



# Clinical and radiological outcomes and analysis of failures of modular revision stems at long-term follow-up: a systematic review and meta-analysis

Michela Saracco<sup>1^</sup>, Vincenzo Ciriello<sup>2^</sup>, Andrea Fidanza<sup>3^</sup>, Giandomenico Logroscino<sup>3^</sup>

<sup>1</sup>Department of Orthopaedics and Trauma, “San Giovanni di Dio” Hospital, ASL Napoli 2 Nord, Naples, Italy; <sup>2</sup>Department of Orthopaedics and Trauma, ASO “S. Croce e Carle”, Cuneo, Italy; <sup>3</sup>Department of Life Health & Environmental Sciences, University of L’Aquila, Minimvasive Orthopaedic Surgery, L’Aquila, Italy

**Contributions:** (I) Conception and design: M Saracco, G Logroscino; (II) Administrative support: G Logroscino; (III) Provision of study materials: A Fidanza; (IV) Collection and assembly of data: A Fidanza; (V) Data analysis and interpretation: M Saracco, V Ciriello; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

**Correspondence to:** Dr. Michela Saracco, MD. Department of Orthopaedics and Trauma, “San Giovanni di Dio” Hospital, ASL Napoli 2 Nord, Via Domenico Pirozzi, 80020 Frattamaggiore, Naples, Italy. Email: michelasaracco@gmail.com.

**Background:** Increasingly hip replacements at young age exposes the patient to an increased risk of failure of the implant over the years. In case of failure, revision specific stems were designed to overcome bone loss. Modularity of these devices is an important resource for the surgeon as they allow the new implant to be better adapted to the patient’s anatomy. The purpose of this systematic review is to provide data about the outcome at long-term follow-up (>8 years) of hip modular revision femoral stems.

**Methods:** This systematic review and meta-analysis were conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement guidelines. PubMed and Google Scholar databases were systematically and independently searched, according to the inclusion and exclusion criteria. Two reviewers performed the data extraction independently. In case of disagreement, the senior authors were sought to resolve the divergences. Quality of the involved studies was evaluated with National Institute for Health and Care Excellence (NICE) guidelines (eight-item list) and the Newcastle-Ottawa scale (NOS). Primary and secondary outcomes were evaluated. The statistical analysis of this meta-analysis was performed by using Excel Microsoft and the software STATA.

**Results:** The primary outcome was the re-revision rate of modular revision stems at long-term follow-up. It ranged from 1.4% to 45.6%: random effect pooled estimate was 5.5% [95% confidence interval (CI): 4% to 7%], with a  $I^2$  of 12.3% ( $P=0.332$ ). Mean Harris Hip Score (HHS) was 83 [min: 79; max: 87.6; standard deviation (SD): 3.55]. Secondary evaluated outcomes were: subsidence >5 mm, rate of periprosthetic infection or fractures (intra- and post-operative) and dislocations. The mean value for the NICE tool was 5.5 (SD: 1.13) and 7.3 (SD: 0.79) for the NOS tool. The survival rate was >90% at long-term follow-up (min: 60%; max: 97%).

**Conclusions:** The modular femoral revision stems have demonstrated good long-term reliability and efficacy. This meta-analysis demonstrates that the re-revision rate after 8 years of follow-up is low and 90% of the implants did not fail.

**Keywords:** Hip revision arthroplasty; modular revision stem; modularity; systematic review

Received: 29 March 2023; Accepted: 06 November 2023; Published online: 25 November 2023.

doi: 10.21037/aoj-23-32

View this article at: <https://dx.doi.org/10.21037/aoj-23-32>

<sup>^</sup> ORCID: Michela Saracco, 0000-0003-2190-9574; Vincenzo Ciriello, 0000-0003-3811-0611; Andrea Fidanza, 0000-0001-7766-0806; Giandomenico Logroscino, 0000-0003-1301-5343.

## Introduction

The number of total hip arthroplasties (THAs) has been increasing significantly in recent years, due prolonged life length expectancy of the population and the need to offer adequate treatment for hip osteoarthritis even in younger active patients.

The technological improvement of the materials and the long duration of the implants has allowed the diffusion of this orthopaedic procedure even at a young age, in patients suffering from hip dysplasia, Perthes or avascular necrosis.

However, the increase of hip replacements at young age exposes the patient to the risk for revision of the implant over the years. According to Kurtz *et al.*, there will be up to 96,700 revision THAs in the United States and up to 137% worldwide by 2030 (1-3).

The main reason for hip revision is the aseptic loosening of the prosthetic component (4,5).

Stem revision usually leaves the femur with metaphyseal bone loss, precluding the implantation of a primary proximal fitting stem. Revision stems were designed and specific techniques developed to overcome bone loss in aseptic loosening. The complexity of femoral revision requires a versatile system that can cope with proximal femoral bone loss, bone quality deficiency, an altered anatomy offset and limb-length discrepancy.

Over the years, several prosthetic, modular and monobloc designs have been developed. Limitations of mono-block stems include limitations in adjustment of anteversion, offset, and length. In addition, the lack of proximal modularity may influence implant stability and prevent restoration of the center of rotation. Therefore, modular fluted tapered stems have become popular in the

last two decades (6).

Modular stems are an important resource for the surgeon as they allow the new implant to be better adapted to the patient's anatomy, often altered by previous surgical procedures.

Despite this, many doubts still exist about the reliability of the modularity and the risk of exposing the patient to other problems, including trunnionosis, fear of breakage, and taper disengagement (7,8). Mechanical failure at the modular interfaces can subsequently lead to production of metal debris and cause adverse local tissue reactions (ALTRs) (9).

Despite this, the literature has reported favourable results in small series at short or mid-term follow-up (10-12). On the other hand, few data are available at long-term follow-up.

The purpose of this systematic review and meta-analysis is to provide data about the outcome of hip revisions at long-term follow-up, performed for aseptic loosening, with modular femoral stems, based on the available studies. We present this article in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) reporting checklist (available at <https://aoj.amegroups.com/article/view/10.21037/aoj-23-32/rc>) (13).

## Methods

### *Inclusion and exclusion criteria*

The inclusion criteria for the retrieved studies were the follows: English language articles, papers about modular femoral stems, modular femoral stems in revision hip arthroplasty at long-term follow-up (>8 years) and papers reporting on the outcome of these types of revision stems for loosening of the primary hip replacement.

The exclusion criteria adopted were: not-English language articles; case-reports, reviews, and not-human researches; mean follow-up less than 8 years; papers about monobloc revision femoral stems; papers about modular femoral stem in primary hip replacement.

### *Search strategy, information sources and study selection*

PubMed and Google Scholar databases were systematically and independently searched to 4<sup>th</sup> February 2023, by two reviewers. Once the relevant studies were identified, their full text were extracted and selected on the base of the inclusion and exclusion criteria. Additional studies were eventually identified from the references of the retrieved papers.

### Highlight box

#### Key findings

- Modular revision femoral stems better fit the patient's anatomy, resulting in excellent long-term results.

#### What is known and what is new?

- Hip revision surgical procedures are expected to increase over the years. Therefore, versatile and reliable implants are required.
- This systematic review and meta-analysis demonstrates that modular femoral stems are in line with these characteristics, even at long-term follow-up.

#### What is the implication, and what should change now?

- Modular femoral stems are an excellent alternative to monobloc ones, also in revisions and also for young patients.

No restrictions were applied to the time period of the studies. In our analysis only papers written in English-language were included.

The search strategy was the follows:

((((((((((revision) AND (hip)) OR (hip)) AND (arthroplasty))) OR (replacement)) AND (modular))) AND (femoral stems)) OR (modular stems))

(((((("revise"[All Fields] OR "revised"[All Fields] OR "revisers"[All Fields] OR "revises"[All Fields] OR "revising"[All Fields] OR "revision"[All Fields] OR "revisions"[All Fields]) AND ("hip"[MeSH Terms] OR "hip"[All Fields])) OR ("hip"[MeSH Terms] OR "hip"[All Fields])) AND ("arthroplasty"[MeSH Terms] OR "arthroplasty"[All Fields] OR "arthroplasties"[All Fields])) OR ("replace"[All Fields] OR "replaceable"[All Fields] OR "replaced"[All Fields] OR "replaces"[All Fields] OR "replacing"[All Fields] OR "replacement"[All Fields] OR "replantation"[MeSH Terms] OR "replantation"[All Fields] OR "replacement"[All Fields] OR "replacements"[All Fields])) AND ("modular"[All Fields] OR "modularities"[All Fields] OR "modularity"[All Fields] OR "modularization"[All Fields] OR "modularized"[All Fields] OR "modularizing"[All Fields] OR "modulars"[All Fields]) AND (("femor"[All Fields] OR "femorals"[All Fields] OR "femur"[MeSH Terms] OR "femur"[All Fields] OR "femoral"[All Fields]) AND ("stem s"[All Fields] OR "stemmed"[All Fields] OR "stemming"[All Fields] OR "stems"[All Fields])))) OR ((("modular"[All Fields] OR "modularities"[All Fields] OR "modularity"[All Fields] OR "modularization"[All Fields] OR "modularized"[All Fields] OR "modularizing"[All Fields] OR "modulars"[All Fields]) AND ("stem s"[All Fields] OR "stemmed"[All Fields] OR "stemming"[All Fields] OR "stems"[All Fields]))

(fluted[All Fields] OR tapered[All Fields] OR distal[All Fields] OR Wagner[All Fields]) AND (revision[All Fields] AND ("hip"[MeSH Terms] OR "hip"[All Fields])) AND ((("arthroplasty"[MeSH Terms] OR "arthroplasty"[All Fields]) OR ("replantation"[MeSH Terms] OR "replantation"[All Fields] OR "replacement"[All Fields])).

After finding the papers, we performed a manual search to find additional articles with long-term follow-up.

Only papers with a follow-up higher than 8 years were considered.

### **Data extraction**

Two reviewers performed the data extraction independently. In case of disagreement, the senior authors were sought to

resolve the divergences.

Data extracted from the eligible studies included: first author names, year of publication, hips (n), follow-up (years), re-revision of the stem (n), survival of the implant >8 years (%), patients mean age (years), Harris Hip Score (HHS), subsidence >5 mm (n), periprosthetic infection (n), dislocation (n), periprosthetic fractures [intra-operative (n); post-operative (n)].

### **Quality evaluation**

Quality of the involved studies was evaluated with National Institute for Health and Care Excellence (NICE) guidelines (eight-item list) and the Newcastle-Ottawa scale (NOS). Quality assessment was performed by two examiners and the mean value was used for analysis. If a big difference was noted between the two researchers (3 points for NOS and 2 for NICE), a third examiner evaluated the quality of the study (14,15).

### **Primary and secondary outcomes**

The primary outcome was the success rate of modular revision femoral stems in case of revision for aseptic loosening of primary hip arthroplasty, at long-term follow-up (>8 years). This was evaluated by reported re-revision rates.

Secondary outcomes were dislocation, intraoperative and postoperative fractures, infection rates, as well as subsidence of the stems (>5 mm). We also considered the patients quality of life and hip function using HHS.

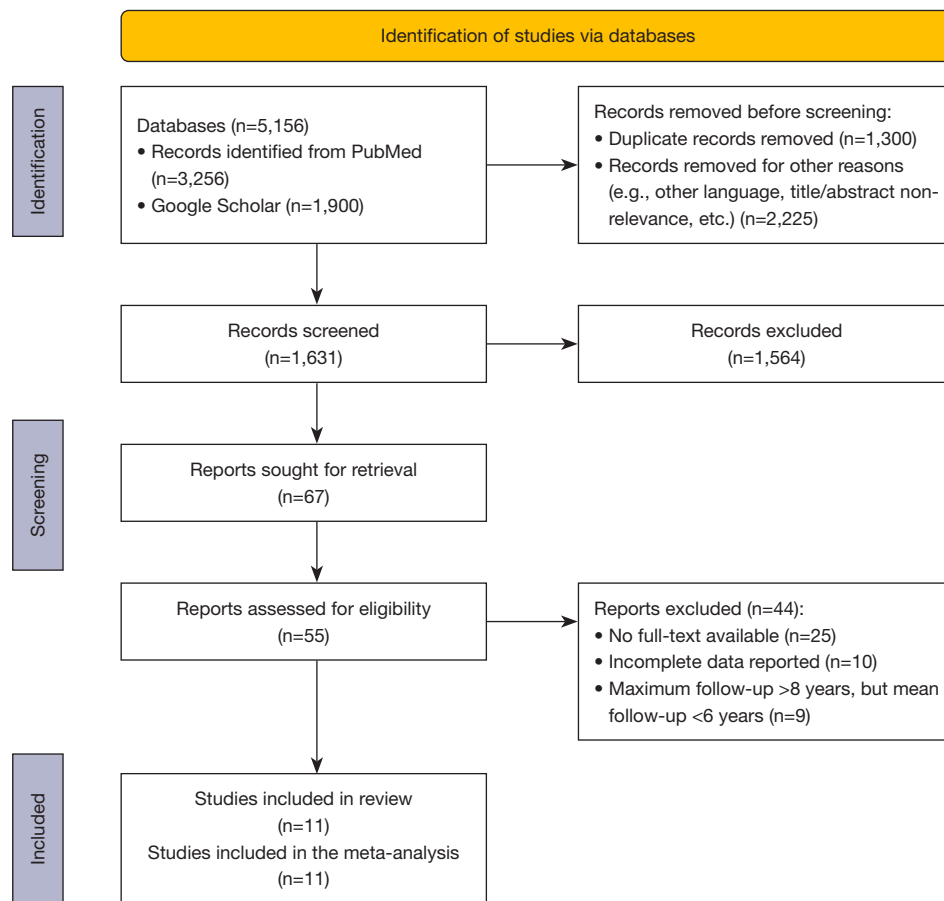
### **Statistical analysis**

The statistical analysis of this meta-analysis was performed by using Microsoft Excel and the software STATA. The heterogeneity of the studies was assessed with the  $I^2$  statistic. Random or fixed effects models were used. Estimates of the main and secondary outcomes are reported with 95% confidence interval (CI). Meta-regression analysis was done to check if subsidence >5 mm rate was correlated with re-revision rate or increased risk of dislocation.

## **Results**

### **Study selection**

The search diagram is shown in *Figure 1*. An initial search



**Figure 1** Flow chart of the systematic research.

identified a total of 5,156 articles: 3,256 articles in PubMed and 1,900 in Google Scholar. After removing duplicates, not-English papers, etc., 1,631 articles remained. After application of the inclusion and exclusion criteria, 55 articles remained available for the analysis. Of these, only 11 studies of 1,539 hips were included in the systematic review, published between 2007 and 2023. The mean follow-up, reported in 11 studies, is 10.8 years [min: 8.2; max: 15; standard deviation (SD): 2.29 years]. The mean age of the patients (data reported in 9 studies) is 67.5 years (min: 61; max: 72.5; SD: 3.37 years).

Data from the included papers are reported in *Table 1* (12,16-25).

### **Main and secondary outcomes**

The reported re-revision rate ranged from 1.4% to 45.6% and was reported in all the studies included in the statistical analysis. The random effect pooled estimate was 9.6% (95%

CI: 5% to 16%), with a  $I^2$  of 92.6% ( $P < 0.001$ ). We excluded two studies which heavily influenced both heterogeneity and pooled effect (18,21) and repeated the analysis: random effect pooled estimate was 5.5% (95% CI: 4% to 7%), with a  $I^2$  of 12.3% ( $P = 0.332$ ). We also obtained a symmetric funnel plot.

The median of the HHS, that was reported in 8 of the included studies, was 83 (min: 79; max: 87.6; SD: 3.55) (12,16,17,19,20,23-25).

Subsidence of the stem greater than 5 mm was reported in 6 of the included studies. The random effect pooled estimate was 5.7% (95% CI: 3% to 9%), with a  $I^2$  of 41.3% ( $P = 0.130$ ) (*Figure 2*) (12,17,19,20,23,25).

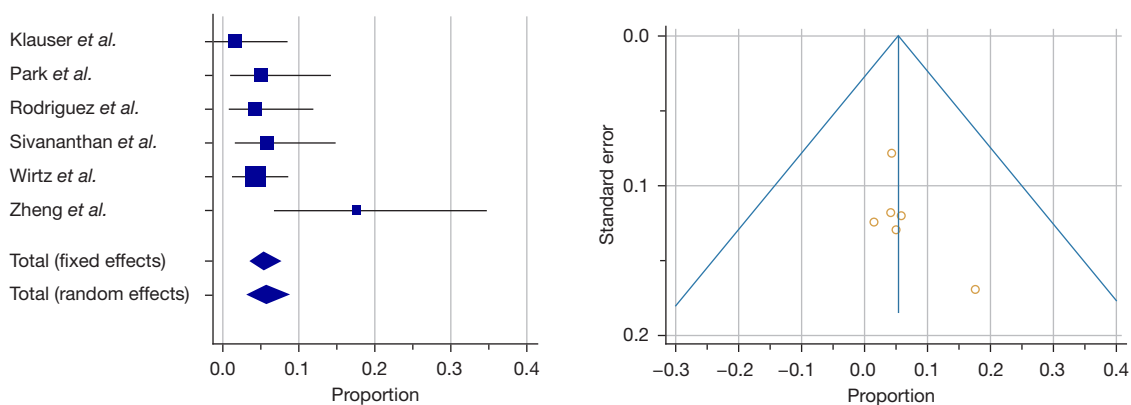
Dislocation of the prosthesis was reported in 10 of the included studies. The random effect pooled estimate was 6.4% (95% CI: 4% to 9%), with a  $I^2$  of 75.2% ( $P < 0.001$ ) (*Figure 3*) (12,16,17,19-25).

The cumulative rate of peri-prosthetic fractures was reported in all the included studies. The random effect

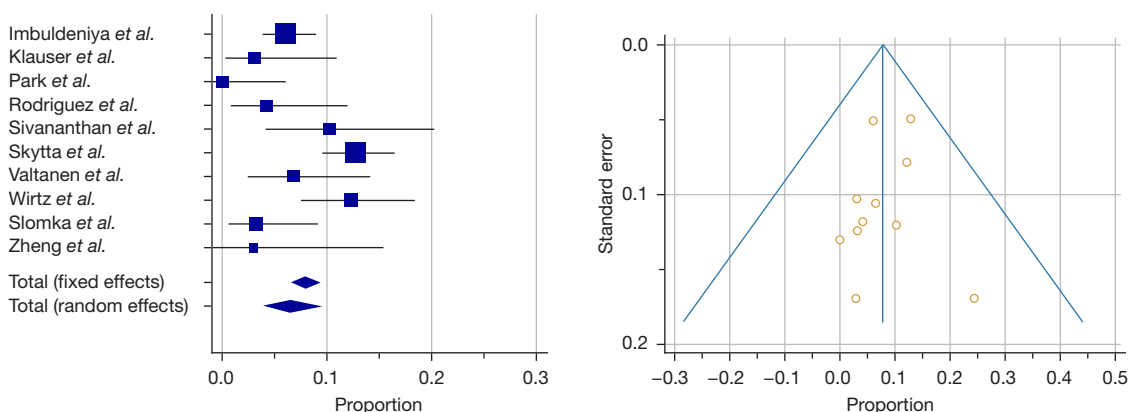
**Table 1** Studies included in the meta-analysis, including quality assessment

No.	Author	Year of publication	Hips	Follow-up <sup>a</sup> (y)	Re-revision of the stem (n, %)	Survival (%) <sup>*</sup>	Mean age (y)	HHS	Subsidence >5 mm	Periprosthetic infection	Dislocations	Periprosthetic fractures	Nos score	Nice score
1	Imbuldeniya et al. (16)	2014	397	12.9 [10-17.7]	16, 3%	90.5% at 15 y	69	80.7	-	8	24	12 (+29 intra-op.)	7	6
2	Klauser et al. (17)	2013	64	8.5 [7.6-12.9]	4, 6%	93.7% at 8.5 y	69	83	1	-	2	4 (+11 intra-op.)	8	5
3	McCarthy et al. (18)	2007	92	14 [8-17]	42, 45.6%	60% at 14 y	-	-	-	6	-	3 (- intra-op.)	6	5
4	Park et al. (19)	2010	59	8.2 [6.4-14]	5, 8.5%	91.5% at 10 y	61	87.6	3	1	0	0 (+4 intra-op.)	7	4
5	Rodriguez et al. (20)	2014	71	10 [8-15]	1, 1.4%	95.6% at 10 y	69	87	3	1	3	2 (+4 intra-op.)	8	6
6	Sivananthan et al. (12)	2017	68	11 [7-14]	4, 5.9%	94% at 11 y	68	80.1	4	4	7	4 (- intra-op.)	8	7
7	Skyttä et al. (21)	2012	408	9	78, 19%	75% at 9 y	72.5	-	-	3	52	2 (- intra-op.)	7	5
8	Valtanen et al. (22)	2023	89	15 [14-18.5]	3, 3.4%	-	69	-	-	3	6	1 (+7 intra-op.)	6	4
9	Wirtz et al. (23)	2014	163	10 [5-16]	10, 6.1%	97% at 10 y	66	79	7	4	20	6 (+29 intra-op.)	8	7
10	Slomka et al. (24)	2022	94	11.2 [8.2-14.2]	8, 8.5%	93.5% at 10 y	-	80	-	9	3	2 (- intra-op.)	7	5
11	Zheng et al. (25)	2021	34	9 [5-13]	3, 8.8%	95% at 10 y	64	86.5	6	3	1	- (+7 intra-op.)	8	7

<sup>a</sup>, data for follow up are presented as mean [range], or number; <sup>\*</sup>, considering revision for any reason. HHS, Harris Hip Score; y, years; op., operative.



**Figure 2** Forest plot and funnel plot depicting the rate of stems that underwent subsidence >5 mm.



**Figure 3** Forest plot and funnel plot for dislocations rate.

pooled estimate was 8.9% (95% CI: 4% to 15%), with a  $I^2$  of 92% ( $P < 0.001$ ) (Figure 4) (12,16-25).

We also repeated the analysis for intra-operative and post-operative periprosthetic fractures separately. Data related to intra-operative fractures were reported in 7 studies, a total of 91 cases on 877 hips (10.3%). The random effect pooled estimate was 11% (95% CI: 7% to 16%), with a  $I^2$  of 71.7% ( $P < 0.001$ ) (Figure 5) (16,17,19,20,22,23,25).

Data related to post-operative fractures were reported in 10 studies, a total of 36 cases on 1,505 hips (2.4%). The random and fixed effect pooled estimate was 3.3% (95% CI: 2% to 4%), with no heterogeneity between studies analysed and symmetric funnel plot (12,16-24).

The postoperative complication of periprosthetic joint infection, including both superficial and deep infection of the surgical site, was reported in 10 of the included studies. The random effect pooled estimate was 3.8% (95% CI:

2% to 6%), with a heterogeneity  $I^2$  of 68.7% ( $P < 0.001$ ) (Figure 6) (12,16,18-25).

Only the studies that reported survival over 8 years were included in this meta-analysis. The survival prosthetic implant rate is >90% at long-term follow-up in 8 studies (min: 60%; max: 97%) (12,16,17,19,20,23-25).

Meta-regression analysis revealed that there was no association between subsidence and dislocations or re-revision rate ( $P = 0.2$ ,  $P = 0.9$ ).

### Quality assessment and risk of bias

Quality assessment of these studies with the NICE guidelines and the NOS is shown in Table 1.

The mean value for the NICE tool was 5.5 (SD: 1.13) and 7.3 (SD: 0.79) for the NOS tool. The level of evidence of the studies was low because all were case series/

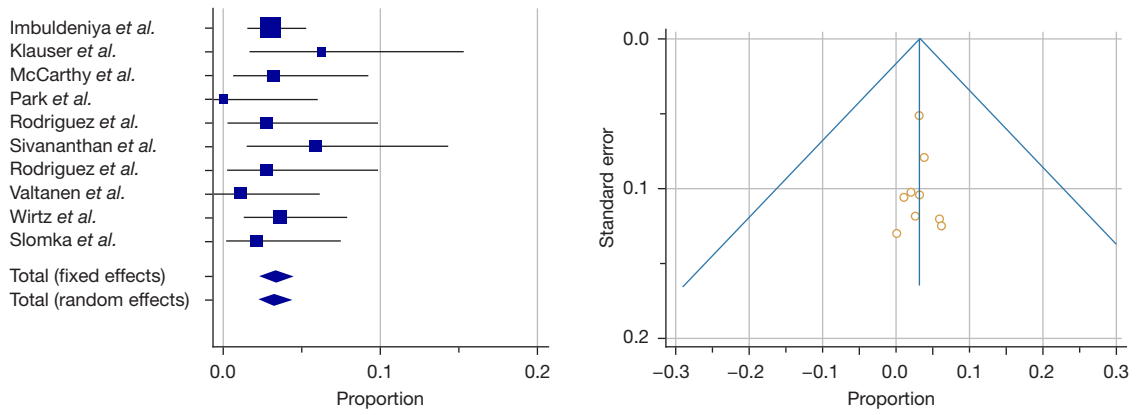


Figure 4 Forest plot and funnel plot for periprosthetic fractures rate (cumulative data: intra- and post-operative ones).

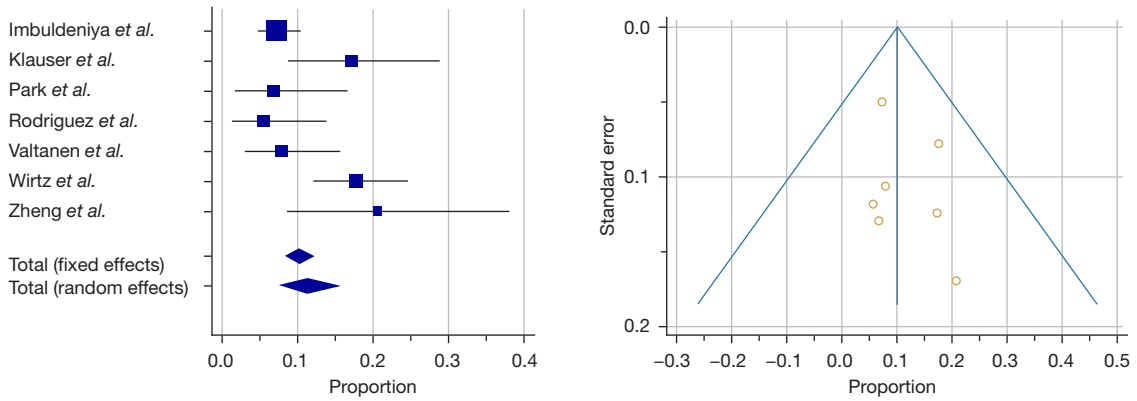


Figure 5 Forest plot and funnel plot for intra-operative periprosthetic fractures rate.

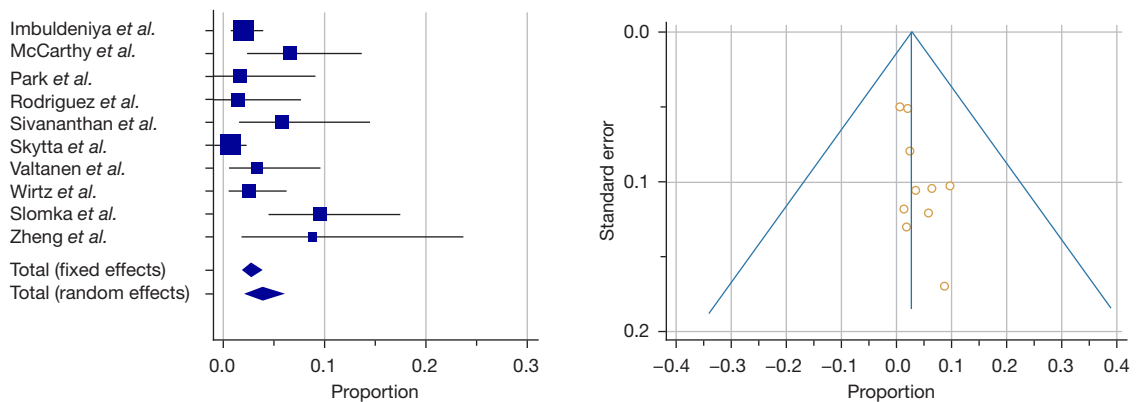


Figure 6 Forest plot and funnel plot for periprosthetic joint infections rate.

retrospective studies. Five studies scored over than eight on the NOS score (12,17,20,23,25). And, only 3 studies were identified as being high quality according to NICE guidelines (>7 points) (12,23,25).

Funnel plots were asymmetric in two parameters analysed (cumulative data for peri-prosthetic fractures and subsidence), showing possible publication bias. On the other hand, if intra- and post-operative periprosthetic fractures were analysed separately, heterogeneity was low and funnel plots symmetric.

Modular femoral stems offer good long-term outcomes, without relevant rate of complications.

## Discussion

The modular revision femoral stems allow to better manage revisions of failed THA. Modular revision stems better adapt to patients' anatomical characteristics achieving implant stability, by reconstructing bone defects, restoring hip biomechanics and correcting leg length discrepancy. To achieve these goals, modularity plays an essential role, compared to traditional monobloc femoral stems. In fact, for proximal femoral defects of Paprosky type II and higher, modular femoral stems have been used to improve stem stability and facilitate restoration of the center of rotation (26).

The re-revision rate reported in our meta-analysis is in line with that found in other systematic reviews (27,28). Failure is closely related to subsidence >5 mm, So, it is recommended to fill the femoral canal to provide better primary press-fit stability with the assistance of intraoperative fluoroscopy (29).

Instability is also a much-feared complication of revision surgery, often dependent on factors other than the implanted components: scar tissue, tissue stiffness, muscle deficiency. A high rate of dislocation was related to low femoral offset and deficient soft tissue. Weiss *et al.* showed that 17 (19%) dislocations occurred after hip revision replacements. Wang *et al.* indicated that 2 of 58 (3.4%) hips dislocated after revision and that one patient needed further re-revision (30,31).

The incidence of periprosthetic infections may instead be conditioned by an important risk factor common to all patients undergoing revision: multiple surgical procedures, regardless of the reason that generated the failure of the primary hip implant (32-34).

High body mass index (BMI), with proximal bone loss and absence of medial support, early weight-bearing and lower bone mass and quality might trigger stem subsidence

and cause higher rate of periprosthetic fractures (35). In our metaanalysis there are some limitations that should be considered. First of all, the enrolled studies are retrospective, with lower level of evidence compared to the prospective ones. A second limitation is that we included a limited number of papers due to the necessity to analyse only studies with long-term follow-up: this could partially condition the results of the meta-analysis, which are notoriously affected by the number of papers included. On the other hand, the subgroup analysis made it possible to refine the results obtained, reducing the heterogeneity between the included studies.

We did not find a high number of complications in modular revision femoral stems at long-term follow-up. In addition, the rate of failure is low, since more than 90% of the implants did not need revision. So, in conclusion, modular femoral revision stems represent a good surgical option to treat aseptic loosening of primary hip replacements. These femoral stems allow the revision implant to be better adapted to the patient's anatomy, often subverted by previous surgical procedures, without leading to poor long-term follow-up results.

Our systematic review highlights how there is no differences in modular and monobloc femoral stems in terms of efficacy, without relevant additional risks for modular stems.

## Conclusions

The use of modular revision femoral stems yields satisfactory results and can reliably be the workhorse in revision THA. Modular stems are implants which may be better adapted to the patient's anatomy without relevant risks.

## Acknowledgments

*Funding:* None.

## Footnote

*Provenance and Peer Review:* This article was commissioned by the Guest Editors (Giuseppe Solarino and Giuseppe Marongiu) for the series "Modular Implants for Revision Arthroplasty in Orthopedics" published in *Annals of Joint*. The article has undergone external peer review.

*Reporting Checklist:* The authors have completed the



PRISMA reporting checklist. Available at <https://aoj.amegroups.org/article/view/10.21037/aoj-23-32/rc>

*Peer Review File:* Available at <https://aoj.amegroups.com/article/view/10.21037/aoj-23-32/prf>

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at <https://aoj.amegroups.com/article/view/10.21037/aoj-23-32/coif>). The series “Modular Implants for Revision Arthroplasty in Orthopedics” was commissioned by the editorial office without any funding or sponsorship. The authors have no other conflicts of interest to declare.

*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

*Open Access Statement:* This is an Open Access article distributed in accordance with the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 International License (CC BY-NC-ND 4.0), which permits the non-commercial replication and distribution of the article with the strict proviso that no changes or edits are made and the original work is properly cited (including links to both the formal publication through the relevant DOI and the license). See: <https://creativecommons.org/licenses/by-nc-nd/4.0/>.

## References

1. Kurtz S, Ong K, Lau E, et al. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am* 2007;89:780-5.
2. Hooper G, Lee AJ, Rothwell A, et al. Current trends and projections in the utilisation rates of hip and knee replacement in New Zealand from 2001 to 2026. *N Z Med J* 2014;127:82-93.
3. Patel A, Pavlou G, Mújica-Mota RE, et al. The epidemiology of revision total knee and hip arthroplasty in England and Wales: a comparative analysis with projections for the United States. A study using the National Joint Registry dataset. *Bone Joint J* 2015;97-B:1076-81.
4. RIAP - Registro Italiano ArtroProtesi (iss.it). Last access: February 21st, 2023. Available online: <https://riap.iss.it/riap/it/attivita/report/2022/10/27/report-annuale-riap-2021/>
5. Home - The National Joint Registry. Last access: February 21st, 2023. Available online: <https://www.njrcentre.org.uk/>
6. Artiaco S, Boggio F, Titolo P, et al. Clinical experience in femoral revision with the modular Profemur R stem. *Hip Int* 2011;21:39-42.
7. Brown SA, Flemming CA, Kawalec JS, et al. Fretting corrosion accelerates crevice corrosion of modular hip tapers. *J Appl Biomater* 1995;6:19-26.
8. Falkenberg A, Biller S, Morlock MM, et al. Micromotion at the head-stem taper junction of total hip prostheses is influenced by prosthesis design-, patient- and surgeon-related factors. *J Biomech* 2020;98:109424.
9. Krishnan H, Krishnan SP, Blunn G, et al. Modular neck femoral stems. *Bone Joint J* 2013;95-B:1011-21.
10. Kang MN, Huddleston JI, Hwang K, et al. Early outcome of a modular femoral component in revision total hip arthroplasty. *J Arthroplasty* 2008;23:220-5.
11. Jibodh SR, Schwarzkopf R, Anthony SG, et al. Revision hip arthroplasty with a modular cementless stem: mid-term follow up. *J Arthroplasty* 2013;28:1167-72.
12. Sivananthan S, Lim CT, Narkbunnam R, et al. Revision Hip Arthroplasty Using a Modular, Cementless Femoral Stem: Intermediate-Term Follow-Up. *J Arthroplasty* 2017;32:1245-9.
13. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71.
14. The National Institute for Health and Care Excellence (NICE). Appendix 4 Quality of case series form. Available online: <https://www.nice.org.uk/guidance/cg3/documents/appendix-4-quality-of-case-series-form2>. Last access: February 21st, 2023.
15. Wells G, Shea B, O'Connell D, et al. The Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Non-Randomised Studies in Meta-Analyses. Available online: [https://www.ohri.ca/programs/clinical\\_epidemiology/oxford.asp](https://www.ohri.ca/programs/clinical_epidemiology/oxford.asp). Last access: February 21st, 2023.
16. Imbuldeniya AM, Walter WK, Zicat BA, et al. The S-ROM hydroxyapatite proximally-coated modular femoral stem in revision hip replacement: results of 397 hips at a minimum ten-year follow-up. *Bone Joint J* 2014;96-B:730-6.
17. Klauser W, Bangert Y, Lubinus P, et al. Medium-term follow-up of a modular tapered noncemented titanium stem in revision total hip arthroplasty: a single-surgeon experience. *J Arthroplasty* 2013;28:84-9.
18. McCarthy JC, Lee JA. Complex revision total hip arthroplasty with modular stems at a mean of 14 years. *Clin Orthop Relat Res* 2007;465:166-9.

19. Park MS, Lee JH, Park JH, et al. A distal fluted, proximal modular femoral prosthesis in revision hip arthroplasty. *J Arthroplasty* 2010;25:932-8.
20. Rodriguez JA, Deshmukh AJ, Robinson J, et al. Reproducible fixation with a tapered, fluted, modular, titanium stem in revision hip arthroplasty at 8-15 years follow-up. *J Arthroplasty* 2014;29:214-8.
21. Skyttä ET, Eskelinen A, Remes V. Successful femoral reconstruction with a fluted and tapered modular distal fixation stem in revision total hip arthroplasty. *Scand J Surg* 2012;101:222-6.
22. Valtanen RS, Hwang KL, Amanatullah DF, et al. Revision Hip Arthroplasty Using a Modular, Cementless Femoral Stem: Long-Term Follow-Up. *J Arthroplasty* 2023;38:903-8.
23. Wirtz DC, Gravius S, Ascherl R, et al. Uncemented femoral revision arthroplasty using a modular tapered, fluted titanium stem: 5- to 16-year results of 163 cases. *Acta Orthop* 2014;85:562-9.
24. Slomka F, Druon J, Rosset P, et al. Fully hydroxyapatite-coated distal locking cementless femoral modular implant for revision total hip arthroplasty: A retrospective study of 94 Renaissance™ stems at a minimum 10 years' follow-up. *Orthop Traumatol Surg Res* 2022;108:103233.
25. Zheng K, Li N, Zhang W, et al. Mid- to Long-Term Outcomes of Cementless Modular, Fluted, Tapered Stem for Massive Femoral Bone Loss in Revision Total Hip Arthroplasty. *Orthop Surg* 2021;13:989-1000.
26. Weeden SH, Paprosky WG. Minimal 11-year follow-up of extensively porous-coated stems in femoral revision total hip arthroplasty. *J Arthroplasty* 2002;17:134-7.
27. Koutalos AA, Varitimidis S, Malizos KN, et al. Clinical, functional and radiographic outcomes after revision total hip arthroplasty with tapered fluted modular or non-modular stems: a systematic review. *Hip Int* 2022;32:475-87.
28. Abdel MP, Cottino U, Larson DR, et al. Modular Fluted Tapered Stems in Aseptic Revision Total Hip Arthroplasty. *J Bone Joint Surg Am* 2017;99:873-81.
29. Rodriguez JA, Fada R, Murphy SB, et al. Two-year to five-year follow-up of femoral defects in femoral revision treated with the link MP modular stem. *J Arthroplasty* 2009;24:751-8.
30. Weiss RJ, Beckman MO, Enocson A, et al. Minimum 5-year follow-up of a cementless, modular, tapered stem in hip revision arthroplasty. *J Arthroplasty* 2011;26:16-23.
31. Wang L, Dai Z, Wen T, et al. Three to seven year follow-up of a tapered modular femoral prosthesis in revision total hip arthroplasty. *Arch Orthop Trauma Surg* 2013;133:275-81.
32. Logroscino G, Campana V, Pagano S, et al. Risk factors for failure of two-stage revision arthroplasty for infected hip prosthesis: review of the literature and single centre cohort analysis. *Eur Rev Med Pharmacol Sci* 2019;23:65-75.
33. Kapadia BH, Berg RA, Daley JA, et al. Periprosthetic joint infection. *Lancet* 2016;387:386-94.
34. Logroscino G, Saracco M. Hip periprosthetic joint infections: prevention, diagnosis and treatment. *Minerva Orthopedics* 2022;73:321-3.
35. Efe T, Schmitt J. Analyses of prosthesis stem failures in noncemented modular hip revision prostheses. *J Arthroplasty* 2011;26:665.e7-12.

doi: 10.21037/aoj-23-32

**Cite this article as:** Saracco M, Ciriello V, Fidanza A, Logroscino G. Clinical and radiological outcomes and analysis of failures of modular revisions stems at long-term follow-up: a systematic review and meta-analysis. *Ann Joint* 2024;9:1.