Loosening and revision rates after total shoulder arthroplasty: a systematic review of cemented all-polyethylene glenoid and design of the modern metal-backed glenoid

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Research article

Keywords: shoulder, osteoarthritis, arthroplasty, glenoid component, metal-back, polyethylene Level of Evidence: Level IV, systematic review

Posted Date: December 12th, 2019

DOI: https://doi.org/10.21203/rs.2.18594/v1

Version of Record: A version of this preprint was published on February 21st, 2020. See the published version at https://doi.org/10.1186/s12891-020-3135-6.

Abstract

Background: Modern designs of metal-backed glenoids (MBG) have been devised to overcome flaws such as loosening and a high failure rate.This review aimed to compare rates of complications and revision surgeries between the modern metal-backed glenoid (MBG) and the cemented polyethylene glenoid (PEG).

Methods: Literature search was carried out using PubMed, Cochrane Library, EMBASE, and Google Scholar using MeSH terms and natural keywords. A total of 1186 articles were screened. We descriptively analyzed numerical data between the groups and statistically analyzed the categorical data, such as the presence of radiolucent line, loosening, and revision surgery (failure). Articles were divided into 3 groups based on follow-up duration: short-term < 36 months, midterm 36–72 months, and long-term > 72 months.

Results: This study included 35 articles (3769 shoulders); 25 on cemented PEG and ten on the modern MBG. Mean age was 66.4 (21–93) and 66.5 years (31–88). The mean duration of follow-up was 73.1 (12–211) and 56.1 months (24–100). Overall, the rate of the radiolucent line was 354/1302 (27%) and 47/282 (17%), the loosening rate was 465/3185 (15 %) and 22/449 (5%), and the failure rate was 189/3316 (6%) and 11/457 (2%), for PEG and MBG, respectively. The results of short- and mid-term FU studies showed lower rates of radiolucency and loosening in the cemented PEG group, but there was no significant difference in failure rate ($P=0.754$ and 0.829, respectively). In long-term FU, MBG was better in terms of loosening ($P < 0.001$) and failure rates ($P = 0.006$).

Conclusions: The modern MBG component, especially TM glenoid, seems to be a promising alternative to cemented PEGs, based on subgroup revision rates according to the follow-up duration and overall results of ROM and clinical scores. All polyethylene glenoids tend to increase loosening and failure over time. The modern MBG seems to have no difference in failure, at least in the short- and mid-term compared to the cemented PEG. More long-term follow-up studies on modern MBG should be ultimately conducted.

Background

Although numerous studies on total shoulder arthroplasty (TSA) have aimed to find the optimal TSA design, no definite conclusions have been made [1]. The glenoid component of TSA is divided into keel type and peg type according to its shape, and can be made of all polyethylene (PE) or be metal-backed. Both metal-backed glenoids (MBG) and cemented polyethylene glenoids (PEG) were initially used, however due to the nature of the initial MBG design, the polyethylene liner was very thin and resulted in a high wear and failure rate [2]. A systematic review conducted in 2014 concluded that MBGs are not recommended as they show higher failure rates [3].

However, advanced MBG designs were devised to address these shortcomings, increasing the chance of good clinical outcomes [4–6]. We aimed to summarize and compare the results of TSA using cemented PEG and modern MBG by examining radiolucency, loosening, and failure rate. Our null hypothesis was that radiolucency, loosening, and failure rates of modern MBGs would be similar to those of cemented PEG.

Methods

This systematic review was conducted in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines [7]. Additionally, we have registered the current review on the website of International prospective register of systematic reviews (PROSPERO, CRD42019137134).

Inclusion and exclusion criteria

We regulated various factors that could cause heterogeneity using strict inclusion and exclusion criteria determined by group discussion. The inclusion criteria were as follows:

i. Adult patients
ii. Clinical study presenting the results of TSA using the cemented PEG or modern MBG with more than a two year mean follow-up (FU)
iii. Any arthritis
iv. English language

Exclusion criteria were as follows:

i. Case report or fewer than 5 cases
ii. Hybrid cage glenoids
iii. Mixed cases of revision arthroplasty
iv. Mixed cases of structural bone graft
v. Not presenting the main outcome (number of revisions or failure)

Search strategy and study selection

PubMed, Embase, Google Scholar, and Cochrane Library were searched to find a large number of relevant articles. Separate keywords were selected for cemented PEG and modern MBG. The search terms for articles on cemented PEG were “total AND shoulder AND (replacement OR arthroplasty) AND polyethylene”. Search terms for articles on modern MBG were “total AND shoulder AND (replacement OR arthroplasty) AND (metal OR backed OR (cementless glenoid))”. After excluding duplicated documents, two independent reviewers screened the title and abstract, and finally selected articles through full-text review. We also performed citation tracking and search updates to find additional related articles using Google Scholar as an additional tool. All disagreements were resolved through group discussions of three or more authors.

Methodological assessment and data extraction

Levels of evidence were assessed according to the Oxford Center for Evidence Based Medicine [8]. The methodological quality of the studies included in this review was assessed using the methodological index for non-randomized studies (MINORS) [9]. A total of 8 items were evaluated for non-comparative studies, and 12 items for comparative studies. As 0, 1, or 2 points can be assigned to each item, non-comparative studies can have a total of 16 points, while comparative studies can have a total of 24 points. A study that obtained more than 60% of the total score was considered as a high-quality article, and the distribution of high-quality articles was analyzed between the two groups.

In order to define “modern design”, the core topic of this study, the most up to date articles on the glenoid component were reviewed in group discussion. The advanced MBG designs presented by Castagna et al., who comprehensively assessed the product development year, conformity, rod, keel shape, and material, were defined as modern MBGs [10]. We included 3 designs in the modern MBG group: 1) second-generation SMR MBG (SMR System, Lima Corporate, Villanova, di San Daniele, Udine, Italy), 2) first-generation trabecular metal (TM) glenoid which consists of a soft MBG, the Sulmesh (Zimmer, Winterthur, Switzerland), and 3) the second-generation TM glenoid (Zimmer, Winterthur, Switzerland).

Three independent reviewers extracted the number of shoulders, age, sex, FU duration, surgery procedures, medical and surgical history, preoperative diagnosis, name of implant and manufacturer, clinical score, range of motion (ROM), radiologic FU such as radiolucent lines, loosening, other complications, and revision or failure from the articles. The radiolucent line was defined as a radiolucency of 1 mm or more, grade 2 or more on the Lazarus radiolucency scoring system, or seven or more points out of a total of 18 points [11]. Failure was defined as complications that resulted in revision surgery involving an implant-related procedure. Loosening included both radiological and clinical loosening. Data presented by other methods and ambiguous data were not extracted.

Statistical analyses

We used strict criteria to minimize heterogeneity. However, trends in age, FU duration, and preoperative diagnosis could be identified after data extraction. In particular, FU duration was considered to be the most important variable associated with implant failure. We collaborated with medical statisticians on data interpretation and data analysis (including scatter plot and subgroup analysis). For categorical variables such as the presence of radiolucent lines, loosening, and failure or revision surgeries, statistical analysis was performed on the difference between cemented PEG and modern MBG.

Since the FU duration varies from study to study, we determined that a simple overall comparison between 2 groups was not sufficient, and therefore two additional analyses were performed according to the FU duration. Firstly, a scatter plot was used that plots the mean FU duration and loosening and revision rates of each study. Trend lines were weighted according to the number of cases to identify trends of loosening and revision rates between the two groups. Secondly, a subgroup analysis was performed that divided the FU duration into three groups based on 3 and 6 years. We analyzed the radiolucency, loosening and revision rates overall, and for the short-term FU, mid-term FU, and long-term FU. All statistical analyses were performed using R version 3.5.1 (R Foundation for Statistical Computing, Vienna, Austria). P-values less than 0.05 were determined to be statistically significant. Since numerical data were often missing important values such as standard deviation, a meta-analysis could not be performed. Therefore, descriptive analysis and weighted means were performed on the numerical data of 2 groups.

Results

Search results

Two hundred forty-one articles on cemented PEG were found in PubMed, 371 in Embase, and 24 articles in Cochrane Library. Subsequently, 177 articles on modern MBG were found in PubMed, 324 articles in Embase, and 29 articles in Cochrane Library. Through screening titles and abstracts and using full-text review, 25 PEG and 9 MBG articles were included. One article was added through citation tracking of selected articles, and no additional articles were found in the search update (Fig. 1). The final cemented PEG group included 3312 patients (25 articles) [12-36], and the modern MBG group included 457 patients (10 articles) [4-6, 37-43].

Assessment of methodological quality and heterogeneity between two groups

Levels of evidence and MINORS scores were determined by agreement between the two investigators, and there was no disagreement; one randomized controlled trial (Level I), one prospective comparative study (Level II), five Level III studies, and 28 Level IV studies were included. The mean MINORS scores, except for one Level I study, were 9.75 ± 1.38 for non-comparative studies and 16.8 ± 1.57 for comparative studies. Fifteen of the 25 studies on the cemented PEG (including Level I study, 60%) and 6 of the ten studies on the modern MBG (60%) were classified as high-quality articles (Fig. 2).

We analyzed the distribution of three factors that could introduce heterogeneity. Age and FU duration are shown using the summary plot (Figs 3A and 3B). Age showed a similar pattern except for three studies in the PEG group with young adults, whereas the cemented PEG group tended to have a longer FU period than the modern MBG group. The distribution of preoperative diagnosis was similar between the two groups (Fig. 4), and the proportion of primary osteoarthritis was not statistically different (P = 0.310).

Summary of outcomes of each article

Table 1 shows the demographic data and the outcome measurements of each study. Each study used a variety of measures; commonly used items were forward elevation (FE, 18 and 5 articles for cemented PEG and modern MBG, respectively), external rotation (ER, 18 and 5 articles), Constant score (13 and 3 articles), and ASES scores (7 and 6 articles), pain visual analogue scale (VAS, 5 and 7 articles), complications (most articles), and revision surgeries or failure (all articles) (Fig. 5). The results for each article for each commonly used item are shown in Table 2.

Clinical outcomes and complications of cemented PEG and modern MBG groups

Based on the data obtained in Table 2, an overall comparison between the two groups was performed (Table 3). The mean gain of the arc of flexion-extension (F-E) was 48.6° and 61.7° and the ER increase was 24.2° and 39.2°, the mean Constant score increase was 34.8 and 40.4, and the ASES score was 44.5 and 56.5 for cemented PEG and modern MBG, respectively (Fig. 6). Rates of radiolucent lines, loosening, and revision surgery were lower in the modern MBG group, although incomplete results did not resolve heterogeneity. The causes of the revision are summarized in Fig. 7; the most common cause of reoperation for the cemented PEG group was loosening of glenoids (83 out of 141 known causes, 59.0%), and fractures of glenoid components for the modern MBG group (6 out of 11 known causes, 54.5%).

Scatter plots and subgroup analysis according to the FU duration

We performed additional scatter plot and subgroup analyses according to the FU duration, which showed a heterogeneous pattern. The trend lines showed that the MBG group tended to have lower loosening and revision rates than the PEG group over time (Figs 8A and 8B). Table 4 shows the results of subgroup analysis by short-term, mid-term, and long-term FU. The results of the short- and mid-term FU studies showed that cemented PEG showed good results in terms of radiolucency and loosening, but that there was no significant difference in failure rate (P=0.754 and 0.829 for short-term and mid-term FU). In contrast, in long-term FU, modern MBG showed better results in terms of loosening (P <0.001) and revision rates (P = 0.006). We additionally compared two groups, after excluding three studies which included only young adults [14, 17, 24]. The scatter plot analysis and subgroup analysis according to the FU duration showed the same trend as that of the main analysis (Table 5, fig. 9A and fig. 9B).

Discussion

Although failure rates did not differ significantly between the two glenoid type groups in short-term and mid-term FU, modern PEGs were found to have lower radiolucency, loosening, and failure rates than cemented PEG (P = 0.033, < 0.001, and 0.006, respectively). This is in line with the results obtained from the scatter plot analysis. Also, the gains of FE and ER, Constant score, and ASES score of the modern MBG group were not lower than those of cemented PEG. Taken together, these results show that the modern MBG is comparable to the cemented PEG, with promisingly better results in a few of these aspects.

The trends in outcomes were found to differ between the two groups as the FU duration increased. In the cemented PEG group, loosening and failure rate typically increased as the FU duration increased. In contrast, long-term FU studies were comparable to short-term FU studies in the modern MBG group. This may be because it is possible that the MBG was stably fixed, and that bony ingrowth was sufficient. If the modern MBG design caused stable fixation and bony ingrowth as the design originally intended, it makes sense that there were some initial failures in the modern MBG group and that the long-term FU results of the modern MBG were better than PEG. Moreover, it is possible that the error occurred due to the small number of studies with a long-term FU on modern MBGs. In order to confirm this conclusion, more long-term FU studies on modern MBGs should be performed.

A previous systematic review by Papadonikolakis and Matsen compared rates of complications and revision surgeries between MBG and PEG. They included all designs of MBGs up to 2013 in the same group and reported that MBGs showed significantly higher revision rates than PEG [3]. Categorical data such as loosening and revision were analyzed by crosstab analysis as in this study. The review is a well-performed study that has served as a reference for the selection of glenoid components. We tried to increase the credibility of the analytical results by conducting heterogeneity assessments and adjustments that did not appear to be performed in the previous review.

The MBG was designed to induce bone ingrowth using the porous-coated component on the glenoid contact surface, and smooth ROM on the joint surface using the PE component. Because of this, they were expected to be the ideal component. However, the results of clinical studies using the conventional MBG design were disappointing [2, 16, 17, 44–51]. These failures were caused by several factors. First, MBG failure is often associated with PE wear, which is often caused by thinner PE thickness in these designs due to the metal back [16]. Second, overstuffing of joints can be induced to ensure sufficient PE thickness, resulting in loosening and rotator cuff tears, which ultimately leads to joint instability. Third, breakages of rods and screws may occur that are not caused by cemented PEG.

Attempts have been made to improve this by modifications to the MBG's design. Second-Generation SMR MBG (SMR System, Lima Corporate, Villanova, di San Daniele, Udine, Italy) is the representative of this modern design. Castagna et al. reported good results using this instrument, due to the curved-backed and less conforming shape of the glenoid, the stiff and thick metal back (5 mm) for reducing stress and wear on the PE component, applying hydroxyapatite to pegs as well as the baseplate, and initial strong fixation using two screws and one central peg [4]. Other representative modern designs are Zimmer's trabecular porous tantalum and titanium TM. The first generation of TM, the Sulmesh, consists of several titanium meshes, with four pegs protecting the metal back. The second-generation TM shows an improved design with porous tantalum keels. Recently, many clinical studies on these modern designs of MBG have been reported, and with the exception of a few studies, good results were reported with low failure rates and fast bony ingrowth around keels [4–6, 37–43, 52].

A study by Page et al. on similar topics analyzed glenoid revision rates using the Australian Orthopaedic Association National Joint Replacement Registry, which began in 2004. Cementless MBG was classified into modular type and fixed type in the study. Among them, SMR L2 and TM glenoid which were considered as modern design in this review were included in the analysis. Cementless glenoids showed a significantly higher revision rate than cemented glenoids. Contrary to the results presented by Castagna et al. [4], The SMR L2 design showed higher revision rate than other designs. Based on the result, SMR L2 was withdrawn from the market. TM glenoids, on the other hand, showed the same low revision rate in this review and the study by Page et al. [53]. Results of this review and the study by Page et al. suggest that surgeons should be cautious in MBG selection because it can produce different results for different designs. Among MBG designs, TM glenoids are most promising and comparable to cemented glenoids.

This study has several limitations. First, there is no clear global consensus on the distinction between modern design and conventional design. However, a rationale was found through a review article on glenoid components by Castagna et al. [10] and three models were defined as modern designs. Second, there is the possibility of remaining heterogeneity between studies. We thoroughly discussed this point at the research design stage and conducted data analysis and pooling after sufficient distribution analysis and adjustment of bias. Third, studies use different criteria for the definition of radiolucency and loosening in the main outcomes. Here, these were summarized using the most common and objective items as was possible, and credibility was increased by eliminating ambiguous data. Ultimately, the most objective and ultimate outcome indicator is failure or revision rate, and the failure rate results presented in this review suggest that modern MBG is promising. There are also not enough studies performed on modern MBGs; many surgeons still prefer cemented PEGs, and the modern designs of MBGs are still quite new. Since new designs are being developed in addition to the modern MBGs included in this study, a definite consensus on MBGs may be formed if more studies on the MBGs are actively conducted.

Conclusion

The modern MBG component, especially TM glenoid, seems to be a promising alternative to cemented PEGs, based on subgroup revision rates according to the follow-up duration and overall results of ROM and clinical scores. All polyethylene glenoids tend to increase loosening and failure over time. The modern MBG seems to have no difference in failure, at least in the short- and mid-term compared to the cemented PEG. More long-term follow-up studies on modern MBG should be ultimately conducted.

List Of Abbreviations

TSA:total shoulder arthroplasty; PE:polyethylene; MBG:metal-backed glenoid; PEG:cemented polyethylene glenoid; MINORS:methodological index for non-randomized studies; TM:trabecular metal; ROM:range of motion; FU:follow up; FE:forward elevation; ER:external rotation; ASES:American shoulder and elbow surgeons; VAS:visual analogue scale; F-E:flexion-extension; RC:rotator cuff; N:not recorded

Declarations

IRB/Ethical Committee Approval: AMC 2019-0739 (Date of issue: 13/06/2019)

Ethics approval and consent to participate: Not applicable

Consent for publication: Not applicable

Availability of data and materials: Not applicable

Competing interests: The authors declare that they have no competing interests

Funding: This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education(NRF-2018R1D1A1A02086025).

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

Authors' contributions: KHK made the conception and design of this study and analyzed the data of the study. DMK, MA, and FA collected and analyzed the data. DMK wrote the initial manuscript. MJS, EK, HJK, and IHJ have contributed to data interpretation and critically revising the manuscript. All authors read and approved the final manuscript.

Acknowledgment: We would like to thank Minkyu Han, PhD for analyzing and interpreting data and processing them to meaningful results. Also, we would like to thank Editage (www.editage.co.kr) for English language editing.

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Tables

Table 1. Demographic data and outcome measurement of individual studies

Cemented all-polyethylene glenoid components (PEG)

Authors	Level of Evidence	Design	Cases	Mean age (y, range)	Mean FU (m, range)	Range of motion	Outcome measurements
Raiss (2008)	IV	Aequalis[a]	21	55 (37–60)	7 years (5–9)	FE, ABD, IR, ER	Constant score
Rice (2008)	IV	Cofield II[b]	14	66 (52–78)	5 years (2–8)	ABD, ER	Neer result rating
Fox (2009)	IV	Mixed[c]	972	66.4	68.1	N	N
Edwards (2010)	I	Aequalis[a]	47	69 ± 11	26 (12–38)	N	N
Throckmorton (2010)	III	Cofield	100	68.6 (52–80)	48.5 (24–98)	FE, IR, ER	VAS
Arnold (2011)	IV	Global Advantage[d]	35	70 (49–89)	43 (24–66)	N	Constant score
Collin (2011)	II	Aequalis[a]	56	66.7 (43–83)	120 (102–155)	N	N
Walch (2011)	IV	Aequalis[a]	333	69.3 (35–90)	89.5 (61–152)	FE, ER	Constant score
Young (2011)	IV	Aequalis[a]	226	66.9 (40–90)	122.7 (61–219)	FE, ER	Constant score
Raiss (2012)	IV	Aequalis[a]	39	64 (43–79)	132 (120–180)	FE, ABD, IR, ER	Constant score
Wirth (2012)	IV	Global Advantage[d]	44	66 (52–79)	48 (24–84)	FE, IR, ER	VAS, ASES score, SST
Denard (2013)	IV	Aequalis[a]	50	50.5 (35–55)	115.5 (60–211)	FE, ER	Constant score
Greiner (2013)	IV	Affinis[e]	97	66.6 (30–85)	58.8 (31.2–92.5)	FE, ABD	Constant score
Raiss (2014)	IV	N (mixed)	329	N	8.0 years (4–17)	FE, ER	Constant score
Gazielly (2015)	IV	Aequalis[a]	39	68.1 (51–81)	102 (56.4–150)	FE, ER	Constant score, pain score
Gulotta (2015)	III	BioModular[f]	40	68.2 ± 9.1	38 (24–45)	N	VAS, ASES
Noyes (2015)	IV	Global Advantage[d]	42	64 (51–80)	80 (63–114)	FE, ER	ASES
Wright (2015)	IV	Equinoxe[g]	24	66.4 ± 9.1	29.6 ± 8.7	FE, ABD, IR, ER	Constant score, ASES, SST, UCLA
Parks (2016)	IV	Affiniti[h]	76	63.5 (39–86)	28.7 (24–60)	FE, ABD, IR, ER	Constant score, ASES

Wijeratna (2016)	IV	Global Advantage[d]	83	68.6 (49–88)	46.7 (24–99)	FE, IR, ER	ASES, Oxford score
McLendon (2017)	IV	Cofield II[i]	287	65 (21–85)	84 (48–171.6)	N	N
Service (2017)	III	Global Advantage[d]	71	68 ± 8.3	30 ± 7.2	N	SST
Gauci (2018)	III	Aequalis[a]	46	55(40–60)	123.6 ± 26 (60–144)	FE, ER	VAS, Constant score, SSV
Raiss (2018)	IV	Aequalis[j]	118	68 (51–85)	38 (24–70)	N	N
Sanchez-Sotelo (2018)	2018/IV	PEG	202	67 (24–93)	32.4 (24–60)	FE, IR, ER	ASES

Modern design of metal-backed glenoid component (MBG)

Authors	**Level of Evidence**	**Design**	**Cases**	**Mean age (y, range)**	**Mean FU (m, range)**	**Range of motion**	**Outcome measurements**
Castagna (2010)	IV	Second-generation SMR[l]	35	62.7 (55.3–70.1)	75.4	N	VAS, Constant score, SST
Fucentese (2010)	IV	Sulmesh[m]	22	68.5 (49–84)	50 (24–89)	N	Constant score
Budge (2013)	IV	Tantalum TM[n]	19	62.8 ± 14.6	31 (24–64)	ER	VAS, ASES score
Styron (2016)	IV	Tantalum TM[n]	66	66.2 (31–88)	50.2	FE, IR, ER	N
Sandow (2016)	IV	Tantalum TM[n]	10	(60–79)	24	FE	VAS, Oxford score, ASES score
Panti (2016)	IV	Tantalum TM[n]	76	69.6 (52–81)	43.2 (24–72)	FE, ABD, ER	VAS, ASES score
Endrizzi (2016)	IV	Tantalum TM[n]	73	67.5 ± 8.6 (46–85)	50.8 (24–68)	N	VAS, ASES score
Merolla (2016)	IV	Tantalum TM[n]	40	63.8 (40–75)	38 (24–42)	FE, ABD, ER	Health state, Constant score, ASES score
Gurin (2017)	IV	Tantalum TM[n]	80	N	100	N	VAS
Watson (2018)	IV	Tantalum TM[n]	36	66.36 (50–85)	34.1 (23–61)	FE, ER	VAS, SANE score, Penn score, ASES score

Common outcome measurements	**Radiolucency, loosening, complication, and revision surgery (failure)**

N, not recorded; y, year; m, month; FU, follow-up; FE, forward elevation; ABD, abduction; IR, internal rotation; ER, external rotation; VAS, visual analogue scale; ASES, American shoulder and elbow surgeons; SST, simple shoulder test; SF-12, short form-12; UCLA, University of California at Los Angeles; SSV, subjective shoulder value; SANE, single alpha-numeric evaluation

[a] Unconstrained, cemented, third-generation implant (Aequalis Primary Shoulder Prosthesis; Tornier Inc., Edina, Minnesota, USA) or Aequalis prosthesis (Tornier, Mont Bonnot, France)

[b] Cofield 2 keeled all-polyethylene cemented components with a posterior augmentation (Smith and Nephew, Inc, Memphis, TN, USA)

[c] Neer II all-polyethylene components (3M, St. Paul, MN; Kirschner Medical Corporation, Fairlawn, NJ; Biomet, Warsaw, IN, USA), Cofield 1 all-polyethylene component, Cofield 2 all-polyethylene keeled, and Cofield 2 all-polyethylene pegged components (Smith & Nephew, Memphis, TN, USA)

[d] Depuy Global Advantage with an Anchor Peg glenoid (Depuy, Warsaw, IN, USA)

[e] Affinis shoulder prosthesis (Mathys Ltd Bettlach, Switzerland)

[f] BioModular Total Shoulder System with an all-polyethylene, cemented, pegged glenoid (Biomet, Inc, Warsaw, IN, USA)

[g] Equinoxe (Exactech, Inc., Gainesville, FL, USA)

[h] Affiniti CortiLoc glenoid (Tornier, Inc., Edina, MN, USA)

[i] Cofield II all-polyethylene pegged component (Smith & Nephew, Memphis, TN, USA)

j Cemented keeled glenoid with different backside radiuses of curvature (Tornier/Wright Medical, Memphis, TN, USA)

[k] ReUnion (Stryker, Mahwah, NJ, USA)

[l] Second generation SMR System (Lima Corporate, Villanova, Italy)

[m] Titanium metal-backed glenoid component (Sulmesh; Zimmer, Winterthur, Switzerland)

[n] Second-generation porous tantalum trabecular metal glenoid (Zimmer, Warsaw, IN, USA)

Table 2. Clinical outcomes of individual studies

Cemented all-polyethylene glenoid components (PEG)

Authors	Cases	Gain of FE (°)	Gain of ER (°)	Radiolucency	Loosening	Revision surgeries	Other reoperations
Raiss (2008)	21	50.7	28.1	10 (48%)	10	0	0
Rice (2008)	14	N	21	1 (7%)	1	0	0
Fox (2009)	972	N	N	N	15	26	0
Edwards (2010)	47	N	N	N	0	2	0
Throckmorton (2010)	100	48.3	28.6	N	10	0	0
Arnold (2011)	35	N	N	5	0	0	0
Collin (2011)	56	N	N	N	20	3	2: RC repair
Walch (2011)	333	51.7 26.3 96	26.3	96	57	5	3: open contracture release
Young (2011)	226	39.7	23.3	144	99	37	2: Periprosthetic fracture 3: instability 2: RC repair 2: infection 2: stiffness
Raiss (2012)	39	49	24	N	N	1	0
Wirth (2012)	44	141.9	34.6	N	N	1	0
Denard (2013)	50	31	21	30 of 48	21 of 48	17	0
Greiner (2013)	97	59.6	N	9	3	7	0
Raiss (2014)	250	46.9	25.0	N	100	22	0
Gazielly (2015)	39	42.4	25.7	8	6	1	0
Gulotta (2015)	40	N	N	N	0	0	1 infection 1 biceps tendinitis
Noyes (2015)	42	30	7	8	N	1	0
Wright (2015)	24	44.2	24.8	5 of 15	0	0	0
Parks (2016)	76	31	13	14	1	7 of 80	N
Wijeratna (2016)	83	N	N	5	1	1	3 contracture release 1: RC repair 1: capsular plication

McLendon (2017)	287	N	N	N	120	36	0
Service (2017)	71	N	N	19	1	3	0
Gauci (2018)	46	40	26	N	10	10	N
Raiss (2018)	118	N	N	N	0	2	0
Sanchez-Sotelo (2018)	202	N	N	0	0	7	2

Modern design of metal-backed glenoid component (MBG)

Authors	Cases	Gain of FE (°)	Gain of ER (°)	Radiolucency	Loosening	Revision surgeries	Other reoperations
Castagna (2010)	35	N	N	8 (22%)	0	0	0
Fucentese (2010)	22	N	N	N	3 (14%)	3 (14%)	0
Budge (2013)	19	N	44	7 (37%)	4 (21%)	3 (16%)	N
Styron (2016)	66	70	36	N	13 of 58 (23%)	1 (2%)	N
Sandow (2016)	10	N	N	0	0	0	0
Panti (2016)	76	54.4	40.8	5 (7%)	0	0	1: RC repair
Endrizzi (2016)	73	N	N	24 of 66 (36.4%)	1 of 66 (1.5%)	1 (1%)	0
Merolla (2016)	40	N	N	2 (5%)	0	0	0
Gurin (2017)	80	N	N	N	0	2 (3%)	0
Watson (2018)	36	N	N	1 (2.8%)	1 (2.8%)	1 (3%)	N

N, not recorded; FE, forward elevation; ER, external rotation; RC, rotator cuff

Table 3. Summary of cemented PEG and modern MBG

		Cemented PEG (n = 3312)	Modern MBG (n = 457)	P–value
Age (years)	Number of cases/articles	3062/24	367/8	NA
	Mean	**66.4 (21–93)**	**66.5 (31–88)**	
Follow–up duration (months)	Number of cases/articles	3312/25	457/10	NA
	Mean	**73.1 (12–211)**	**56.1**	
Gain of FE (°)	Number of cases/articles	1387/14	142/2	NA
	Mean	**48.6**	**61.7**	
Gain of ER (°)	Number of cases/articles	1304/14	161/3	NA
	Mean	**24.2**	**39.2**	
Constant score improvement	Number of cases/articles	1208/9	3/97	NA
	Mean	**34.8**	**40.4**	
ASES score improvement	Number of cases/articles	226/5	135/3	NA
	Mean	**44.5**	**56.5**	
Primary osteoarthritis	**Yes (%)**	**2866 (86.5%)**	**350 (88.4%)**	0.310
	No (%)	446 (13.5%)	46 (11.6%)	
	Diagnosis unknown	1	61	
Radiolucent lines	**Present (%)**	**354 (27.2%)**	**22 (4.9%)**	NA
	Absent (%)	948 (72.8%)	427 (95.1%)	
	Not reported	2010	8	
Loosening	**Present (%)**	**465 (14.6%)**	**22 (4.9%)**	NA
	Absent (%)	2720 (85.4%)	427 (95.1%)	
	Not reported	127	8	
Revision surgery	**Present (%)**	**189 (5.7%)**	**11 (2.4%)**	NA
	Absent (%)	3127 (94.3%)	446 (97.6%)	
	Not reported	0	0	

PEG, all-polyethylene glenoid; MBG, metal-backed glenoid; NA, not applicable; FE, forward elevation; ER, external rotation; ASES, American shoulder and elbow surgeons,

Table 4. Subgroup analysis according to the follow-up duration

Items	Short-term FU[a]		Mid-term FU[b]		Long-term FU[c]	
	PEG	MBG	PEG	MBG	PEG	MBG
Age (years)	66.7	64.8	66.9	67.3	65.3	62.7
Number of radiolucency (%)	38/439 (7.3%)	8/65 (12.3%)	20/229 (8.7%)	31/182 (17.0%)	296/709 (41.7%)	8/35 (22.9%)
	P = 0.355		**P = 0.015 ***		**P = 0.033 ***	
Number of loosening	2/420 (0.5%)	5/65 (7.7%)	19/1459 (1.3%)	17/269 (6.3%)	443/1306 (33.9%)	0/115 (0%)
	P < 0.001 *		**P < 0.001 ***		**P < 0.001 ***	
Number of failure (=revision)	19/424 (4.5%)	4/65 (6.2%)	37/1503 (2.5%)	5/277 (1.8%)	133/1389 (9.6%)	2/115 (1.7%)
	P = 0.754		P = 0.829		**P = 0.002 ***	

FU, follow-up; PEG, cemented all-polyethylene glenoid; MBG, metal-backed glenoid

[a] follow-up duration less than 36 months

[b] follow-up duration between 36 and 72 months

[c] follow-up duration more than 36 months

*statistically significant change

Table 5. Subgroup analysis except for 3 articles which included only young adults

Items	Short-term FU[a]		Mid-term FU[b]		Long-term FU[c]	
	PEG	MBG	PEG	MBG	PEG	MBG
Age (years)	66.7	64.8	66.9	67.3	66.7	62.7
Number of radiolucency (%)	38/439 (7.3%)	8/65 (12.3%)	20/229 (8.7%)	31/182 (17.0%)	256/640 (40.0%)	8/35 (22.9%)
	P = 0.355		**P = 0.015 ***		**P = 0.05**	
Number of loosening	2/420 (0.5%)	5/65 (7.7%)	19/1459 (1.3%)	17/269 (6.3%)	402/1191 (33.8%)	0/115 (0%)
	P < 0.001 *		**P < 0.001 ***		**P < 0.001 ***	
Number of failure (=revision)	19/424 (4.5%)	4/65 (6.2%)	37/1503 (2.5%)	5/277 (1.8%)	106/1272 (8.3%)	2/115 (1.7%)
	P = 0.754		P = 0.829		**P = 0.006 ***	

FU, follow-up; PEG, cemented all-polyethylene glenoid; MBG, metal-backed glenoid

[a] follow-up duration less than 36 months

[b] follow-up duration between 36 and 72 months

[c] follow-up duration more than 36 months

*statistically significant change

Prisma Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	3
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	PROSPERO CRD42019137134
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4, 5, Fig. 1
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	4, 5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	Fig. 1
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5, 6
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	5, 6
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	5, 6 Fig. 2
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	6
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	5, 6

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	5, 6 (demographic bias)
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	5, 6 (Subgroup analysis)
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	7
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	7, Table 1
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	7, 8, Fig. 2
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	7, 8, Table 2
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	N/A
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	7, 8 Fig. 2
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	8, Fig. 8, fig. 9, and table 5
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	9, 10, 11
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	10, 11
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	11
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	13

Figures

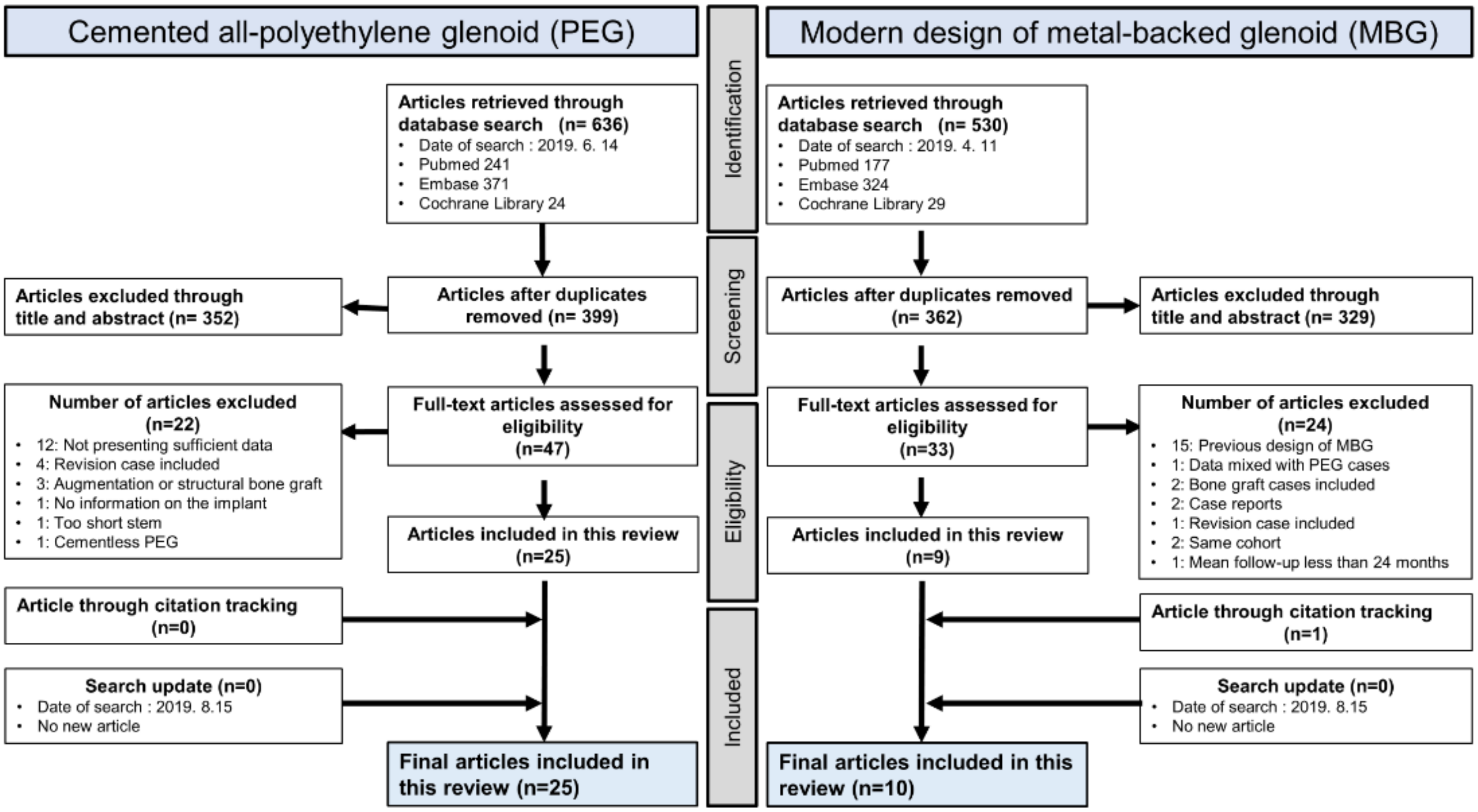

Figure 1

PRISMA flow diagram showing the selection of appropriate articles

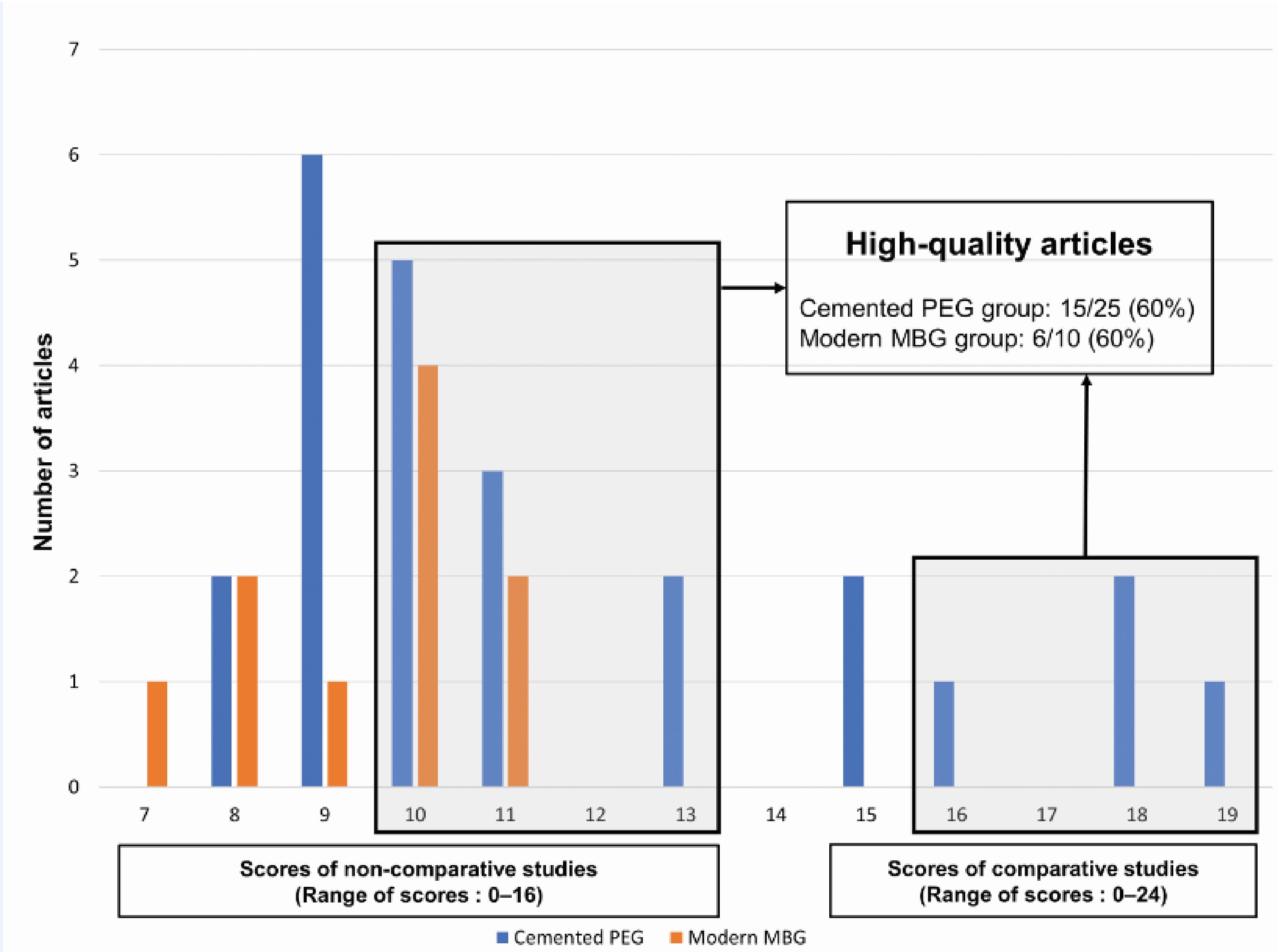

Figure 2

“Methodological index for non-randomized studies” scores of individual articles and the range that indicates high-quality articles PEG, polyethylene glenoid; MBG, metal-backed glenoid

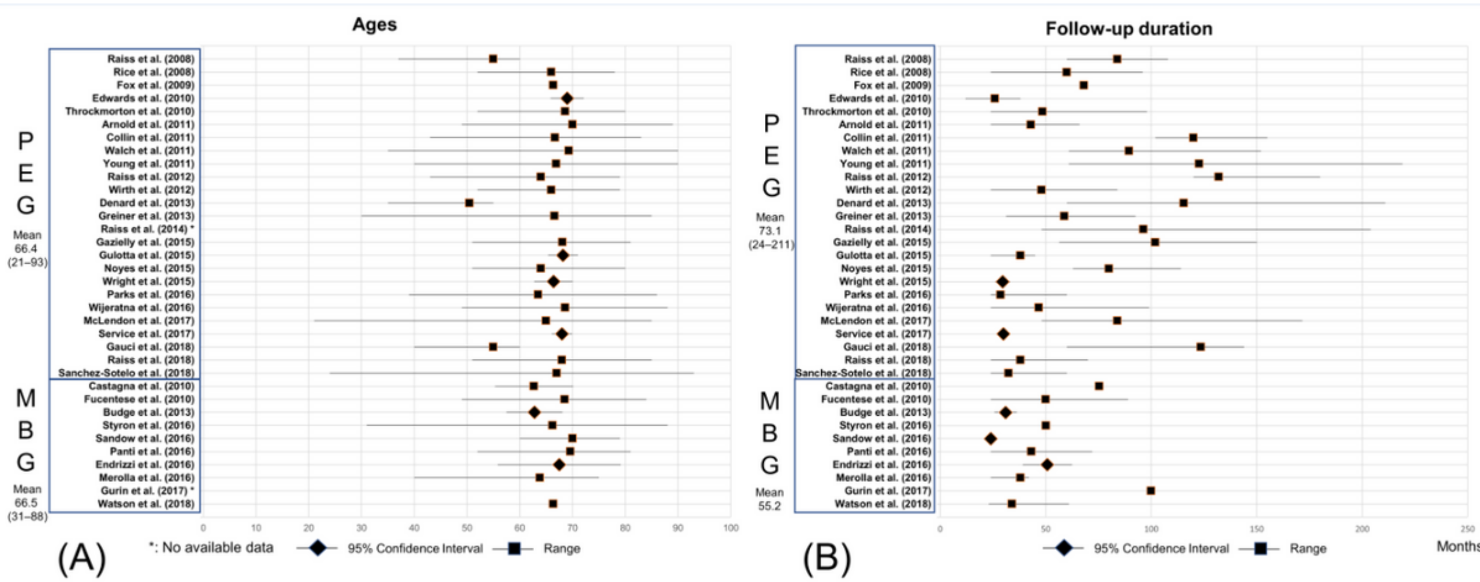

Figure 3

(A) Summary plots for age (B) Summary plots for follow-up duration PEG, polyethylene glenoid; MBG, metal-backed glenoid

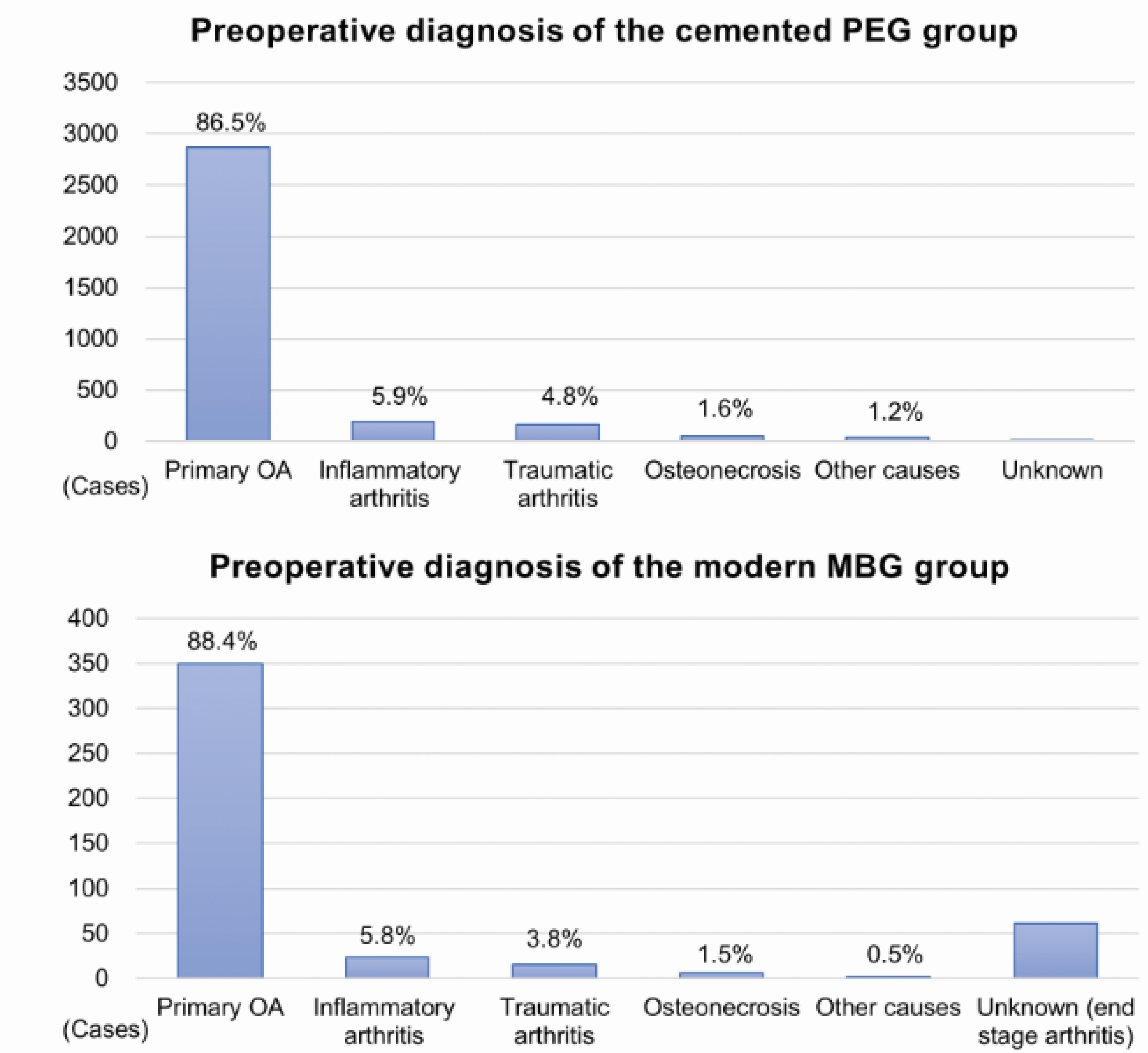

Figure 4

Graph showing the distribution of preoperative diagnosis for each group PEG, polyethylene glenoid; MBG, metal-backed glenoid; OA, osteoarthritis;

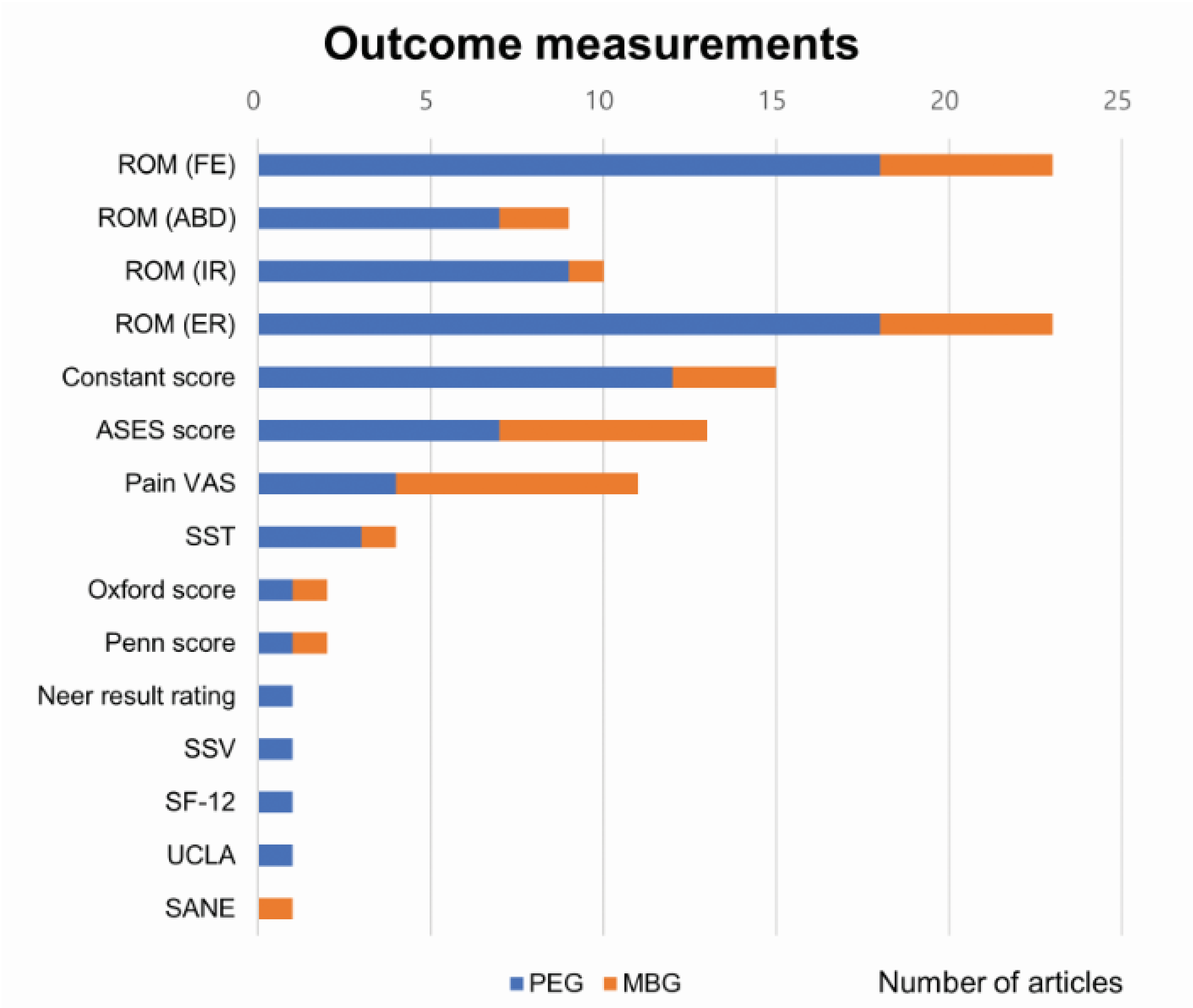

Figure 5

Distribution of outcome measurements FE, forward elevation; ABD, abduction; IR, internal rotation; ER, external rotation; ASES, American shoulder and elbow surgeons; VAS, visual analogue scale; SST, simple shoulder test; SSV, subjective shoulder value; SF-12, short form-12; UCLA, University of California at Los Angeles; SANE, single alpha-numeric evaluation

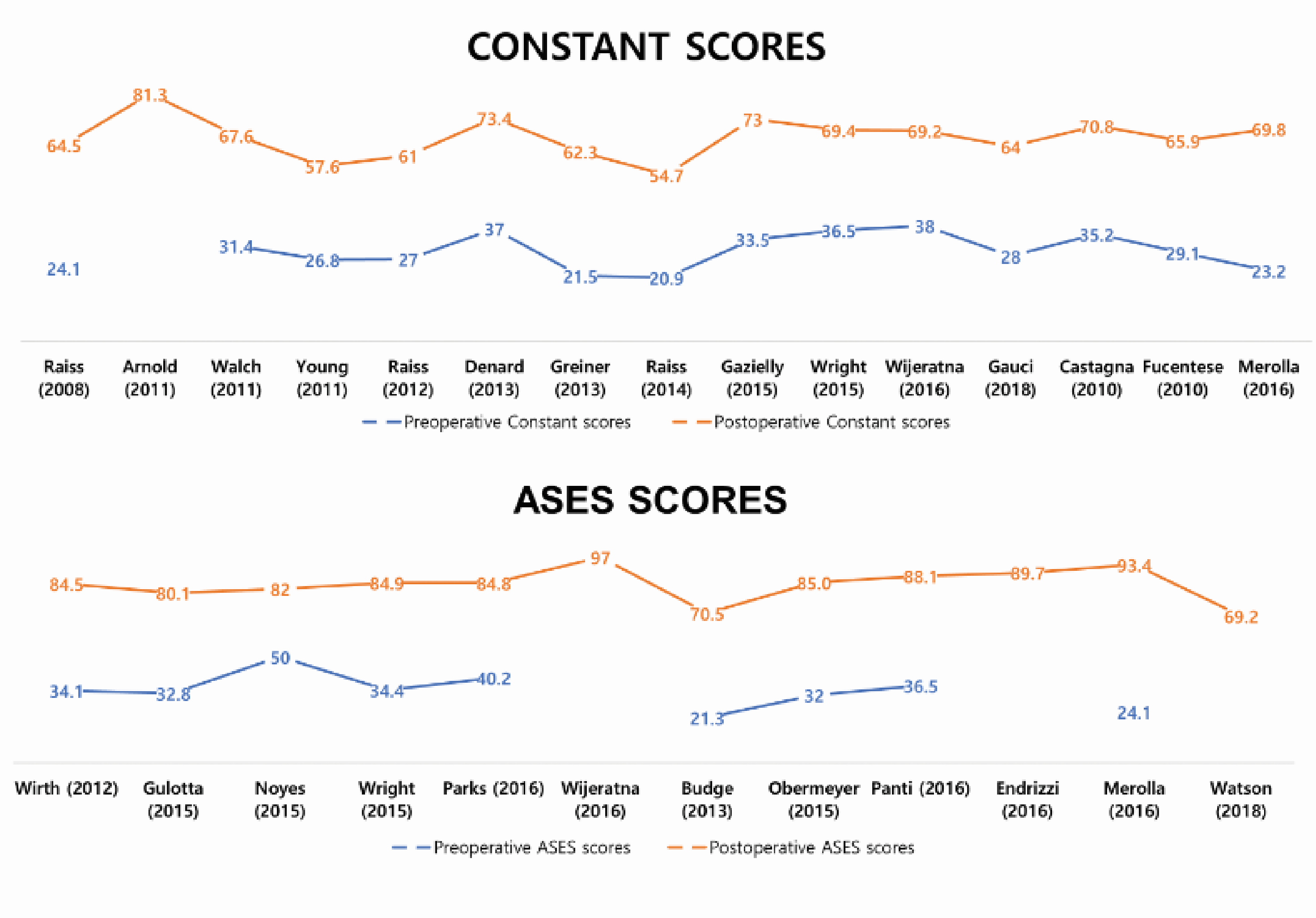

Figure 6

Graph showing the distribution of preoperative and postoperative clinical scores for each article ASES, American shoulder and elbow surgeons

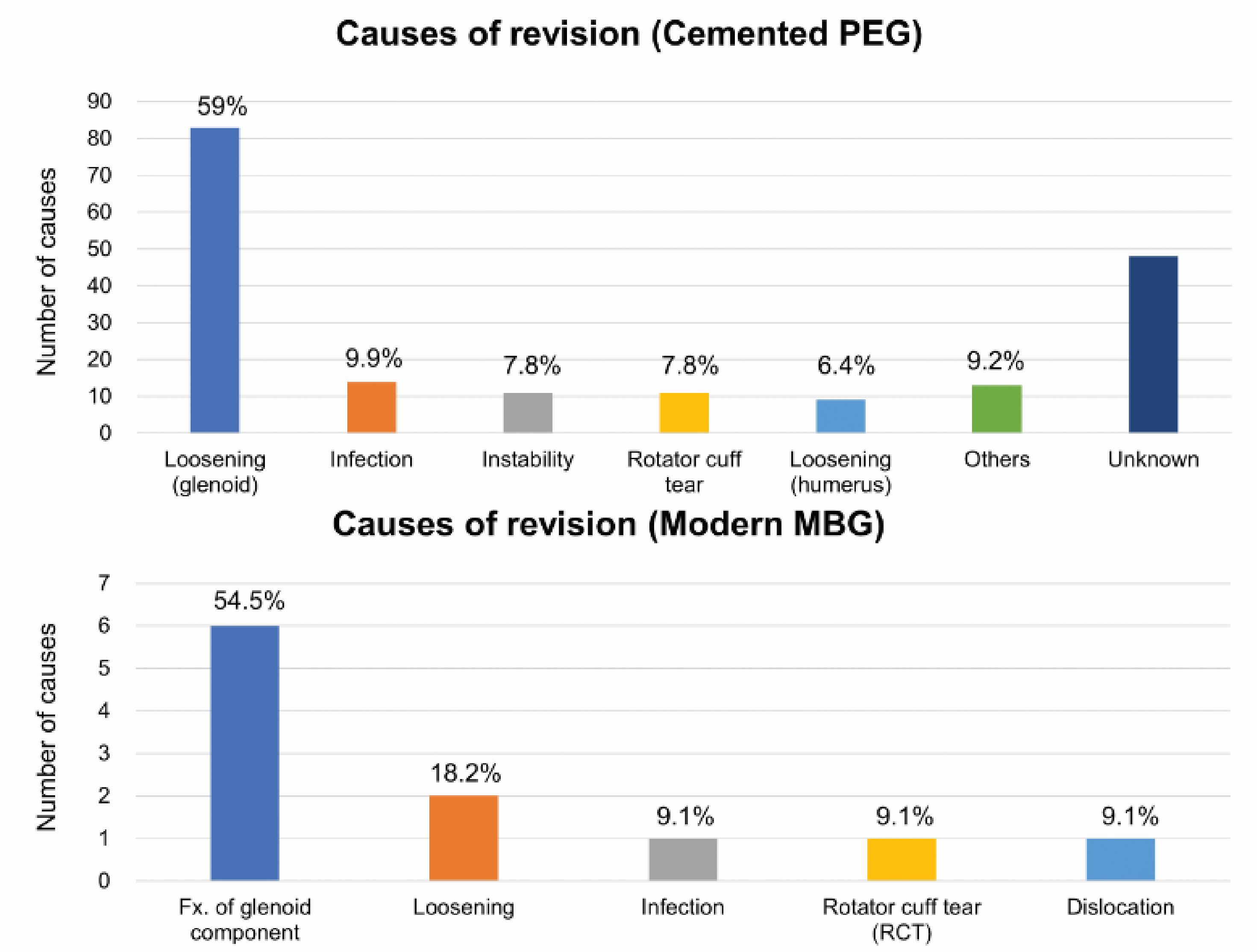

Figure 7

Graph showing the causes of revisions PEG, polyethylene glenoid; MBG, metal-backed glenoid; Fx., fracture

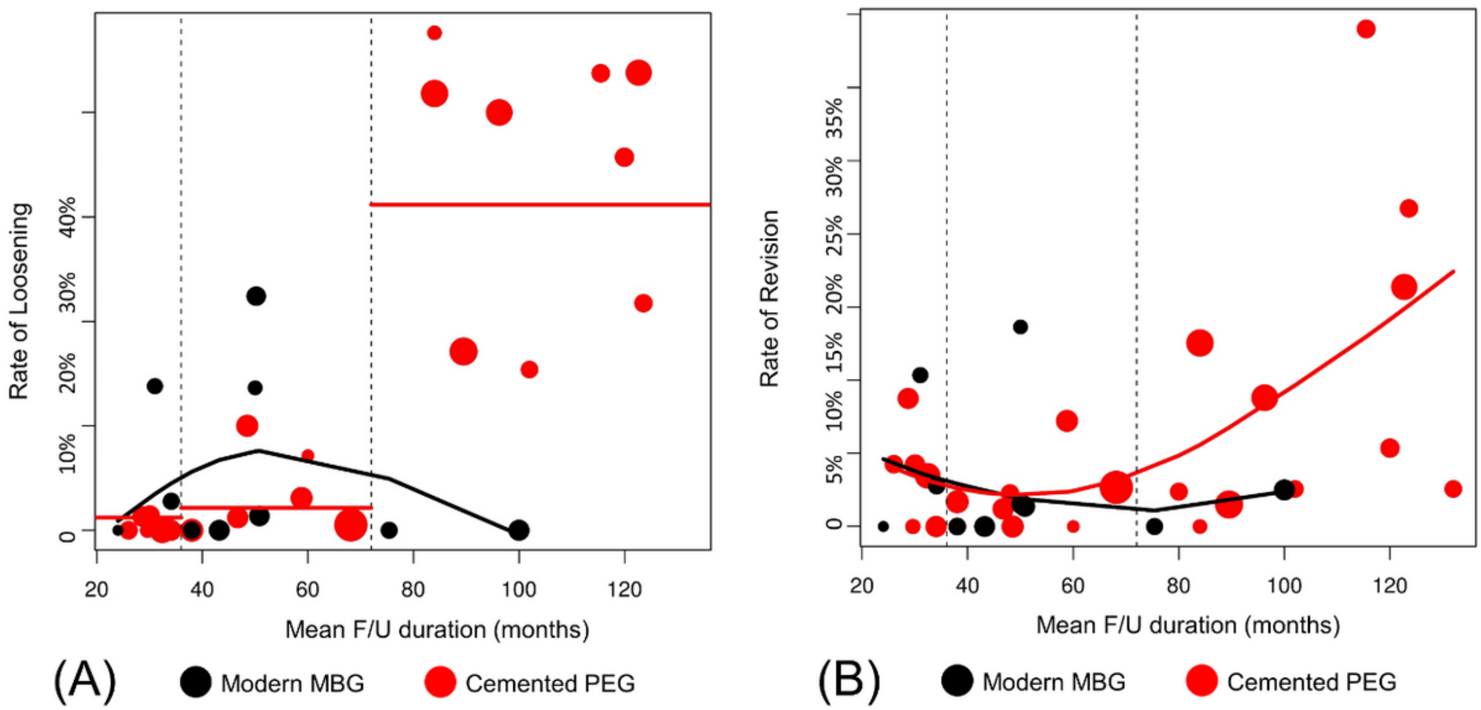

Figure 8

(A) Scatter plots showing the loosening rates for each study. (B) Scatter plots showing the revision rates for each study PEG, polyethylene glenoid; MBG, metal-backed glenoid; Vertical dotted lines, thresholds (3 and 6 years) for dividing short-term, mid-term, and long-term follow-up; Black line, the trendline of modern metal-backed glenoid group; Red line, trendline of cemented polyethylene glenoid group

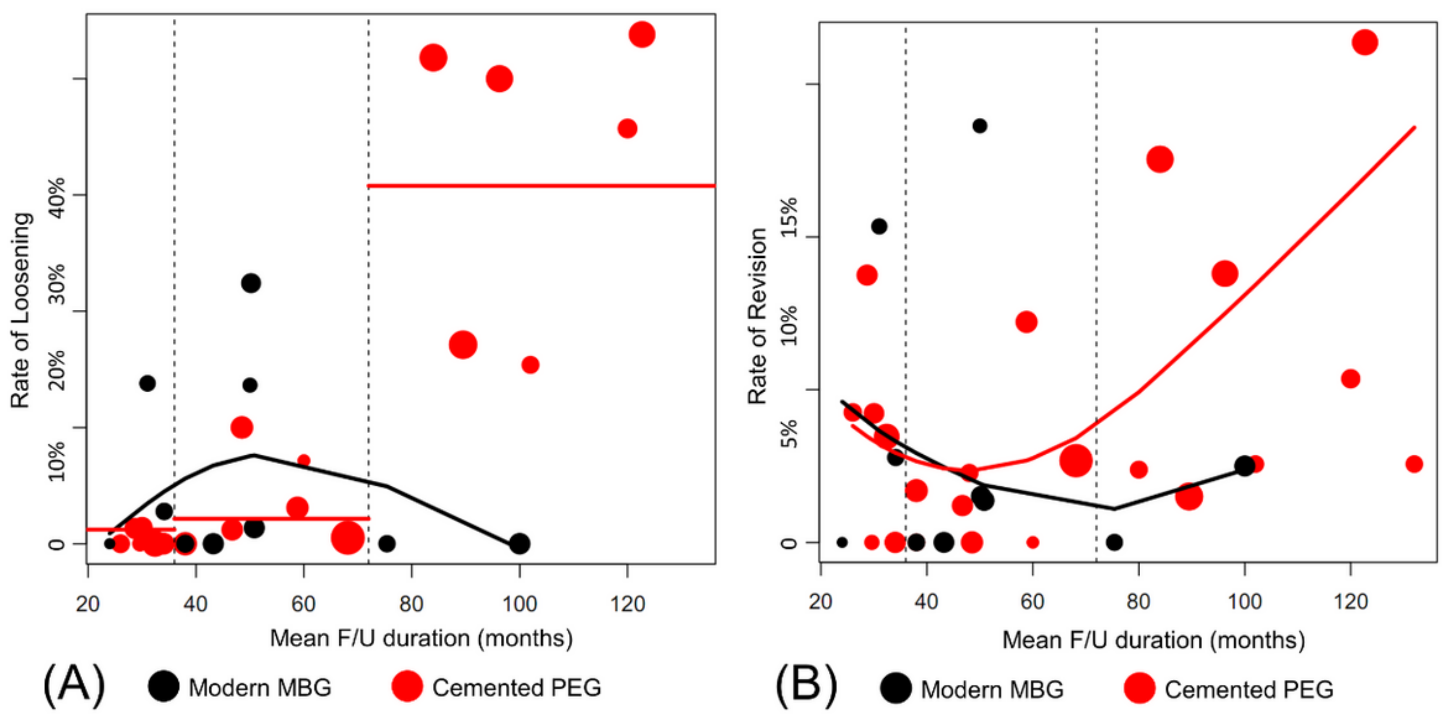

Figure 9

(A) Scatter plots showing the loosening rates for each study excluding three studies which included only young adults (B) Scatter plots showing the revision rates for each study excluding three studies which included only young adults PEG, polyethylene glenoid; MBG, metal-backed glenoid; Vertical dotted lines, thresholds (3 and 6 years) for dividing short-term, mid-term, and long-term follow-up; Black line, trendline of modern metal-backed glenoid group; Red line, trendline of cemented polyethylene glenoid group