

# Comparison of survival and cost-effectiveness between unicondylar arthroplasty and total knee arthroplasty in patients with primary osteoarthritis

A follow-up study of 50,493 knee replacements from the Finnish Arthroplasty Register

Esa Koskinen<sup>1</sup>, Antti Eskelinen<sup>2, 4</sup>, Pekka Paavolainen<sup>1</sup>, Pekka Pulkkinen<sup>3</sup>, and Ville Remes<sup>2</sup>

<sup>1</sup>Orton Orthopedic Hospital, Helsinki, <sup>2</sup>Department of Orthopedics, Surgical Hospital, Helsinki University Central Hospital, <sup>3</sup>Department of Public Health, University of Helsinki, Helsinki, <sup>4</sup>Coxa Hospital for Joint Replacement, Tampere, Finland  
Correspondence: esa.koskinen@utu.fi  
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**Background and purpose** Both unicondylar arthroplasty (UKA) and total knee arthroplasty (TKA) are commonly used for the treatment of unicompartmental osteoarthritis (OA) of the knee. The long-term survivorship and cost-effectiveness of these two treatments have seldom been compared on a nationwide level, however. We therefore compared the survival of UKA with that of TKA and conducted a cost-benefit analysis comparing UKA with TKA in patients with primary OA.

**Patients and methods** We analyzed 1,886 primary UKAs (3 designs) and 48,607 primary TKAs that had been performed for primary OA and entered in the Finnish Arthroplasty Register between 1980 and 2003 inclusive.

**Results** UKAs had a 60% (95% CI: 54–66) survival rate and TKAs an 80% (95% CI: 79–81) survival rate at 15 years with any revision taken as the endpoint. Overall survival of UKAs was worse than that of TKAs ( $p < 0.001$ ). All 3 UKA designs had poorer overall survival than the corresponding TKA designs. In the theoretical cost-benefit analysis, the cost saved by lower implant prices and shorter hospital stay with UKA did not cover the costs of the extra revisions.

**Interpretation** At a nationwide level, UKA had significantly poorer long-term survival than TKA. What is more, UKA did not even have a theoretical cost benefit over TKA in our study. Based on these results, we cannot recommend widespread use of UKA in treatment of unicompartmental OA of the knee. ■

Epidemiological studies of knee osteoarthritis (OA) have shown that there are distinct patterns of disease, which principally affect the medial, lateral, or patellofemoral compartments (McAlindon et al. 1992, Davies et al. 2002, Iorio et al. 2003). It is noteworthy that up to 25% of patients with OA of the knee suffer from isolated medial compartment disease (Ackroyd 2003). However, unicondylar knee arthroplasty (UKA) and total knee arthroplasty (TKA) are both currently used for unicompartmental disease.

Using data from the Swedish national register, Knutson and co-workers (1994) reported that surgeons who favored TKA over UKA for unicompartmental OA of the knee cited the significantly lower revision rates of TKA as the reason for their choice. On the other hand, those who favor UKA have a broader basis for their preference including: less extensive surgical procedure, bone stock preservation, faster recovery, and a lower risk of major complications such as deep infections (Cameron and Jung 1988, Goodfellow et al. 1988, Marmor 1988, Bengtson and Knutson 1991, Bert 1991, Rougraff et al. 1991, Robertsson et al. 1999). Moreover, UKA has been found to give better results than TKA regarding the mechanics of walking, due to the intact cruciate ligaments of the former (Waite et al. 2005).

The purpose of this study was to analyze and

compare the results of UKA in patients with primary OA to the results of a similar patient population treated with TKA. We used the survival data of UKAs and TKAs recorded in the Finnish Arthroplasty Register. In addition, we compared the costs of these two primary procedures—in particular, implant costs and costs ascribed to the hospital stay. In addition, we also calculated the cost difference between UKA and TKA in proportion to costs associated with the number of revisions that would be expected.

### Patients and methods

Our study was based on information recorded in the Finnish Arthroplasty Register (Paavolainen et al. 1991) relating to patients who underwent UKA or TKA from 1980 through 2003. An English translation of the form used for this purpose has been reported (Puolakka et al. 2001). Information on 2,021 UKAs and 60,182 TKAs had been recorded individually for every operation since the inception of the register in 1980. Revisions were linked to the primary operation using the unique personal identification numbers that are assigned to each resident of Finland. Of the 2,021 UKAs entered in the register, 1,886 (93%) were performed for primary OA. The corresponding numbers of primary OA operations for TKA were 48,607 (81%). These two groups were included in this study. Both unilaterally and bilaterally operated patients were included, and they were not analyzed separately.

These operations were performed for 39,736 patients, 10,757 (27%) of whom underwent bilateral knee arthroplasties and 28,979 (73%) unilateral arthroplasties. A total of 10,280 patients underwent bilateral TKAs, 176 bilateral UKAs and 301 bilateral arthroplasties with one knee operated on with a TKA and the other with a UKA, respectively. In the survival as well as in the cost-benefit analyses the unit analyzed was knee. Thus, both knees of bilateral cases were included separately.

#### Survival analysis—UKAs vs. TKAs

The effects of implant concept (TKA vs. UKA) on the survival of the prosthesis were analyzed separately for the whole study period and for 3 time periods (1980–1987, 1988–1995, and 1996–2003).

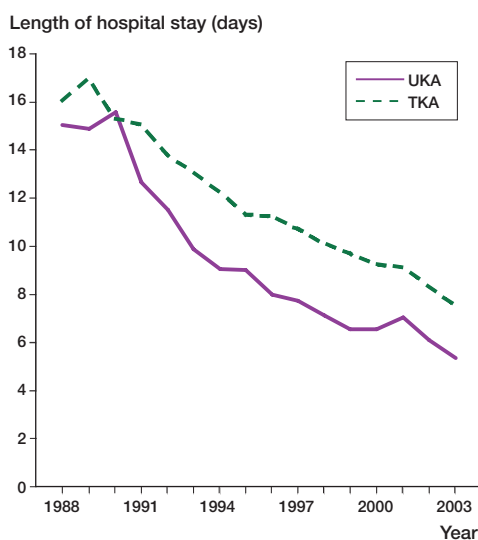


Figure 1. Average length of hospital stay after UKA and TKA in Finland, 1988–2003.

Survival of both implant concepts (TKA and UKA) was also compared between these time cohorts.

In addition, we compared survival of the 3 most commonly used UKAs with that of TKAs from the same manufacturer (Table 1). Due to the lack of equivalent TKAs with meniscal bearing concept, the Oxford meniscal bearing was compared with the AGC TKA (Biomet, Warsaw, IN) with a molded polyethylene plate. Duracon unicondylar was compared with Duracon TKA (Howmedica, Rutherford, NJ) and Miller-Galante II unicondylar was compared with Miller Galante II TKA or NexGen TKA (Zimmer, Warsaw, IN).

#### Cost-benefit analysis

Costs in Finnish hospitals are partly based on the average length of the hospital stay. The cost of 1 postoperative hospital day per patient is constant. We calculated the mean cost of 1 postoperative hospital day in the 3 hospitals in Finland performing total joint replacements (Helsinki and Turku University Central Hospitals and the Orton Orthopedic Hospital, Helsinki). We acquired the price of the 3 most commonly used UKAs and those of the corresponding TKAs from the manufacturers. The implant costs (as of 2003) were calculated as a weighted mean cost of the 3 commonly used designs. The mean length of the hospital stay was obtained from the discharge register of the Finn-

ish National Research and Development Center for Welfare and Health (STAKES) between the years 1988 and 2003 (Figure 1). We used the weighted mean length of the hospital stay in cost-benefit calculations. It was not possible to obtain data on the length of hospital stay during 1980–1987. Differences in survival between the UKA and TKA groups, i.e. the observed difference in survival rates at 10 years obtained from both the Kaplan-Meier survival analysis (unadjusted difference) and the Cox regression analysis (adjusted for age and sex), were used in the cost-benefit analysis. Based on experience from daily clinical practice, we estimated that most of the differences in costs between UKA and TKA would result from differences in implant costs, length of hospital stay, and incidence of revision surgery. All the calculations were made with prices adjusted to 2003 prices.

### Statistics

Sex distribution in the TKA and UKA groups was compared by the Chi-square test. Student's t-test was used for comparisons between 2 normally distributed groups. The endpoint for survival was defined as revision for any reason. Kaplan-Meier survival data were used to construct the survival probabilities of the implant concepts (UKA vs. TKA) and implant designs at 7, 10, and 15 years, whenever possible. Survival data obtained in the Kaplan-Meier analysis were compared by the log-rank test. The Cox multiple-regression model was applied to analyze differences between groups and to adjust for potential confounding factors. Survival of the implant concepts (UKA vs. TKA) was analyzed by the Cox model, in which an adjustment was made for age and gender. For further analysis, the Cox regression model provided estimates of survival probabilities and revision risk ratios (RR) for different factors. Estimates from the Cox analyses were used to construct adjusted survival curves at mean values of the risk factors. The Wald test was used to calculate p-values for data obtained from the Cox multiple regression analysis. Differences between groups were considered statistically significant if the p-values were less than 0.05 in a two-tailed test. We used SPSS 14.0 statistical software.

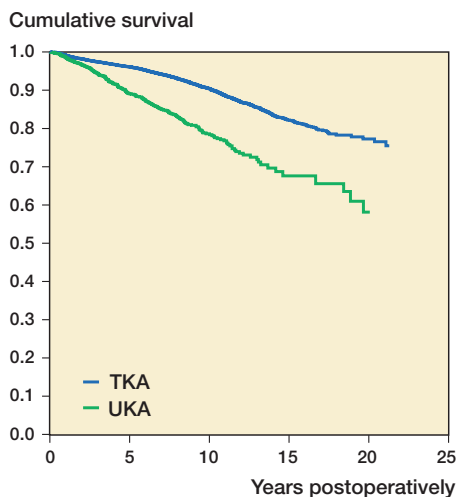


Figure 2. Cox-adjusted survival curves for 48,607 TKAs and 1,886 UKAs. The endpoint was defined as revision for any reason. Adjustment was made for age and sex.

## Results

### Primary operation

**Patient characteristics.** Of the 1,886 UKAs, 69% were performed for females; and of the 48,607 TKAs, 75% were performed for females ( $p < 0.001$ ). Mean age of the patients with UKA was 65 (38–91) years and mean age of the patients with TKA was 70 (31–98) years ( $p < 0.001$ ).

**Follow-up results for all primary operations.** Analysis of the whole study period showed that TKAs had a 90% (95% CI: 89–90) survival rate at 10 years and an 80% (95% CI: 79–81) survival rate at 15 years. The corresponding figures for UKAs were 73% (95% CI: 70–76) at 10 years and 60% (95% CI: 54–66) at 15 years. Kaplan-Meier analysis showed that the overall survival of TKAs was higher than that of UKAs ( $p < 0.001$ ). In the Cox regression analysis, we found that UKAs had a risk of revision that was 2.2-fold (95% CI: 2.0–2.5) higher than for TKAs (Figure 2).

### Time cohort analysis

There were no significant differences in overall survival rates between TKAs and UKAs implanted during the first period (1980–1987), either by Kaplan-Meier analysis ( $p = 0.2$ ) or by Cox regression analysis ( $p = 0.5$ ) (Table 1). However, Kaplan-Meier analysis of both the second period (1988–1995) and the third period (1996–2003) showed a

**Table 1.** Survival of UKAs and TKAs implanted during three time periods. Endpoint defined as any revision. 7-, 10-, and 15-year survival rates were obtained from the Kaplan-Meier analysis

A	B	C	D	E	F	G	H	I	J	K	L
1980–	UKA	95	12	74	91 (85–97)	61	83 (75–91)	40	73 (63–84)	1.2 (0.8–1.8)	0.5
1987	TKA	1,995	11	1,525	92 (91–93)	1,208	87 (85–88)	700	78 (76–81)	1.0	
1988–	UKA	540	8.4	398	81 (77–84)	244	72 (68–77)	15	–	2.1 (1.8–2.5)	< 0.001
1995	TKA	12,480	8.7	9,810	92 (92–93)	5,539	89 (88–89)	381	78 (76–80)	1.0	
1996–	UKA	1251	2.1	23	82 (77–87)	0	–	0	–	3.0 (2.4–3.8)	< 0.001
2003	TKA	34,132	3.3	1,201	95 (95–96)	0	–	0	–	1.0	

A Time cohort	H Percent 10-year survival (95% CI)
B Implant concept	I At risk at 15 years
C Number of operations (knees)	J % 15-year survival (95% CI)
D Mean follow-up (years)	K Adjusted risk ratio from the Cox regression analysis (UKAs compared to TKAs; adjustment made for age and sex) for revision (95% CI)
E At risk at 7 years	L P-value
F Percent 7-year survival (95% CI)	
G At risk at 10 years	

**Table 2.** Survival of the three implant pairs. The endpoint was defined as any revision. 7-, 10-, and 15-year survival rates were obtained from the Kaplan-Meier analysis

B	C	D	E	F	G	H	I	J	K	L
Miller-Galante II UKA	330	7.1	188	86 (82–90)	82	79 (73–84)	0	–	2.7 (1.9–3.8)	< 0.001
Miller-Galante II / Nexgen TKA	4,427	3.9	1,035	96 (95–96)	379	93 (91–95)	0	–	1.0	
Duracon UKA	140	6.5	73	81 (75–88)	24	79 (70–87)	0	–	4.3 (2.9–6.3)	< 0.001
Duracon TKA	15,823	4.1	1,326	96 (95–96)	854	94 (93–95)	0	–	1.0	
Oxford meniscal bearing	1,113	2.0	62	90 (86–95)	45	80 (72–89)	0	–	1.9 (1.4–2.5)	< 0.001
AGC V2	10,721	4.7	2,908	95 (94–95)	976	91 (90–93)	66	86 (83–89)	1.0	

For Legends see Table 1

significant difference in overall survival in favor of TKAs ( $p < 0.001$ ) (Table 1). Even during the last time period (1996–2003), the 7-year survival rate of UKAs declined to below 85% (Table 1). Similar results were obtained in the Cox regression analysis, with adjustment for age and sex.

#### Cohort effect in the case of UKAs

In the Cox regression analysis, UKAs implanted during 1988–1995 had a 1.9-fold (95% CI 1.1–3.0) increased risk of revision and UKAs implanted during 1996–2003 a 2.3-fold (95% CI 1.1–4.8) increased risk of revision as compared to UKAs implanted during 1980–1987. There was no significant difference ( $p = 0.5$ ) in revision risk between the cohorts of 1988–1995 and 1996–2003.

#### Cohort effect in the case of TKAs

In the Cox regression analysis, there was no significant difference in revision risk between TKAs implanted during the first period (1980–1987) and TKAs implanted during the second period (1988–1995) ( $p = 1$ ). TKAs implanted during the last period (1996–2003) did, however, show a reduced risk of revision as compared to TKAs implanted during the first period (RR = 0.6, 95% CI: 0.5–0.7) and to TKAs implanted during the second period (RR = 0.6, 95% CI: 0.6–0.7).

#### Survival of TKAs vs. UKAs—design analysis

In the Kaplan-Meier analysis, the overall survival of all 3 TKA designs was better than that of corresponding UKA designs from the same manufacturers ( $p < 0.001$  for all comparisons). The Cox

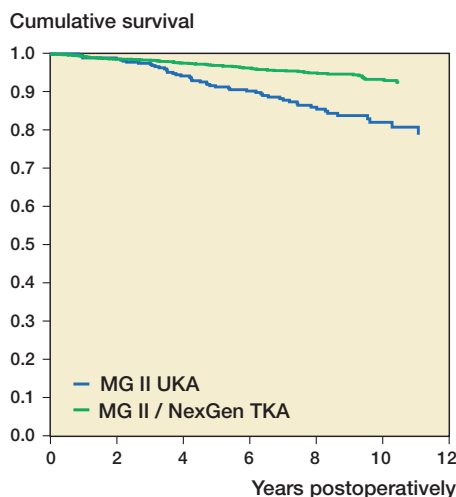


Figure 3. Survival curves for Miller-Galante II / Nexgen TKAs and Miller-Galante II UKAs from the Cox regression model (adjusted for age and sex). The endpoint was defined as revision for any reason.

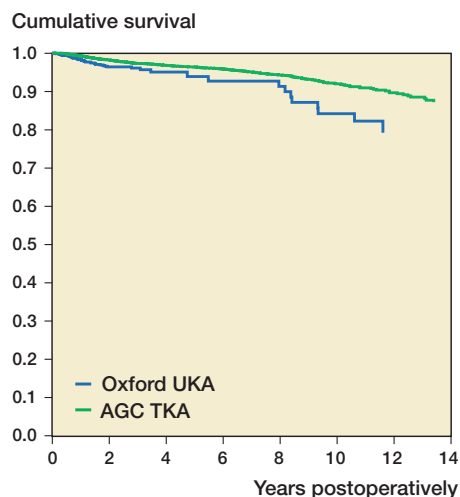


Figure 5. Survival curves for AGC V2 TKAs and Oxford meniscal bearing UKAs from the Cox regression model (adjusted for age and sex). The endpoint was defined as revision for any reason.

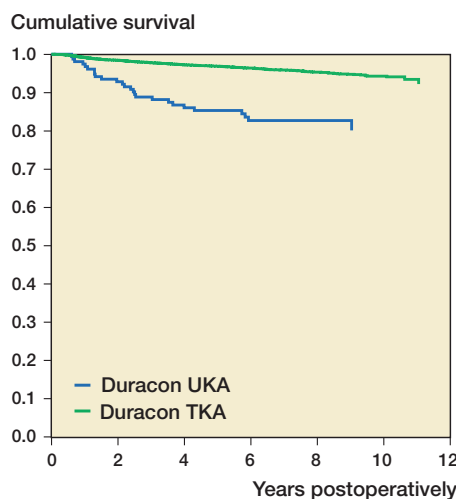


Figure 4. Survival curves for Duracon TKAs and Duracon UKAs from the Cox regression model (adjusted for age and sex). The endpoint was defined as revision for any reason.

regression analysis, with adjustment for age and sex, gave similar results. At 10 years, the survival rates of all three UKA designs declined by < 85%, whereas all three TKA designs still had survival rates of > 90% (Table 2 and Figures 3–5).

#### Cost-benefit analysis

For the UKA and TKA groups, the mean length of hospital stay decreased over the period 1988–2003

(Figure 1). The weighted mean length of hospital stay was 1.9 days shorter (8.5 days) for UKA-operated patients than for TKA patients (10.4 days) from 1988 through 2003.

At the time of the study, prices (excluding tax) of the 3 most commonly used UKAs in Finland were 1,321 euros for the Oxford meniscal bearing (Biomet), 1,323 euros for Duracon unicondylar (Howmedica), and 1,370 euros for Miller Galante II unicondylar (Zimmer). Similarly, the prices of the three most commonly used TKAs (without the patellar component) were 1,818 euros for Duracon (Howmedica), 1,548 euros for AGC (Biomet), and 1,850 euros for PFC Sigma (DePuy). The weighted mean costs for the 3 most widely used UKAs and TKAs were 1,327 and 1,629 euros, respectively.

The mean cost of 1 hospital day in 2003 was 313 euros; so, theoretically the mean cost of the hospital stay was 602 euros less for UKA-operated patients than for TKA patients. If all 1,886 patients with UKAs implanted between 1980 and 2003 had had a TKA implant instead, this cost, at 2003 prices, would have been 1,705,000 euros more. On the other hand, if TKA had been performed instead of UKA, this would have saved 320 revision operations using the unadjusted survival difference from the Kaplan-Meier model, or 223 revisions when using the age- and sex-adjusted

data from the Cox regression model. This means that by initially performing a UKA, the cost saved would leave 5,328 euros (unadjusted) or 7,633 euros (age- and sex-adjusted) for payment for each of the extra revisions, in a retrospective calculation with average costs of implants and hospital stay using 2003 as the reference year. The mean cost of one revision from UKA to TKA (i.e. using primary components for TKA) was 8,660 euros including implant, hospital stay, operation, and other direct costs at 2003 prices. Thus, the costs saved by lower implant prices and shorter hospital stay for UKA as compared to TKA would not cover the costs of the extra revisions.

When comparing cost benefits of the currently most commonly used UKA implant in Finland (Oxford meniscal bearing) against TKA (AGC), and again performing the above calculations, one would have 7,212 euros (879,871 euros for 122 revisions) towards payment of each of the extra revisions. The corresponding sum for the other UKA available in Finland (Miller – Galante II unicondylar) would be 7,078 euros (325,584 euros for 46 revisions) for payment of each of the extra revisions. Again, the costs saved by performing UKAs would not cover the costs of extra revisions.

## Discussion

In this nationwide register-based study, we found that UKA had significantly poorer survival than TKA for patients with primary OA of the knee in Finland during the period 1980–2003. In addition, the survival rates of UKAs showed no improvement during the 24-year follow-up period, while survival rates of TKAs substantially increased during the same period of time. In contrast, survival of the UKAs actually decreased after 1988. In addition to the marked difference in survival rates, UKA did not have even a theoretical cost benefit over TKA despite the lower costs of implants and shorter hospital stay.

We acknowledge that our current register-based study has certain limitations. We were not, for example, able to report any subjective outcome measurements, e.g. Knee Society scores or disease-specific quality of life measurements. In addition to these limitations with the outcome

measures, access to care might introduce bias into the results of such register-based studies. However, healthcare in all Nordic countries is available to everyone, and patients who have undergone TKA are therefore likely to be evenly distributed throughout the socioeconomic strata (Hermanson et al. 1994). In the cost-benefit analysis, we only included direct hospital-related gross costs using 2003 as the reference year. We admit that there are also indirect patient-related costs such as the need for pain medication at home, sick-leave, physiotherapy etc. What is more, all the hospitals used a specific price for each day in hospital. In practice, the last days the patient stays in hospital are probably cheaper than the first postoperative days, as patients need less help and medication and they are more independent. As far as prices of revisions are concerned, it must be kept in mind that every new procedure also predisposes the patient to complications. Moreover, a new procedure has its own learning curve—which may have influenced the results of the first years and generations of UKA. Register-based studies do, however, provide valuable insights into the use of the UKA and TKA procedures in a certain patient group, as the number of operations is greater than in studies from single centers; also, a register-based study reflects the true performance of a surgical procedure on a nationwide basis.

We did not take into account the effect of bilaterality in survivorship or in cost-benefit analyses. This fact may have had an effect in our cost-benefit analysis, as one-stage bilateral TKAs for instance, will most probably have a longer hospital stay than the unilaterally operated patients. On the other hand, one-stage bilaterally operated patients may need less sick vacancy than patients who undergo two-stage bilateral arthroplasties. We decided to analyze the results of operations, i.e. knees, not the results of patients. In our opinion, this is an essential choice in survivorship analyses of registry-based studies. Analyzing patients instead of operations would be a potential source of bias: for example, if one knee of a bilaterally operated patient is revised at a certain time point, the other knee would be censored from analyses at the same time point. Thus, the true survivorship of the other knee would not be any longer taken into account in survival analysis. When both knees of a single

patient are analyzed separately, survivorship of both knees is reliably included in analyses.

Although the long-term reviews of TKA have shown very satisfactory results, a small number of patients will suffer from major complications in the short-term and medium-term follow-up (Bengtsson and Knutson 1991, Robertsson et al. 2001). Patients operated on with TKA have a higher risk of severe complications than UKA patients (Knutson et al. 1994, Callahan et al. 1995). These include deep infections, and also other major complications ending in fusion or a definitive removal of the implant. Some patients with a TKA suffer from unexplained pain with unsatisfactory functional results. Together, these amount to 10–20% of the total number of TKAs (Ritter et al. 1989, Ansari et al. 1998, Murray et al. 1998, Ackroyd 2003). Gait analyses have shown that gait is less affected when both cruciate ligaments are preserved, as is the case with UKA (Georgoulis et al. 2006). What is more, in a randomized prospective clinical study comparing UKA with TKA, Newman and co-workers (1998) showed that the number of patients able to flex  $\geq 120^\circ$  was higher in the UKA group.

Similarly to previous reports (Rougraff et al. 1991, Robertsson et al. 1999, Price et al. 2001), the patients operated on with UKA in our study had a shorter mean length of hospital stay than those operated on with TKA. A shorter recovery time for UKA is probably attained by less soft tissue and quadriceps damage and by intraarticular femoral condyle preparation.

In a study from the Swedish knee arthroplasty register, Knutson et al. (1994) found that the overall cumulative revision rates were higher for UKAs than for TKAs. This finding was confirmed in our study from the Finnish Arthroplasty Register. It is clear that nationwide results of UKA differ from those reported by surgeons designing UKAs, or with results from specialized centers (Price 2005). It is also notable that the survival rates of UKAs did not improve during the 24-year follow-up period in our study. On the contrary, UKAs implanted before 1988 had higher survival than UKAs implanted after that year. This was evident even though more modern UKA designs came on market in the late 1990s. This is in accordance with the findings reported by Knutson and co-workers (1994) from the Swedish Arthroplasty Register: survival

rates for some recently introduced UKA concepts (Oxford, Bringham) were inferior to those of older designs. At the same, however, survival of TKAs improved in Finland. It is clear that in widespread use, UKA has a poorer survival than TKA.

Why has the survival rate of UKA not improved in Finland after 1988, and why has it actually decreased from the start of the follow-up? The reason for this somewhat surprising phenomenon is unclear. One can assume that the widespread use of UKA has not done any good to the long-term results: before 1986 only 7 hospitals performed UKAs in Finland, while 36 hospitals were performing UKAs in 2003—and 23 of them did less than 10 operations that year (Koskinen et al. 2007). Based on the Swedish Arthroplasty Register, Robertsson and colleagues (2001) showed that the long-term results of UKA are related to the number of UKAs performed by a hospital. In particular, the technically demanding Oxford implant was most affected by volume in that hospital. It is reasonable to assume that the 400 UKAs implanted annually and decentralized over 30 different hospitals in Finland do not lead to any good long-term results.

Robertsson and co-workers (1999) published a cost-benefit analysis comparing UKA and TKA, based on data recorded in the Swedish Knee Arthroplasty Register. In that study, patients operated on with UKA had a recovery time that was 2.0 days shorter than for the patients in the TKA group, which is in accordance with our results. The 10- and 15-year cumulative revision rates were 12% and 17% for TKA, and 15% and 19% for UKA, with a 1.2-fold increased revision risk ratio for UKA. Thus, the difference in revision risk did not increase after 10 years of follow-up. Regarding cost-effectiveness, the authors concluded that by initially implanting UKA the cost saved left 32,722 US dollars for payment of each of the extra revisions.

In our study, UKA did not even show a theoretical cost-benefit over TKA. The savings due to lower implant costs and shorter hospital stay with UKA were not sufficient to cover the costs of numerous extra revisions. On the other hand, revision of UKA is probably cheaper than revision of TKA due to lower implant costs. In Finland, however, hospitals commonly use DRG prices (diagnosis-related group). This does not differentiate between

revision for UKA or TKA. Thus, we are unable to provide different prices for UKA and TKA revision. In addition, it is possible that need of pain medication and rehabilitation is less after UKA, and that survival after revision of UKA is better than survival after revision of TKA. All these factors would even out the observed difference.

In summary, we found that UKA has a substantially poorer survival than TKA at the nationwide level. Whether or not the outcome could be improved by better patient selection and centralization of UKAs in tertiary centers remains unknown. In addition to poorer survival rates, UKA did not have even a theoretical cost benefit over TKA. Due to the better function achieved with UKA, it may be a viable alternative in the treatment of medial unicompartmental OA of the knee in young adults if patient selection is successful and the procedure is performed in centers with high UKA volume. Based on our results, however, we cannot recommend widespread use of UKA in the treatment of unicompartmental OA of the knee.

#### Contributions of authors

EK, PPa, VR: study design and preparation of the manuscript. AE: study design, data analysis, and preparation of the manuscript. PPU: data analysis and preparation of the manuscript; statistical supervisor for the Finnish Arthroplasty Register.

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No competing interests declared

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