The Knee 26 (2019) 897–904

Contents lists available at ScienceDirect

The Knee

Mid- to long-term function and implant survival of ACL reconstruction and medial Oxford UKR☆

J.A. Kennedy [a,*], J. Molloy [a], H.R. Mohammad [a], S.J. Mellon [a], C.A.F. Dodd [b], D.W. Murray [a,b]

[a] Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences, University of Oxford, United Kingdom
[b] Nuffield Orthopaedic Centre, Oxford University Hospitals NHS Foundation Trust, United Kingdom

ARTICLE INFO

Article history:
Received 18 January 2019
Received in revised form 15 April 2019
Accepted 14 May 2019

Keywords:
Anterior cruciate ligament reconstruction
Unicompartmental knee replacement
Outcomes
Implant survival

ABSTRACT

Purpose: The purpose of this study was to describe mid- to long-term outcomes of anterior cruciate ligament (ACL) reconstruction with simultaneous or staged medial unicompartmental knee replacement (UKR), and compare outcomes between (1) young patients aged younger than 55 at surgery and those older, (2) those with long-term follow-up greater than 10 years, (3) cemented and cementless UKR, and (4) compare outcomes to those with an intact ACL.

Patients and methods: We identified knees with staged or simultaneous ACL reconstruction and medial UKR from a prospectively followed designer UKR cohort, and describe mean Oxford Knee Score (OKS), mean Tegner activity score and Kaplan–Meier survival estimates. We matched these knees to ACL-intact knees.

Results: Seventy-six consecutive UKR with staged or simultaneous ACL reconstruction were identified with mean six-year follow-up (range 1–15). There was significant improvement in OKS and Tegner score with surgery. At most recent follow-up, OKS was 41.0 (range 11 to 48), and Tegner score 3.6 (0 to 8). There were three revisions occurring at a mean of five years post-operatively. The five-, 10- and 15-year survival estimates were 97% (95% confidence interval [CI] 93–100), 92% (83–100), and 92% (83–100). There was no difference in functional scores or implant survival in young patients, those with long-term follow-up (>10 years), those with cementless fixation, or when compared to ACL intact knees.

Conclusion: These results demonstrate excellent mid- to long-term function and survival of selected patients who have undergone ACL reconstruction and medial UKR. Their outcome was similar to those with intact ACLs.

1. Introduction

A deficient anterior cruciate ligament (ACL) is considered a contraindication to medial unicompartmental knee replacement (UKR) due to increased risk of tibial component loosening [1–3]. However, occasionally patients present with medial osteoarthritis and meet all the indications for UKR except have a deficient ACL. These patients tend to be young and active. The management is therefore challenging due to the need for a high functioning and durable knee. Current management options include high tibial osteotomy (HTO) with or without ACL reconstruction, UKR with or without ACL reconstruction, and total knee replacement (TKR).

☆ **Funding:** This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
* Corresponding author.
E-mail address: james.kennedy@ndorms.ox.ac.uk. (J.A. Kennedy).

https://doi.org/10.1016/j.knee.2019.05.009
0968-0160/

Anteroposterior knee joint laxity owing to deficiency of the ACL allows the femur to sublux posteriorly on the tibia, and it is thought that recurrent loading on the posterior part of the medial meniscus and underlying articular cartilage of the tibia produces attritional meniscal damage and leads to posteromedial osteoarthritis [4]. Frequently when posteromedial osteoarthritis develops as a result of ACL deficiency the rest of the knee is in good condition with full thickness cartilage laterally and a normal functioning MCL. In this situation, it is reasonable to consider a combined ACLR and UKR. It is important to determine that ACL deficiency occurred primarily, and is not secondary to the osteoarthritic process. In primary medial compartment osteoarthritis, the disease tends to begin in extension and the competent ACL restricts loading to the anterior tibia resulting in anteromedial osteoarthritis. Although a varus deformity develops, this is correctable as the MCL is not shortened as it is pulled out to full length each time the knee flexes and the femur rolls back onto normal cartilage posteriorly. With time, the ACL is progressively damaged, and the arthritis extends posteriorly [5–7]. By the time the ACL is destroyed, the medial collateral ligament has usually shortened and the lateral compartment shows evidence of osteoarthritis involvement [8,9]. This means that a UKR would be inappropriate, and the best option is a TKR.

In appropriate patients, there has been increasing interest in UKR with ACL reconstruction. Good patient reported outcomes (PROMs) and mainly short-term implant survival has been reported from three centres [10–12]. We have previously published our experience with ACL reconstruction and the Oxford Phase III meniscal-bearing UKR [9,10]. The primary aim of the current study is to extend follow-up and include a larger sample, by reassessing PROMs and implant survival from patients who have undergone ACL reconstruction with a staged or simultaneous medial UKR. Our secondary aims were to compare the outcomes of patients (1) younger or older than 55 years of age, (2) less than or greater than 10-year follow-up, (3) cemented or cementless UKR fixation, and (4) to compare outcomes with a matched UKR cohort with intact ACLs.

2. Material and methods

2.1. Patients

We identified consecutive patients from our prospectively collected database. We included all patients that had undergone ACL reconstruction and staged or simultaneous medial meniscal-bearing UKR between January 2001 and July 2016 that were performed by the two senior surgeons (CAFD, DWM,) who are designers of the UKR prosthesis. In 2010, the prosthesis changed from the cemented Oxford UKR (Zimmer Biomet, Bridgend, United Kingdom) implanted with the minimally invasive Phase III instruments, to cementless Oxford UKR components (Zimmer Biomet, Bridgend, United Kingdom) that use hydroxyapatite coating to allow bone ingrowth into the component. Most of these were implanted with the new minimally invasive Microplasty instruments.

Patients were offered ACL reconstruction and Oxford UKR if they had significant symptoms and presented with isolated medial bone-on-bone osteoarthritis. Other inclusion criteria included a correctable intra-articular varus deformity (thereby indicating a functionally normal MCL), full thickness cartilage laterally and an intact posterior cruciate ligament (PCL). If a patient's primary complaint was pain, then a simultaneous ACL reconstruction and Oxford UKR were performed. If instability was the presenting complaint, then an ACL reconstruction was undertaken as a primary procedure. If the patient subsequently presented with pain attributable to their arthritis, then an Oxford UKR was undertaken. This was classified as a staged ACL reconstruction and UKR. The technique for simultaneous and staged ACL reconstruction and UKR, using either hamstring or patella tendon graft has previously been described [9]. Additionally, patients who had undergone previous ACL reconstruction without osteoarthritis, and subsequently developed osteoarthritis sufficient for UKR were also offered UKR. If the ACL was functioning, the reconstruction was not revised, even in the presence of suboptimal tunnel placement and/or laxity of the reconstructed ACL. These were also classified as staged ACL reconstruction and UKR.

Patients were followed up and seen in person by physiotherapists independent of the clinical and surgical teams involved in patient care. Where patients were unable to attend, a telephone or postal questionnaire was used. Functional outcomes were assessed using the Oxford Knee Score (OKS; 0 to 48 with 48 being best outcome) [13], and the Tegner Activity Score [14] (0 to 10 with 10 being participation as an elite national athlete). Revision was defined as the removal, exchange or addition of any implant component. This included bearing exchange for bearing dislocation, addition of a lateral UKR for lateral compartment progression, or conversion to TKR.

2.2. Statistical analysis

2.2.1. Variables

Demographic variables included were age, sex, and body mass index (BMI). Baseline preoperative OKS and Tegner Score were recorded. Age, BMI, preoperative OKS and preoperative Tegner Score were normally distributed.

2.2.2. Outcome variables

Most recent OKS and Tegner score were assessed. The most recent OKS was left skewed, while the Tegner Score was normally distributed. A binary variable was used to denote whether a patient had been revised. Each patient follow-up was recorded, with follow-up being censored if revised. Revision was defined as any component removal, addition or exchange.

2.2.3. Main analysis

We present means (standard deviation) and medians (interquartile range) depending on the underlying distribution. Student's *t*-tests, Mann–Whitney *U* or chi-squared tests were used to assess for baseline differences between groups. Wilcoxon signed rank tests were used to assess scores over time. Statistical significance was set at an alpha value of <0.05, and power to 0.8. Implant survival is assessed with Kaplan–Meier estimates and component time incidence rates. A log rank test was used to test for significant differences between groups.

2.2.4. Subgroup analysis

Four subgroup analyses were performed. We looked at those younger and older than 55 years of age at surgery, those with a minimum of 10 years of follow-up and compared cemented and cementless fixation. Finally, we performed a matched comparison with a group of ACL intact patients. Matching was performed against a database of 1000 cemented Phase III Oxford UKR which has previously been reported in detail [15,16]. We used the MatchIt algorithm [17] in R to perform 1:1 matching using covariates: age, weight, sex, preoperative OKS, and preoperative Tegner score as matched variables.

2.2.5. Missing values

Four knees in four patients were lost to follow-up. Of the remaining knees, preoperative PROMs were missing in about 30%. One did not have postoperative OKS and Tegner Score available due to early revision, but the remaining 75 were available. The revision status of the knee was available in all cases apart from the four lost to follow-up. Analysis was conducted on available data.

Statistical analysis was performed in Stata (STATA Corp, Texas, United States of America) and R (R Core Team 2016, Vienna, Austria).

2.3. Conflict of interest

The author or one of more of the authors have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article. In addition, benefits have been or will be directed to a research fund, foundation, educational institution, or other non-profit organisation with which one or more of the authors are associated.

3. Results

3.1. Baseline characteristics

We identified 80 consecutive knees (79 patients) that met the inclusion criteria. Four knees were lost to follow-up leaving 76 knees in 75 patients for final analysis. The mean age was 52.6 (range 36 to 71), and mean follow-up was 6.4 years (1 to 15) (Table 1).

3.2. Functional outcome

There was significant improvement in OKS and Tegner score with surgery. Mean preoperative OKS was 29.0 (14 to 46), improving to 41.0 (11 to 48; $p<0.001$; Table 2), and mean preoperative Tegner score was 2.8 (1 to 5), improving to 3.6 (0 to 8; $p=0.005$). Sixty-three (83%) achieved good or excellent OKS outcome.

Table 1
Cohort demographics

	Cohort
Number of patients	75
Number of knees	76
Mean age in years (range)	52.6 (36 to 71)
Mean BMI (SD)	28.2 (4)
Number female (%)	16 (21%)
Mean preoperative OKS (SD)	29.0 (8)
Mean preoperative Tegner score (SD)	2.8 (1)
Mean follow-up in years (range)	6.4 (1 to 15)

BMI = body mass index, OKS = Oxford Knee Score, SD = standard deviation

Table 2
Postoperative outcomes of subgroups.

	Cementless	Cemented	P value	Age < 55	Age > 55	P value	FU < 10	FU > 10	P value	Simultaneous	Staged	P value
Median postoperative OKS (IQR)	44.0 (41 to 47)	45.0 (37 to 47)	0.82	**44 (36 to 46)**	**46 (42 to 47)**	**0.03**	44 (36 to 47)	46 (39 to 48)	0.25	45 (41 to 47)	39 (35 to 46)	0.24
Mean postoperative Tegner score (SD)	3.6 (2)	3.5 (1)	0.94	3.6 (1)	3.5 (1)	0.91	3.5 (2)	3.9 (1)	0.19	3.6 (2)	3.4 (1)	0.69
N revised (%)	0 (0%)	3 (7%)	0.29	2 (4%)	1 (3%)	0.89	3 (5%)	0 (0%)	0.17	2 (3%)	1 (6%)	0.99
Five-year Kaplan–Meier survival (CI)	100%	95.3% (89–100)		97.4% (93–100)	96.6% (90–100)		96.2 (91–100)	100%		98.3% (95–100)	94.1% (84–100)	

3.3. Implant survival

There were three revisions (3.9%) occurring at a mean of five years, all of which were revised to TKR. One diabetic patient who underwent a simultaneous ACLR and cemented UKR required a two-stage revision to a TKR after five months due to an early deep infection. The next revision occurred four years after surgery due to disease progression in a patient who underwent a staged ACL reconstruction and cemented UKR. However, in this patient the ACL reconstruction had been performed elsewhere seven years prior to primary UKR. On assessment at the time of UKR, the tibial tunnel was suboptimal, and the ACL graft was found to be lax. Another patient who underwent simultaneous reconstruction and cemented UKR also developed disease progression in the lateral compartment at 9.9 years, and this was also converted to a primary TKR.

Kaplan–Meier survival estimates at five, 10 and 15 years were 97.0% (n at risk = 47, 95% confidence interval [CI] 88–99), 92.3% (at risk 14; CI 74–98), and 92.3% (at risk 2; CI 74–98; Figure. 1).

3.4. Subgroup analyses

3.4.1. Baseline

Subgroups were comparable, though with significant differences in the follow-up of patients, and small differences in age (Appendix Table A).

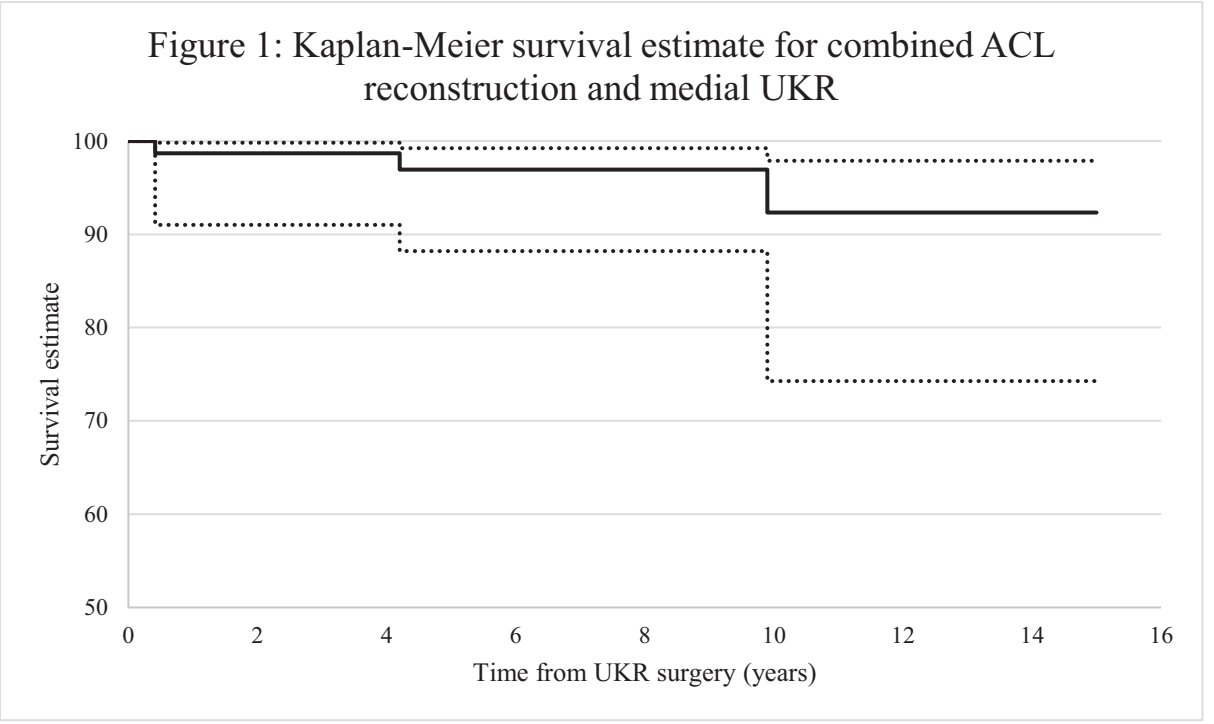

Figure 1. Kaplan–Meier survival estimate for combined ACL reconstruction and medial UKR.

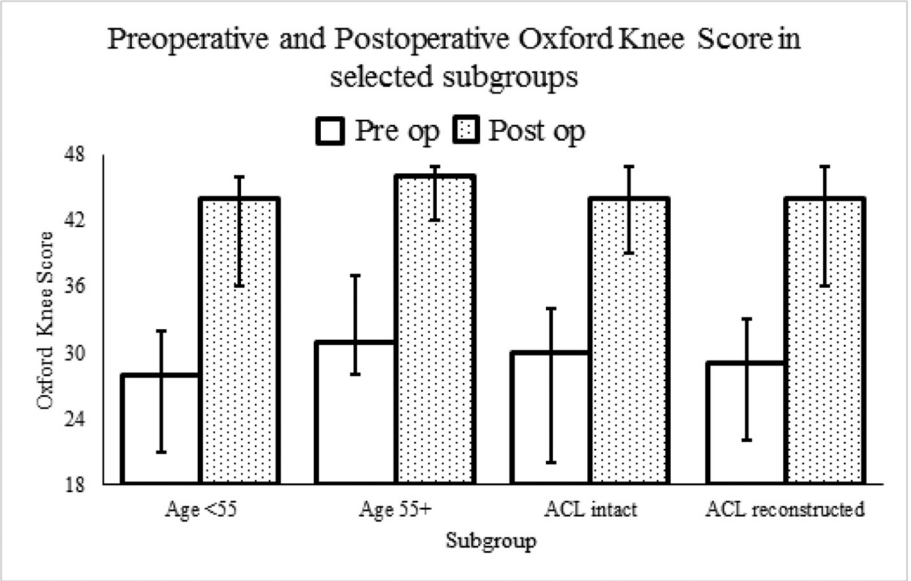

Figure 2. Preoperative and Postoperative Oxford Knee Score in selected subgroups. ACL = anterior cruciate ligament. Age recorded in years at surgery. Median value represented by bar height, error bars represent interquartile range.

3.4.2. Age <55 vs 55 + years

Those aged younger than 55 years at surgery had lower preoperative OKS (mean 27.3 standard deviation [SD] 8 vs 32.2 SD 7, $p = 0.01$). Those younger than 55 at surgery ($n = 47$) had slightly worse OKS (median 44 vs 46, $p = 0.03$, Table 2, Figure 2), but comparable Tegner score (mean 3.6 vs 3.5, $p = 0.19$) and revisions ($p = 0.89$).

3.4.3. Follow-up > 10 years

Thirteen knees in 13 patients had minimum 10-year follow-up (median 12, range 10 to 15 years). These knees had a median OKS of 46 compared with 44 for those with less than 10 years of follow-up ($p = 0.25$; Table 2), and mean Tegner score of 3.9 (SD 1) vs 3.5 (SD 1, $p = 0.19$). Additionally there were no revisions in any knee with greater than 10 years of follow-up ($p = 0.17$).

3.4.4. Cemented vs cementless

Cementless components ($n = 33$) had a shorter follow-up due to their staged introduction (median follow-up 2.5 years vs 9.8 years for cemented components) but were not associated with any difference in outcome (Table 2).

3.4.5. Staged vs simultaneous UKR and ACL reconstruction

Fifty-eight (76%) underwent simultaneous reconstruction and UKR, the remaining 18 knees having a staged procedure with mean time between reconstruction and UKR being 6.1 years. The simultaneously reconstructed group were older (mean 49 years vs 54 years, $p = 0.02$). There were no differences in outcome (Table 2).

3.4.6. ACL reconstructed UKR vs ACL intact UKR

A subgroup of knees with complete preoperative demographics ($n = 46$) were matched 1:1 on age, sex, weight, preoperative OKS, and preoperative Tegner score with cemented medial UKR with an intact ACL (Appendix Table B). No differences were found in outcome in OKS (ACL reconstructed median OKS 44 [interquartile range (IQR) 36–47] vs 44 [IQR 39–47], $p = 0.47$), Tegner score (mean 3.5 [SD 1] vs 3.7 [SD 2], $p = 0.52$), or five-year Kaplan–Meier survival (97.8% vs 100%, $p = 0.17$).

4. Discussion

Our results demonstrate good mid- to long-term function and survival for ACL reconstructed patients undergoing medial UKR, with a mean OKS of 41 points, and a 10-year survival of 92.3%. The survival estimate was the same out to 15 years, albeit with small numbers. In addition, we show that the results are excellent for patients of all ages. In particular, there are excellent results in young patients (younger than 55 years of age) who often have ongoing symptoms following arthroplasty [18]. Furthermore, the results did not deteriorate after 10 years. We believe this cohort now constitutes the largest number of patients with longest follow-up of ACL reconstruction and medial UKR reported in the literature, and

provides further evidence that in appropriately selected patients ACL reconstruction with medial UKR provides excellent function and implant survival.

The management of young patients with osteoarthritis is difficult. Primary osteoarthritis is rare in patients aged <50 years [19,20], and in this group, osteoarthritis is often secondary to an ACL injury [4]. This condition is becoming increasingly common with more sports injuries, and these patients are functionally demanding. Restoring function and relieving pain are important objectives, but concern over subsequent operations and preservation of bone exist. Our results demonstrated a median OKS of 44 in our subgroup younger than 55 at operation. This was two points lower than those older than 55 at surgery. However this group had a lower preoperative OKS so their change in OKS was greater, but also the patients having ACL reconstruction over the age of 55 represent a highly active group for their age.

There are multiple series now reporting excellent 10-year survival results with Oxford UKR in ACL intact knees [16,21–28]. A key determinant of successful Oxford UKR outcome is correct indications for use [21,24,29]. These are well-defined with the main indication being anteromedial osteoarthritis with the requirement of bone-on-bone osteoarthritis of the medial compartment, full thickness cartilage in the lateral compartment, and functionally intact medial collateral and anterior cruciate ligaments. These are satisfied in up to half of patients undergoing knee replacement [21,30]. Arthritis occurring after a primary ACL rupture that is appropriate for combined UKR and ACLR is much rarer and accounts for one to two percent of our knee replacement practice.

We switched to cementless components midway through the study period. When combined with ACL reconstruction we have not experienced any failures with these components. It is reassuring to see that changes in the component fixation have not affected the outcome. A confounding factor in this analysis was the temporal aspect to the switch, with both surgeons switching to cementless components after their cemented components. In addition, the majority of cementless components were implanted with the improved microplasty instruments [31,32]. This raises the possibility of increased surgeon experience contributing to the results. There were no significant differences between the ACL reconstructed group and the ACL intact group which suggests a return of premorbid ACL function following reconstruction.

Other studies have reported outcomes with ACL reconstruction and subsequent fixed or mobile bearing UKR. Ventura et al. [12] reported their outcomes in 14 patients with a fixed bearing device. They report a mean OKS of 43 at a mean follow-up of 26.7 months. They have not had any revisions. Tian et al. [11] report on 28 patients also treated with Oxford UKR, and report a mean OKS of 43 at a mean follow-up of 52 months. They reported two bearing dislocations, and in both a thicker bearing was inserted with no further problems. Tinius et al. [33] reported 27 patients with fixed bearing UKR, mean follow-up was 50 months, and they had not had any revisions. They did not report OKS.

The risk of TKR revision in younger patients is substantially higher than in older patients with the National Joint Registry reporting a nine percent 10-year revision rate for TKR in patients younger than 55 years [34] which is similar to the revision rate of our ACLR UKR patients. Furthermore, by carrying out this procedure there is usually the option of later conversion to a primary TKR if the knee fails. Revision of TKR often involves greater bone loss requiring use of more stems and augments compared to UKR revision [35–37]. Furthermore, in matched comparisons PROMs tend to be lower in TKR than UKR [38,39]. Despite this, it remains an option in this scenario. An alternative operation in the young patient with isolated compartment osteoarthritis and varus alignment is HTO with or without ACL reconstruction. However, patients that do well with HTO tend to be different from those who do well with Oxford UKR. The UKR is very reliable if there is true bone-on-bone osteoarthritis whether there is varus alignment or not [40,41], and is contraindicated when there is not bone-on-bone [42]. In contrast, HTO is most reliable if there is not bone-on-bone, and there is varus alignment [43–45]. Despite this, the United Kingdom Knee Osteotomy Registry First Annual Report [46] shows that almost one in five osteotomy patients had bone-on-bone, and that the majority (70%) of the 1652 registered patients were aged between 40 and 55, similar to the age in our study. It does not report on the status of the ACL, or if combined reconstruction was undertaken. No study exists comparing UKR and HTO in patients with ACL reconstruction. A comparison of PROMs in ACL intact knees suggests that, even though the groups may not be well-matched, HTO when compared to UKR has worse PROMs [47–49]; perioperative complications are higher [48,50], and the requirement for subsequent surgery is also higher [47,48,50,51]. Thus, the management of patients who have bone-on-bone medial osteoarthritis with combined ACL reconstruction and UKR is attractive. It preserves bone stock, and allows patients a very active life.

The main limitation of the study is that we did not perform a radiological analysis as part of this study. We are therefore unable to comment on radiological changes such as lateral disease progression that has not been revised, nor the technical quality of the ACL reconstruction. In addition, the temporal change to cementless components raises the possibility of confounding owing to increased surgeon experience for this comparison. All the comparative analyses are limited by small sample sizes, and are at risk of false positive and false negative findings. The strength of this series is that this is a prospectively followed series of consecutive cases.

Conclusions

In conclusion, ACL reconstruction and Oxford UKR in appropriate patients appears to provide excellent outcomes in the management of osteoarthritis and ACL deficiency in the mid- to long-term.

Acknowledgments

The authors would like to thank the administrative input of Barbara Marks and Jo Brown, and the clinical input of Cathy Jenkins.

Appendix A. Appendices

Table A
Baseline demographics for subgroup comparisons.

	Cementless	Cemented	P value	Age < 55	Age 55 +	P value	FU < 10	FU > 10	P value	Simultaneous	Staged	
N knees (N patients)	**33 (33)**	**43 (43)**	**NA**	**47 (47)**	**29 (29)**	**NA**	**63 (62)**	**13 (13)**	**NA**	58	18	
Mean age in years (range)	**55.4 (42 to 71)**	**50.4 (36 to 68)**	**0.01**	**47.1 (36 to 54)**	**61.5 (55 to 71)**	**0.001**	**53.5 (37 to 71)**	**48.0 (36 to 68)**	**0.04**	**53.8 (41 to 71)**	**48.7 (36 to 69)**	**0.02**
Mean BMI (SD)	**28.7 (4)**	**27.9 (4)**	**0.35**	**28.5 (4)**	**27.8 (4)**	**0.46**	**28.3 (4)**	**28.1 (3)**	**0.85**	28.1 (4)	28.8 (4)	0.48
N female (%)	**10 (30%)**	**6 (14%)**	**0.15**	**9 (19%)**	**7 (24%)**	**0.82**	**14 (22%)**	**2 (15%)**	**0.86**	14 (24%)	2 (11%)	0.39
Mean preoperative OKS (SD)	**30.1 (7)**	**28.3 (9)**	**0.36**	**27.3 (8)**	**32.2 (7)**	**0.01**	**28.5 (8)**	**30.8 (8)**	**0.36**	29.1 (8)	28.8 (8)	0.87
Mean preoperative Tegner score (SD)	**3.0 (1)**	**2.6 (1)**	**0.15**	**2.7 (1)**	**3.0 (1)**	**0.34**	**2.8 (1)**	**2.9 (1)**	**0.85**	2.9 (1)	2.4 (1)	0.22
Median follow-up in years (range)	**2.5 (1 to 7)**	**9.8 (1 to 15)**	**0.001**	**6.9 (1 to 15)**	**4.9 (1 to 15)**	**0.01**	**5.0 (1 to 10)**	**11.9 (10 to 15)**	**0.001**	**5.5 (1 to 12)**	**10.3 (2 to 15)**	**<0.001**

FU follow-up; N number; SD standard deviation; OKS Oxford Knee Score.

Table B
Baseline data of subgroup of matched ACL intact patients to ACL reconstructed.

	ACL intact	ACL reconstructed	P value
N patients (N knees)	46 (46)	46 (46)	NA
Mean age in years (range)	51.7 (40 to 67)	52.1 (37 to 71)	0.84
Mean BMI (SD)	28.4 (4)	28.4 (3)	0.97
N female (%)	12 (26%)	11 (24%)	1
Mean preoperative OKS (SD)	27.5 (8)	28.1 (8)	0.72
Mean preoperative Tegner score (SD)	2.8 (1)	2.8 (1)	0.79
Median follow-up in years (range)	7.9 (1 to 12)	5.8 (1 to 12)	<0.01

ACL anterior cruciate ligament; N number; SD standard deviation; OKS Oxford Knee Score. ACL intact patients were matched from a separate database of 1000 cemented medial unicompartmental knee replacements.

Table C
Comparison of subgroup outcomes of matched ACL intact patients to ACL reconstructed patients.

	ACL intact	ACL reconstructed	P value
Median postoperative OKS (IQR)	44 (39 to 47)	44 (36 to 47)	0.47
Mean postoperative Tegner score (SD)	3.7 (2)	3.5 (1)	0.52
Five-year survival (CI)	97.8% (94–100)	100.0% (100–100)	0.17

ACL anterior cruciate ligament; OKS Oxford Knee Score; IQR interquartile range; SD standard deviation, CI 95% confidence interval.

References

[1] Goodfellow JW, Kershaw CJ, Benson MK, O'Connor JJ. The Oxford Knee for unicompartmental osteoarthritis. The first 103 cases. J Bone Joint Surg Br 1988;70(5):692–701.
[2] Hernigou P, Deschamps G. Posterior slope of the tibial implant and the outcome of unicompartmental knee arthroplasty. J Bone Joint Surg Am 2004;86-A(3):506–11.
[3] Goodfellow J, O'Connor J. The anterior cruciate ligament in knee arthroplasty. A risk-factor with unconstrained meniscal prostheses. Clin Orthop Relat Res 1992(276):245-52.
[4] Lohmander LS, Englund PM, Dahl LL, Roos EM. The long-term consequence of anterior cruciate ligament and meniscus injuries: osteoarthritis. Am J Sports Med 2007;35(10):1756–69.
[5] White SH, Ludkowski PF, Goodfellow JW. Anteromedial osteoarthritis of the knee. J Bone Joint Surg Br 1991;73(4):582–6.
[6] Moschella D, Blasi A, Leardini A, Ensini A, Catani F. Wear patterns on tibial plateau from varus osteoarthritic knees. Clin Biomech (Bristol, Avon) 2006;21(2):152–8.
[7] Hasegawa A, Otsuki S, Pauli C, Miyaki S, Patil S, Steklov N, et al. Anterior cruciate ligament changes in the human knee joint in aging and osteoarthritis. Arthritis Rheum 2012;64(3):696–704.
[8] Bellemans J, Vandenneucker H, Vanlauwe J, Victor J. The influence of coronal plane deformity on mediolateral ligament status: an observational study in varus knees. Knee Surg Sports Traumatol Arthrosc 2010;18(2):152–6.
[9] Pandit H, Beard DJ, Jenkins C, Kimstra Y, Thomas NP, Dodd CA, et al. Combined anterior cruciate reconstruction and Oxford unicompartmental knee arthroplasty. J Bone Joint Surg Br 2006;88(7):887–92.
[10] Weston-Simons JS, Pandit H, Jenkins C, Jackson WF, Price AJ, Gill HS, et al. Outcome of combined unicompartmental knee replacement and combined or sequential anterior cruciate ligament reconstruction: a study of 52 cases with mean follow-up of five years. J Bone Joint Surg Br 2012;94(9):1216–20.

[11] Tian S, Wang B, Wang Y, Ha C, Liu L, Sun K. Combined unicompartmental knee arthroplasty and anterior cruciate ligament reconstruction in knees with osteoarthritis and deficient anterior cruciate ligament. BMC Musculoskelet Disord 2016;17:327.
[12] Ventura A, Legnani C, Terzaghi C, Iori S, Borgo E. Medial unicondylar knee arthroplasty combined to anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 2017;25(3):675–80.
[13] Dawson J, Fitzpatrick R, Murray D, Carr A. Questionnaire on the perceptions of patients about total knee replacement. J Bone Joint Surg Br 1998;80(1):63–9.
[14] Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res 1985(198):43–9.
[15] Kennedy JA, Matharu GS, Hamilton TW, Mellon SJ, Murray DW. Age and outcomes of medial meniscal-bearing unicompartmental knee arthroplasty. J Arthroplasty 2018;33(10):3153–9.
[16] Pandit H, Hamilton TW, Jenkins C, Mellon SJ, Dodd CA, Murray DW. The clinical outcome of minimally invasive Phase 3 Oxford unicompartmental knee arthroplasty: a 15-year follow-up of 1000 UKAs. Bone Joint J 2015;97-B(11):1493–500.
[17] Ho DE, Imai K, King G, Stuart EA. MatchIt: nonparametric preprocessing for parametric causal inference. Journal of Statistical Software: R Foundation of Statistical Programming 2011;42(8):1–28.
[18] Parvizi J, Nunley RM, Berend KR, Lombardi AV, Ruh EL, Clohisy JC, et al. High level of residual symptoms in young patients after total knee arthroplasty. Clin Orthop Relat Res 2014;472(1):133–7.
[19] Arden N, Nevitt MC. Osteoarthritis: epidemiology. Best Pract Res Clin Rheumatol 2006;20(1):3–25.
[20] Johnson VL, Hunter DJ. The epidemiology of osteoarthritis. Best Pract Res Clin Rheumatol 2014;28(1):5–15.
[21] Hamilton TW, Pandit HG, Lombardi AV, Adams JB, Oosthuizen CR, Clave A, et al. Radiological decision aid to determine suitability for medial unicompartmental knee arthroplasty: development and preliminary validation. Bone Joint J 2016;98-B(10 Supple B):3–10.
[22] Yoshida K, Tada M, Yoshida H, Takei S, Fukuoka S, Nakamura H. Oxford phase 3 unicompartmental knee arthroplasty in Japan–clinical results in greater than one thousand cases over ten years. J Arthroplasty 2013;28(9):168–71 Suppl.
[23] Lim HC, Bae JH, Song SH, Kim SJ. Oxford phase 3 unicompartmental knee replacement in Korean patients. J Bone Joint Surg Br 2012;94(8):1071–6.
[24] Hamilton TW, Rizkalla JM, Kontochristos L, Marks BE, Mellon SJ, Dodd CAF, et al. The interaction of caseload and usage in determining outcomes of unicompartmental knee arthroplasty: a meta-analysis. J Arthroplasty 2017;32(10):3228–37 e2.
[25] Bottomley N, Jones LD, Rout R, Alvand A, Rombach I, Evans T, et al. A survival analysis of 1084 knees of the Oxford unicompartmental knee arthroplasty: a comparison between consultant and trainee surgeons. Bone Joint J 2016;98-B(10 Supple B):22–7.
[26] Emerson RH, Alnachoukati O, Barrington J, Ennin K. The results of Oxford unicompartmental knee arthroplasty in the United States: a mean ten-year survival analysis. Bone Joint J 2016;98-B(10 Supple B):34–40.
[27] Keys GW, Ul-Abiddin Z, Toh EM. Analysis of first forty Oxford medial unicompartmental knee replacement from a small district hospital in UK. Knee 2004;11(5):375–7.
[28] Lisowski LA, Meijer LI, Bekerom MP, Pilot P, Lisowski AE. Ten- to 15-year results of the Oxford phase III mobile unicompartmental knee arthroplasty: a prospective study from a non-designer group. Bone Joint J 2016;98-B(10 Supple B):41–7.
[29] Hamilton TW, Pandit HG, Jenkins C, Mellon SJ, Dodd CAF, Murray DW. Evidence-based indications for mobile-bearing unicompartmental knee arthroplasty in a consecutive cohort of thousand knees. J Arthroplasty 2017;32(6):1779–85.
[30] Willis-Owen CA, Brust K, Alsop H, Miraldo M, Cobb JP. Unicondylar knee arthroplasty in the UK National Health Service: an analysis of candidacy, outcome and cost efficacy. Knee 2009;16(6):473–8.
[31] Tu Y, Xue H, Ma T, Wen T, Yang T, Zhang H, et al. Superior femoral component alignment can be achieved with Oxford microplasty instrumentation after minimally invasive unicompartmental knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2017;25(3):729–35.
[32] Morris MJ, Frye BM, Ekpo TE, Berend KR. Unicompartmental knee replacement with new Oxford instruments. Operative Techniques in Orthopaedics 2012;22(4):189–95.
[33] Tinius M, Hepp P, Becker R. Combined unicompartmental knee arthroplasty and anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 2012;20(1):81–7.
[34] Campi S, Pandit HG, Dodd CAF, Murray DW. Cementless fixation in medial unicompartmental knee arthroplasty: a systematic review. Knee Surg Sports Traumatol Arthrosc 2017;25(3):736–45.
[35] Lunebourg A, Parratte S, Ollivier M, Abdel MP, Argenson JN. Are revisions of unicompartmental knee arthroplasties more like a primary or revision TKA? J Arthroplasty 2015;30(11):1985–9.
[36] Saldanha K, Keys G, Svard U, White S, Rao C. Revision of Oxford medial unicompartmental knee arthroplasty to total knee arthroplasty—results of a multicentre study. Knee 2007;14(4):275–9.
[37] Leta TH, Lygre SHL, Skredderstuen A, Hallan G, Gjertsen J-E, Rokne B, et al. Outcomes of unicompartmental knee arthroplasty after aseptic revision to total knee arthroplasty: a comparative study of 768 TKAs and 578 UKAs revised to TKAs from the Norwegian Arthroplasty Register (1994 to 2011). JBJS 2016;98(6):431–40.
[38] Liddle AD, Pandit H, Judge A, Murray DW. Patient-reported outcomes after total and unicompartmental knee arthroplasty: a study of 14,076 matched patients from the National Joint Registry for England and Wales. Bone Joint J 2015;97-B(6):793–801.
[39] Burn E, Sanchez-Santos MT, Pandit HG, Hamilton TW, Liddle AD, Murray DW, et al. Ten-year patient-reported outcomes following total and minimally invasive unicompartmental knee arthroplasty: a propensity score-matched cohort analysis. Knee Surg Sports Traumatol Arthrosc 2016;26(5):1455–64.
[40] Berend KR, Berend ME, Dalury DF, Argenson JN, Dodd CA, Scott RD. Consensus statement on indications and contraindications for medial unicompartmental knee arthroplasty. J Surg Orthop Adv 2015;24(4):252–6.
[41] Kennedy JA, Molloy J, Jenkins C, Mellon SJ, Dodd C, Murray DW. Functional outcome and revision rate are independent of leg alignment following medial Oxford UKR. JBJS '[in press]'.
[42] Niinimäki TT, Murray DW, Partanen J, Pajala A, Leppilahti JI. Unicompartmental knee arthroplasties implanted for osteoarthritis with partial loss of joint space have high re-operation rates. Knee 2011;18(6):432–5.
[43] Flecher X, Parratte S, Aubaniac J-M, J-NA Argenson. A 12-28-year followup study of closing wedge high tibial osteotomy. Clin Orthop Relat Res 2006;452:91–6.
[44] Ivarsson I, Myrnerts R, Gillquist J. High tibial osteotomy for medial osteoarthritis of the knee. A 5 to 7 and 11 year follow-up. J Bone Joint Surg 1990;72(2):238–44.
[45] Rossi R, Bonasia DE, Amendola A. The role of high tibial osteotomy in the varus knee. JAAOS-Journal of the American Academy of Orthopaedic Surgeons 2011;19(10):590–9.
[46] No authors listed. United Kingdom Knee Osteotomy Registry, First Annual Report 2018 2018 [Available from: https://secure.amplitude-registry.com/UKKOR/Content/Ukkor_AnnualReport_RGB.pdf.
[47] Krych AJ, Reardon P, Sousa P, Pareek A, Stuart M, Pagnano M. Unicompartmental knee arthroplasty provides higher activity and durability than valgus-producing proximal tibial osteotomy at 5 to 7 years. J Bone Joint Surg Am 2017;99(2):113–22.
[48] Maxwell R, Johnston A, Lees D, Walker C. Knee OUTcome study: a comparison of the patient perceived outcome between high tibial osteotomy, unicompartmental and total knee arthroplasty for medial compartment osteoarthitis in men under age 55. Orthop J Sports Med 2017;5(5_suppl5):2325967117S00165.
[49] Petersen W, Metzlaff S. Open wedge high tibial osteotomy (HTO) versus mobile bearing unicondylar medial joint replacement: five years results. Arch Orthop Trauma Surg 2016;136(7):983–9.
[50] Stukenborg-Colsman C, Wirth CJ, Lazovic D, Wefer A. High tibial osteotomy versus unicompartmental joint replacement in unicompartmental knee joint osteoarthritis: 7-10-year follow-up prospective randomised study. Knee 2001;8(3):187–94.
[51] Weale AE, Newman JH. Unicompartmental arthroplasty and high tibial osteotomy for osteoarthrosis of the knee. A comparative study with a 12- to 17-year follow-up period. Clin Orthop Relat Res 1994(302):134–7.