tibial translation, as for a successful HTO or TKA.

Limitations of this study include the non-randomized design and small number of patients. However, this series has longer follow-up than most recent ACL-deficient medial UKA studies.[19] We included a matched ACL-intact cohort to allow comparison, strengthening the study. Medial UKA in the ACL-deficient knee is a technically demanding procedure with a high learning curve. Therefore, caution should be taken when proceeding with this operation, as evidenced by the three failures that occurred early in the senior surgeon's series. We encourage the less experienced surgeon to refine their technique in the bioskills laboratory before proceeding to the operating room and to operate with an experienced surgeon in the first cases to avoid technical errors, including not removing osteophytes, overstuffing the joint, and a lack of balance in the collateral ligaments, which required re-evaluation in this series. Data were not available to evaluate changes in PROMs over time. However, these data showed that 85% of patients after UKA in both ACL-intact and ACL-deficient knees achieved PASS at up to 15 years postoperatively, suggesting that UKA can be considered the procedure of choice in appropriately selected patients with isolated medial compartment UKA.

In summary, this is the first study to our knowledge to use a state attainment criterion to evaluate outcomes of non-robotic, fixed-bearing medial UKA. In the ACL-deficient knee, this resulted in an extremely low failure rate (3%) and excellent long-term outcomes, with more than 85% of patients reaching PASS for KOOS ADL at a follow-up of three to 15 years, comparable to TKA. The results for the ACL-deficient group were not significantly different for all outcomes compared with UKA in ACL-intact knees. We recommend that surgeons undertake this procedure in patients who wish for high levels of activity postoperatively.

Take home message

- With proper patient selection, fixed-bearing unicompartmental knee arthroplasty (UKA) can be successful in the anterior cruciate ligament (ACL)-deficient knee.
- Patient-acceptable symptom state can be used in UKA to identify patients that have achieved an acceptable level of function. Low failure rates were seen in non-robotically-assisted, fixed-bearing medial UKA in both ACL-deficient and ACL-intact knees.

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