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Trabecular metal acetabular components reduce the risk of revision following primary total hip arthroplasty: A propensity score matched study from the National Joint Registry for England and Wales

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Abstract

Background

Trabecular metal (TM) coated acetabular components are increasingly used in both primary and revision total hip arthroplasty (THA). However, previous studies assessing TM acetabular components have been small single-centre cohorts with most lacking a control group. We compared revision rates following primary THA between TM and non-TM coated acetabular components.

Methods

A retrospective observational study was performed using National Joint Registry data, which included primary THAs with the same cementless acetabular component (either TM or non-TM coated). TM and non-TM implants were matched for multiple potential confounding factors using propensity scores. Outcomes following primary THA (revision for all-cause acetabular indications, aseptic acetabular loosening, and infection) were compared between matched groups using competing risk regression analysis.

Results

In 18,200 primary THAs (9,100 TM and 9,100 non-TM), the overall prevalence of acetabular revision, revision for aseptic acetabular loosening, and septic revision was 1.2%, 0.13%, and 0.59% respectively. Five-year revision rates for all-causes (1.0% vs. 1.8%; sub-hazard ratio

(SHR)=0.57, 95% CI=0.43-0.76; p<0.001), aseptic acetabular loosening (0.1% vs. 0.2%; SHR=0.35, CI=0.14-0.90; p=0.029), and infection (0.5% vs. 0.9%; SHR=0.51, CI=0.34-0.76; p=0.001) were all lower in TM compared with non-TM implants.

Conclusion

Following primary THA, TM coated implants had a reduced risk of both aseptic and septic revision compared with non-TM implants. Although absolute differences in revision risk were small, they may be clinically significant if TM designs were implanted in more complex cases.

Word count = 229

Keywords

primary total hip arthroplasty; revision surgery; trabecular metal; aseptic loosening; infection

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Introduction

Revision surgery for failed total hip arthroplasties (THAs) remains a significant problem, especially in young patients with high activity levels [1-3]. Aseptic component loosening represents the leading reason for THA failure, whilst periprosthetic joint infection is a common cause of early revision that presents a challenging problem to surgeons [4-6].

Over the years, THA implants have been modified with the aim to reduce subsequent failures. Trabecular metal^{TM} (TM; Zimmer-Biomet; Warsaw, Indiana, USA) is a material made from elemental tantalum, which is highly porous with a high coefficient of friction and a modulus of elasticity similar to cancellous bone, with studies observing that TM has a higher potential for osteointegration, which may reduce subsequent implant failures [7-9]. These attractive properties have led to increased usage of TM coated acetabular components in both primary and revision THA [4, 8, 10, 11]. In primary THA, TM implants have demonstrated good fixation at medium-term follow-up on radiostereometric analysis,[11-13] with one small cohort suggesting good clinical outcomes can be achieved at 15-years follow-up [14]. Following revision THA, lower failure rates have been observed when using TM implants compared with non-TM designs,[10, 15, 16] with recent evidence suggesting that TM may reduce the risk of re-infection following septic revisions [10].

However studies assessing TM acetabular components to date have been limited by being small single-centre cohorts, with many lacking a comparator group [8, 10-16]. Given the risk of failure is generally low, especially after primary THA, it is important to assess the clinical efficacy of TM acetabular components in large cohorts that are appropriately powered to detect differences in revision rates between TM and non-TM implants. Furthermore whilst there may be potential clinical benefits of TM implants it is important to also consider the

financial implications, as these can be up to 30% more expensive than non-TM components. Therefore, TM acetabular components must demonstrate significantly lower failure rates compared with non-TM components to support their continued use.

The National Joint Registry (NJR) for England and Wales was established in April 2003 to identify poorly performing implants early [4]. It is the largest arthroplasty registry in the world, and contains details of two million joint replacement procedures. We used NJR data to compare revision rates following primary THA between TM and non-TM coated acetabular components.

Patients and Methods

A retrospective observational study was performed using NJR data. The NJR records all hip arthroplasty procedures performed at all hospitals in England and Wales since 2003, with 93% of patients consenting for their details to be recorded within the NJR [4]. The NJR collects data on patient factors (including age, gender, American Society of Anesthesiologists (ASA) grade) and surgical factors (including surgical approach, indication, and components implanted) for each arthroplasty procedure, which is obtained using data capture forms completed by the operating surgeon. Unique patient identifiers allow primary THAs to be linked to any subsequent surgical procedures in which components are removed or exchanged, with 94.5% linkability currently reported [4]. Before obtaining the dataset, the NJR database was linked using unique patient identifiers with the Office for National Statistics, which provides data on all-cause mortality.

Anonymised patient data were extracted from the NJR, which included all primary THAs recorded between 1st April 2003 and 30th July 2015 in which one of four cementless acetabular component designs were implanted (n=53,963). The latter study date allowed a minimum 1-year follow-up period for determining outcomes after primary THA. The four acetabular component designs studied were all produced by one manufacturer (Zimmer-Biomet), and either had a TM (TM Modular and Continuum) or non-TM (Trilogy and Trilogy IT) surface coating. For the purposes of this study these acetabular component designs could be implanted with any bearing surface and femoral component, regardless of manufacturer. Hips were subsequently excluded if any data regarding the primary THA procedure performed (stem fixation, femoral head size, bearing surface) were either missing or ambiguous (n=1,997). There were 51,966 primary THAs (12,056 TM and 39,910 non-TM) eligible for study inclusion (Table 1).

The Trilogy acetabular component was released in 1993, and has a fully hemispherical design with a pure titanium fiber metal coating. The component is available in 2 mm increments (ranging from 40 mm to 70 mm outer diameter depending on the specific shell design), and has a locking ring mechanism for securing polyethylene liners. The TM Modular acetabular component was released in 2003, and has identical internal geometry to the Trilogy, with the only difference between the two designs being the surface coating. The Trilogy IT acetabular component was released in 2009, and is similar in design to the Trilogy, but internally possess both an integrated taper and a locking groove which can accommodate polyethylene and ceramic liners. The Continuum acetabular component was introduced in 2009, and has identical internal geometry to the Trilogy IT, with the only difference between the two designs being the surface coating. All four acetabular components can be implanted in primary and revision THA.

The binary study exposure of interest was whether the primary THA included a TM coated or a non-TM coated acetabular component. These two groups were matched for multiple potential confounding factors using propensity scores (detailed below). By controlling for patient and surgical covariates, the use of propensity score matching would allow the true effect of implant coating on the risk of revision surgery to be more accurately assessed. This a priori decision was supported by the substantial differences in the patient and surgical characteristics that were observed between the unmatched TM and non-TM groups (Table 1); these differences could not have been adequately controlled for using adjusted multivariable regression models.

Study outcomes of interest following primary THA were: (1) acetabular component revision for all-causes (with or without femoral component revision), (2) acetabular component revision for aseptic loosening (with or without femoral component revision), and (3) revision for infection (regardless of whether or not the acetabular component was revised).

Statistical analysis

All analyses were performed using Stata (Version 14.2; Lakeway Drive, Texas, USA) apart from propensity score matching, which was performed using R (Version 3.4.0; R Foundation for Statistical Computing, Vienna, Austria). The significance level for all analyses was a p-value <0.05, with 95% confidence intervals (CI) also used.

Primary THAs with TM and non-TM implants were matched for multiple potential patient and surgical confounding factors using propensity score techniques [17, 18]. Matching was performed using a one-to-one ratio. The algorithm used matched on the logit of the propensity score with a 0.02 standard deviation caliper width. Greedy matching (each TM hip was matched to the nearest non-TM hip) without replacement was used (once a match was made that specific hip was no longer available for matching subsequent cases), which has demonstrated superior performance for estimating treatment effects [17].

The TM and non-TM groups were matched for the following covariates where complete data was available for the entire cohort: age, gender, bilateral THAs, primary hip diagnosis, ASA grade, year of primary THA, venous thromboembolism prophylaxis, surgeon grade, surgical approach, and components implanted at primary THA (stem fixation, femoral head size, bearing surface, and the use of bone graft). Due to the high proportion of missing data (41%),

the groups were not matched based on body mass index (BMI). Logistic regression was used to generate a propensity score, representing the probability that a TM implant was used at primary THA. The TM and non-TM groups were matched based on the individual propensity scores. Standardised mean differences (SMDs) were examined both before and after matching to assess for any covariate imbalance between the TM and non-TM groups.

Cumulative implant survival rates following primary THA for the three study outcomes were determined using the Kaplan-Meier method. Patients who were alive with a non-revised primary THA were censored on the study end date (30th July 2016). For the purposes of implant survival analysis aseptic revision procedures other than the defined outcomes of interest, such as isolated femoral component revisions or femoral head/acetabular liner only exchanges, were censored on the date of revision surgery. Outcomes following primary THA were compared between the matched TM and non-TM groups using Fine and Gray regression modelling, which accounted for the competing risk of death. The proportional sub-hazards assumption was assessed and satisfied for all analyses. To account for clustering within the matched cohort a robust variance estimator was used in the regression models [19]. Univariable regression models were assessed in the matched cohort as well as adjusted models. These adjusted models accounted for any residual covariate imbalance following matching, defined as an SMD of 10% or more for any covariate following matching [20]. As a sensitivity analysis (not presented) regression was repeated using Cox models, which produced very similar results to the Fine and Gray models.

Results

The matched cohort of 18,200 primary THAs included 9,100 TM hips (3,490 TM Modular and 5,610 Continuum) and 9,100 non-TM hips (6,144 Trilogy and 2,956 Trilogy IT) (Table 1). Most covariates with imbalance between the TM and non-TM groups before matching were appropriately balanced after matching. Four covariates had residual imbalance following matching (age, year of primary THA, ASA grade, and chemical venous thromboembolism prophylaxis), which were adjusted for in the regression analyses.

All-cause revision surgery of any component was performed in 594 hips (3.3%) at a mean time of 1.6 years (range 1 day to 10.0 years) from primary THA. There were 3,412 (18.8%) deaths occurring at a mean time of 3.6 years (range 1 day to 12.8 years) following primary THA. The mean follow-up time for the remaining 14,194 (78.0%) unrevised hips was 3.7 years (range 1.0-12.6 years).

Acetabular component revision for all causes

The overall prevalence of all-cause acetabular component revision was 1.2% (n=211), with these failures occurring at a mean time of 1.3 years (1 day to 8.6 years) after primary THA. The commonest indications for acetabular component revision were dislocation/subluxation (n=100; 47.4% of all acetabular component revisions), infection (n=32; 15.2%), malalignment (n=29; 13.7%), and aseptic loosening (n=23; 10.9%). All-cause acetabular component revision rates were significantly lower in primary THAs with TM implants compared with non-TM implants (Table 2). The 5-year cumulative acetabular component survival rate following primary THA was 99.0% (CI=98.7%-99.2%) in the TM group compared with 98.2% (CI=97.8%-98.5%) in the non-TM group (SHR=0.57, CI=0.43-0.76;

p<0.001) (Figure 1). A regression model adjusting for the four covariates with residual imbalance following matching produced similar results to the unadjusted models (Table 2).

Acetabular component revision for aseptic loosening

The overall prevalence of acetabular component revision for aseptic loosening was 0.13% (n=23), with these occurring at a mean time of 1.2 years (0.02-3.6 years) following primary THA. Revision rates for aseptic acetabular loosening were significantly lower in primary THAs with TM implants compared with non-TM implants (Table 2). The 5-year cumulative implant survival rate free from aseptic acetabular loosening was 99.9% (CI=99.8%-99.9%) in the TM group compared with 99.8% (CI=99.6%-99.9%) in the non-TM group (SHR=0.35, CI=0.14-0.90; p=0.029).

Revision for infection

The overall prevalence of revision for infection was 0.59% (n=108), with revisions performed at a mean time of 1.3 years (0.04-10.0 years) following primary THA. Revision rates for infection were significantly lower in primary THAs with TM implants compared with non-TM implants (Table 2). The 5-year cumulative implant survival rate free from infection after primary THA was 99.5% (CI=99.3%-99.7%) in the TM group compared with 99.1% (CI=98.8%-99.3%) in the non-TM group (SHR=0.51, CI=0.34-0.76; p=0.001).

Discussion

The use of TM coated acetabular components in primary and revision THA has been increasing given that a number of studies have reported good outcomes with these implants, with some suggesting TM implants have lower failure rates compared with non-TM implants [4, 10]. However large cohort studies demonstrating any clinical benefits of TM compared with non-TM implants in primary THA patients are lacking. We used NJR data to compare revision rates following primary THA between TM and non-TM coated acetabular components. The present study observed that in matched patients undergoing primary THA, TM coated implants had a reduced risk of both aseptic and septic revision compared with non-TM implants.

Revision rates following primary THA with conventional bearing surfaces are low,[4, 5] therefore large cohort studies are required to compare implant failures between different primary THA designs. We observed that both TM and non-TM coated acetabular components were associated with low revision rates at 5 years following primary THA. The 5-year acetabular component survival rates for primary TM (99.0%) and non-TM (98.2%) implants observed in this study both meet the top rating (A* which is equivalent to a revision rate of less than 0.5% per year) from the Orthopaedic Data Evaluation Panel (ODEP) [21]. Indeed all four acetabular component designs studied have already achieved the top ODEP rating [21].

In this study however, revision rates for all-causes, aseptic acetabular loosening, and infection were all significantly lower in primary THAs with TM coatings compared with non-TM coatings. The absolute differences in revision rates for all endpoints between primary TM and non-TM implants were relatively small, and could initially be deemed not to be of

clinical significance, especially given that TM implants are more expensive. However in light of the perceived advantages, many surgeons have used TM coated implants in the most complex procedures [8, 10, 15]. Therefore the observed differences in revision rates between primary TM and non-TM implants may be clinically significant if the TM cases studied were largely implanted in complex cases. Despite matching the TM and non-TM groups for some factors that may relate to primary THA complexity (such as age, gender, primary hip diagnosis, and the requirement for bone grafting),[22, 23] it is suspected that this complexity was not adequately controlled for in this registry dataset. Therefore further studies comparing primary TM and non-TM coated implants are not only required at extended follow-up to establish whether the observed differences in implant survival persist, but also to establish if the use of TM is clinically efficacious compared with non-TM components when used to treat patients with similar pathology. Such studies also need to be coupled with cost-effectiveness evaluations regarding the use of TM in primary THA.

Reduced failure rates in TM implants compared with non-TM implants have been reported previously in studies where these components have been used at revision THA [10, 15]. We believe this represents the first large cohort to demonstrate similar findings specifically in primary THA patients. It is suspected that the reduced failure rates in TM implants are a clinical manifestation of the attractive properties of the TM coating; namely the high porosity, high coefficient of friction, possession of a similar modulus of elasticity to cancellous bone, and having an increased potential for osteointegration compared with non-TM implants [7-9]. Studies have observed superior mechanical stability of TM acetabular components compared with non-TM components,[24] with good fixation of TM implants confirmed on radiostereometric analysis at medium-term follow-up after primary THA [11-13]. However given that aseptic component loosening predominantly occurs at long-term follow-up it is

important to continue to monitor the performance of TM implants into the second decade after surgery. Small studies have suggested that TM acetabular components can achieve good outcomes at 15 years following primary THA,[14] and at 10 years following revision THA [16].

A recent study observed that in THAs revised for infection, the use of TM implants was associated with a reduced risk of subsequent septic failure compared with non-TM implants [10]. In primary THAs, we similarly observed decreased revision rates for infection with TM implants compared to non-TM implants. Possible explanations for the reduced risk of infection associated with TM coated implants include the increased potential for osteointegration which subsequently reduces the dead space for colonising organisms, and the TM surface being more hostile to organisms possibly due to its three-dimensional structure or other unidentified property [7, 10]. Further research is required to investigate the potential antibacterial properties of TM coated implants to infecting organisms given that periprosthetic joint infection continues to pose a devastating problem to arthroplasty patients with limited advances made in its treatment over the last decade [6].

Strengths and limitations

Study strengths include using linked data from the world's largest arthroplasty registry, which ensures adequate statistical power. Furthermore assessing an unselected population reduces the likelihood of sampling bias. Therefore it is suspected that the findings have good external validity and generalisability, though this requires formal validation. Only acetabular components with identical designs apart from the TM surface coating were studied to reduce the risk of confounding related to any other design features. Furthermore robust statistical methods were used, which included having a large propensity matched comparator group,

which reduces the risk of the findings being influenced by other potential patient and surgical confounding factors. Finally, recent studies validating NJR data reported that when procedures were captured within the NJR the data completion and accuracy were excellent [25, 26].

This study has recognised limitations. Using observational data means causality cannot be inferred. Although a randomised controlled trial would be the ideal study design to assess revision rates between two different implants, these are unlikely to be feasible given the large patient numbers required for adequate statistical power. Revision rates following primary THA in registries can be underestimated,[25, 26] therefore the observed implant survival rates represent a best-case scenario. However we suspect that this potential underreporting would not differ between the TM and non-TM groups. The NJR does not collect histopathological and microbiological data, therefore revision rates reported for specific aseptic and septic endpoints presented may differ from the true rates. Registries do not collect radiological data to assess component migration, although this has been studied extensively [11-13]. Registries do not collect data on non-revision procedures, such as those performed for dislocations (closed reductions), infections (debridement and washout), and periprosthetic fractures (internal fixation), which represents an important outcome measure.

Despite matching the TM and non-TM groups there is potential for residual confounding. This is most relevant when considering case complexity. Although this variable was not adequately accounted for within the NJR, the findings supported lower revision rates in patients receiving primary TM cups despite these designs being more frequently used in complex procedures [8, 10, 15]. Nevertheless further studies are needed to assess the clinical efficacy of TM implants compared with non-TM implants in primary THA patients with

similar degrees of case complexity, with our data being useful to power such studies. Matching may also have reduced the generalisibility of our findings given that only 35% of the unmatched cohort was included in the matched analysis. However the significant baseline difference between the TM and non-TM groups (Table 1) could not have been adequately addressed using multivariable regression analysis, therefore supporting the matched approach. Missing BMI data could have potentially affected our analysis, however BMI was appropriately balanced between the TM and non-TM groups after matching (Table 1: SMD of less than 10%). The NJR does not collect data on important factors such as patient smoking status, comorbidities (including diabetes, rheumatoid arthritis, and other conditions causing immunosuppression) and medication use (steroids and immunosuppression drugs). The present study is limited by not being able to match the TM and non-TM groups for these factors given that they may influence revision rates, specifically revisions performed for infection. It is recommended that future studies match for these important factors, for example by using the Charlson Comorbidity Index. Finally, the findings cannot be assumed to apply to similar highly porous acetabular component designs produced by other manufacturers.

Conclusions

This large nationwide study observed that both TM and non-TM coated acetabular components were associated with low revision rates at 5 years following primary THA. However, in matched patients undergoing primary THA, TM coated implants had a reduced risk of both aseptic and septic revision compared with non-TM implants. Although the differences in revision risk between the groups were small, they may be clinically significant if the TM designs were implanted in the most complex cases. Future studies should assess whether the observed differences in revision rates persist at extended follow-up. Furthermore

it must be determined whether the use of TM coated acetabular components in primary THA is clinically efficacious given their increased cost.

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Figure 1

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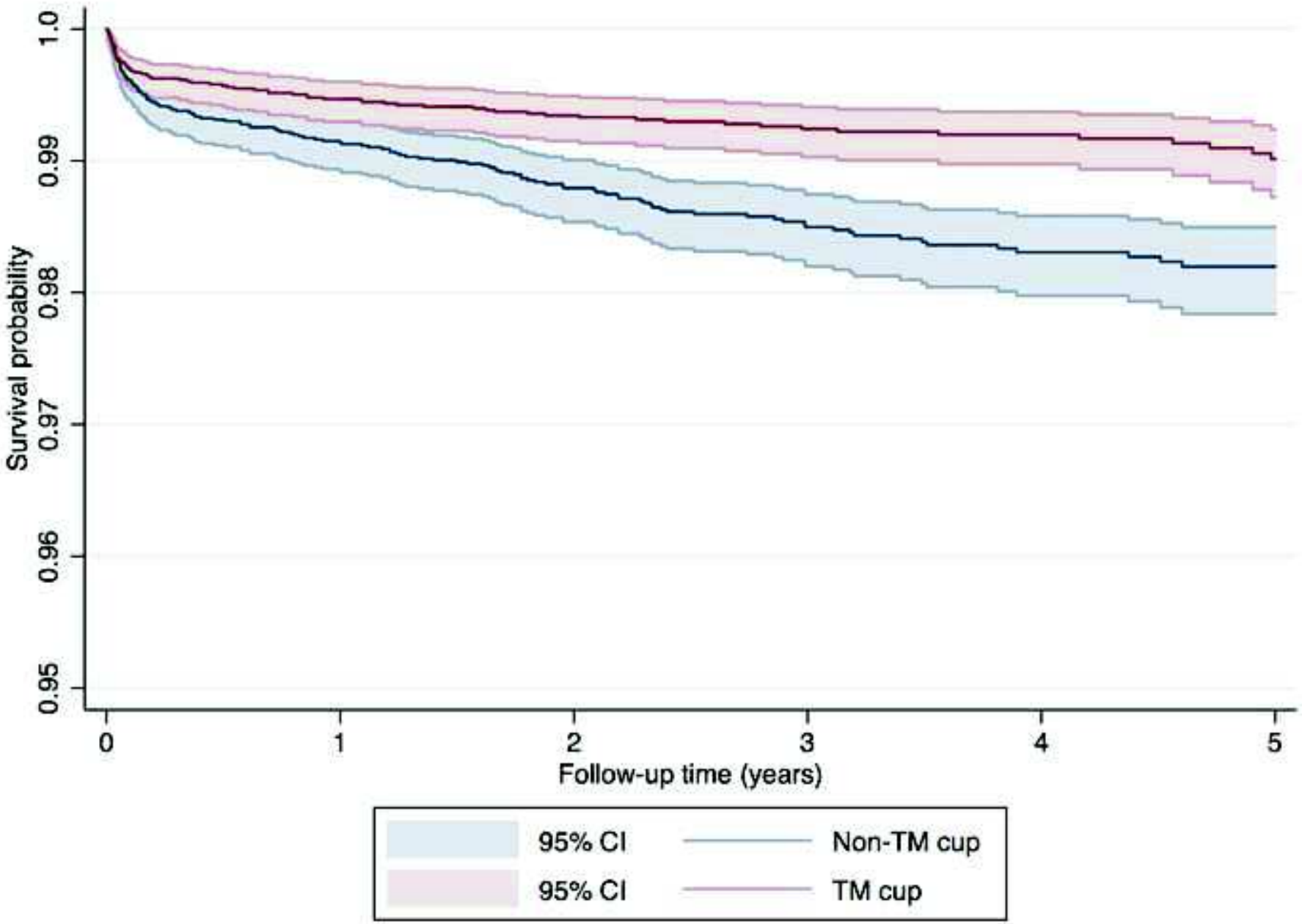

Figure Legends

Figure 1 Cumulative acetabular component survival rate following primary total hip arthroplasty at up to five-years in trabecular metal and non-trabecular metal coated implants

CI = confidence interval; TM = trabecular metal

Shaded area represents the respective upper and lower limits of the 95% confidence interval

Table 1 Patient and surgical factors before and after propensity score matching

	Unmatched cohort				Matched cohort			
	All primary THAs (n=51,966) (100%)	**Non-TM cups (n=39,910) (76.8%)**	**TM cups (n=12,056) (23.2%)**	**SMD**	**All primary THAs (n=18,200) (100%)**	**Non-TM cups (n=9,100) (50%)**	**TM cups (n=9,100) (50%)**	**SMD**
Covariate								
Gender								
Female *vs. male*	32,127 (61.8)	24,954 (62.5)	7,173 (59.5)	0.062	11,291 (62.0)	5,625 (61.8)	5,666 (62.3)	0.009
Age at primary (yr)								
Mean (SD)	68.4 (11.1)	69.5 (10.1)	64.8 (13.2)	**0.394**	68.0 (12.4)	68.8 (12.1)	67.2 (12.6)	**0.130**
BMI (kg/m^2) *								
Mean (SD)	28.5 (5.3)	28.3 (5.2)	29.1 (5.7)	**0.133**	28.7 (5.5)	28.6 (5.3)	28.9 (5.7)	0.055
Bilateral hips	9,677 (18.6)	7,499 (18.8)	2,178 (18.1)	0.019	2,919 (16.0)	1,353 (14.9)	1,566 (17.2)	0.064
Primary diagnosis								
Primary OA *vs. other*	47,820 (92.0)	37,347 (93.6)	10,473 (86.9)	**0.227**	15,897 (87.4)	7,864 (86.4)	8,033 (88.3)	0.056
Primary year								
2002	2 (0.004)	2 (0.01)	0 (0.0)	**0.829**	0 (0.0)	0 (0.0)	0 (0.0)	**0.180**
2003	625 (1.2)	624 (1.6)	1 (0.01)		5 (0.03)	4 (0.04)	1 (0.01)	
2004	1,494 (2.9)	1,490 (3.7)	4 (0.03)		14 (0.08)	10 (0.1)	4 (0.04)	
2005	2,120 (4.1)	2,070 (5.2)	50 (0.4)		143 (0.79)	93 (1.0)	50 (0.5)	
2006	2,950 (5.7)	2,814 (7.1)	136 (1.1)		368 (2.0)	232 (2.5)	136 (1.5)	
2007	3,434 (6.6)	3,146 (7.9)	288 (2.4)		738 (4.1)	452 (5.0)	286 (3.1)	
2008	3,747 (7.2)	3,426 (8.6)	321 (2.7)		785 (4.3)	466 (5.1)	319 (3.5)	
2009	3,849 (7.4)	3,432 (8.6)	417 (3.5)		867 (4.8)	472 (5.2)	395 (4.3)	
2010	4,120 (7.9)	2,881 (7.2)	1,239 (10.3)		1,772 (9.7)	918 (10.1)	854 (9.4)	
2011	5,469 (10.5)	3,562 (8.9)	1,907 (15.8)		2,379 (13.1)	1,176 (12.9)	1,203 (13.2)	
2012	5,964 (11.5)	3,875 (9.7)	2,089 (17.3)		2,685 (14.8)	1,282 (14.1)	1,403 (15.4)	
2013	6,222 (12.0)	4,266 (10.7)	1,956 (16.2)		2,791 (15.3)	1,318 (14.5)	1,473 (16.2)	
2014	7,416 (14.3)	5,071 (12.7)	2,345 (19.5)		3,493 (19.2)	1,643 (18.1)	1,850 (20.3)	
2015	4,554 (8.8)	3,251 (8.2)	1,303 (10.8)		2,160 (11.9)	1,034 (11.4)	1,126 (12.4)	
Primary ASA grade								
1	8,418 (16.2)	6,262 (15.7)	2,156 (17.9)	0.097	2,602 (14.3)	1,203 (13.2)	1,399 (15.4)	**0.129**
2	35,533 (68.4)	27,709 (69.4)	7,824 (64.9)		11,783 (64.7)	5,760 (63.3)	6,023 (66.2)	
3 or above	8,015 (15.4)	5,939 (14.9)	2,076 (17.2)		3,815 (21.0)	2,137 (23.5)	1,678 (18.4)	
VTE – chemical								
LMWH (+/-other)	36,809 (70.8)	28,492 (71.4)	8,317 (69.0)	**0.441**	12,404 (68.2)	6,023 (66.2)	6,381 (70.1)	**0.106**
Aspirin only	3,858 (7.4)	3,498 (8.8)	360 (3.0)		604 (3.3)	316 (3.5)	288 (3.2)	
Other	6,906 (13.3)	4,119 (10.3)	2,787 (23.1)		3,918 (21.5)	2,017 (22.2)	1,901 (20.9)	
None	4,393 (8.5)	3,801 (9.5)	592 (4.9)		1,274 (7.0)	744 (8.2)	530 (5.8)	
VTE – mechanical								
Any *vs. none*	47,960 (92.3)	36,805 (92.2)	11,155 (92.5)	0.012	17,079 (93.8)	8,513 (93.6)	8,566 (94.1)	0.024
Surgeon grade								
Consultant *vs. other*	40,040 (77.1)	29,565 (74.1)	10,475 (86.9)	**0.327**	15,389 (84.6)	7,730 (84.9)	7,659 (84.2)	0.022
Surgical approach								
Posterior *vs. other*	35,035 (67.4)	26,849 (67.3)	8,186 (67.9)	0.013	12,163 (66.8)	6,028 (66.2)	6,135 (67.4)	0.025
Stem fixation								
Cemented	35,868 (69.0)	29,908 (74.9)	5,960 (49.4)	**0.545**	10,707 (58.8)	5,344 (58.7)	5,363 (58.9)	0.004
Uncemented	16,098 (31.0)	10,002 (25.1)	6,096 (50.6)		7,493 (41.2)	3,756 (41.3)	3,737 (41.1)	

Femoral head size (mm)								
Mean (SD)	32.1 (3.3)	31.6 (3.2)	34.1 (3.0)	**0.818**	33.6 (2.8)	33.6 (2.8)	33.5 (2.8)	0.026
Bearing surface								
MoP	34,638 (66.7)	29,406 (73.7)	5,232 (43.4)	**0.820**	10,128 (55.7)	5,160 (56.7)	4,968 (54.6)	0.045
CoP	12,221 (23.5)	9,028 (22.6)	3,193 (26.5)		5,306 (29.2)	2,567 (28.2)	2,739 (30.1)	
CoC	5,107 (9.8)	1,476 (3.7)	3,631 (30.1)		2,766 (15.2)	1,373 (15.1)	1,393 (15.3)	
Bone graft (femoral)	200 (0.4)	123 (0.3)	77 (0.6)	0.048	104 (0.6)	57 (0.6)	47 (0.5)	0.015
Bone graft (acetabular)	2,834 (5.5)	2,068 (5.2)	766 (6.4)	0.050	1,214 (6.7)	631 (6.9)	583 (6.4)	0.021

ASA = American Society of Anesthesiologists; BMI = body mass index; CoC = ceramic-on-ceramic; CoP = ceramic-on-polyethylene; LMWH = low molecular weight heparin; MoP = metal-on-polyethylene; OA = osteoarthritis; SD = standard deviation; SMD = standardised mean difference; THA = total hip arthroplasty; TM = trabecular metal; VTE = venous thromboembolism.

Values in brackets are percentages unless otherwise indicated.

***** Missing data for stated number of hips**:** BMI (n=21,310).

Standardised mean differences of 10% or more ($\geq$0.100) have been highlighted in bold text

Table 2 Outcomes following primary total hip arthroplasty using trabecular metal and non-trabecular metal coated acetabular components in the matched cohort

Matched cohort	Number of hips (%)	5-year all-cause cup revision (95% CI)	5-year aseptic cup loosening revision (95% CI)	5-year revision for infection (95% CI)
Overall	18,200 (100)	98.6% (98.4%-98.8%)	99.8% (99.8%-99.9%)	99.3% (99.1%-99.4%)
TM cup	9,100 (50)	99.0% (98.7%-99.2%)	99.9% (99.8%-99.9%)	99.5% (99.3%-99.7%)
Non-TM cup	9,100 (50)	98.2% (97.8%-98.5%)	99.8% (99.6%-99.9%)	99.1% (98.8%-99.3%)
Univariable SHR (95% CI)		0.57 (0.43-0.76) **p < 0.001**	0.35 (0.14-0.90) **p = 0.029**	0.51 (0.34-0.76) **p = 0.001**
Adjusted SHR * (95% CI)		0.53 (0.40-0.70) **p < 0.001**	0.29 (0.12-0.71) **p = 0.007**	0.46 (0.31-0.69) **p < 0.001**

CI = confidence interval; SHR = sub-hazard ratio; TM = trabecular metal

Sub-hazard ratios below 1 represent a reduced risk of the specified outcome in TM cups.

* Regression models were adjusted for four covariates with residual imbalance following matching (age, year of primary surgery, ASA grade, and chemical venous thromboembolism prophylaxis).

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