Implant Survival of 6,080 Tritanium Cups in Primary Total Hip Arthroplasty

Data from the Finnish Arthroplasty Register from 2009 to 2017

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Background: To enhance osseointegration in total hip arthroplasty (THA), ultraporous or highly porous-coated cups were introduced. Implant survival data on these new devices have been scarce. The aim of our study was to assess the survivorship of ultraporous Tritanium cups (Stryker) in a population-based register study.

Methods: In this study, we collected data on 6,080 primary THAs using a Tritanium cup and 25,670 THAs using a conventional cup (control group) from the Finnish Arthroplasty Register; these procedures were performed from January 1, 2009, to December 31, 2017. We calculated the Kaplan-Meier survival estimates with 95% confidence intervals (CIs). The end point was revision for any reason or for aseptic loosening of the cup. The revision risks were assessed with use of the Cox multiple regression model. The variables assessed in the Cox model were femoral head size, age group, involved side, operation year, sex, diagnosis, and fixation of the stem. The proportional hazards assumption of the Cox model was not fulfilled, so the follow-up time was divided into 3 time periods: 0 to 2 years, >2 to 4 years, and >4 years.

Results: When comparing the 2 groups with regard to revision for any reason, the 5-year Kaplan-Meier survivorship of the Tritanium group (94.7% [95% CI, 94.0% to 95.4%]) was inferior to that of the control group (96.0% [95% CI, 95.7% to 96.3%]). In the Cox regression analysis of the 2 groups for the time period of >4 years, the Tritanium group had an increased risk of revision for any reason compared with the control group (hazard ratio [HR], 3.12 [95% CI, 1.82 to 5.35]; $p < 0.001$). With regard to revision for aseptic loosening of the cup, the Tritanium group had an increased risk of revision compared with the control group for both 0 to 2 years (HR, 3.80 [95% CI, 1.76 to 8.24]; $p < 0.001$) and >2 to 4 years (HR, 11.2 [95% CI, 3.28 to 38.0]; $p < 0.001$).

Conclusions: There was no advantage to using the ultraporous-coated Tritanium cup for primary THA compared with conventional uncemented cups. However, wide CIs for some HR estimates may point to a lack of precision. Therefore, further research on subject is needed.

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

Porous-coated cementless cups made of titanium alloy have achieved great success in total hip arthroplasty (THA) because of their unique properties, such as strength, corrosion resistance, and biocompatibility[1]. The porous metal surface of the implant mimics the properties of cancellous bone, providing reliable bone ingrowth and a reduced rate of aseptic loosening compared with cemented cups[2]. Ultraporous-coated acetabular components have been developed to further enhance osseointegration[3]. It has been stated that the lower modulus of the elasticity of ultraporous-coated cups compared with conventional porous metal cups minimizes stress-shielding and bone loss in the periacetabular region, thus increasing implant survival[4].

Stryker introduced the Tritanium primary acetabular component with an ultraporous surface to the U.S. market in 2008. The porous surface of the Tritanium cup is manufactured by commercially pure titanium being deposited onto a machined scaffold of reticulated, open-cell, polyurethane foam[5]. The cup is designed to have a high coefficient of friction and a high porosity, which enhance the biological fixation between

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TABLE I Acetabular Cups Included in the Study

Cup Design (Manufacturer)	No. of Cups
Tritanium (Stryker)	6,080
Control group	25,670
Exceed (Zimmer Biomet)	1,516
G7 (Zimmer Biomet)	1,094
Pinnacle (DePuy)	14,656
R3 (Smith & Nephew)	7,147
RingLoc (Zimmer Biomet)	1,257

the cup and the surrounding bone. Good clinical performance for this device has been shown in short-term to medium-term data[2,6,7]. Also, the risk of revision of Tritanium cups has been comparable with that of Trabecular Metal cups (Zimmer Biomet)[8]. However, a recent study raised concerns about radiolucent lines around the Tritanium cups at a 4-year follow-up, even though the revision rate for aseptic loosening was low[9].

Tritanium cups have been used frequently in Finland since 2009. We performed a retrospective study based on the Finnish Arthroplasty Register (FAR) database to assess the implant survival of the Tritanium cup. Our primary aim was to evaluate the overall revision risk of primary THAs performed with either Tritanium cups or conventional titanium alloy cups. Our secondary aim was to compare the risk of revision for aseptic loosening of the cup between the 2 groups. Our statistical hypothesis was that there is no significant difference in implant survival between the 2 groups.

Material and Methods

Our study is based on data from the FAR. Every Finnish orthopaedic unit must deliver all information essential for the register's maintenance to the Finnish National Institute for Health and Welfare. Patients are identified using a unique Social Security number. The register gathers information about THAs from the entire country of Finland. All arthroplasty units deliver data; thus, the coverage of hospitals is 100%. According to the FAR, the completeness of data is >95% for primary THA and 81% for revision THA. The dates of death were obtained from the Population Information System, maintained by the Population Register Centre in Finland. Since May 2014, all implants have been identified by the electronic reading of the reference codes perioperatively in the operating rooms in Finland. Information about the operation is sent electronically to the register[10,11]. The data for the register are collected prospectively by all arthroplasty units and are submitted to the register online or after a short delay. In May 2014, the data content of the register was examined and revised. The updated data now include detailed information on items such as patient body mass index (BMI) and American Society of Anesthesiologists (ASA) class and the surgical approach.

Between January 2009 and December 2017, there were 133,488 primary THA cases registered in the FAR. The Tritanium cup was used in 6,080 of these cases. The 25,670 cases in the control group involved the 5 most commonly used uncemented cups made of titanium alloy (Table I). Cases that had a cup head size that was not 28, 32, or 36 mm were excluded, as well as cases that had a dual-mobility cup or a constrained liner. Table II presents the demographic data of the study groups for the entire study period from January 1, 2009, to December 31, 2017, and Table III presents the data after the data content revision from May 15, 2014, to December 31, 2017. Mortality during the study period was 7.0% for the Tritanium group and 4.6% for the control group. There were 3,126 patients with bilateral hip prostheses, and 512 of these patients underwent the procedures simultaneously. The number of patients included was 28,624.

The primary outcome was the first revision for any reason, and the secondary outcome was the first revision for aseptic loosening of the cup. Revision was defined as a change

TABLE II Demographic Data for the Entire Study Period

	Tritanium Group* (N = 6,080)	Control Group* (N = 25,670)
Male sex†	2,372 (39%)	11,832 (46%)
Right side involved‡	3,376 (56%)	14,117 (55%)
Diagnosis		
Primary osteoarthritis	5,225 (86%)	22,059 (86%)
Rheumatoid arthritis	107 (2%)	432 (2%)
Other	748 (12%)	3,179 (12%)
Femoral head size of prosthesis		
28 mm	21 (0.4%)	266 (1%)
32 mm	726 (12%)	5,161 (20%)
36 mm	5,333 (88%)	20,243 (79%)
Status at end of follow-up		
Not revised	5,820 (96%)	24,738 (96%)
Revised	260 (4%)	932 (4%)
Liner material		
Ceramic	108 (2%)	7,557 (29%)
Highly cross-linked polyethylene	5,972 (98%)	17,942 (70%)
Unknown	0 (0%)	171 (1%)
Operation year		
2009 to 2013	2,414 (40%)	10,017 (39%)
2014 to 2017	3,666 (60%)	15,653 (61%)
Femoral stem fixation		
Uncemented	3,446 (57%)	22,995 (90%)
Cemented	2,634 (43%)	2,675 (10%)

*The values are given as the number of patients, with the percentage in parentheses. †There were 10 patients who had missing data for sex. ‡There were 32 patients who had missing data for the involved side.

or removal of at least 1 component. The reasons for revision are presented in Table IV, which shows the revisions prior to the data content revision on May 15, 2014, and in Table V, which shows the revisions from May 15, 2014, until the end of the follow-up on December 31, 2017.

Statistical Analysis

The Kaplan-Meier survival estimates with 95% confidence intervals (CIs) were assessed for both study groups at 1, 3, 5, and 7 years for revision for any reason and for revision for the loosening of the cup. The log-rank test was used to compare the survival curves.

In the Cox multiple regression model, to reduce the risk of selection bias, we adjusted the estimated revision risk by age group (18 to 55, 56 to 65, 66 to 75, and 76 to 100 years), sex, diagnosis (primary osteoarthritis, rheumatoid arthritis, and other), femoral head size (28, 32, 36 mm), involved side, operation year (2009 to 2013, 2014 to 2017), and fixation of the femoral stem. The type of surgical approach (Hardinge, posterior, anterior), ASA class (I, II, III, IV), and BMI were added to the Cox model as possible confounders concerning the time period from May 15, 2014, to December 31, 2017, in addition to age group, sex, diagnosis, femoral head size, involved side, operation year, and fixation of the femoral stem. The results based on the Cox regression model are presented as hazard ratios (HRs) and 95% CIs.

The revision risk for any reason was assessed separately for the 2 time periods: January 1, 2009, to December 31, 2017, and May 15, 2014, to December 31, 2017. The revision risk for aseptic loosening of the cup was assessed for January 1, 2009, to December 31, 2017. Patients were censored for any event other than the outcome or at the end of the follow-up.

The model was stratified by an adjusting variable if the proportional hazards assumption was not fulfilled in the Cox model. With regard to stratification in Cox models, the hazard functions can be estimated for all level combinations of the stratified variables, and the HRs for the other variables (those that meet the proportional hazards assumption) are then optimized for all of these hazard functions. Without stratification, we would assume that the hazards were the same for all levels of such variables. Only after the follow-up time was divided into 3 time periods (0 to 2 years, >2 to 4 years, and >4 years) was the proportional hazards assumption fulfilled for the study groups for all variables.

We also performed statistical analyses using the competing risk method, but the results did not qualitatively change. Therefore, these results are not presented in this article.

All analyses were performed using SAS version 9.4 (SAS Institute).

Results

The proportion of female patients was 61% in the Tritanium group and 53% in the control group. The mean follow-up time was 3.6 years (range, 0 to 8.8 years) in the Tritanium group and 3.7 years (range, 0 to 9.5 years) in the control group. In

TABLE III Demographic Data for the Period After Data Content Revision in the FAR*

	Tritanium Group	Control Group
Age† *(yr)*	71 ± 10	66 ± 11
BMI†‡ *(kg/m²)*	28 ± 5	28 ± 5
Male sex§#	1,241 (39%)	6,758 (47%)
Involved right side§**	1,770 (55%)	7,890 (55%)
Diagnosis§		
Primary osteoarthritis	2,681 (84%)	12,167 (85%)
Rheumatoid arthritis	53 (2%)	170 (1%)
Other	459 (14%)	2,003 (14%)
Femoral head size of prosthesis§		
28 mm	5 (0.2%)	90 (0.6%)
32 mm	505 (16%)	3,124 (22%)
36 mm	2,683 (84%)	11,126 (78%)
Status at end of follow-up§		
Not revised	3,077 (96%)	13,857 (97%)
Revised	116 (4%)	483 (3%)
Liner material§		
Ceramic	36 (1%)	2,152 (15%)
Highly cross-linked polyethylene	3,157 (99%)	12,158 (85%)
Unknown	0 (0%)	30 (0.2%)
Approach§††		
Posterior	2,641 (85%)	11,048 (79%)
Anterolateral (modified Hardinge)	480 (15%)	2,740 (20%)
Anterior (Watson-Jones)	3 (0.1%)	11 (0.1%)
Anterior (Smith-Petersen)	0 (0%)	137 (1%)
Trochanteric osteotomy performed	0 (0%)	1 (0.01%)
ASA class§‡‡		
I	214 (7%)	1,997 (14%)
II	1,446 (47%)	7,270 (52%)
III	1,392 (46%)	4,522 (32%)
IV	65 (2%)	175 (1%)
Femoral stem fixation§		
Uncemented	1,224 (38%)	12,356 (86%)
Cemented	1,969 (62%)	1,984 (14%)

*This time period included was May 15, 2014, to December 31, 2017. †The values are given as the mean and standard deviation. ‡There were missing BMI data for 1,760 patients. §The values are given as the number of patients, with the percentage in parentheses. #There were missing data for sex for 8 patients. **There were missing data for the involved side for 2 patients. ††There were missing data for the surgical approach for 472 patients. ‡‡There were missing data for the ASA class for 452 patients.

TABLE IV Indications for Revision Prior to FAR Data Content Revision*

Main Reason for Revision†	Tritanium Group‡	Control Group‡
Aseptic loosening		
Cup and stem	1 (2%)	1 (0.4%)
Cup	7 (11%)	10 (4%)
Stem	3 (5%)	15 (6%)
Infection	31 (47%)	44 (17%)
Dislocation	6 (9%)	78 (31%)
Component malposition	3 (5%)	29 (12%)
Fracture	8 (12%)	49 (19%)
Component breakage	1 (2%)	4 (2%)
Other	6 (9%)	22 (9%)

*The time period studied was January 1, 2009, to May 14, 2014. †No data were available for 58 revisions with regard to the reason for revision. ‡The values are given as the number of patients, with the percentage in parentheses.

both groups, the most commonly used femoral head size was 36 mm. Uncemented stems were used in 57% of cases in the Tritanium group compared with 90% in the control group.

Table III displays descriptive statistics for the subset of patients since May 2014 with additional data collected. In both groups, the majority of the THAs were performed via the posterior approach. The mean BMI was 27.8 kg/m^2 in the Tritanium group and 28.3 kg/m^2 in the control group. The most common ASA class was II in both groups (Table III).

Revision for Any Reason

For any reason for revision, the 5-year Kaplan-Meier survivorship was inferior in the Tritanium group (94.7% [95% CI, 94.0% to 95.4%]) compared with the control group (96.0% [95% CI, 95.7% to 96.3%]) (Table VI, Fig. 1). In the Cox regression analysis, there was an increased risk of revision for any reason in the Tritanium group compared with the control group at >4 years (HR, 3.12 [95% CI, 1.82 to 5.35]; $p < 0.001$) (Table VII).

The 3-year Kaplan-Meier survivorship assessed separately for May 15, 2014, to December 31, 2017, was similar between groups: 95.9% (95% CI, 95.1% to 96.6%) for the Tritanium group and 96.4% (95% CI, 96.0% to 96.7%) for the control group. In the Cox regression analysis, the Tritanium group had a similar risk of revision compared with the control group (HR, 1.11 [95% CI, 0.88 to 1.42]; $p = 0.38$) (Appendix 1).

Cup Revision for Aseptic Loosening

With regard to revision for aseptic loosening, the 5-year Kaplan-Meier survivorship was inferior for the Tritanium group (99.0% [95% CI, 98.5% to 99.3%]) compared with the control group (99.9% [95% CI, 99.9% to 99.9%]) (Fig. 2). In the Cox regression analysis, there were increased risks of revision for the Tritanium group compared with the control group both at 0 to 2 years (HR, 3.80 [95% CI, 1.76 to 8.24]; $p < 0.001$) and at >2 to 4 years (HR, 11.2 [95% CI, 3.28 to 38.0]; $p < 0.001$) (Table VIII). There were no revisions for cup loosening in the control group for >4 years, so it was not possible to assess that time period separately.

Discussion

Despite the promising early results of the Tritanium cup, there has been some concern about higher radiolucency prevalence compared with other porous designs[8,9]. In our study, based on data from the FAR, patients with the Tritanium cup had an increased risk of revision for any reason at >4 years compared with the control group, which had other commonly used conventional titanium alloy cups. Additionally, with the

TABLE V Indications for Revision After New Indications for Revision Were Added to the FAR*

Main Reason for Revision†	Tritanium Group‡	Control Group‡
Aseptic loosening		
Cup	28 (16%)	7 (1%)
Stem	8 (5%)	24 (4%)
Osteolysis		
Cup	2 (1%)	0 (0%)
Stem	1 (0.6%)	0 (0%)
Liner wear	0 (0%)	2 (0.4%)
Component breakage		
Cup	0 (0%)	1 (0.2%)
Liner	0 (0%)	11 (2%)
Head	0 (0%)	1 (0.2%)
Modular neck	1 (0.6%)	1 (0.2%)
Infection	61 (35%)	165 (30%)
Dislocation	18 (10%)	136 (25%)
Component malposition		
Cup	9 (5%)	22 (4%)
Stem	3 (2%)	14 (3%)
Periprosthetic fracture		
Acetabulum	0 (0%)	1 (0.2%)
Femur	20 (11%)	87 (16%)
Adverse reaction to metal debris (ARMD)	3 (2%)	0 (0%)
Squeaking	0 (0%)	5 (1%)
Unexplained pain	13 (7%)	30 (6%)
Leg-length discrepancy	0 (0%)	7 (1%)
Other	2 (1%)	21 (4%)

*The time period was from May 15, 2014, to December 31, 2017. †There were no data available for 89 revisions with regard to the reason for revision. ‡The values are given as the number of patients, with the percentage in parentheses.

TABLE VI The Kaplan-Meier Survivorship for the Study Groups Undergoing Primary THA*

	Tritanium Group	Control Group
No. of THAs	6,080	25,670
No. of revisions	260	932
Survival up to 1 year		
At risk	5,428	23,095
Percentage†	97.3 (96.8 to 97.6)	97.3 (97.1 to 97.5)
Survival up to 3 years		
At risk	3,160	14,867
Percentage†	96.1 (95.6 to 96.6)	96.4 (96.2 to 96.7)
Survival up to 5 years		
At risk	1,572	7,695
Percentage†	94.7 (94.0 to 95.4)	96.0 (95.7 to 96.3)
Survival up to 7 years		
At risk	257	2,285
Percentage†	94.0 (92.9 to 94.9)	95.6 (95.3 to 95.9)

*Revision for any reason was the end point at each time point. †The values are given as the mean, with the 95% CI in parentheses.

end point of revision for aseptic loosening of the cup, the Tritanium group had an increased risk of revision compared with the control group.

There have been only a few peer-reviewed publications about the implant survival of the ultraporous-coated Tritanium cup, and the results have been somewhat contradictory. Naziri et al.[2] assessed 288 hips in 252 patients who had undergone a primary THA performed using a Tritanium cup from 2008 to 2010. The mean follow-up was 36 months, and, at the final follow-up, no cup failures had occurred. Carli et al.[9] compared the clinical and radiographic results of 95 patients (109 hips) who had received a Tritanium primary cup and 100 patients (matched by age, BMI, and sex) who had received a contemporary cup (Stryker Trident PSL HA). In radiographs made at 1 year postoperatively, radiolucent lines appeared in ≥2 DeLee and Charnley zones in 30% of

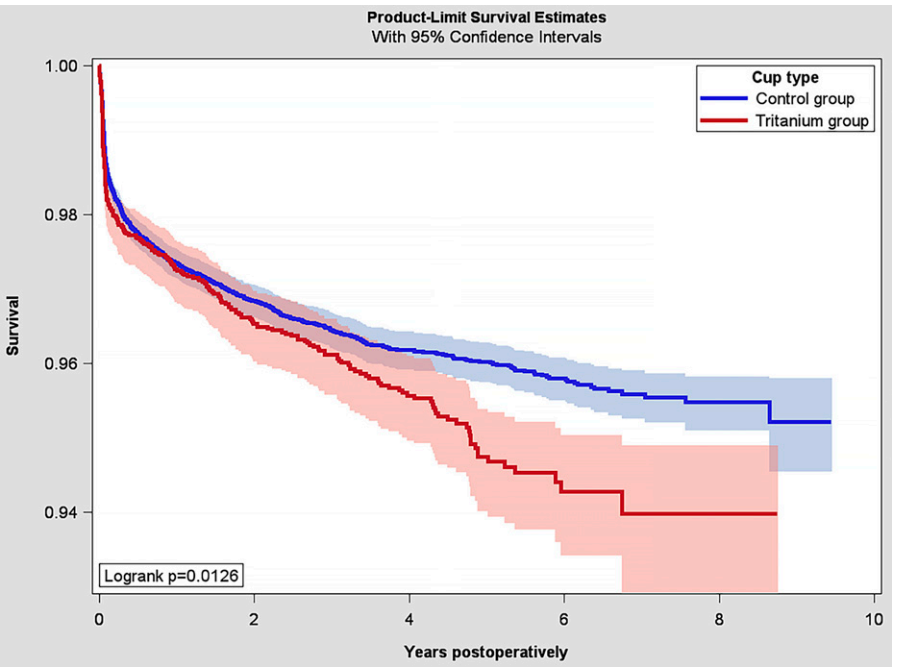

Fig. 1

The Kaplan-Meier survivorship of the Tritanium group and the control group free from revision for any reason, with the 95% CIs shown by the shaded areas.

TABLE VII Risk of Revision for Any Reason According to the Cox Regression Model for the Entire Time Period

	HR*	P Value
Revision for any reason, 0 to 2 years		
Control group	1	
Tritanium group	1.16 (0.98 to 1.37)	0.079
Adjusting variables (stratified by sex and operation year)		
Involved side: left vs. right	0.96 (0.84 to 1.09)	0.502
Stem fixation: cemented vs. cementless	0.74 (0.61 to 0.91)	0.003
Age		
18 to 55 yr	0.62 (0.49 to 0.79)	<0.001
56 to 65 yr	0.80 (0.67 to 0.96)	0.018
66 to 75 yr	0.82 (0.69 to 0.97)	0.017
≥76 yr	1	
Diagnosis		
Rheumatoid arthritis	1	
Other	0.83 (0.54 to 1.28)	0.407
Primary osteoarthritis	0.61 (0.40 to 0.91)	0.016
Head size		
28 mm	0.95 (0.47 to 1.91)	0.874
32 mm	1.11 (0.94 to 1.31)	0.232
36 mm	1	
Revision for any reason, >2 to 4 years		
Control group	1	
Tritanium group	1.36 (0.90 to 2.04)	0.141
Adjusting variables		
Involved size: left vs. right	1.15 (0.83 to 1.61)	0.402
Stem fixation: cemented vs. cementless	0.99 (0.58 to 1.70)	0.982
Age		
18 to 55 yr	1.07 (0.59 to 1.96)	0.827
56 to 65 yr	0.97 (0.58 to 1.62)	0.906
66 to 75 yr	1.03 (0.65 to 1.65)	0.891
≥76 yr	1	
Diagnosis		
Rheumatoid arthritis	1	
Other	1.00 (0.34 to 2.90)	0.993
Primary osteoarthritis	0.70 (0.26 to 1.91)	0.483
Head size		
28 mm	1.11 (0.27 to 4.54)	0.888
32 mm	0.85 (0.53 to 1.38)	0.513
36 mm	1	
Sex: female vs. male	1.16 (0.81 to 1.65)	0.412
Operation year: 2009 to 2013 vs. 2014 to 2017	1.13 (0.79 to 1.62)	0.498
Revision for any reason, >4 years		
Control group	1	
Tritanium group	3.12 (1.82 to 5.35)	<0.001
Adjusting variables (stratified by head size)		
Involved side: left vs. right	0.75 (0.45 to 1.25)	0.271
Stem fixation: cemented vs. cementless	0.67 (0.23 to 1.94)	0.455
Age		
18 to 55 yr	1.48 (0.57 to 3.86)	0.424
56 to 65 yr	1.32 (0.58 to 3.01)	0.508
66 to 75 yr	1.34 (0.62 to 2.92)	0.459
≥76 yr	1	
Diagnosis		
Rheumatoid arthritis	1	
Other	0.79 (0.22 to 2.87)	0.719
Primary osteoarthritis	0.45 (0.14 to 1.48)	0.189
Sex: female vs. male	1.04 (0.62 to 1.73)	0.889
Operation year: 2009 to 2013 vs. 2014 to 2017	0.44 (0.10 to 2.07)	0.300

*The values are given as the HR, with the 95% CI in parentheses.

cups and in 3 zones in 8% of cups. At a minimum follow-up of 5 years, 40% of cups had radiolucent lines in ≥2 DeLee and Charnley zones and 17% of cups had radiolucent lines in 3 zones. Faizan et al.[12] assessed the radiolucent lines for Tritanium (3-dimensional) and Trident (2-dimensional) (Stryker) cups in a cadaveric setting; they also briefly presented the differences in cup structure for the 2 cups. They found that both cups had an equivalent mean metal-bone contact, but artifactual radiolucencies were found in the contact radiographs of the 3-dimensional cup. Yoshioka et al.[13] compared consecutive primary THA cases performed between 2011 and 2014 for 2 groups: 130 cases in 118 patients who received a Tritanium cup and a matched cohort of 130 cases in 130 patients who received a Trident cup. With regard to radiolucent lines, there were significant differences between the groups, but there were no differences in the clinical results. The occurrence of radiolucent lines was significantly higher in the Tritanium group than in the Trident group at each follow-up period.

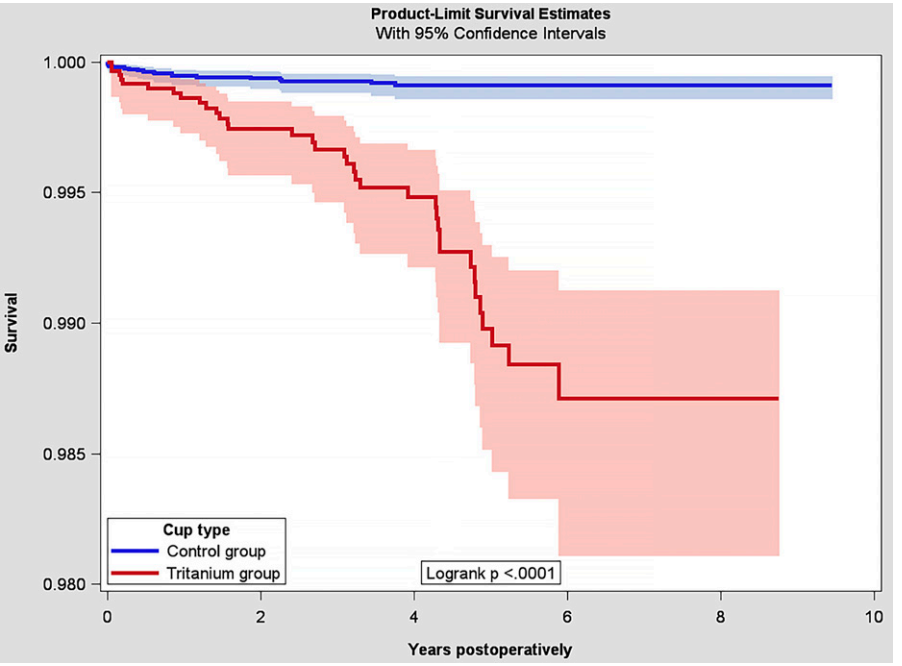

Fig. 2

The Kaplan-Meier survivorship of the Tritanium group and the control group free from revision for aseptic loosening of the cup, with the 95% CIs shown by the shaded areas.

In a population-based register study like ours, we were not able to assess the radiographic findings of the study patients. However, although we did not have radiographic data, our findings of the inferior survivorship of the Tritanium group both for any reason of revision and for the aseptic loosening of the cup support the findings of Carli et al.[9] and Yoshioka et al.[13].

In addition to peer-reviewed publications, the implant survivals of the most common hip implants are presented in the annual yearbooks of some national arthroplasty registers. In Australia (Australian Orthopaedic Association National Joint Replacement Registry [AOANJRR])[14], the 5-year Kaplan-Meier estimate (cumulative percent revision) of the 756 cementless THA cases using the Accolade I stem (Stryker) and the Tritanium cup was 3.6% (95% CI, 2.4% to 5.2%). The 1-year Kaplan-Meier estimate of 878 cementless Accolade II stems and Tritanium cups for THA was 3.0% (95% CI, 1.9% to 4.6%). For 3,884 hybrid THA cases with a cemented Exeter stem (Stryker) and a Tritanium cup, the 5-year Kaplan-Meier estimate was 3.2% (95% CI, 2.6% to 4.0%). The implant survival of the Tritanium cup in the current study is slightly inferior compared with that of the Accolade I stem and Tritanium cup and the Exeter stem and Tritanium cup in Australia. The stem models used in Finland are essentially the same (Accolade I and II, Exeter). The cumulative revision rate of the Accolade II stem and Tritanium cup in Australia is relatively high and is similar to our results. However, the signal detection method of the AOANJRR has not considered the Tritanium cup as an outlier product in Australia[14].

In the National Joint Registry for England, Wales, Northern Ireland, the Isle of Man and the States of Guernsey (NJR)[15], the 5-year Kaplan-Meier estimate of 3,681 hybrid Exeter stems and Tritanium cups for THA was 2.3% (95% CI, 1.7% to 3.0%). The New Zealand Orthopaedic Association (NZOA) Joint Registry[16] described the risk of revision using the rate per 100 component years. The revision rate was 0.57% (95% CI, 0.3% to 1.1%) for 735 THA cases performed with Accolade II stems and Tritanium cups and 0.7% (95% CI, 0.6% to 1.0%) for 2,702 hybrid THA cases performed with Exeter stems and Tritanium cups[16]. These unadjusted survivorship data from national registers do not seem alarming. Adjusted analyses targeting aseptic loosening of the cup would be required to properly compare survivorship between registers.

We acknowledge that our study had some limitations. First, in a population-based register study like ours, we were not able to assess radiographic findings. Theoretically, it is possible that Tritanium cups were used in more demanding cases compared with the cups in the control group. However, the number of Tritanium cups in the current study overall was high, and the proportion of patients with primary osteoarthritis was similar compared with the control group (86%), so we believe that the bias is of minor importance. Because of a lack of radiographs, we were not able to assess postoperative radiolucent lines around the cup, which is the major limitation of our study. Second, data on patient comorbidities were not included. Patient comorbidities may have differed between the 2 study groups and may have biased our results. However, we have ASA data available since May 2014, and there were no major differences according to ASA class distribution between the study groups. Third, we could only assess revision operation as the outcome. Some patients may have experienced pain

TABLE VIII Risk of Revision for Aseptic Loosening of the Cup According to the Cox Regression Model*

	HR†	P Value
Revision for aseptic loosening of the cup, 0 to 2 years		
Control group	1	
Tritanium group	3.80 (1.76 to 8.24)	<0.001
Adjusting variables†		
Involved side: left vs. right	0.89 (0.43 to 1.87)	0.765
Stem fixation: cemented vs. cementless	0.43 (0.14 to 1.38)	0.157
Age		
18 to 55 yr	0.28 (0.06 to 1.33)	0.109
56 to 65 yr	0.40 (0.14 to 1.13)	0.085
66 to 75 yr	0.50 (0.21 to 1.21)	0.124
≥76 yr	1	
Diagnosis		
Rheumatoid arthritis	1	
Other	0.85 (0.10 to 7.36)	0.886
Primary osteoarthritis	0.41 (0.06 to 3.10)	0.390
Head size: 32 mm vs. 36 mm§	0.66 (0.19 to 2.27)	0.511
Sex: female vs. male	1.09 (0.51 to 2.33)	0.834
Operation year: 2009 to 2013 vs. 2014 to 2017	3.30 (1.42 to 7.67)	0.006
Revision for aseptic loosening of the cup, >2 to 4 years		
Control group	1	
Tritanium group	11.2 (3.28 to 38.0)	<0.001
Adjusting variables		
Involved side: left vs. right	0.84 (0.27 to 2.57)	0.759
Stem fixation: cemented vs. cementless	0.33 (0.04 to 2.86)	0.315
Age#		
56 to 65 yr	1.61 (0.38 to 6.75)	0.518
66 to 75 yr	0.80 (0.18 to 3.68)	0.779
≥76 yr	1	
Diagnosis: other vs. primary osteoarthritis**	2.02 (0.44 to 9.28)	0.366
Head size: 32 mm vs. 36 mm§	2.07 (0.54 to 7.99)	0.292
Sex: female vs. male	2.10 (0.56 to 7.82)	0.269
Operation year: 2009 to 2013 vs. 2014 to 2017	6.11 (0.77 to 48.65)	0.088

*There were no events for revision for aseptic loosening of the cup, >4 years. †The values are given as the HR, with the 95% CI in parentheses. ‡Adjusted for age group, sex, diagnosis, femoral head size, involved side, operation year group, and fixation of the femoral stem. §The head size of 28 mm had no events. #There were no events in the age group of 18 to 55 years. **There were no events in the diagnosis of rheumatoid arthritis.

or other implant-related problems without undergoing a revision, for example, if they had poor general health that contraindicated a risky revision surgical procedure. We also do not have data on any patient-reported outcomes measures. Furthermore, <5% of the study hips had 7 years of follow-up. Even for 3-year outcomes, only about 50% of the sample reached that milestone. We realize that the generalizability of Kaplan-Meier estimates at these time points may have been reduced. Also, wide CIs for some HR estimates may have pointed to a lack of precision. Moreover, the completeness of data of the revision operations in the FAR is 81%, so 19% of revision data are missing, which may have caused bias. However, we do not think that these issues notably influenced our results and message.

In conclusion, in our large, nationwide study, we show that using the ultraporous-coated Tritanium cup for primary THA is not superior to using a traditional uncemented cup. Instead, with regard to its use in THA, the Tritanium cup, compared with a conventional cup, was associated with an increased revision risk, which was largely due to revisions for aseptic loosening of the cup. Further research is needed to assess the long-term survivorship of these devices.

Appendix

Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJS/F916). ■

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