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Failure Mechanisms After Unicompartmental and Tricompartmental Primary Knee Replacement with Cement

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Background: Concern exists regarding the durability of unicompartmental knee replacements. The purpose of the present study was to compare the early failure rates and failure mechanisms of primary cemented unicompartmental knee replacements with those of primary cemented tricompartmental total knee replacements.

Methods: The rates of failure of primary cemented unicompartmental knee replacements (n = 2288) and tricompartmental total knee replacements (n = 3032) as reported to the Norwegian Arthroplasty Register from January 1994 through December 2004 were compared with use of Kaplan-Meier estimated survival rates and Cox multiple regression.

Results: The ten-year survival probability was 80.1% (95% confidence interval, 76.0% to 84.2%) for unicompartmental knee replacements, compared with 92.0% (95% confidence interval, 90.4 to 93.6%) for total knee replacements, with a relative risk of revision of 2.0 (95% confidence interval, 1.6 to 2.5) ($p < 0.001$). This increased risk of revision following unicompartmental knee replacement was seen in all age-categories. Unicompartmental knee replacement was associated with an increased risk of revision due to pain (relative risk, 11.3 [95% confidence interval, 4.8 to 26.8]; $p < 0.001$), aseptic loosening of the tibial component (relative risk, 1.9 [95% confidence interval, 1.2 to 3.0]; $p = 0.01$) and of the femoral component (relative risk, 4.8 [95% confidence interval, 2.3 to 10.3]; $p < 0.001$), and periprosthetic fracture (relative risk, 3.2 [95% confidence interval, 1.2 to 8.9]; $p = 0.02$) as compared with total knee replacement. Unicompartmental knee replacement was associated with a lower risk of infection compared with total knee replacement (relative risk, 0.28 [95% confidence interval, 0.10 to 0.74]; $p = 0.01$) .

Conclusions: The survival of cemented unicompartmental knee replacements is inferior to that of cemented tricompartmental total knee replacements in all age-categories.

Level of Evidence: Therapeutic Level II. See Instructions to Authors for a complete description of levels of evidence.

The Norwegian Orthopaedic Association started a national register for total hip replacement in 1987[1]. In January 1994, the register was expanded to include all artificial joint replacements, including those of the knee[2,3]. One of the aims of the register is to detect inferior implants, cements, and techniques as early as possible.

Unicompartmental knee replacements were popular in the 1970s and 1980s in Europe, but, because of problems with fixation and the high number of failures, the use of these implants was reduced in the 1990s[4]. In the late 1990s, good ten-year results of unicompartmental knee replacement were reported from single centers in both the United States and Britain[5,6]. These results, together with new instrumentation for minimally invasive surgery, have renewed interest in this procedure, but there have been numerous reports of concern about the durability of this type of prosthesis[7-10].

The aim of the present study was to compare early failure rates and failure mechanisms of primary cemented unicompartmental knee replacements with those of primary cemented tricompartmental total knee replacements with use

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TABLE I Patient Characteristics for Primary Cemented Unicompartmental and Tricompartmental Total Knee Prostheses as Reported to the Norwegian Arthroplasty Register from 1994 to 2004

Type of Prosthesis	Number of Prostheses	Age† *(yr)*	Proportion of Procedures Performed in Patients ≤60 Years Old	Proportion of Procedures Performed in Men
Tricompartmental total knee replacement*	3032	70 (17 to 92)	15%	26%
Unicompartmental knee replacement	2288	66 (25 to 91)	29%	38%

*Tricompartmental total knee replacements are total knee replacements performed with insertion of a patellar component (patellar resurfacing). †The values are given as the mean, with the range in parentheses.

of the nationwide prospective observational knee implant register of all Norwegian hospitals.

Materials and Methods

After each operation, a standard form is filled out by the surgeon and is sent to the register[11]. The reporting is similar to that for hip replacement[1]. Stickers with catalogue numbers are delivered by the manufacturers along with the implants and are attached to the form by the operating surgeon. Femoral, tibial baseplate, tibial polyethylene insert, and patellar components are registered separately.

Information on revisions, defined as a surgical removal or exchange of a part of the implant, or of the whole implant, was linked to data on the primary operation with use of the unique identification number assigned to each inhabitant of Norway.

The types of primary cemented unicompartmental knee replacements used in Norway were the MOD III (Smith and Nephew, Memphis, Tennessee), Genesis Uni (Smith and Nephew), Oxford II and III (Biomet, Bridgend, South Wales, United Kingdom), Duracon all-polyethylene tibial Uni (Stryker, Berkshire, United Kingdom), Miller-Galante all-polyethylene tibial Uni (Zimmer, Warsaw, Indiana), and Preservation (DePuy, Leeds, United Kingdom) prostheses as well as other prostheses. There were no uncemented unicompartmental knee replacements. The size of the Preservation knee group and the "other" group were too small for separate analyses.

The survival of cemented unicompartmental knee replacements and cemented patellar resurfaced total knee replacements, inserted in the period from January 1, 1994, to December 31, 2004, was compared at five, seven, and ten years of follow-up. For primary unicompartmental knee replacements, we compared the time until revision for each brand of prosthesis used. The five-year survival rates for the different total knee replacement brands used in Norway were reported in an earlier study[11]. The different causes of failure leading to revision were compared for cemented unicompartmental knee replacements and cemented total knee replacements. The surgeon could report one or more causes of failure leading to revision. Possible causes were aseptic loosening of the femoral, tibial, or patellar component; dislocation or instability; malalignment; deep infection; periprosthetic fracture; pain; wear of a tibial insert; or other causes. To be classified as having a revision because of pain alone, no other reason for revision could be marked. When seen in combination with any other cause, infection was considered as the primary reason for revision.

The reports from the Norwegian Arthroplasty Register were compared with the compulsory national hospital administrative database, the Norwegian Patient Register. An estimated 99% of the primary and 97% of the revision knee prostheses were reported to the Norwegian Arthroplasty Register as compared with the Norwegian Patient Register during the years 1999 through 2002[12].

Statistical Analysis

Prosthesis survival was calculated with use of the Kaplan-Meier method. Because of the low number of prostheses at risk after eleven years of follow-up, survival results were estimated at ten years, and for two of the prostheses with the shortest follow-up (the Oxford III and the Miller-Galante prostheses), the results were estimated at five years. The median duration of follow-up was calculated with use of the reverse Kaplan-Meier method[13]. The survival curves were stopped when the number of knees at risk was lower than twenty. Patients who died or emigrated during the follow-up period were identified from files provided by Statistics Norway, and the follow-up time for prostheses in these patients was censored at the date of death or emigration. A Cox multiple regression model was used to study the relative risks of revision among unicompartmental knee replacement prosthesis brands, to study differences between unicompartmental knee replacements and total knee replacements, and to adjust for potential confounding by age (sixty years old or less, sixty-one to sixty-nine years old, and seventy years old or more), gender, and diagnosis (primary gonarthrosis, rheumatoid arthritis, sequela after fracture, sequela after ligamentous instability, sequela after meniscal injury, and others). The confounding effect of age was further investigated as a continuous variable within age-categories. The average annual volume of surgery at individual hospitals (zero to nine operations, ten to nineteen operations, and twenty to forty-nine operations) was tested in a Cox model with adjustment for age, gender, and prosthesis design.

The statistical analyses were performed with use of SPSS software (Advanced Statistics 13.0; SPSS, Chicago, Illinois) and S-PLUS 2000 (Insightful, Seattle, Washington). Two-sided p values of <0.05 were considered significant.

Results

Epidemiology of Knee Replacement Surgery

During the study period, 19,669 primary knee replacements were reported; of these, 3032 were cemented total knee replacements with patellar resurfacing and 2288 were

unicompartmental knee replacements (Table I). The majority of the rest of the replacements were cemented total knee replacements without patellar resurfacing. Unicompartmental knee replacements accounted for 15% of the primary knee replacements in 2004 and 12% of the primary knee replacements during the entire eleven-year study period. There was a decrease in use from 1994 to 1998, with the lowest annual percentage of 5% in 1997, and then an increase in use. Ninety-eight percent of the total knee replacements were posterior cruciate-retaining designs[11].

Patients managed with unicompartmental knee replacement were younger and were more likely to be male in comparison with those managed with total knee arthroplasty (Table I). In patients managed with unicompartmental knee replacement, 89% had primary osteoarthritis, 7.6% had sequelae after meniscal injury, 1.7% had sequelae of a fracture, 1.1% had sequelae of osteochondritis, 1.4% had sequelae of osteonecrosis, 0.5% had other diseases, and only 0.3% had rheumatoid arthritis.

A higher proportion of the Oxford III and Miller-Galante prostheses were implanted in patients who were sixty years old or less than was the case for prostheses that had longer follow-up. An intact anterior cruciate ligament after the operation was reported following 96% of the unicompartmental knee replacements (see Appendix). All of the unicompartmental knee replacements were cemented, with 89% being cemented with use of Palacos cement with gentamicin (Schering-Plough, Kenilworth, New Jersey). Only three types of prostheses were meniscal-bearing: the Oxford II, the Oxford III, and the Preservation. The Duracon and the Miller-Galante unicompartmental knee replacements were always used with an all-polyethylene tibial component, and the Genesis and Preservation replacements were used with an all-polyethylene tibial component in approximately one-quarter of the cases. The most common polyethylene thicknesses for the tibial insert were 8 and 10 mm, except for the Oxford II and III prostheses, for which 3.5, 4.5, and 5.5-mm-thick polyethylene inserts were most common. The thinnest polyethylene components (7.5 mm) for the MOD III implant were used at the beginning of the period. It was not possible to determine whether the prosthetic components were placed in the medial or the lateral compartment in two of the prosthesis designs at the beginning of the registration period because these two implants could be used both in the lateral and the medial compartment. The form was changed in 2001 to include registration of the lateral or medial compartment.

Volume of Surgery

The 2288 unicompartmental knee replacements had been performed in fifty-one hospitals over an eleven-year period (see Appendix). On the average, there had been four unicompartmental knee replacement operations per hospital per year during the study period, and, at forty-three of the fifty-one hospitals, there had been an average of fewer than ten procedures per year. Seven types of unicompartmental knee replacements had been used in more than twenty knees each. Four prostheses had been used in >100 knees. When we investigated all prostheses and all hospitals, we found that the hospitals at which an average of twenty to forty-nine knee operations had been performed per year (n = 3) had a 40% lower revision risk as compared with those at which zero to nine operations had been performed per year (n = 43) (relative risk, 0.6 [95% confidence interval, 0.40 to 1.0]; p = 0.05). For the Miller-Galante knee replacement, there was no hospital at which an average of more than ten operations had been performed per year, and therefore the influence of hospital surgery volume could not be tested for this implant. For the Oxford III knee replacement, there was no difference, with the numbers available, between hospitals at which zero to nine (n = 30), ten to nineteen (n = 4), or twenty to forty-nine (n = 3) procedures had been performed per year.

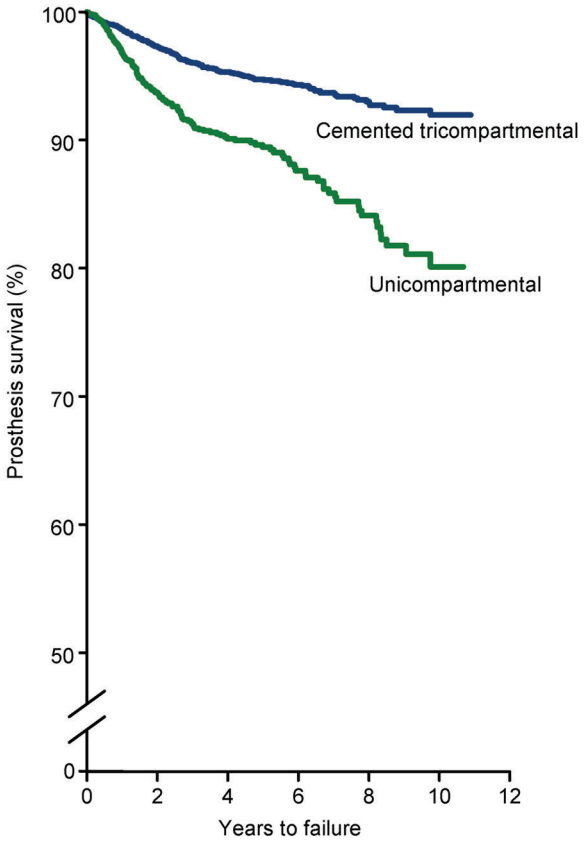

Fig. 1

Kaplan-Meier survival curves for cemented tricompartmental total knee replacements and cemented unicompartmental knee replacements.

Survival Rates

The ten-year survival rate was 80.1% (95% confidence interval, 76.0% to 84.2%) for unicompartmental knee replacements and 92.0% (95% confidence interval, 90.4% to 93.6%) for total knee replacements (Fig. 1 and Appendix). The relative risk of revision following unicompartmental knee replacement as compared with total knee replacement was 2.0 (95% confidence interval, 1.6 to 2.5; p < 0.001). The increased risk of revision following unicompartmental knee replacement

was seen in all age-categories (see Appendix).

Compared with total knee replacement, unicompartmental knee replacement was associated with more revisions because of pain (relative risk, 11.3 [95% confidence interval, 4.8 to 26.8]; $p < 0.001$), aseptic loosening of the tibial component (relative risk, 1.9 [95% confidence interval, 1.2 to 3.0]; $p = 0.01$) and of the femoral component (relative risk, 4.8 [95% confidence interval, 2.3 to 10.3]; $p < 0.001$), and periprosthetic fracture (relative risk, 3.2 [95% confidence interval, 1.2 to 8.9]; $p = 0.02$). There was, however, a decreased risk of revision because of infection following unicompartmental knee replacement as compared with total knee replacement (relative risk, 0.28 [95% confidence interval, 0.10 to 0.74]; $p = 0.01$) (Table II).

After ten years of follow-up, there was no significant difference in survival among the MOD III, Genesis Uni, and Oxford II knee replacements, with the numbers available. However, although the number of Duracon prostheses was low (n = 47), Duracon knee replacements were associated with a significantly higher risk of revision as compared with the other unicompartmental knee replacements (relative risk at five years, 3.0 [95% confidence interval, 1.3 to 6.8]; $p = 0.01$) (Fig. 2-A and Appendix). After five years, the Miller-Galante knee prosthesis (survival rate, 83.0%; 95% confidence interval, 76.3% to 89.7%) had a significantly higher rate of revision than the Oxford III knee prosthesis (survival rate, 91.1%; 95% confidence interval, 88.7% to 93.5%) (relative risk of revision, 1.8 [95% confidence interval, 1.1 to 2.8]; $p = 0.01$) (Fig. 2-B and Appendix). The results for the prostheses used primarily over the last five years were not better than those for the prostheses used mainly the first five years of registration, with the numbers available (see Appendix). The higher failure rates of the Duracon and Miller-Galante knees were mainly due to more loosening of the tibial component. For the MOD III prosthesis, there were significantly more revisions in association with the 7.5-mm tibial components as compared with the 9-mm components (relative risk, 3.5 [95% confidence interval, 1.3 to 9.1]; $p = 0.009$). For the Genesis prosthesis, there were also more revisions for the 8-mm tibial inserts as compared with the 10 and 12-mm inserts (relative risk, 6.2 [95% confidence interval, 1.3 to 28.8]; $p = 0.02$).

Two hospitals were found to have <60% survival of the Miller-Galante knee prosthesis after five years, while other hospitals had 100% survival after five years ($p = 0.001$ [see Appendix]).

Few lateral unicompartmental knee arthroplasties were performed. For the Genesis knee replacement, which was inserted in the lateral compartment 12% of the time, we found no difference in survival between lateral and medial compartment prostheses with the numbers available (relative risk, 0.53 [95% confidence interval, 0.12 to 2.29]).

Discussion

The major finding of the present study was that the rate of revision following unicompartmental knee replacement was twice as high as that following total knee replacement as a result of higher rates of revision due to femoral and tibial loosening, periprosthetic fracture, and pain. The increased risk of revision following unicompartmental knee replacement was seen in all age-categories and had not improved during the last five-year period as compared with the earlier period. The finding confirms those of other register studies[14,15] but not those of studies from specialized centers[5,6,16].

The volume of surgery mattered, with the risk of revision being 40% lower in hospitals at which twenty to forty-nine operations were performed per year as compared with hospitals at which zero to nine operations were performed per year. This finding corresponds well with those of registry studies on hip replacement[17,18]. For the Oxford III knee replacement, there was no difference in the risk of revision between low and high-volume hospitals, but the duration of follow-up was short and the number of hospitals with high numbers of procedures was low. Our findings for the Oxford III knee replacement are in accordance with those of more recent results from the Australian registry[19] but contradict the findings from the Swedish registry[20] on the earlier Oxford phase-II knee replacement, in which the results were better in hospitals with more than twenty-three procedures per hospital per year. This might be explained by better education of surgeons and better instrumentation in association with Oxford III knees as com-

TABLE II Reasons for Revision of Cemented Unicompartmental Knee Replacements and Cemented Tricompartmental Total Knee Replacements as Reported to the Norwegian Arthroplasty Register from 1994 to 2004

Type of Prosthesis	Loose Femoral Component	Loose Tibial Component	Loose Patellar Component
Tricompartmental total knee replacement (n = 3032)	11	41	9
Unicompartmental knee replacement (n = 2288)	38	44	0
Relative risk of revision*	4.8 (2.3 to 10.3)	1.9 (1.2 to 3.0)	No estimate
P value	<0.001	0.01	

*The Cox relative risk of revision, with the 95% confidence interval in parentheses, is given for unicompartmental knee replacement as compared with total knee replacement. Regression analyses were adjusted for age (sixty years or less, sixty-one to sixty-nine years, seventy years or more), gender, diagnosis, and type of prosthesis. The Cox estimates were based on replacements in which systemic antibiotics were given and prostheses were cemented with Palacos, with or without gentamicin. Posterior stabilized and constrained prostheses were excluded from the comparison.

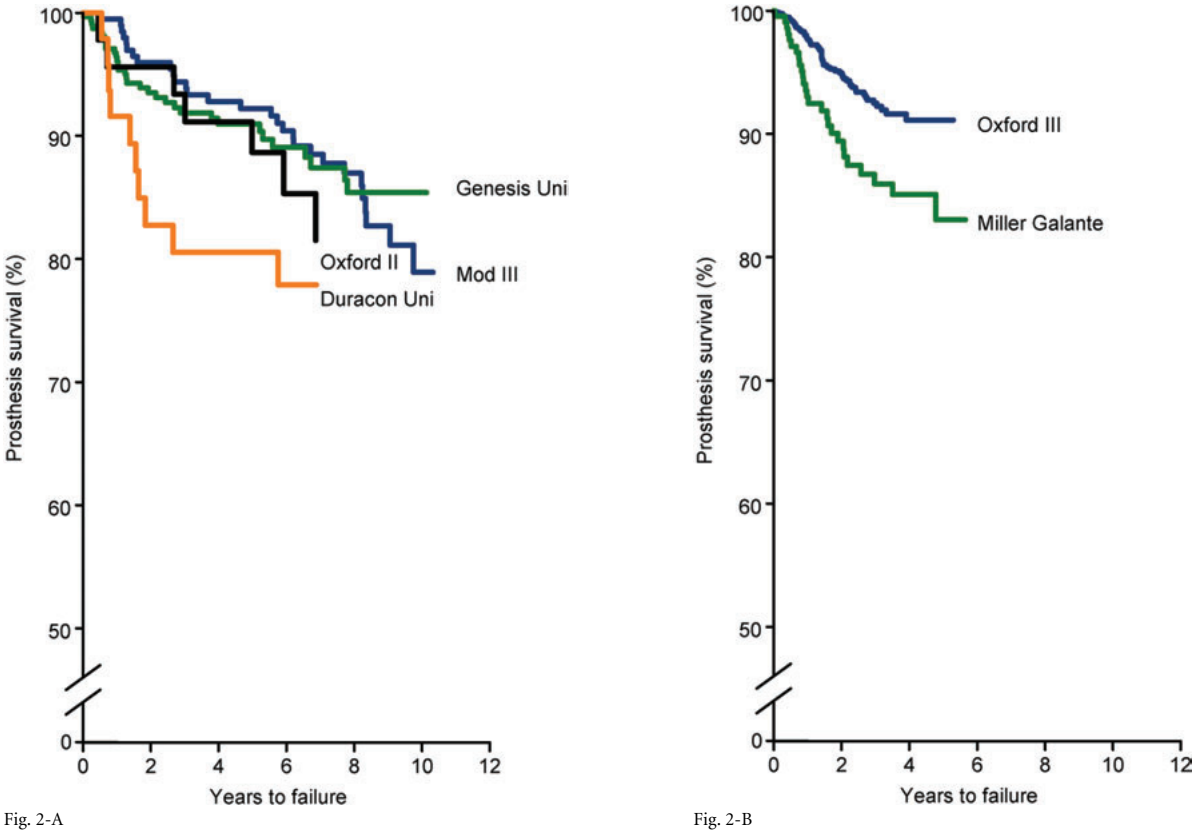

Fig. 2-A

Fig. 2-B

Figs. 2-A and 2-B Kaplan-Meier survival curves for unicompartmental knee replacements according to the duration of follow-up.

pared with Oxford II knees. In the present study, we were not able to control for the volume of operations per surgeon, and this might have confounded our results.

Several studies have indicated that unicompartmental knee replacement is associated with less pain and better function in comparison with total knee replacement[21,22]. In a randomized, controlled study in which the St. Georg Sled unicompartmental knee replacement was compared with the Kinematic total knee replacement with a patellar component, the authors found better function and less morbidity in association with the unicompartmental knee replacement after five years and reported the same survival for the two prostheses on the basis of the numbers available[23]. These results persisted for as long as ten years[24] and contradict the findings of our study. Our study was an observational one, and the patients who were selected for unicompartmental knee replacement could have been more active and healthier and therefore could have put the prostheses under more stress, leading to more loosening. A few dedicated sur-

TABLE II *(continued)*

Infection	Instability/ Dislocation	Periprosthetic Fracture	Pain Alone	Wear of Tibial Insert	Other Causes
37	40	9	7	22	16
5	21	11	48	19	18
0.28 (0.10 to 0.74)	0.96 (0.53 to 1.7)	3.2 (1.2 to 8.9)	11.3 (4.8 to 26.8)	1.8 (0.92 to 3.6)	2.0 (0.96 to 4.3)
0.01	0.9	0.02	<0.001	0.09	0.06

geons participating in a randomized study might also have performed the more technically demanding unicompartmental knee replacements better than surgeons across an entire country.

As we do not have information on the degree of pain and functional scores of the patients, we cannot conclude whether the patients in the unicompartmental knee replacement group actually had more pain than did those in the total knee replacement group or whether the revision operation helped. Only two of the revisions following unicompartmental knee replacement in our study were reported as being due to progression of arthritis. Progression of arthritis has been regarded a major cause of revision in earlier studies[7,15,16,25]. Our findings are supported by the study of St. Georg Sled unicompartmental knee replacements, in which none of the knees progressed to arthrosis[23], and also by the study by Berger et al., in which only one of sixty-one knees progressed[5]. Our findings could have been due to better patient selection or to a registration bias related to the fact that progression of arthritis is not part of the eleven standard reasons for revision on the registration form and therefore the surgeons must mark the reason for revision as "other" and specify progression of arthritis. Thus, some surgeons could have wrongly marked "pain" even though the reason was progression of arthritis.

The lower infection rate following the unicompartmental knee replacements confirms the early results from the Swedish Knee Arthroplasty Register[26].

The Duracon prosthesis had inferior survival results than did the other designs. The results must be interpreted with caution as the implant had been used in a small number of patients and at only five hospitals. The Duracon prosthesis was associated with inferior results in another study[27]. The authors concluded that the reason for the poor results was due to the use of polyethylene that had been gamma-sterilized in air and had a shelf life of over four years.

The Miller-Galante implant with an all-polyethylene tibial component had a five-year survival rate of 83% in our study, which was significantly inferior to the 91% survival rate for the Oxford III prosthesis. Berger et al. reported a ten-year survival rate of 98% for the Miller-Galante prosthesis[5], and Naudie et al. reported a ten-year survival rate of 90% for that prosthesis[28]. In both of those studies, a metal-backed tibial component was used, whereas in Norway an all-polyethylene tibial component was used. In a previous two-year study of Miller-Galante unicompartmental knee replacements, the results of procedures performed with an all-polyethylene tibial component were similar to those of procedures performed with a metal-backed tibial component[29], contradicting the findings of our study. In the last yearly report from the Swedish knee register, the Miller-Galante unicompartmental knee replacement was reported to be associated with a higher risk for revision than the Link unicompartmental knee replacement, but, because metal and all-polyethylene tibial components were analyzed together, no conclusion regarding the issue of the use of all-polyethylene tibial components can be drawn on the basis of that report[14]. In a report from Australia, the Miller-Galante unicompartmental knee replacement was associated with good short-term results, but the report did not specify whether an all-polyethylene or a metal-backed tibial component had been used[19]. Our finding of poor performance due to the aseptic loosening of the tibial components of the Duracon and Miller-Galante prostheses questions the concept of using an all-polyethylene tibial component for unicompartmental knee replacement.

As we did not register whether minimally invasive techniques were used at the time of surgery, their influence on the individual prosthesis could not be resolved. However, we did conduct a postal survey that was sent to all Norwegian operating clinics in September 2003 in which we inquired about the use of minimally invasive techniques for unicompartmental knee replacement. The results were analyzed according to the year of surgery (beginning in 1994) and prosthesis design. The Oxford III and the Miller-Galante prostheses were inserted with a minimally invasive technique in 98% and 90% of cases, respectively, and it is thus unlikely that the use of minimally invasive techniques explains the difference in performance between these two prostheses.

Loosening was most commonly seen in association with tibial components with thin polyethylene, which is in accordance with the findings of other studies[30].

There was no difference in survival between lateral and medial prostheses in cases in which the Genesis unicompartmental prosthesis had been used, which is in accordance with the results of the Swedish knee register[25,31].

It has been recommended that a unicompartmental prosthesis should be suitable for 20% to 30% of knee replacement procedures[6,32], but some authors have disputed this great percentage[33]. The fact that the Oxford knee has been the most used unicompartmental knee replacement in Norway in recent years probably explains the growing popularity of unicompartmental knee replacement, from 5% of the total number of primary knee replacements in 1997 to 15% in 2004. This rate is comparable with the percentages from Sweden and Australia[14,19]. Our data were used in a decision-analysis study that showed that unicompartmental knee replacement can be cost effective as compared with total knee replacement in patients older than seventy years of age[34].

The procedure of unicompartmental knee replacement, especially that involving minimally invasive techniques, has been reported to result in less morbidity in the form of pain, faster recovery, shorter hospitalization, less infection, less thromboembolic disease, and better range of movement[23,35,36] as compared with total knee replacement. The present study demonstrates that these short-term advantages must be weighed against higher revision rates due to aseptic loosening of the tibial and femoral components, persistent pain, and periprosthetic fractures.

Appendix

(eA) Additional tables and figures showing the data broken down by prosthesis type, patient age, and hospital are available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on

"Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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