Title: Age and outcomes of medial meniscal-bearing unicompartmental knee replacement

(1) Abstract:

Background: National joint registries report increasing revision rates with decreasing patient age for all types of joint replacement. This study aimed to explore the effect of age on function and revision risk in patients undergoing medial meniscal-bearing UKR.

Methods: A prospectively followed cohort of 1000 consecutive medial meniscal-bearing UKR at a designer centre was analysed. All knees were implanted for recommended indications and had mean 10-year follow-up. Patients were grouped by age at surgery (<55, 55 to <65, 65 to <75, 75+). Oxford Knee Scores (OKS) were assessed at five and ten years. Component-time revision incidence rates and Kaplan-Meier implant survival were calculated.

Results: Mean patient age at surgery was 66.6 years (range 33 to 88). All age groups had significant ($p<0.001$) improvement in OKS over time, and at five year achieved a median OKS of 44. At ten years median OKS, from youngest group to eldest, were 44, 45, 42, and 39, with the eldest group having a significantly lower OKS ($p<0.01$). Ten-year implant survival was 97%, 94%, 94%, and 93% respectively, and was not significantly associated with age at UKR.

Conclusion: Medial meniscal-bearing UKR provides good functional outcomes in all age groups, however in older patients (75+) the functional outcome deteriorated at ten years presumably due to deteriorating health. Contrary to registry observations, the revision rate was not higher in younger patients. These results suggest that with correct indications patient age should not be considered a contra-indication to medial meniscal-bearing UKR.

Key words: unicompartmental knee replacement; age; outcomes; revision

Introduction

Unicompartmental and total knee replacement (UKR and TKR) are treatment options for medial compartment osteoarthritis and avascular necrosis of the knee [1]. When used for appropriate indications UKR provides better function [2-5], faster recovery[6, 7] and lower morbidity and mortality[8-10] compared to TKR. However, this is at the expense of a higher revision rate. National joint registries consistently report increasing revision rates with decreasing patient age for both TKR and UKR [1, 11-13]. They also report very high UKR revision rates in the young, being about 20% at ten years in patients under 55 [1, 11, 12]. Due to the high revision rate of UKR in the young, youth has long been considered to be a contraindication to UKR[14].

Previous studies exploring the effect of age on UKR outcomes have been limited by small numbers[15, 16], short-term follow-up[17-19], lack of comparator groups[20-23], or binary analyses[24-28] (i.e. outcomes in those younger or older than 60 years of age). Taken together they suggest that short-term functional outcomes are good in young patients. There are no long-term studies of UKR patients which compare age and patient reported outcome measures (PROMs). Furthermore, the relationship between age and implant survival is variable.

The increased failure rate in younger patients is generally considered to be due to higher levels of activity. This results in more frequent and greater mechanical loads being applied to the prosthesis and the bone-prosthesis interface. Meniscal-bearing UKR has theoretical advantages that may decrease the revision rate in this situation. The fully congruent bearing has low contact stresses so should minimise wear[29, 30], and transmits predominately compressive forces to the bone-implant interfaces so should minimise loosening[31]. It is therefore possible that

meniscal-bearing UKR, if used for appropriate indications, may not have a marked increase in revision rates in young patients.

This study assessed the effect of patient age on functional outcomes and revision rates following medial meniscal-bearing UKR in a large non-registry cohort. The cohort was selected for UKR using the recommended indications with age not considered to be a contraindication.

Materials and Methods

We performed a prognostic cohort study using a prospectively followed consecutive cohort of cemented medial meniscal-bearing UKR to assess the influence of age on PROMs and implant survival.

Between June 1998 and March 2009, 1000 consecutive cemented medial meniscal-bearing (Oxford) Phase 3 UKR (Zimmer-Biomet, Bridgend, United Kingdom) were implanted through a minimally invasive approach in 818 patients by two designer surgeons (*withheld while under review*) for the recommended indications as described by Goodfellow et al[32]. The pathological diagnosis was anteromedial osteoarthritis (AMOA) in 977 knees and spontaneous osteonecrosis of the knee in 23. Patients were followed up for a mean of 10 years (range 5 to 17). Details of this cohort have been reported in detail[33-35]; the present study was designed to specifically explore the effect of age on outcomes.

Patients were followed up by research physiotherapists independent of surgical and clinical teams. Functional outcomes were assessed using the Oxford Knee Score (OKS; 0 to 48 with 48 the best outcome)[36], and the Tegner Activity Score (0 to 10 with 10 being participation

as an elite athlete)[37]. Patients were assessed pre-operatively and at one, five, ten, and 15 years post-operatively. Data were extracted from our prospectively maintained database on 1 September 2014. All patients had been contacted in the previous 18 months prior to data extraction to ascertain the current functional status of their knee and to identify any re-operations/revisions. If a patient had died, information about their knee status and any further operation was obtained from primary and secondary care records, and from the patient's relatives where appropriate. At the time of follow up, 118 patients (141 knees; 14%) had died without requiring a revision.

Statistical methods:

Variables: Age and weight at surgery were normally distributed. Pre-operative OKS was normally distributed, whilst post-operative scores were left skewed. Tegner activity score was normally distributed pre- and post-operatively.

Exposure: Age was grouped into four *a priori* to allow direct comparison with the reporting styles of the National Joint Registry of England, Wales, Northern Ireland and the Isle of Man (NJR) [1], and the Australian [12] and New Zealand [11] joint registries. These groups were patients younger than 55 years, 55 to <65, 65 to <75, and 75 years or older (75+) at surgery.

Functional outcomes: We present mean (standard deviation) and median (interquartile range). Differences between groups were tested with Kruskal-Wallis tests, whilst differences over time within a group were assessed with Wilcoxon's signed rank tests. The percentage of knees at each time point achieving an OKS of 34 or greater (considered a good or excellent outcome) was calculated. Differences in Tegner activity score between age groups were assessed with ANOVA with bonferroni correction, while differences over time were assessed with a paired t-test.

Implant revision risk: We defined implant failure as revision surgery. Revision was defined, as per the NJR, as component removal, exchange or addition. It therefore included insertion of a new bearing, addition of a lateral UKR or conversion to a total knee replacement (TKR). Ten year Kaplan-Meier survival estimates are reported, and component-time incidence rates for overall and individual failure modes were calculated. Significance was tested with a log-rank test. Association between age group and type of revision components used was tested with ordered logistic regression, and the lowest p value for each comparison is reported.

Missing values: Age at surgery was present for all knees, however, four knees (three patients) could not be traced for follow-up so their final revision status remains unknown. Missing values were present for OKS and Tegner Activity Score, and were excluded for individual analyses, but not from the dataset as a whole. When explored with logistic regression there was no association between missing values and age.

Statistical analyses were performed in Stata Version 14 (STATA corp, Texas, USA) and R (R Core Team 2016, Vienna, Austria). Statistical significance was defined as a p value of <0.05.

Results:

Baseline characteristics: The mean age at surgery was 66.6 years (SD 9.6, range 33 to 88). Preoperatively, older patients were significantly lighter than younger patients (table 1). There was no significant difference in the distribution of sex or preoperative OKS between groups.

Post-operative PROMS: There was significant improvement in post-operative OKS from pre-operative OKS at one, five and ten years for all age groups ($p < 0.001$). There were no significant

differences between groups at one or five year follow-up (table 2). At five years in all groups the median OKS was 44. At ten years there was a significant difference between scores ($p<0.01$) with the median OKS of those 75+ at surgery dropping to 38.5, and the others not changing significantly.

The Tegner score improved in all age groups with surgery ($p<0.02$; table 2). Younger patients had higher activity levels at each time point. There was varied response over time amongst age groups: those less than 55 showed continued improvement at one and five years post surgery ($p<0.05$), 55-65 year olds plateaued from their one-year scores ($p>0.05$), and those 65+ declined from their one-year score ($p<0.05$).

Implant revision risk: There were 52 revisions. Those under 55 years had the lowest revision risk, compared with the other three age groups, though this was not significant ($p=0.6$). The cumulative ten year UKR survival rate for those younger than 55 was 97.2% (95% CI 92 to 99, at risk=46), between 55 and <65 was 93.7% (CI 90 to 96, at risk=137), between 65 and <75 was 94.3% (CI 91 to 97, at risk=159), and for those 75+ was 93.0% (CI 86 to 96, at risk=54). The revision rate per 100 component years was also lowest in those under the age of 55 although, again, the difference was not statically significant (Table 3, $p=0.74$). There were no statistical differences between age groups for any specific revision indication.

Most revisions (62%) were managed with conversion to primary TKR (Table 4). Two (4%) required revision TKR components, two (4%) had UKR components exchanged, and the remainder had lateral UKR (19%) added for disease progression or bearing dislocations with insertion of a new bearing (12%). There was no association between age group at surgery and revision with TKR ($p>0.68$), lateral UKR ($p>0.26$), or bearing exchange ($p>0.47$).

Discussion

The most important finding of this paper is that the revision rate of medial meniscal-bearing UKR did not increase with decreasing age. This observation was contrary to registry data [1, 11-13]. It is generally accepted that the revision rate of all joint replacements increases with decreasing age. This difference may relate to the implant or to the indications for which it is used. In all age groups there were very good functional outcomes and these were maintained in the long term except in elderly patients (75+) who had some deterioration at ten years. Younger patients also had higher activity levels at each time point.

It is widely perceived that younger patients will have higher revision rates due to high activity leading to mechanical failure of the implant or its fixation. In this study, as expected, we found that younger patients are more active than older patients, with significantly higher Tegner scores. We and others have previously observed that increasing activity is not associated with an increasing revision rate with the meniscal-bearing UKR, but is actually associated with a decreasing revision rate[20, 23, 38]. The meniscal-bearing has fully congruent contact and thus low contact stresses[29], so failure due to wear is theoretically very low[39]. As the bearing is mobile the loads transmitted to the bone implant interfaces are predominantly compressive so there is a very low theoretical risk of aseptic loosening[31]. In contrast, with TKR and with fixed bearing UKR, after there is some wear, shear may be transmitted to the interfaces, which increase the risk of wear and loosening[40, 41]. Furthermore, the instrumentation aims to accurately restore ligament tension and function[31], thereby restoring normal knee kinematics[42, 43]. These features should minimise the risk of failure in active patients, but would not make the revision rate progressively decrease with increasing activity. Our youngest patients had the highest activity scores, and yet the lowest risk of revision due to disease

progression. Although this may seem counterintuitive, it suggests that more active and younger patients have better quality cartilage and bone and are therefore less likely to fail from lateral osteoarthritis or aseptic loosening, which represent the two main modes of UKR failure.

National joint registries all demonstrate increased risk of revision in younger patients after both UKR and TKR (figure 1). In the NJR [1] the revision rate for mobile-bearing UKR is 2.9 (95% CI 2.1 to 4.2) times higher in those <55 years of age compared with those 75+. As the majority of mobile-bearing UKR in the NJR are meniscal-bearing UKR, it is likely that the revision rate for the meniscal-bearing UKR is about three times higher in those <55 compared with those 75+. In contrast, in our series the revision rate for the meniscal-bearing UKR was similar in those <55 compared with those 75+. As these results were achieved by the same implant the differences are likely related to the indications.

The indications for meniscal-bearing UKR are based on disease patho-anatomy. We do not exclude patients on the basis of age, weight, or activity[26, 34]. The primary indication is AMOA. There should be bone-on-bone arthritis medially, full-thickness cartilage laterally and functionally intact anterior cruciate and medial collateral ligaments. These are best identified radiographically[44]. If bone-on-bone is not identified medially on radiograph then arthroscopic assessment prior to surgery can be useful[44]. The indications are satisfied in up to half of patients needing knee replacements[3, 44]. In the NJR, a substantial proportion of surgeons use UKR for a small proportion of knee replacements, it is used in younger patients and has a high revision rate [45]. This suggests that these surgeons are using UKR for patients with early disease, possibly with partial-thickness cartilage loss, in patients on whom the surgeon is reluctant to perform TKR. Indeed there is a widespread view that UKR should be used predominantly in this situation. However patients with partial-thickness cartilage loss do

not do well following UKR, with ongoing pain and higher revision rates[46-48]. If surgeons only implanted UKR in patients with bone-on-bone arthritis the high revision rate of the meniscal-bearing UKR in young patients would probably be avoided.

It is possible that the reason we did not see an increase in revision rate with decreasing age was a type II error due to the small number of revisions. As can be seen from the confidence intervals in figure 1 it is unlikely that this accounts for the differences in trends between our data and registry data. There have also been a few previous studies, like ours, that have looked at the influence of age on revision rate for meniscal-bearing UKR but their conclusions were not consistent[15, 17-19, 24, 26-28] (Table 5). Most of these studies only compared patients over and under 60 years old. Of the five non-designer centre studies, two reported an increased risk of revision in the young, and three did not. This provides support for our data, and confirms that the revision rate of the meniscal-bearing UKR does not necessarily increase with decreasing age.

All age groups had substantial improvement following UKR in terms of pain and function. The OKSs were high (median 44) at five years and there were no differences between age groups. It was only at ten years that a significant difference occurred between the age groups, with the oldest group (75+) starting to deteriorate. This is not surprising as this group is now a minimum of 85 years old, and OKS is known to decline with age[49]. In the other groups the OKS did not show an appreciable decline at 10 years. In all groups the Tegner score improved substantially. The score was higher in younger patients, and these patients continued to improve with time. We are not aware of any other papers that have studied the influence of age on the OKS and/or Tegner score after UKR.

226

227 If the indications for meniscal-bearing UKR are satisfied then, by definition, the ligaments are
228 functionally normal. During the surgical technique ligaments are never released and the
229 instrumentation allows the surgeon to accurately restore normal ligament tension and balance
230 by removing bone[50]. Therefore not only are normal kinematics restored but also leg
231 alignment is restored to what it was before the patient developed arthritis[31]. In keeping with
232 observed knee alignment in the general population[51], this frequently results in varus knee
233 alignment (~25%)[52]. The combination of normal leg alignment and normal kinematics is
234 probably the reason why patients report high functional scores, particularly if they are
235 young[52].

236

237 When considering whether to implant UKR or TKR their relative merits must be compared.
238 Advantages of UKR include faster recovery[6, 7], lower morbidity and mortality[8-10] and
239 better functional outcomes and patient satisfaction[2-5]. The disadvantage is that UKR has a
240 variable, but often higher revision rate, which may be attributed to use in early arthritis, low
241 surgeon experience, and a lower threshold for performing revision[53]. Our study suggests that
242 the relative merits are affected by age. We found all age groups had good OKS. In the elderly,
243 the patient's life expectancy is relatively short and the chance of a revision being required in
244 their lifetime will be low, so there is little advantage of doing a TKR. In contrast, there are
245 major advantages of UKR, particularly the faster recovery, and lower morbidity and mortality.
246 The evidence would therefore suggest use of UKR whenever possible in elderly patients. In
247 the young we have found that the revision rate of meniscal-bearing UKR is surprisingly low.
248 If the recommended indications are adhered to, it is probably similar to or lower than that of
249 primary TKR (Figure 1). Furthermore if a revision is required it is likely to be a simpler

procedure than a revision TKR (Table 4)[54-56]. Therefore in young patients if the indications are satisfied, and in particular if there is bone-on-bone arthritis, UKR is recommended.

The strengths of this study are long term follow-up (mean of 10 years), very low patient loss to follow-up (0.4%) and the large cohort – this is the largest non-registry UKR cohort to analyse the effect of age on outcomes. Limitations include the number of revisions being small which could influence findings regarding revision risk. There is no radiographic or clinical examination, however, our primary outcome is revision, for which these do not contribute. It is also a single centre series from designer surgeons. However, previous reviews of the published 10-year data of the Phase 3 UKR suggest that if surgeons use the recommended indications, and use UKR in greater than 20% of their knee replacement practice they can expect to get similar results[44, 57-59].

In conclusion, we have demonstrated that following medial meniscal-bearing UKR good functional outcomes can be achieved in all age groups. Contrary to registry observations, the revision rate for UKR in this study was not influenced by age and was low in all age groups. Therefore with correct indications patient age should not be considered to be a contraindication to medial meniscal-bearing UKR, and in all age groups UKR has advantages over TKR.

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