Re-revision risk of modular and monobloc revision stems after revision hip arthroplasty

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Cite this article:
Bone Jt Open 2025;6 (6 Supple B):1–6.

DOI: 10.1302/2633-1462.66.BJO-2024-0201.R1

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Aims
Modular revision stem fracture is a rare but difficult complication after hip arthroplasty revision. The purpose of this German Arthroplasty Registry (EPRD)-based study was to investigate whether the overall re-revision rate and the re-revision reasons of modular revision stems compared with monobloc stems are different.

Methods
A total of 291 re-revisions occurring within five years after implantation of a revision stem (n = 2,039) documented in the EPRD were analyzed using Kaplan-Meier survival analysis and Cox regression. Stem type (modular: n = 1,026, monobloc: n = 1,013) and revision reason were investigated as independent variables, while BMI, sex, age, hospitals' annual revision volume, and Elixhauser score were treated as confounding variables. Cases with an infection at index surgery were analyzed separately.

Results
Re-revision risk after five years was similar for either stem type (modular: 18.7% (95% CI 15.9 to 21.9); monobloc: 15.6% (95% CI 13.2 to 18.4); p = 0.200). One stem fracture of a modular revision stem was reported. The main reasons for re-revision were infection (modular/monobloc: 50%/60% of all revisions; p = 0.200), dislocation (19.8%/9.6%; p = 0.045), and loosening (12.2%/11.4%; p > 0.999). An Elixhauser score of 4 and above was associated with a higher hazard ratio (HR) for re-revision for either stem type (modular/monobloc: HR 2.01; p = 0.026/HR 2.44; p = 0.004), as well as a BMI category above 25/40 (modular/monobloc: HR 1.73 to 3.25; all p < 0.025/HR 3.61; p < 0.001). An infected index surgery increased the re-revision risk after one year to 26.0% (95% CI 22.2% to 30.3%) compared with 8.3% for noninfected cases (95% CI 7.0% to 9.8%) (p < 0.001) independent of stem type.

Conclusion
A high BMI increases the HR for revision for either stem design but not due to mechanical implant failure. Infection at the index operation increases re-revision risk significantly, and is also the dominant reason for re-revision independent of stem type.

Take home message
- A mechanical failure of a modular revision stems is a rare but difficult situation. The analysis of the EPRD data shows that the overall re-revision risk of modular and monobloc revision stem is similar, and that the choice for either should be made purely based on clinical considerations.

Introduction
Revision hip arthroplasty (rHA) comprises about 10% of all hip arthroplasty operations in Germany: the German Arthroplasty Register (EPRD) documents 177,826 primary and 18,145 revision cases for the year 2022.[1] Modular and monobloc revision stems show comparable and satisfactory clinical and radiological outcomes for revision total hip arthroplasty (rTHA) in clinical studies,[2,3]

Table I. Patient cohort characteristics of the two stem type groups.

Variable	Modular revision stem (n = 1,026)	Monobloc revision stem (n = 1,013)	p-value
Sex, n (%)			0.823*
Female	641 (62)	628 (62)	
Male	385 (38)	385 (38)	
Median age, yrs (IQR)	74 (65 to 81)	74 (65 to 80)	0.763†
Median BMI, kg/m^2 (IQR)	26.9 (24.0 to 30.9)	27.8 (24.2 to 31.6)	0.020†
BMI categories, n (%)			0.034*
Underweight, < 18.5 kg/m^2	11 (1.1)	12 (1.2)	
Normal, 18.5 to 24.99 kg/m^2	290 (28)	254 (25)	
Pre-obese, 25.0 to 29.99 kg/m^2	322 (31)	271 (27)	
Obese 1, 30.0 to 34.99 kg/m^2	150 (15)	181 (18)	
Obese 2, 35.0 to 39.99 kg/m^2	69 (6.7)	87 (8.6)	
Obese 3, ≥ 40 kg/m^2	34 (3.3)	33 (3.3)	
Missing	150 (15)	175 (17)	
Elixhauser score categories, n (%)			0.039*
< 0	94 (9.2)	128 (13)	
1 to 3	417 (41)	404 (40)	
≥ 4	515 (50)	481 (47)	
Vital status, death, n (%)	184 (18)	165 (16)	0.324*
Annual volume of rHAs by hospital, n (%)			0.163*
≤ 20	339 (33)	292 (31)	
21 to 50	393 (39)	409 (43)	
≥ 51	279 (28)	249 (26)	

*Pearson's chi-squared test.
†Mann-Whitney U test.
rHA, revision hip arthroplasty.

despite the inherent fracture risk associated with modular stems due to the reduced diameter at the taper connection and contamination during assembly.[4] Stem fracture is a difficult complication for the patient.[5-7] Implant fracture as reason for primary revision is reported for up to 3.1% of primary cases and for up to 3.3% of re-revision cases.[8] Studies looking at specific modular revision stem designs report fracture rates of 0.3%[9] to 0.66%,[10] whereas fractures of monobloc revision stems are only reported anecdotally. This and the lower price are probable reasons for the increasing popularity of monobloc designs despite good long-term results for modular designs.[11]

It is unclear how the differences and similarities in outcome between monobloc and modular revision stems documented in clinical studies affect the overall revision rate of these two stem types across all specific designs and users. The purpose of this EPRD-based study was to investigate whether the overall re-revision rate and the re-revision reasons are different between modular and monobloc revision stems.

Methods

A total of 291 first re-revisions of revision stems implanted during elective or trauma revision surgeries of any hip arthroplasty (n = 2,039) occurring within five years after implantation documented in the EPRD from August 2013 to September 2023 were analyzed using Kaplan-Meier survival and Cox regression analysis. Re-revision risk (RR) was used as dependent variable and stem design (modular: n = 1,026, monobloc: n = 1,013) and revision reason were used as independent variables. BMI, sex, age, hospitals' annual revision volume, and Elixhauser score[12] served as confounding variables (Table I). The influence of infection at the time of the index surgery (implantation of the revision stem) on the outcome was also investigated. Infection was ascertained if it was specified as the main revision reason or when reimbursement data were coded with International Classification of Diseases of the World Health Organization (ICD)-10 T84.5 code. As the EPRD cooperates with implant manufacturers and healthcare insurances, detailed implant specifications are available (15 different modular, 27 different monobloc designs) and no revisions are missed, even if they are not reported to the registry. Of the total 68,203 rHA cases in the

Table II. The specified revision reasons for the two different stem type groups (number of cases and percentage within the respective stem type group; the cases for which the reason for revision is not known are not considered for the calculation of percentages).

Reason for revision	Modular revision stem revised (n = 156)	Monobloc revision stem revised (n = 135)
Infection	66 (50.4)	68 (59.6)
Dislocation	26 (19.8)	11 (9.6)
Component failure	1 (0.8)	0 (0)
Loosening	16 (12.1)	13 (11.4)
Periprosthetic fracture	6 (4.5)	9 (7.9)
Malalignment	3 (2.3)	2 (1.8)
Condition after removal	2 (1.5)	2 (1.8)
Wear	1 (0.8)	1 (0.9)
Other reasons	10 (7.6)	8 (7.0)
Unknown	25 (16.0)	21 (15.6)

Table III. Cox regression results.

Variable	Modular revision stem			Monobloc revision stem		
	HR	95% CI	p-value	HR	95% CI	p-value
Age, yrs						
< 65	Ref			Ref		
65 to 74	0.96	0.63 to 1.47	0.848	0.85	0.53 to 1.34	0.480
75 to 84	0.89	0.57 to 1.39	0.620	0.92	0.59 to 1.45	0.727
> 84	0.63	0.30 to 1.31	0.217	0.40	0.16 to 0.96	0.041
Sex						
Female	Ref			Ref		
Male	1.18	0.85 to 1.64	0.317	1.25	0.88 to 1.77	0.204
Elixhauser score						
< 0	Ref			Ref		
0 to 3	1.04	0.55 to 1.97	0.897	1.20	0.64 to 2.24	0.564
> 3	2.01	1.09 to 3.70	0.026	2.44	1.33 to 4.48	0.004
BMI category						
Normal, 18.5 to 24.99 kg/m^2	Ref			Ref		
Underweight, < 18.5 kg/m^2	0.00	0.00 to Inf	0.992	0.00	0.00 to Inf	0.992
Pre-obese, 25.0 to 29.99 kg/m^2	1.73	1.08 to 2.79	0.024	1.03	0.61 to 1.75	0.898
Obese 1, 30.0 to 34.99 kg/m^2	1.96	1.12 to 3.40	0.017	1.32	0.75 to 2.31	0.338
Obese 2, 35.0 to 39.99 kg/m^2	3.25	1.73 to 6.09	< 0.001	1.44	0.71 to 2.89	0.310
Obese 3, ≥ 40 kg/m^2	2.65	1.17 to 6.02	0.020	3.61	1.71 to 7.65	0.001
Hospital rHA volume						
0 to 20	Ref			Ref		
21 to 50	0.95	0.66 to 1.38	0.794	1.29	0.84 to 1.99	0.250
> 50	0.86	0.56 to 1.31	0.471	1.54	0.96 to 2.47	0.072

HR, hazard ratio; rHA, revision hip arthoplasty.

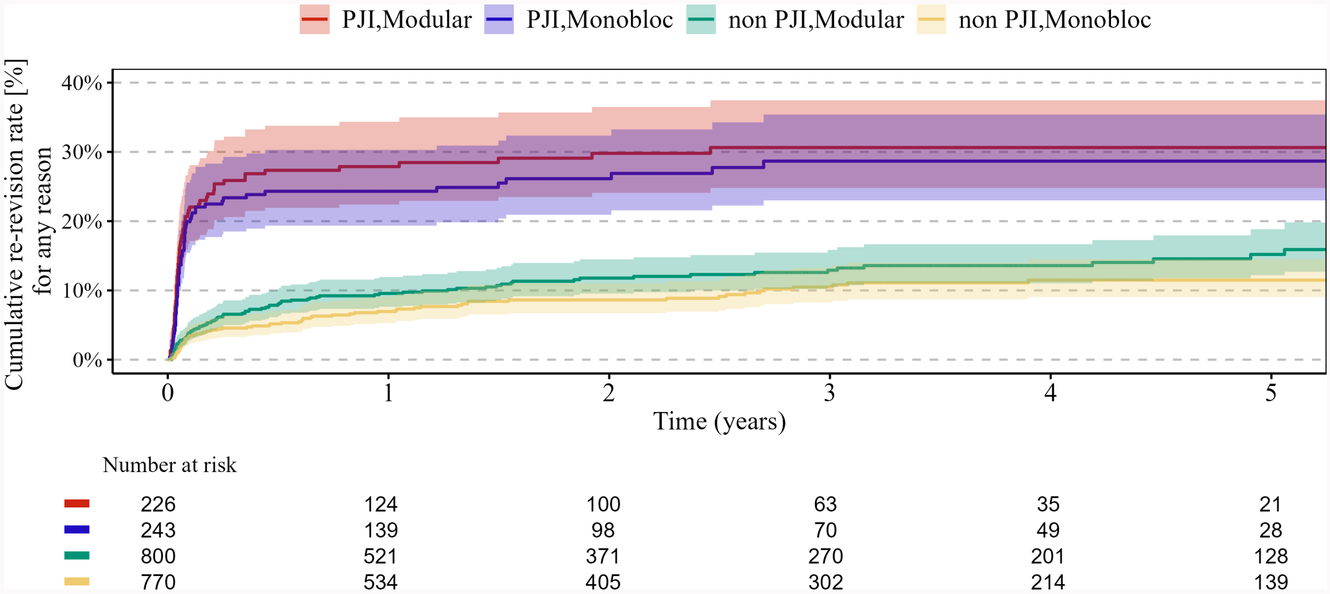

Fig. 1
Cumulative re-revision rate for any reason for the two stem type groups with and without infection at the index operation during the first five years after the implantation of the revision stem. The numbers at risk indicate how many cases in each of the groups are still under observation at a specific timepoint. PJI, periprosthetic joint infection.

registry, first revisions comprise 13,419 cases. Monobloc or modular revision stems were used in 2,039 of these revisions.

Statistical analysis

Statistical analysis was performed using R statistical software v.4.2.0 (R Foundation for Statistical Computing, Austria). Continuous variables were reported as medians with IQRs, while categorical variables were summarized as frequencies and percentages. Group comparisons for continuous data were conducted using the Mann-Whitney U test, and categorical data were analyzed using the chi-squared test. The proportion test was used to compare the differences in categorical outcomes between the groups. The log-rank test was used to evaluate the equivalence of survival across groups. Hazard ratios (HRs) with 95% CI were calculated using the log-log method. The Wald test was used to compare HRs between groups. A p-value threshold of 0.05 was considered indicative of statistical significance.

Re-revision was defined as removal or exchange of one or all implanted components and used as the endpoint for the analysis. The reason for re-revision is specified by the hospital at the time of data entry, selecting one of the reasons specified in the data entry sheet (Table II). The probability of a type I error was set to 5%.

The EPRD has received a general institutional review board approval from the University of Kiel (approval number D 473/11), and all patients agree to the storage of their data and sign a declaration of consent.

Results

The two patient cohorts differed slightly. Patients treated with a monobloc stem had a slightly higher BMI (p = 0.020, Mann-Whitney U test) and a lower Elixhauser score (p = 0.039, Mann-Whitney U test) (Table I). The mortality was similar between the two groups (modular 18% within the five years after revision/monobloc 16%; p = 0.324, chi-squared test)). The risk for re-revision five years after implantation was similar for either design (modular/monobloc: 18.7% (95% CI 15.9 to 21.9)/15.5% (95% CI 13.1 to 18.3); p = 0.161, log-rank test; the HR for monobloc stems was 0.86 (95% CI 0.68% to 1.09%); p = 0.249, Wald test). One stem fracture of a modular revision stem was reported (fracture rate: 0.8%). None of the monobloc stems showed a component failure. The main reasons for re-revision differed to a certain extent between the two stem designs (Table II). Dislocation was more frequent in the modular group (19.5% compared with 9.8% in the monobloc group; p = 0.041). Monobloc stems were revised for infection in 59.6% of the cases (50.4% for the modular designs; p = 0.185, proportion test). The frequency of loosening was similar in both groups (modular 12.1 %/monobloc 11.5%; p > 0.999). Older age decreased the HR for revision for either stem design (Table III). This was significant for patients aged above 85 years with a monobloc stem (HR 0.41; p = 0.039). An Elixhauser score of four and above was associated with a significantly higher HR for re-revision in modular designs (HR 2.01; p = 0.026), which was even pronounced for the monobloc designs (HR 2.44; p = 0.004) (Table III).

In the modular group, patients in all BMI categories above 25 showed a significantly increased HR for re-revision compared with the 'Normal' group (HR 1.73 to 3.25; p = 0.025; Table III). In the monobloc group only patients in the 'obese 3' category (BMI above 40) were associated with a higher HR (HR 3.61; p < 0.001).

The hospital volume of re-revision surgeries only showed an influence of volume on the HR for monobloc stems (Table III): hospitals with implantation of more than 50 monobloc stems showed a slightly elevated HR for re-revision (HR 1.54; p = 0.072).

An infected index surgery increased the RR after one year to 26.0% (95% CI 22.2% to 30.3%) compared with 8.3% for noninfected cases (95% CI 7.0% to 9.8%) (p < 0.001) independent of stem design (Figure 1).

Discussion

This registry study confirms clinical studies showing that monobloc and modular revision stem types have a similar overall survival rate.[2,3] It also highlights the overwhelming influence of infection on the RR after rHA. The limitations of this study mean that the findings, with regard to the reasons responsible for re-revision after the implantation of a revision stem in the first revision, should be treated carefully. These limitations include the missing revision reason specifications for approximately 20% of the cases, the earlier shown simultaneous association of a higher BMI with increased component failure and infection,[13,14] and the generally very heterogeneous patient population for re-revision procedures as in this study. In addition, the current observation time of the EPRD only allows mid- to long-term follow-up analyses. A comparison between the different designs within one stem type group would be very interesting, but statistically highly questionable due to the many different designs used in the EPRD and a total of only 291 re-revision cases.

The underlying problem of registry-based studies trying to compare different treatment options is the assumed similarity of the patient cohorts. For large numbers of patients, propensity score matching based on characteristics is one option to obtain comparable cohorts. For the relatively small number of re-revisions in this analysis (n = 291), this approach would have reduced the number of cases greatly, leaving an insufficient number of cases for comparison. This was the reason for using a Cox regression approach accounting for differences in the considered confounding variables. The analysis of the influence of the BMI revealed for the monobloc stem group a continuous but not significant HR increase, with increasing obesity from a HR of 1.04 for the 'Pre-obese' category to the 'Obesity 2' category and a significant increase up to the 'Obesity 3' category with a HR of 3.71 ($p < 0.001$; Table III). This is a strong indication that the negative effect of an increased BMI is the impact on infection and not the impact on mechanical loading, since no revision for mechanical construct failure occurred in the monobloc group. For the modular stem group, this association was even stronger, with a significant increase of the HR for revision in all categories with BMIs above 25 (Table III), but only one revision for mechanical construct failure.

The higher risk of dislocation in the modular group contradicts expectations, since one of the claimed benefits of modular stems is the better recreation of the anatomical situation. This result – as the slightly elevated HR for hospitals performing more than 50 monobloc implantations – might be due to a patient selection bias not fully compensated by the variables available.

In conclusion, registries are strong tools to document the outcome of treatments across a wide surgeon and implant population, but care has to be taken to formulate suggestions based on registry results, due to an inherent patient selection bias. In most registry studies, this bias can be only partially addressed due to the limited patient information available for analysis, very limited options for risk stratification, differences in data coding between the hospitals, and incomplete datasets.

The results of this study indicate that the present trend towards monobloc revision stems might be biased by the high attention to an overall small number of catastrophic failures of modular designs and the difficult revision of these cases.[5-7] Even if one might speculate that some cases in which the revision was not specified by the surgeon were component failures, the observed similar overall revision rate stands: due to the structure of the EPRD, no revision is missed as long as the hospital applies for reimbursement, which can actually be assumed in all cases.

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A. Grimberg: Conceptualization, Data curation, Supervision, Writing – original draft, Writing – review & editing, Investigation.
K-P. Günther: Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing.
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Funding statement

The author(s) received no financial or material support for the research, authorship, and/or publication of this article.

ICMJE COI statement

K-P. Günther reports an institutional research grant and payment for lectures from Zimmer Biomet, both of which are unrelated to this study. K-P. Günther also reports travel reimbursement as Past President of EFORT and a member of the executive committee of the German Society of Orthopaedics and Traumatology and the German Arthroplasty Registry, as well as scientific committee membership of the European Hip Society. M. Morlock reports research support from DePuy Synthes, Peter Brehm, and Ceramtec, consultant fees from DePuy Synthes, and payment for lectures from DePuy Synthes, Peter Brehm, Mathys, and Kyocera, unrelated to this study. M. Morlock is also a member of the executive committee of the German Arthroplasty Registry. C. Perka reports royalties or licenses from DePuy Synthes, Smith & Nephew, and Zimmer Biomet, and consulting fees from DePuy Synthes, Becton Dickinson, and Zimmer Biomet, all of which are unrelated to this study. C. Perka also holds leadership or fiduciary roles on DGOOC, the International Hip Society, the German Arthroplasty Registry, and *The Bone & Joint Journal*.

Data sharing

The data that support the findings for this study are property of the EPRD. A formal request to the EPRD is required to get access to the data.

Ethical review statement

The EPRD has received a general institutional review board approval from the University of Kiel (approval number D 473/11), and all patients agree to the storage of their data and sign a declaration of consent.

This paper was presented at the International Hip Society 2024 Meeting in Athens, Greece.