Original Article

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

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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

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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).

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 metanalysis 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.

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 4th 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.

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

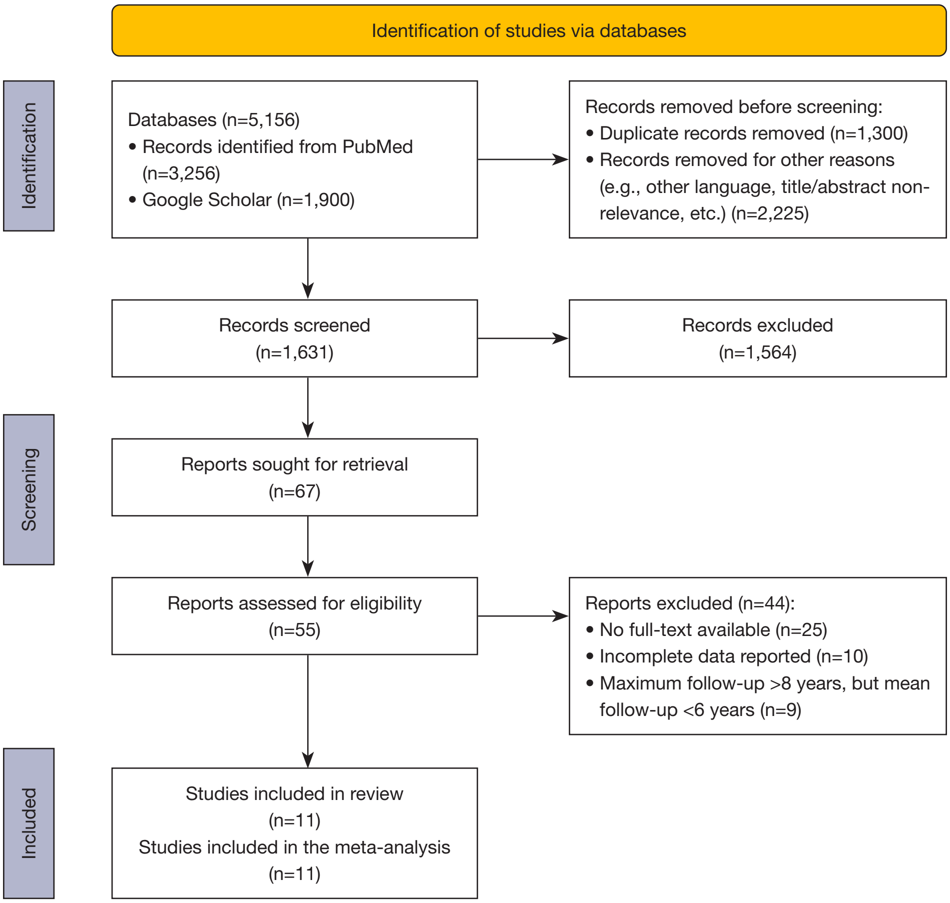

Figure 1 Flow chart of the systematic research.

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[&] (y)	Re-revision of the stem (n, %)	Survival (%)*	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

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

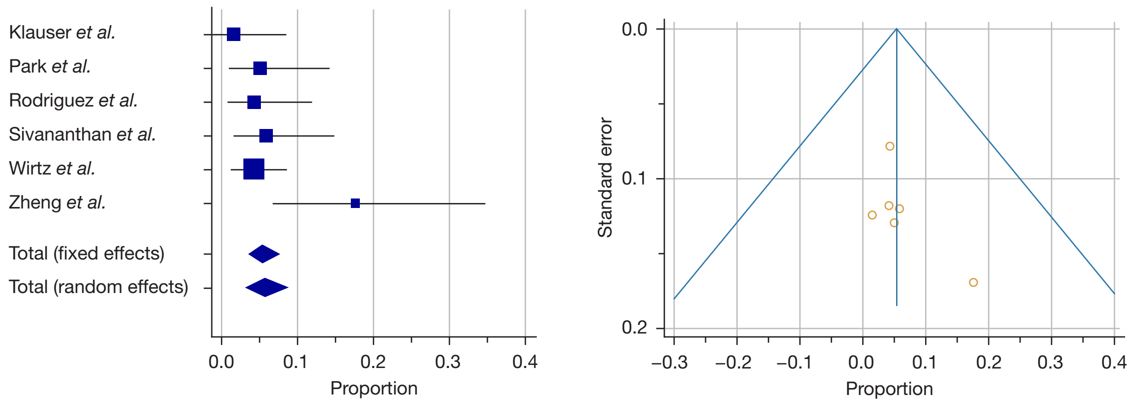

Figure 2 Forest plot and funnel plot depicting the rate of stems that underwent subsidence >5 mm.

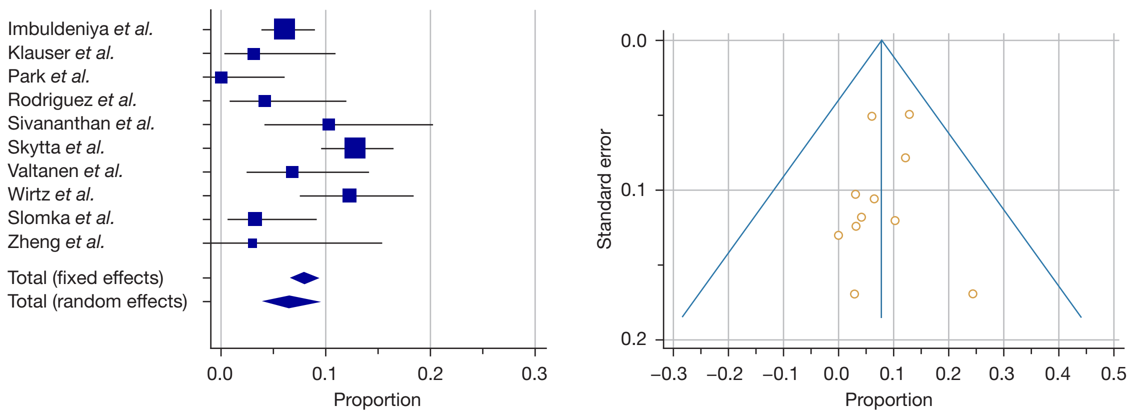

Figure 3 Forest plot and funnel plot for dislocations rate.

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/

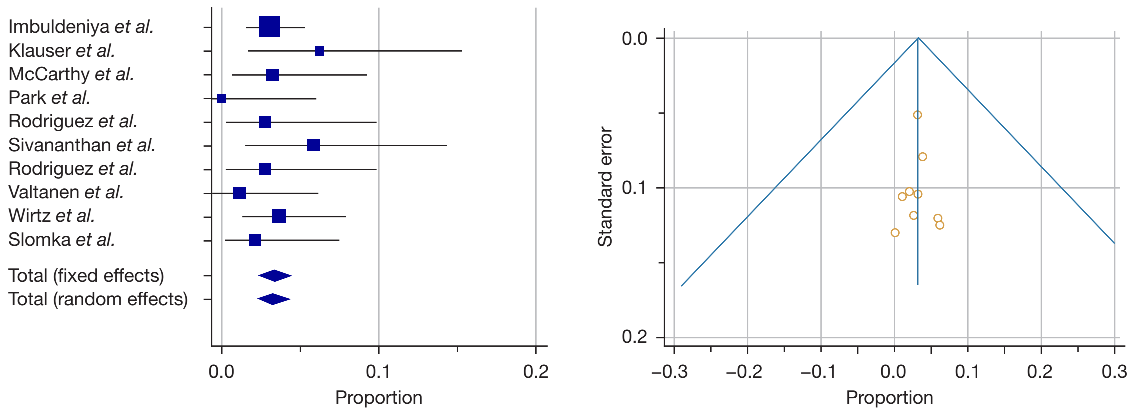

Figure 4 Forest plot and funnel plot for periprosthetic fractures rate (cumulative data: intra- and post-operative ones).

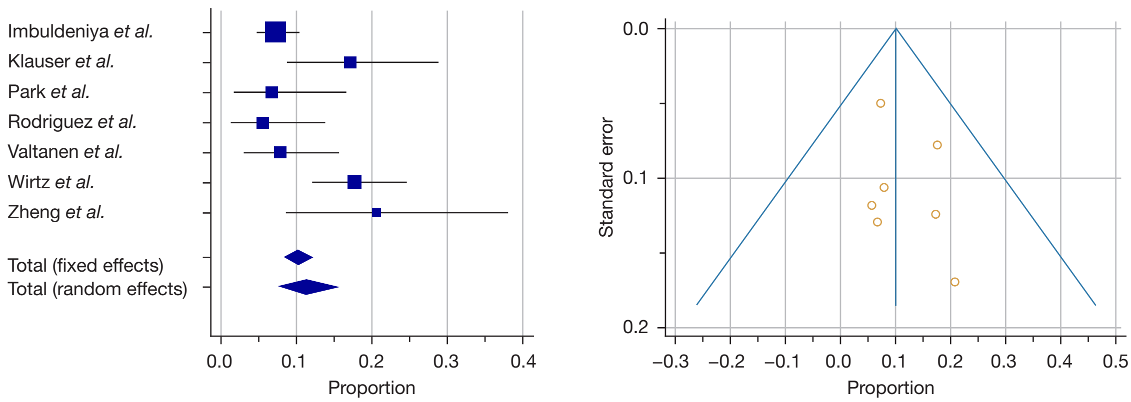

Figure 5 Forest plot and funnel plot for intra-operative periprosthetic fractures rate.

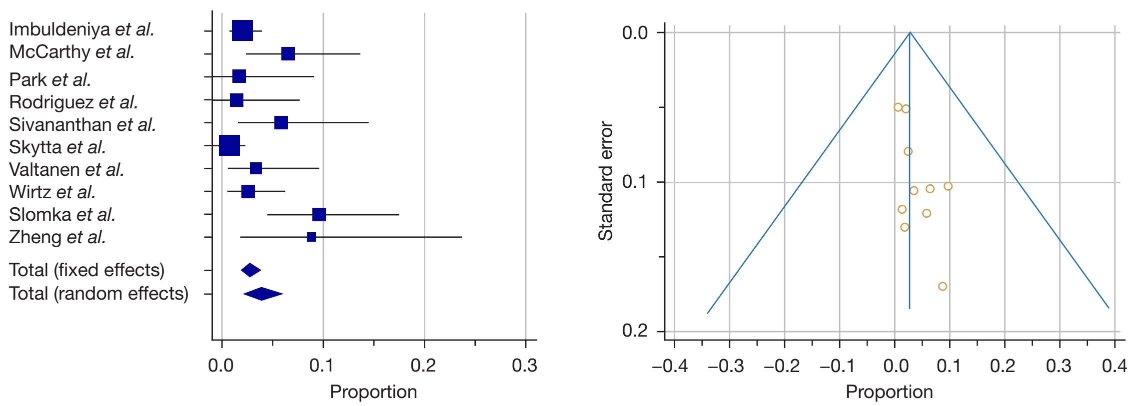

Figure 6 Forest plot and funnel plot for periprosthetic joint infections rate.

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 metanalysis 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.

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Footnote

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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.

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