■ HIP

# Using an asymmetric crosslinked polyethylene liner in primary total hip arthroplasty is associated with a lower risk of revision surgery

## AN ANALYSIS OF THE NATIONAL JOINT REGISTRY

**E. T. Davis,**
**J. Pagkalos,**
**B. Kopjar**

*From Royal Orthopaedic Hospital NHS Foundation Trust, Birmingham, UK*


### Aims
**The aim of our study was to investigate the effect of asymmetric crosslinked polyethylene liner use on the risk of revision of cementless and hybrid total hip arthroplasties (THAs).**

### Methods
**We undertook a registry study combining the National Joint Registry dataset with polyethylene manufacturing characteristics as supplied by the manufacturers. The primary endpoint was revision for any reason. We performed further analyses on other reasons including instability, aseptic loosening, wear, and liner dissociation. The primary analytic approach was Cox proportional hazard regression.**

### Results
**A total of 213,146 THAs were included in the analysis. Overall, 2,997 revisions were recorded, 1,569 in THAs with a flat liner and 1,428 in THAs using an asymmetric liner. Flat liner THAs had a higher risk of revision for any reason than asymmetric liner THAs when implanted through a Hardinge/anterolateral approach (hazard ratio (HR) 1.169, 95% confidence interval (CI) 1.022 to 1.337) and through a posterior approach (HR 1.122, 95% CI 1.108 to 1.346). There was no increased risk of revision for aseptic loosening when asymmetric liners were used for any surgical approach. A separate analysis of the three most frequently used crosslinked polyethylene liners was in agreement with this finding. When analyzing THAs with flat liners only, THAs implanted through a Hardinge/anterolateral approach were associated with a reduced risk of revision for instability compared to posterior approach THAs (HR 0.561 (95% CI 0.446 to 0.706)). When analyzing THAs with an asymmetric liner, there was no significant difference in the risk of revision for instability between the two approaches (HR 0.838 (95% CI 0.633 to 1.110)).**

### Conclusion
**For THAs implanted through the posterior approach, the use of asymmetric liners reduces the risk of revision for instability and revision for any reason. In THAs implanted through a Hardinge/anterolateral approach, the use of an asymmetric liner was associated with a reduced risk of revision. The effect on revision for instability was less pronounced than in the posterior approach.**


**Cite this article:** ***Bone Joint J*** **2021;103-B(9):1479–1487.**

### Introduction
Total hip arthroplasty (THA) remains a common procedure with 95,677 cases recorded in the National Joint Registry (NJR) in 2019.[1] Instability remains a considerable problem and was recorded as a reason for revision surgery in 17.2% of hip arthroplasty revisions.[1] As modern bearing surfaces markedly reduced the risk of revision for aseptic loosening,[2] instability remains the commonest reason for early revision.[3] A recent systematic review[4] summarized the published THA dislocation rate between 0.5%[5] and 7.2%.[6]

Instability following THA has a multifactorial aetiology, including surgical approach,[7] head

Correspondence should be sent to E. T. Davis; email: edward.davis@nhs.net


doi:10.1302/0301-620X.103B9.BJJ-2021-0365.R1 $2.00

*Bone Joint J*
2021;103-B(9):1479–1487.

**Table I.** Baseline characteristics in asymmetric and flat liner total hip arthroplasties.

| Characteristic | Asymmetric liner, n (%) | Flat liner, n (%) |
|---|---|---|
| **Age, yrs** | | |
| < 55 | 9,891 (8.6) | 7,372 (7.5) |
| 55 to 64 | 24,751 (21.6) | 18,789 (19.1) |
| 65 to 74 | 44,943 (39.2) | 38,265 (38.9) |
| 75 and over | 35,195 (30.7) | 33,940 (34.5) |
| **Sex** | | |
| Male | 46,284 (40.8) | 59,816 (60) |
| Female | 67,239 (59.2) | 39,805 (40) |
| **Approach** | | |
| Hardinge/anterolateral | 23,471 (20.7) | 32,800 (32.9) |
| Other | 3,396 (3) | 5,893 (5.9) |
| Posterior | 86,658 (76.3) | 60,928 (61.2) |
| **Head material** | | |
| Metal | 72,808 (66.8) | 62,677 (61.1) |
| Ceramic* | 36,115 (33.2) | 39,942 (38.9) |
| **Stem fixation** | | |
| Cemented | 44,211 (39.3) | 44,595 (45.3) |
| Cementless | 68,188 (60.7) | 53,773 (54.7) |
| **Head size, mm** | | |
| ≤ 32 mm | 90,475 (79.7) | 51,595 (51,8%) |
| ≥ 36 mm | 23,050 (20.3) | 48,025 (48.2%) |
| **Indication** | | |
| Osteoarthritis | 105,079 (92.6) | 91,393 (91.7) |
| Other | 8,446 (7.4) | 8,228 (8.3) |
| **Follow-up, yrs** | | |
| Mean person-time | 4.3 | 4.4 |
| Maximum | 14.5 | 13.6 |
| **Outcome** | | |
| Not revised | 105,613 (93) | 90,916 (91.3) |
| Revised (any reason) | 1,428 (1.3) | 1,569 (1.6) |
| Revised for instability† | 326 | 412 |
| Revised for aseptic loosening† | 266 | 286 |
| Revised for wear† | 39 | 58 |
| Revised for liner dissociation† | 30 | 49 |
| Censored | 6,484 (5.7) | 7,136 (7.2) |

*Includes ceramicized metal.
†Categories not mutually exclusive; multiple reasons can be recorded per revision.

size,[8] and more recently spinopelvic mobility.[9,10] When using a polyethylene-based bearing surface, surgeons have the option of using a liner with a flat or an asymmetric face. Depending on the exact morphology, the terms 'lipped', 'elevated rim', and 'hooded' are used.[11-13] This asymmetry allows for an increase in the travelling distance of the femoral head before dislocation of the prosthetic joint can occur with a view to ensuring stability through the functional range of motion.[14]

Several studies have reported on the beneficial effect of this liner design on the risk of dislocation following THA.[12,15] Their use has, however, raised concerns about increased impingement with several retrieval studies reporting higher levels of impingement damage in elevated rim liners.[16] The potential effects of impingement can be loosening of the components due to accelerated polyethylene wear[17] or increased torque and/or rim fracture leading to failure.[18] When subjected to impingement damage and edge loading, crosslinked polyethylene can behave differently to conventional polyethylene.[19] Previous studies using data from the NJR and other registries have reported a reduced risk of revision for instability and aseptic loosening with the use of lipped liners.[2,11,13] Despite these reports, the hip arthroplasty community remains sceptical about the validity of this finding and attribute the association to unaccounted confounding factors.[20]

The aim of our study was to investigate the effect of asymmetric, crosslinked polyethylene (XLPE) liner use in primary THA on the risk of revision for different indications after accounting for relevant confounding factors.

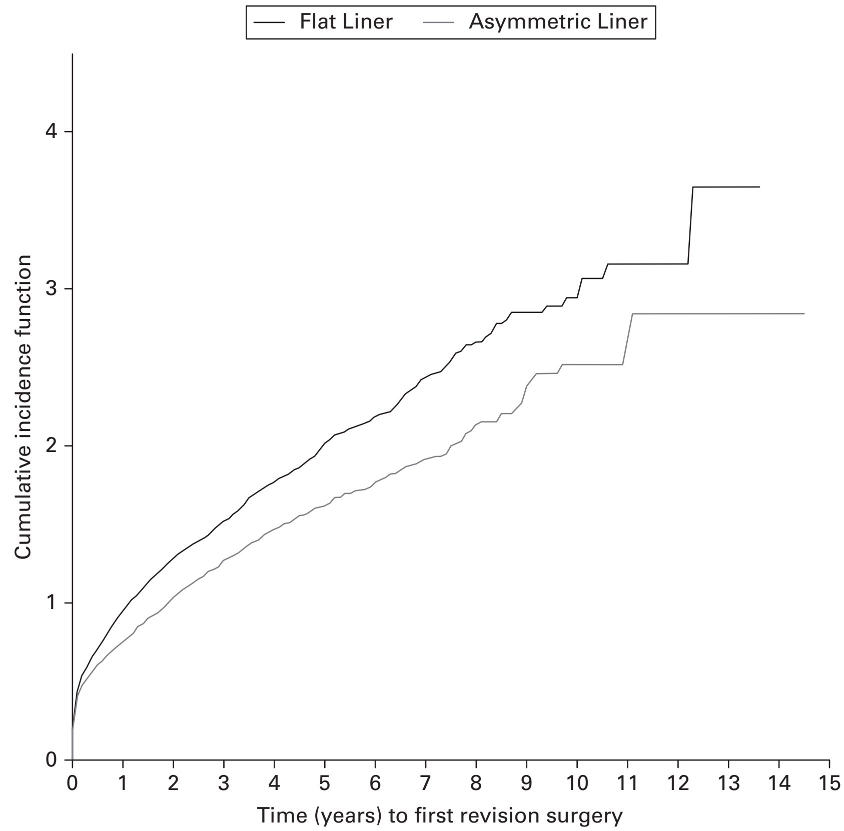
## Methods

Two data sources were used in our analysis: the NJR dataset provided patient and prosthesis characteristics, and the dataset supplied by the manufacturers provided details on polyethylene modifications. Our analysis was restricted to THAs with an uncemented acetabular component (cementless and hybrid THAs), due to the differing geometry and failure mechanisms between cemented and uncemented acetabular components.[21] To further eliminate confounding factors and focus on current bearing choices, we restricted the sample to polyethylene liners irradiated with 5MRad or more, classified as highly crosslinked (XLPE), in keeping with our previous work and other registries.[2,22,23] Our methodology has been described in detail in our previous study on polyethylene modifications.[2]

The surgical approach has been recorded in the NJR primary hip arthroplasty data collection form as 'posterior', 'Hardinge/ Anterolateral', 'Trochanteric Osteotomy', and 'other'. The direct anterior approach has been an option on the data collection form since 2018. As our dataset predates this and therefore did not include direct anterior approach as an option, this approach does not feature in the analysis. The trochanteric osteotomy THAs were merged with 'other' due to the low numbers on the registry.

The polyethylene liner product details were used to classify liners as symmetric (flat) or asymmetric. Liners described as 'elevated', 'hooded', 'lipped', 'oblique', '10°', '15°', '20°', '30°', 'asymmetric', 'posterior wall', 'high wall', and 'long posterior wall (LPW)' were classified and described collectively here as asymmetric.

The primary endpoint was revision of any component. Where no revision was recorded by the last follow-up (28 July 2016), the observation was censored. When patients passed away without undergoing revision, the observation was censored at the time of death. We investigated the risk of revision for any reason, aseptic loosening, dislocation, wear, and liner dissociation. Exploratory analysis was based on Kaplan-Meier product limit estimator followed by a multivariate Cox proportional hazard regression model. The characteristics included in the Cox model were age, sex, liner asymmetry, approach, head material, stem fixation method, head size, and indication for implantation. The competing risk of death was accounted for during survival analyses to obtain cumulative incidence function (CIF) estimates (Gray CIF method).[24] During cause-specific analyses, revision for other reasons was treated as a competing risk too. Femoral




| OCY | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asym. | 113,525 | 94,441 | 73,164 | 54,334 | 38,502 | 25,769 | 16,287 | 9,311 | 4,657 | 2,321 | 1,204 | 516 |
| Flat | 99,621 | 82,574 | 63,828 | 47,623 | 35,110 | 24,514 | 16,447 | 9,978 | 5,280 | 2,692 | 1,305 | 623 |

Fig. 1

Cumulative incidence function of revision for any reason by liner symmetry (all crosslinked polyethylene liners). OCY, observed component years.

head composition of ceramic and ceramicized metal were merged together due to similar risk in exploratory analyses.

An additional product-specific analysis was performed limiting the sample to the three most common XLPE liner products in the registry that were used in both a flat and an asymmetric version. The three XLPE products included in this analysis were the Longevity (Zimmer Biomet, USA), Marathon (DePuy Synthes, USA) and X3 (Stryker, USA).

**Statistical analysis.** All analyses were performed using SAS/STAT software for PC, v. 9.4 (SAS Institute, USA). Approvals were granted by the NJR Research Committee and the Trust Research & Development department. A p-value < 0.05 was considered statistically significant.

## Results

**Reasons for revision.** A total of 213,146 THAs were included in the analysis. Revisions were recorded in 2,997 of THAs with 1,569 in THAs with flat liners and 1,428 in THAs using an asymmetric liner (Table I). The cumulative incidence of revision at ten years was 2.94 per 100 THAs for flat liners (95% CI 2.70 to 3.21) and 2.52 per 100 THAs for asymmetric liner THAs (95% CI 2.24 to 2.82; p < 0.001) (Figure 1). The Cox regression hazard ratios for revision for any reason, aseptic loosening, and instability can be seen in Table II. The association between the surgical approach and the use of an asymmetric liner is presented in Table III and Table IV.

A total of 552 revisions for aseptic loosening were recorded: 286 in THAs with flat liners and 266 in THAs with asymmetric liners. The cumulative incidence of revision for aseptic loosening at ten years was 0.57 per 100 THAs (95% CI 0.48 to 0.66) for flat liner THAs and 0.44 per 100 THAs (95% CI 0.37 to 0.52) for asymmetric liner THAs (p = 0.033; Figure 2).

A total of 738 revisions for instability were recorded, 412 in flat liner THAs and 326 in asymmetric liner THAs. The cumulative incidence of revision for instability at 10 years was 0.61 per 100 THAs (95% CI 0.53 to 0.70) for THAs with flat liners and 0.50 per 100 THAs (95% CI 0.40 to 0.61) for THAs with asymmetric liners (p = 0.018, Gray test; Figure 3).

Wear was recorded as a reason for revision in 97 THAs; 58 with a flat liner and 39 THAs with an asymmetric liner. The cumulative incidence of revision for wear at ten years was 0.15 per 100 THAs (95% CI 0.10 to 0.23) for flat liner THAs and 0.11 per 100 THAs (95% CI 0.05 to 0.22) for asymmetric liner THAs (p = 0.016, Gray test). Liner dissociation was recorded as

**Table II.** Cox regression hazard ratios for revision due to any reason, aseptic loosening, and instability.

| Parameter | Revision for instability, HR (95% CI) | Revision for aseptic loosening, HR (95% CI) | Revision for any reason, HR (95% CI) |
|---|---|---|---|
| **Age, yrs** | | | |
| 55 to 64 | 0.786 (0.587 to 1.053) | 0.710 (0.528 to 0.956) | 0.809 (0.701 to 0.934) |
| 65 to 74 | 0.777 (0.590 to 1.024) | 0.555 (0.418 to 0.738) | 0.756 (0.660 to 0.865) |
| 75 and over | 0.855 (0.642 to 1.139) | 0.379 (0.276 to 0.520) | 0.725 (0.629 to 0.836) |
| < 55 | 1 | 1 | 1 |
| **Sex** | | | |
| Male | 1.022 (0.877 to 1.191) | 1.147 (0.959 to 1.371) | 1.112 (1.032 to 1.200) |
| Female | 1 | 1 | 1 |
| **Liner asymmetry** | | | |
| No | 1.788 (1.523 to 2.099) | 1.044 (0.871 to 1.250) | 1.195 (1.104 to 1.293) |
| Yes | 1 | 1 | 1 |
| **Approach** | | | |
| Hardinge | 0.653 (0.544 to 0.785) | 1.603 (1.338 to 1.922) | 1.167 (0.770 to 1.119) |
| Other | 0.429 (0.268 to 0.688) | 0.967 (0.608 to 1.538) | 0.928 (0.770 to 1.119) |
| Posterior | 1 | 1 | 1 |
| **Head material** | | | |
| Metal | 1.250 (1.046 to 1.495) | 1.263 (1.042 to 1.532) | 1.230 (1.130 to 1.340) |
| Ceramic* | 1 | 1 | 1 |
| **Stem fixation** | | | |
| Cemented | 0.953 (0.818 to 1.11) | 0.450 (0.367 to 0.553) | 0.765 (0.707 to 0.827) |
| Cementless | 1 | 1 | 1 |
| **Head size, mm** | | | |
| ≤ 32 | 1.957 (1.635 to 2.342) | 0.557 (0.460 to 0.675) | 0.900 (0.829 to 0.977) |
| ≥ 36 | 1 | 1 | 1 |
| **Indication** | | | |
| Other | 2.171 (1.765 to 2.672) | 1.047 (0.761 to 1.441) | 1.541 (1.371 to 1.733) |
| Osteoarthritis | 1 | 1 | 1 |

*Includes ceramicized metal.
CI, confidence interval; HR, hazard ratio; N/A, not applicable.

**Table III.** Cox regression hazard ratios revision due to any reason, aseptic loosening, and instability and interaction for surgical approach.

| Liner | Approach comparison | Revision for instability, HR (95% CI) | Revision for aseptic loosening, HR (95% CI) | Revision for any reason, HR (95% CI) |
|---|---|---|---|---|
| Flat | Hardinge vs other | 1.529 (0.841 to 2.779) | 1.614 (0.913 to 2.885) | 1.327 (1.042 to 1.690) |
| Flat | Hardinge vs posterior | 0.561 (0.446 to 0.706) | 1.790 (1.393 to 2.300) | 1.144 (1.026 to 1.274) |
| Flat | Other vs posterior | 0.367 (0.206 to 0.654) | 1.109 (0.626 to 1.963) | 0.862 (0.679 to 1.094) |
| Asymmetric | Hardinge vs other | 1.441 (0.623 to 3.331) | 1.776 (0.772 to 4.084) | 1.138 (0.831 to 1.559) |
| Asymmetric | Hardinge vs posterior | 0.838 (0.633 to 1.110) | 1.415 (1.079 to 1.854) | 1.195 (1.057 to 1.351) |
| Asymmetric | Other vs posterior | 0.582 (0.259 to 1.306) | 0.797 (0.352 to 1.800) | 1.050 (0.776 to 1.422) |

CI, confidence interval; HR, hazard ratio.

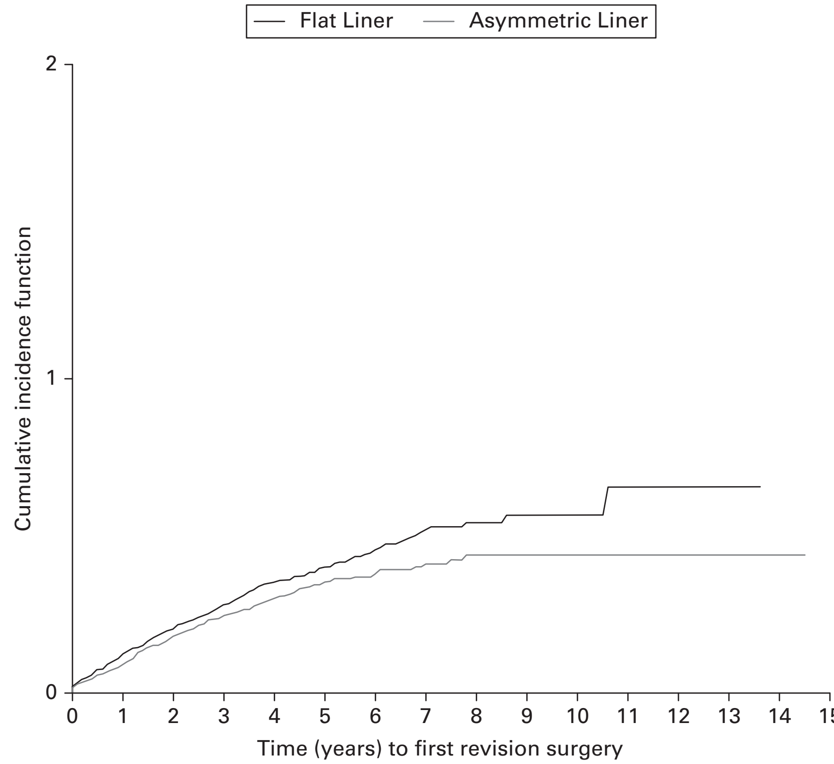
**Table IV.** Cox regression hazard ratios revision due to any reason, aseptic loosening, and instability and interaction for asymmetric liner use.

| Approach | Liner comparison | Revision for instability, HR (95% CI) | Revision for aseptic loosening, HR (95% CI) | Revision for any reason, HR (95% CI) |
|---|---|---|---|---|
| Hardinge | Flat vs asymmetric | 1.323 (0.963 to 1.816) | 1.190 (0.895 to 1.582) | 1.169 (1.022 to 1.337) |
| Posterior | Flat vs asymmetric | 1.976 (1.650 to 2.367) | 0.940 (0.739 to 1.197) | 1.122 (1.108 to 1.346) |
| Other | Flat vs asymmetric | 1.246 (0.468 to 3.320) | 1.309 (0.497 to 3.448) | 1.002 (0.690 to 1.456) |

CI, confidence interval; HR, hazard ratio.

a reason for revision in 79 THAs, 49 THAs with a flat liner and 30 THAs with an asymmetric liner. The cumulative incidence of revision for liner dissociation at ten years was 0.11 (95% CI 0.07 to 0.16) for THAs with a flat liner and 0.07 (95% CI 0.03 to 0.12) for THAs with an asymmetric liner ($p = 0.010$, Gray test).

**Liner asymmetry and surgical approach.** Flat liner THAs had a higher risk of revision for any reason than asymmetric liner THAs when implanted through a Hardinge/anterolateral and through a posterior approach. There was no difference in THAs implanted through other approaches. There was no difference in risk of revision for aseptic loosening between flat and asymmetric liner THAs for any surgical approach. In addition, the use of an asymmetric liner was associated with a reduced risk of revision for instability in THAs implanted through the posterior approach. When analyzing THAs with flat liners, THAs implanted through a Hardinge/anterolateral approach were associated with a reduced risk of revision for instability compared to posterior approach THAs (HR 0.561 (95% CI 0.446 to




| OCY | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asym. | 113,525 | 94,411 | 73,164 | 54,344 | 38,502 | 25,769 | 16,287 | 9,311 | 4,657 | 2,321 | 1,204 | 516 |
| Flat | 99,621 | 82,574 | 63,828 | 47,623 | 35,110 | 24,514 | 16,447 | 9,978 | 5,280 | 2,692 | 1,305 | 623 |

Fig. 2

Cumulative incidence function of revision for aseptic loosening by liner symmetry (all crosslinked polyethylene liners).

0.706)). When analyzing THAs with asymmetric liners, there was no significant difference in the risk of revision for instability between THAs implanted through a Hardinge/anterolateral approach and posterior approach THAs (HR 0.838 (95% CI 0.633 to 1.110); Table III).

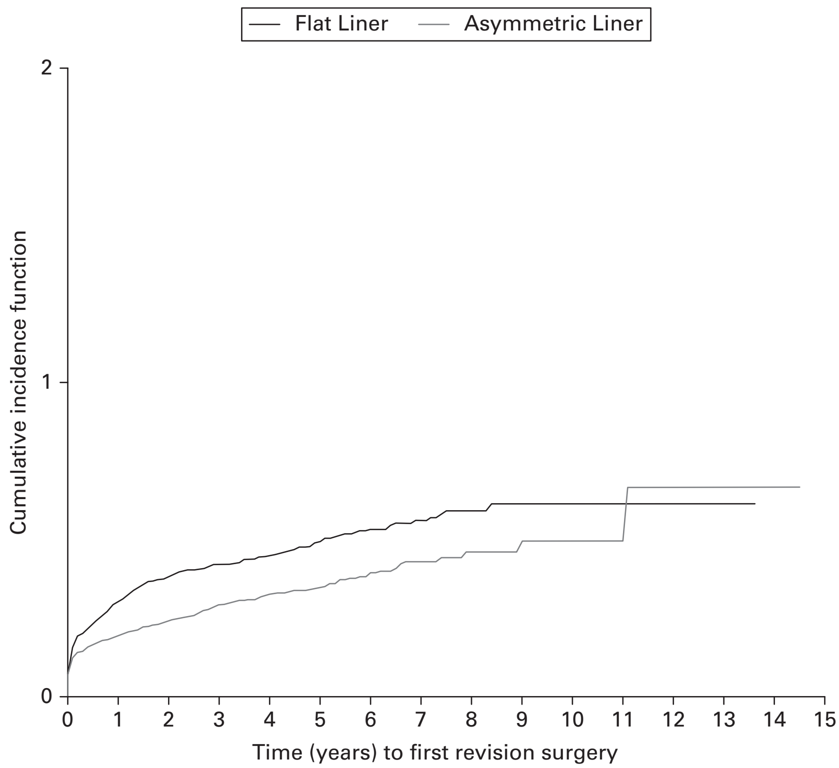
**Common product analysis.** A total of 160,320 THAs were included in the product-specific analysis; 2,303 revisions (for any reason) were recorded with 1,180 in flat liner THAs and 1,123 revisions in THAs with asymmetric liners. When the three commonly used product THAs were combined, the cumulative incidence of revision for any reason at ten years was 3.05 per 100 THAs (95% CI 2.79 to 3.34) for flat liner THAs and 2.54 per 100 THAs (95% CI 2.21 to 2.90) for asymmetric liner THAs ($p < 0.001$). The Cox regression hazard ratios for revision (any reason) per product can be seen in Table V and Figure 4.

## Discussion

Our analysis revealed a reduced risk of revision for all reasons and for instability in THAs using asymmetric XLPE liners. There was no significant increase in the risk of revision for aseptic loosening between asymmetric and flat XLPE liner THAs. The analyses of revisions for wear and liner dissociation were limited by the small number of events (revisions). However, the risk of revision for wear and liner dissociation was significantly lower in asymmetric liner THAs. The association between asymmetric liner use and surgical approach was further investigated. When the posterior approach is used, the risk of revision for instability was significantly reduced with the use of an asymmetrical liner. When analyzing THAs with asymmetric liners, there was no significant difference in the risk of revision for instability between THAs implanted through a Hardinge/anterolateral approach and the posterior approach.

Our findings are in agreement with a study on hooded liners using the Australian Orthopaedic Association National Joint Arthroplasty Registry (AOANJRR) dataset.[13] The authors reported a higher risk of revision for instability when flat (non-hooded) liners were used (HR 1.31 (95% CI 1.17 to 1.47)). This is in keeping with the reduction seen in our study. The authors reported a protective effect of hooded liners (revision for instability) in both THAs with head sizes of 32 mm and those using heads larger than 32 mm. This is also in keeping with our finding of a reduced risk of revision for instability when controlling for head size. In addition, our study investigated the effect of surgical approach on the risk of revision for instability, which was not accounted for in the study by Bauze et al.[13]

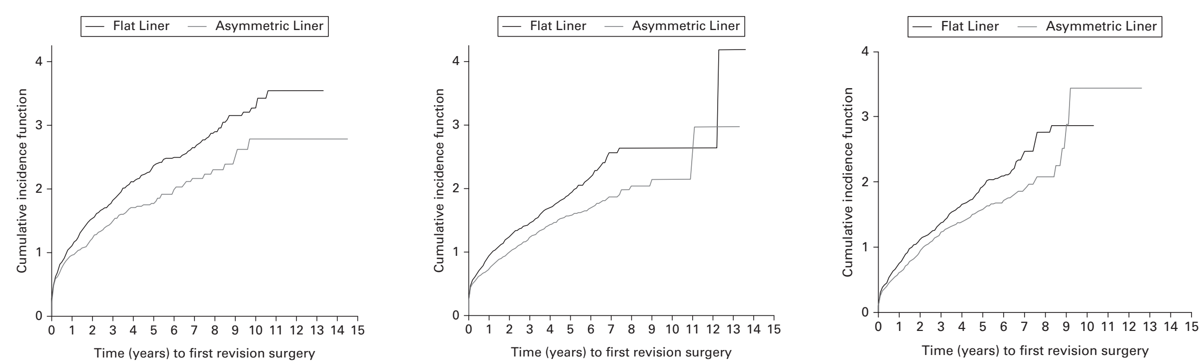
Our findings agree with the study by Wyatt et al[11] using the New Zealand Joint Registry dataset. The authors included surgical approach in their multivariate regression analysis and identified a higher risk of revision for instability (HR 1.84 (95% CI 1.41 to 2.41)), when flat (neutral) liners were used.




| OCY | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asym. | 113,525 | 94,411 | 73,164 | 54,344 | 38,502 | 25,769 | 16,287 | 9,311 | 4,657 | 2,321 | 1,204 | 516 |
| Flat | 99,621 | 82,574 | 63,828 | 47,623 | 35,110 | 24,514 | 16,447 | 9,978 | 5,280 | 2,692 | 1,305 | 623 |

Fig. 3

Cumulative incidence function of revision for instability by liner symmetry (all crosslinked polyethylene liners).




| OCY | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asym. | 15,659 | 12,576 | 9,524 | 7,088 | 5,034 | 3,515 | 2,387 | 1,706 | 1,159 | 733 | 436 | 200 |
| Flat | 24,337 | 20,633 | 16,813 | 13,273 | 10,421 | 7,931 | 5,835 | 4,467 | 2,968 | 1,930 | 1,031 | 465 |

a

| OCY | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asym. | 38,741 | 33,134 | 26,220 | 19,843 | 14,276 | 9,561 | 5,821 | 3,113 | 1,550 | 771 | 426 | 199 |
| Flat | 22,453 | 18,686 | 14,385 | 10,474 | 7,637 | 7,637 | 5,096 | 3,111 | 1,508 | 753 | 421 | 240 |

b

| OCY | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asym. | 35,948 | 29,390 | 22,380 | 16,484 | 11,511 | 7,563 | 4,869 | 2,656 | 984 | 241 | 9 | 6 |
| Flat | 23,182 | 19,654 | 15,702 | 12,220 | 9,347 | 6,705 | 4,527 | 2,570 | 1,163 | 264 | 10 | 1 |

c

Fig. 4

a) Cumulative incidence function of revision for any reason for the Longevity crosslinked polyethylene (XLPE) by liner symmetry. b) Cumulative incidence function of revision for any reason for the Marathon XLPE by liner symmetry. c) Cumulative incidence function of revision for any reason for the X3 XLPE by liner symmetry.

**Table V.** Cox regression hazard ratios revision due to any reason for the three crosslinked polyethylene liner products used in both a flat and asymmetric form.

| Parameter | Longevity, HR (95% CI) | Marathon, HR (95% CI) | X3, HR (95% CI) |
|---|---|---|---|
| **Age, yrs** | | | |
| 55 to 64 | 0.793 (0.060 to 1.048) | 0.627 (0.479 to 0.821) | 0.993 (0.745 to 1.324) |
| 65 to 74 | 0.789 (0.607 to 1.025) | 0.558 (0.431 to 0.721) | 0.895 (0.679 to 1.810) |
| 75 and over | 0.719 (0.546 to 0.946) | 0.568 (0.432 to 0.748) | 0.822 (0.615 to 1.099) |
| < 55 | 1 | 1 | 1 |
| **Sex** | | | |
| Male | 1.034 (0.886 to 1.206) | 1.066 (0.922 to 1.231) | 1.285 (1.108 to 1.491) |
| Female | 1 | 1 | 1 |
| **Liner asymmetry** | | | |
| No | 1.118 (0.978 to 1.442) | 1.268 (1.088 to 1.478) | 1.099 (0.939 to 1.285) |
| Yes | 1 | 1 | 1 |
| **Approach** | | | |
| Hardinge | 1.156 (0.969 to 1.378) | 0.971 (0.829 to 1.138) | 1.388 (1.183 to 1.629) |
| Other | 0.658 (0.386 to 1.119) | 0.845 (0.586 to 1.128) | 1.084 (0.747 to 1.571) |
| Posterior | 1 | 1 | 1 |
| **Head material** | | | |
| Metal | 1.126 (0.946 to 1.342) | 1.258 (1.054 to 1.501) | 1.386 (1.159 to 1.657) |
| Ceramic* | 1 | 1 | 1 |
| **Stem fixation** | | | |
| Cemented | 0.783 (0.666 to 0.921) | 0.981 (0.811 to 1.205) | 0.561 (0.483 to 0.652) |
| Cementless | 1 | 1 | 1 |
| **Head size, mm** | | | |
| ≤ 32 | 0.844 (0.706 to 1.010) | 0.988 (0.811 to 1.205) | 0.869 (0.740 to 1.021) |
| ≥ 36 | 1 | 1 | 1 |
| **Indication** | | | |
| Other | 1.747 (1.414 to 2.158) | 1.546 (1.203 to 1.986) | 1.459 (1.166 to 1.825) |
| Osteoarthritis | 1 | 1 | 1 |

*Includes ceramicized metal.
CIs, confidence intervals; N/A, not applicable.

Single institution studies have also supported the decreased risk of instability when an asymmetric liner was used. Cobb et al[25] reported a marked reduction in the two-year probability of dislocation with the use of an elevated liner (2.19% vs 3.85%) in their analysis of both cemented and uncemented acetabular components. This agrees with our findings after controlling for stem fixation and surgical approach.

In order to account for the geometrical and polyethylene modification differences of asymmetric liners between manufacturers, we proceeded with a liner-specific analysis. The three most popular polyethylene liners that were used both in a flat and an asymmetric form were analyzed independently. The three liners analyzed include a liner irradiated with 10MRad and remelted (Longevity), one irradiated with 5MRad and remelted (Marathon), and one that underwent sequential irradiation and annealing to 9MRad (X3). These liners have significant geometrical differences at the rim and use different locking mechanisms. The finding of reduced risk of revision for instability was confirmed in all three products (Cox regression). The risk of revision for aseptic loosening was not significantly different in any of the three products. Revision for any reason was reduced in the asymmetric liner THAs in the Marathon liner analysis, and showed the same trend but did not reach significance in the other two products (Longevity and X3). This finding supports the view that the association reported in our study and previous registry reports is indeed a result of the asymmetric liner face and not of unaccounted confounders.

The main concern with the use of elevated rim liners has been the increased risk of impingement. Retrieval studies have reported increased impingement posterosuperiorly when the elevated rim of the liner was placed in this position.[16] Shon et al[26] reported impingement damage in 56% of retrieved acetabular components. They reported variable arcs of impingement from 20° to 300°, with the most common being an arc between 40° and 80° (43 of 96 components). The position of the asymmetric liner remains a topic of debate.[12,27,28] The association of component positioning, design, and size on range of motion and stability has been extensively investigated.[29] The effect of the position of the asymmetric part of the liner (lip) can have a marked effect on the range of motion prior to dislocation as revealed in in vivo and ex vivo studies.[12,27,30] The association between increased impingement in elevated rim liners and reduced prosthetic joint survival has not been proven. Cobb et al[17] analyzed their institutional database and reported no increase in the risk of revision due to loosening of the acetabular or femoral components when elevated rim liners were used. Our study provides further reassurance that the use of asymmetric liners was not associated with increased failure due to impingement-related failure mechanisms.

Crowninshield et al[19] performed cycling loading experiments on highly crosslinked and conventional polyethylene liners, with the liner loaded near the rim with high cup inclination leading to subluxation. The highly crosslinked liners failed by fracture of the rim while conventional polyethylene deformed with cyclic loading leading to instability. This marked difference in behaviour in a rim loading scenario has implications in the likely failure mechanism of a prosthetic joint, as recorded in joint registry data. Furthermore, Birman et al[31] reported a marked association between cracks in retrieved acetabular liners and oxidation. They noted that impingement leads to cracks in the polyethylene, though no cracking was observed in nonoxidized liners. The authors suggested that eliminating oxidation is likely to significantly reduce cracking in polyethylene.

Our study is limited by the inherent limitations of observational and registry studies. Unaccounted confounders may apply to our results despite extensive statistical modelling. The use of elevated rim liners may be routine practice for some surgeons and selective for others. We feel that selective surgeons are more likely to use an elevated liner in patients at high risk of dislocation or when they are concerned about stability intraoperatively. The selection bias would therefore be towards a reduced risk of dislocation with a flat liner, which is not supported in our findings. We have not controlled for surgeon case volume in this analysis, which might differ between groups. Multiple reasons can be recorded when revision indications are recorded in joint registries. In order to account for this, we analyzed revisions for all reasons, as well as cause-specific revisions in the NJR dataset. The registry dataset used in our analysis did not include data on the direct anterior approach and as a result this approach was not included in our study. Our analysis is limited to the NJR dataset maximum follow-up of 15 years. The results of different polyethylene modifications and/or elevated rim liners may therefore change with longer follow-up as a result of different wear patterns or in situ oxidation.

In conclusion, the use of asymmetric liners was associated with a reduced risk of revision for instability in the NJR dataset. This finding was upheld in the multivariate analysis controlling for surgical approach and head size. The concern of increased impingement leading to aseptic loosening as a mode of failure was not supported by our findings. In hips implanted through a Hardgine/anterolateral approach, the use of an asymmetric liner was associated with a reduced risk of revision. The effect on revision for instability was less pronounced than in the posterior approach. We therefore recommend that surgeons using the Hardinge/anterolateral approach consider the use of an asymmetric liner. For THAs implanted through the posterior approach, the use of asymmetric liners was associated with a reduced risk of revision for instability and revision for any reason. We therefore recommend the use of asymmetric liners in posterior approach THAs.

## Take home message

- The use of an asymmetric crosslinked polyethylene liner was associated with a lower risk of revision for instability and revision for any reason when compared to flat liners.

## Twitter

Follow E. T. Davis @ProfEdwardDavis

Follow the Royal Orthopaedic Hospital NHS Foundation Trust @ ROHNHSFT

## References

1. **No authors listed**. 17th annual report of the National Joint Registry for England, Wales, Northern Ireland and the Isle of Man. National Joint Registry. 2020. https://reports.njrcentre.org.uk/Portals/0/PDFdownloads/NJR%2017th%20Annual%20Report%202020.pdf (date last accessed 27 July 2021).
2. **Davis ET**, **Pagkalos J**, **Kopjar B**. Polyethylene manufacturing characteristics have a major effect on the risk of revision surgery in cementless and hybrid total hip arthroplasties. *Bone Joint J*. 2020;102-B(1):90–101.
3. **Novikov D**, **Mercuri JJ**, **Schwarzkopf R**, **Long WJ**, **Bosco Iii JA**, **Vigdorchik JM**. Can some early revision total hip arthroplasties be avoided? *Bone Joint J*. 2019;101-B(6_Supple_B):97–103.
4. **Seagrave KG**, **Troelsen A**, **Malchau H**, **Husted H**, **Gromov K**. Acetabular cup position and risk of dislocation in primary total hip arthroplasty: A systematic review of the literature. *Acta Orthop*. 2017;88(1):10–17.
5. **Dudda M**, **Gueleryuez A**, **Gautier E**, **Busato A**, **Roeder C**. Risk factors for early dislocation after total hip arthroplasty: a matched case-control study. *J Orthop Surg (Hong Kong)*. 2010;18(2):179–183.
6. **Pollard JA**, **Daum WJ**, **Uchida T**. Can simple radiographs be predictive of total hip dislocation? *J Arthroplasty*. 1995;10(6):800–804.
7. **Masonis JL**, **Bourne RB**. Surgical approach, abductor function, and total hip arthroplasty dislocation. *Clin Orthop Relat Res*. 2002;405:46–53.
8. **Mononen H**, **Sund R**, **Halme J**, **Kröger H**, **Sirola J**. Following total hip arthroplasty: Femoral head component diameter of 32 mm or larger is associated with lower risk of dislocation in patients with a prior lumbar fusion. *Bone Joint J*. 2020;102-B(8):1003–1009.
9. **Innmann MM**, **Merle C**, **Gotterbarm T**, **Ewerbeck V**, **Beaulé PE**, **Grammatopoulos G**. Can spinopelvic mobility be predicted in patients awaiting total hip arthroplasty? *Bone Joint J*. 2019;101-B(8):902–909.
10. **Eftekhary N**, **Shimmin A**, **Lazennec JY**, **Buckland A**, **Schwarzkopf R**, **Dorr LD**. A systematic approach to the hip-spine relationship and its applications to total hip arthroplasty. *Bone Joint J*. 2019;101-B(7):808–816.
11. **Wyatt MC**, **Whitehouse MR**, **Kieser DC**, **Frampton CMA**, **Hooper GJ**. Are lipped polyethylene liners associated with increased revision rates in patients with uncemented acetabular components? An observational cohort study. *Clin Orthop Relat Res*. 2020;478(3):581–589.
12. **Sultan PG**, **Tan V**, **Lai M**, **Garino JP**. Independent contribution of elevated-rim acetabular liner and femoral head size to the stability of total hip implants. *J Arthroplasty*. 2002;17(3):289–292.
13. **Bauze A**, **Agrawal S**, **Cuthbert A**, **de Steiger R**, **de SR**. Are hooded, crosslinked polyethylene liners associated with a reduced risk of revision after THA? *Clin Orthop Relat Res*. 2019;477(6):1315–1321.
14. **Barrack RL**, **Thornberry RL**, **Ries MD**, **Lavernia C**, **Tozakoglou E**. The effect of component design on range of motion to impingement in total hip arthroplasty. *Instr Course Lect*. 2001;50:275–280.
15. **Insull PJ**, **Cobbett H**, **Frampton CM**, **Munro JT**. The use of a lipped acetabular liner decreases the rate of revision for instability after total hip replacement: A study using data from the New Zealand Joint Registry. *Bone Joint J*. 2014;96-B(7):884–888.
16. **Yamaguchi M**, **Akisue T**, **Bauer TW**, **Hashimoto Y**. The spatial location of impingement in total hip arthroplasty. *J Arthroplasty*. 2000;15(3):305–313.
17. **Cobb TK**, **Morrey BF**, **Ilstrup DM**. Effect of the elevated-rim acetabular liner on loosening after total hip arthroplasty. *J Bone Joint Surg Am*. 1997;79-A(9):1361–1364.
18. **Tower SS**, **Currier JH**, **Currier BH**, **Lyford KA**, **Van Citters DW**, **Mayor MB**. Rim cracking of the cross-linked longevity polyethylene acetabular liner after total hip arthroplasty. *J Bone Joint Surg Am*. 2007;89-A(10):2212):2212–2217:.
19. **Crowninshield RD**, **Maloney WJ**, **Wentz DH**, **Humphrey SM**, **Blanchard CR**. Biomechanics of large femoral heads: what they do and don't do. *Clin Orthop Relat Res*. 2004;429:102–107.
20. **Langlois J**, **Hamadouche M**. Recent update on crosslinked polyethylene in total hip arthroplasty. *SICOT J*. 2020;6:13.
21. **Ranawat CS**, **Deshmukh RG**, **Peters LE**, **Umlas ME**. Prediction of the long-term durability of all-polyethylene cemented sockets. *Clin Orthop Relat Res*. 1995;317:89–105.
22. **Davis ET**, **Pagkalos J**, **Kopjar B**. Effect of bearing surface on survival of cementless and hybrid total hip arthroplasty: Study of data in the national joint registry

for England, Wales, Northern Ireland and the Isle of Man. *JB JS Open Access*. 2020;5(2):e0075e0075.

23. **Davis ET**, **Pagkalos J**, **Kopjar B**. A higher degree of polyethylene irradiation is associated with a reduced risk of revision for aseptic loosening in total hip arthroplasties using cemented acetabular components. *Bone Joint Res*. 2020;9(9):563–571.
24. **Gray RJ**. A class of K-sample tests for comparing the cumulative incidence of a competing risk. *The Annals of Statistics*. 1988;16(3):1141–1154.
25. **Cobb TK**, **Morrey BF**, **Ilstrup DM**. The elevated-rim acetabular liner in total hip arthroplasty: relationship to postoperative dislocation. *J Bone Joint Surg Am*. 1996;78-A(1):80–86.
26. **Shon WY**, **Baldini T**, **Peterson MG**, **Wright TM**, **Salvati EA**. Impingement in total hip arthroplasty a study of retrieved acetabular components. *J Arthroplasty*. 2005;20(4):427–435.
27. **Hau R**, **Hammeschlag J**, **Law C**, **Wang KK**. Optimal position of lipped acetabular liners to improve stability in total hip arthroplasty—an intraoperative in vivo study. *J Orthop Surg Res*. 2018;13(1):289):289.
28. **Sculco PK**, **Cottino U**, **Abdel MP**, **Sierra RJ**. Avoiding hip instability and limb length discrepancy after total hip arthroplasty. *Orthop Clin North Am*. 2016;47(2):327–334.
29. **Widmer K-H**. The impingement-free, prosthesis-specific, and anatomy-adjusted combined target zone for component positioning in THA depends on design and implantation parameters of both components. *Clin Orthop Relat Res*. 2020;478(8):1904–1918.
30. **Qurashi S**, **Parr W**, **Jang B**, **Walsh WR**. Elevated lip liner positions improving stability in total hip arthroplasty – an experimental study. *Reconstructive Review*. 2018;7(4).
31. **Birman MV**, **Noble PC**, **Conditt MA**, **Li S**, **Mathis KB**. Cracking and impingement in ultra-high-molecular-weight polyethylene acetabular liners. *J Arthroplasty*. 2005;20(7 Suppl 3):87–92.

**Author information:**

E. T. Davis, MSc, PGCME, FRCS(Tr&Orth), Consultant Arthroplasty Surgeon, The Royal Orthopaedic Hospital NHS Foundation Trust, Birmingham, UK; Institute of Inflammation and Ageing, University of Birmingham, Birmingham, UK.

J. Pagkalos, MSc, FRCS(Tr&Orth), Consultant Arthroplasty Surgeon, The Royal Orthopaedic Hospital NHS Foundation Trust, Birmingham, UK.

B. Kopjar, MD, MS, PhD, FACE, FAcadTM, Associate Professor, The Royal Orthopaedic Hospital NHS Foundation Trust, Birmingham, UK; School of Public Health, University of Washington Department of Health Services, Seattle, Washington, USA.

**Author contributions:**

E. T. Davis: Conceptualization, Investigation, Writing – original draft.
J. Pagkalos: Conceptualization, Investigation, Writing – original draft.
B. Kopjar: Conceptualization, Formal analysis, Writing – original draft.

**Funding statement:**

The author or one or more of the authors have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article. In addition, benefits have been or will be directed to a research fund, foundation, educational institution, or other non-profit organization with which one or more of the authors are associated.

**ICMJE COI statement:**

The authors report an unrestricted investigator-initiated research grant from Smith & Nephew for the open access funding for this study. B. Kopjar also reports personal consultancy payments from Hip Innovation Technology, Bioventus, Joint Purification Systems, Innovative Surgical Designs, and Cerapedics, and a consultancy payment to their institution from AOSNA, all unrelated to the study. E. T. Davis reports personal fees from Smith & Nephew and Stryker, unrelated to the study.

**Acknowledgements:**

The authors would like to thank the patients and staff of all the hospitals in England, Wales, Northern Ireland and the Isle of Man who have contributed data to the National Joint Registry (NJR). The authors are also grateful to the Healthcare Quality Improvement Partnership (HQIP), the NJR Research Sub-committee, and NJR Centre staff for facilitating this work. The authors would also like to thank Keith Tucker (Spire Hospital Norwich, Norwich, UK), Martin Pickford (Craneswater Consulting, Locks Heath, UK), and Claire Newell (Northgate Information Solutions Ltd, Hemel Hempstead, UK). The authors have conformed to the standard protocol of NJR for data access and publication. The views expressed represent those of the authors and do not necessarily reflect those of the NJR Steering Committee or the HQIP, who did not vouch for how the information was presented. In addition, the authors are grateful for the support of the implant manufacturers in supplying the details on their polyethylene manufacturing.



This article was primary edited by K. Logishetty.