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Surgical approaches of shoulder calcific tendonitis: a systematic review and meta-analysis

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Background: Calcific tendonitis is a painful shoulder disorder characterized by calcium deposits (CDs) in the rotator cuff tendon. This systematic review and meta-analysis examined the most efficient surgical procedure for calcific tendonitis. This includes the comparison between the three main surgical techniques: CD removal, CD removal with subacromial decompression (SAD) and CD removal with tendon repair with respect to functional outcomes and pain control scores.

Methods: Four electronic databases (MEDLINE, EMBASE, CINAHL, and Cochrane Central Register of Controlled Trials) were searched in February 2023. Studies were eligible for inclusion if they were peer-reviewed, and participants were patients diagnosed with calcific tendonitis of one or more rotator cuff tendon based on diagnostic imaging who underwent shoulder calcific tendonitis surgery. Other shoulder pathology diagnoses were excluded. Meta-analyses were conducted for results that were sufficiently homogeneous in terms of statistical, clinical, and methodological characteristics. Subgroup analyses were performed to determine if effect sizes differed based on the patient's position during the surgery, physiotherapy, and follow-up time.

Results: All surgical interventions resulted in significant improvements in shoulder function and pain control. There were no significant differences between CD removal vs. CD removal with SAD or CD removal vs. CD removal with tendon repair. However, there was a trend in favor of CD removal alone or CD removal with SAD approaches, as they provided better outcome scores than CD removal with tendon repair in terms of shoulder function and pain control.

Conclusions: All surgical interventions provide substantial improvement in shoulder functions and pain control scores with no significant difference between these surgical techniques.

Calcific tendonitis is a condition leading to calcium deposits (CDs) within rotator cuff tendons. This condition primarily affects the supraspinatus tendon and may occur as a result of chronic degenerative changes.[21] Another proposed mechanism is suggested by Uhthoff et al, which describes the tendon undergoing a cell-mediated calcification process started by precalcific fibrocartilaginous metaplasia followed by a dormant resting stage and a subsequent painful resorptive phase.[39,40] Although this condition can be asymptomatic, it typically presents as a painful shoulder with a limited range of motion. The mainstay of management is nonoperative therapy, which includes oral nonsteroidal anti-inflammatory drugs, physical therapy, ultrasound therapy, extracorporeal shock wave therapy (ESWT), subacromial corticoid injections, ultrasound-guided needling/barbotage, and others.[4,7,11,14-16,24,30,32,42]

Surgery is primarily utilized to treat problems that are resistant to nonoperative treatment. There are various surgical methods for CDs removal, including tendon needling, lavage, débridement, and aspiration.[1,3-6] A subacromial decompression procedure (SAD), with or without CD removal, as well as rotator cuff tendon repair together with CD removal are other surgical options.[3,5,12,18,19,22,43,47] Both

Institutional review board approval was not required for this systematic review/meta-analysis.

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open surgery and arthroscopic surgery are options for these three techniques.[30,31]

A systematic review published in 2017 concluded that there are no differences in function and clinical outcomes between SAD alone, CD removal with SAD, or CD removal alone.[42] However, the previous review missed several studies as it focused mostly on randomized control trials (RCTs) and did not conduct a meta-analysis. Also, it did not include CD removal with tendon repair techniques. Therefore, a comprehensive systematic review and meta-analysis that compares CD removal alone, CD removal with SAD, and CD removal with tendon repair regarding functional and pain scores is warranted.

The aim of this systematic review and meta-analysis was to determine the most optimal surgical procedure for calcific tendonitis based on the evidence derived from the orthopedic literature. This includes a comparison between the three main surgical techniques with respect to functional outcome and pain control scores. We also examined the effect of the patient's surgical position, postoperative rehabilitation, and follow-up period.

Methods

Protocol and registration

This systematic review is registered with the International Prospective Register of Systematic Reviews (PROSPERO registration no. CRD42023391752). It is reported per the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement for reporting systematic reviews and meta-analyses.[25]

Eligibility criteria

To assist the search process and identify key study concepts a priori, the Patients, Interventions, Comparisons, Outcomes, Study design framework was used.[33]

Patient(s)

Patients were diagnosed with one or more calcified rotator cuff tendons based on diagnostic imaging (x-ray, ultrasound, computed tomography, or magnetic resonance imaging) and underwent shoulder calcific tendonitis surgery. Patients with any other shoulder pathology diagnoses such as rotator cuff tear, adhesive capsulitis (frozen shoulder), shoulder instability, trauma, or multiple pathologies (including calcific tendonitis of the shoulder combined with one or more other pathologies) were excluded.

Intervention(s)

The intervention was open or arthroscopic surgery for shoulder calcific tendonitis.

Comparator(s)

The comparator was different surgical approaches that include calcification removal, subacromial decompression, and/or rotator cuff repair.

Outcome(s)

The outcomes were functional measures of the shoulder and pain control. This included different score measures such as the Constant-Murley Score (CMS), the visual analog scale (VAS), the disabilities of the arm, shoulder, and hand (DASH), the American Shoulder and Elbow Surgeons (ASES), the University of California-Los Angeles (UCLA), the Western Ontario rotator cuff index (WORC), the Short Form-12 (SF-12), and the Shoulder and Pain Disability Index (SPADI). All of these scores have acceptable to excellent psychometric properties.[2,23,27,34,38,41,44,46]

Study designs

All quantitative study designs were eligible except for reviews, meta-analyses, and case studies. Any length of follow-up period between surgery and the outcomes was allowed. There were no sample size limitations.

Information sources and search strategy

A three-step search strategy was developed by a health sciences librarian (AR) to locate published studies and unpublished studies (grey literature) in the form of preprints, conference materials, and/or data from clinical trial registries. A preliminary search was conducted in PubMed and Google Scholar, followed by an analysis of relevant studies to identify applicable text words and database-specific subject headings. The search strategy was then developed in Embase (Ovid), which was reviewed by a second librarian at Queens University. The final search was conducted in Embase (Ovid), MEDLINE (Ovid), EBM Reviews for Cochrane Central Register of Controlled Trials (Ovid), and CINAHL (EBSCO). All databases were searched from inception to February 2023 without any language or date restrictions applied.

The total number of studies from all databases was 5804. The number of records after removing duplicates in Covidence systematic review software was 3776. The total number of records identified from each database and all search strategies are provided in the Supplementary Tables S1-S5.

Study selection and data extraction

Bibliographic records were extracted and imported into Covidence software (Veritas Health Innovation, Melbourne, Australia) to remove any duplicate records. In level 1, titles and abstracts of potentially relevant articles were screened by two independent reviewers. In level 2, full-text articles were obtained for those records meeting initial screening by either or both of the two reviewers. Two independent reviewers examined all full-text articles. If there was a discrepancy between reviewers as to whether an article should be included, the discrepancy was resolved by discussion between reviewers or with a third reviewer, if needed.

Microsoft Excel (Microsoft Corp., Redmond, WA, USA) was used for data extraction. Data extraction was completed by one reviewer and checked for accuracy by another. Information was extracted regarding study characteristics (eg, author, publication year, study design, country), participant characteristics (eg, sample size, age, sex, duration of symptoms), surgical procedures including type and patient position, functional and clinical surgical outcomes scores at baseline and follow-up, and follow-up length. Authors were contacted for missing data. Reviewers were not blinded to the authors or journals when extracting data. Study findings were considered statistically significant at $P < .05$.

Risk of bias and quality assessment

Risk of bias assessment for each study was examined using guidelines outlined in the Cochrane Handbook.[9] The quality of evidence for each outcome scores was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework.[8] The GRADE framework categorizes the quality of evidence as "high", "moderate", "low", or "very low"

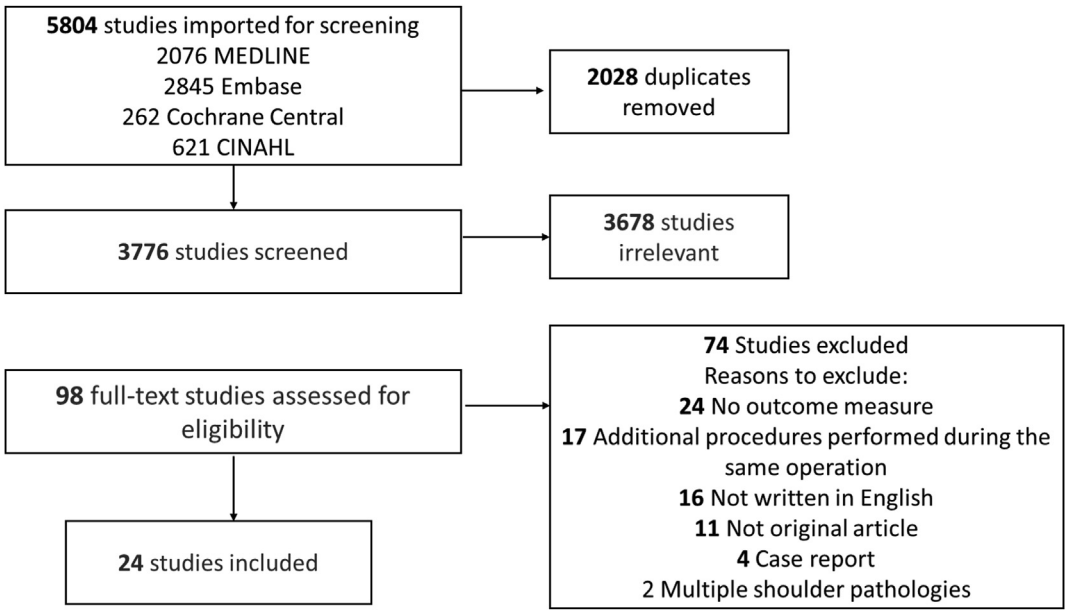

Figure 1 PRISMA flow diagram.

based on criteria for risk of bias, inconsistency, indirectness, imprecision, and other. The rating system starts at "high" for randomized studies and at "low" for all other studies and can be adjusted upwards or downwards based on these other criteria.[8] Risk of bias and quality assessments were completed by 2 reviewers, and any disagreements were resolved by a third reviewer.

Strategy for data synthesis

Meta-analyses were conducted for results that were sufficiently homogeneous in terms of statistical, clinical, and methodological characteristics. Subgroup analyses were used to determine if effect sizes differed based on patient's position during the surgery (beach chair vs. lateral decubitus), physiotherapy (delayed vs. immediate), and follow-up time between the surgery and outcome assessment (<12 months vs. ≥12 months). A subgroup analysis for arthroscopic vs. open procedures was not conducted because there were not enough studies to compare.

Studies were included in the meta-analysis if they (1) reported outcome measure scores such as CMS, VAS, UCLA and (2) had pre and postoperative means and standard deviations or standard errors with sample sizes. Studies that did not report such information were excluded from the meta-analysis and only described using narrative syntheses. We contacted the authors of these excluded studies, and none of them provided us with the requested information. When a study included more than one follow-up measure, the final measure was used for the meta-analysis. Meta-analyses were conducted using Meta-Essentials software version 1.5 (Erasmus Research Institute of Management, Rotterdam, the Netherlands) to calculate effect sizes and generate forest plots[37] When 3 or more studies contributed data for the same outcome score, pairwise meta-analyses were conducted. For each score measure, a random-effects model meta-analysis for within- and between-subject study designs was chosen. Within subject design compares the overall score change of each intervention based on the type of surgery, the position of the patients, the physiotherapy, and the length of follow-up, whereas between-subject design compares the effect of different type of surgical interventions such as CD removal vs. CD removal with SAD vs. CD removal with tendon repair.

Because the units of measure and ranges of scores varied considerably for the different functional and pain outcomes, Cohen's d standardized mean differences were calculated for the meta-analyses. Cohen's d values were subsequently converted to Hedges' g values to correct for small sample size.[45] We used a commonly applied interpretation to refer to these standardized effect sizes as small ($g = 0.2$), medium ($g = 0.5$), or large ($g = 0.8$), or very large ($g = 1.5$). The degree of heterogeneity of results in the studies included in each meta-analysis was tested using the I^2, and values of 25%, 50%, and 75% were considered low, moderate, and high, respectively.[10] The I^2 calculations required a correlation between the pre and postoperative measures, which were not provided in any of the studies included in the meta-analysis. Therefore, based on previous recommendations, we used a correlation of 0.5 for all I^2 calculations.[37] A sensitivity analysis revealed that I^2 did not change when the correlation used in the calculation ranged from 0.25 to 0.75.

Results

Description of studies

Figure 1 presents the Preferred Reporting Items for Systematic Reviews and Meta-Analysesdiagram for the study selection process. A total of 5804 studies were identified through the database searches (MEDLINE, n = 2076; Embase, n = 2845; Cochrane Central, n = 262; CINAHL, n = 621). After duplicates were removed, there were 3776 unique studies. After titles and abstracts were screened in level 1, 98 full-text articles were obtained for level 2 screening. Twenty-four studies passed level 2 screening and were included in the systematic review.[1,3,5,6,11-13,15-20,22,26,28-31,35,36,43,47,48] The main two reasons for excluding studies during level 2 screening were the absence of any functional or pain outcome measure and the use of additional procedures during the same surgery.

Supplementary File Sheet S1 in the supplement summarizes the characteristics and findings of the 24 studies included in the review. All studies measured shoulder function and/or pain control using one or more of the following scores: CMS, VAS, DASH, ASES, UCLA, WORC, SF-12, and SPADI. The sample size in the 24 studies ranged from 24 to 251, with a total of 1401 patients examined. The

majority of participants in these articles had supraspinatus tendon involvement (1265 out of 1401, 90.3%). Only 101 (7.2%) had infraspinatus and only 35 (2.4%) participants had subscapularis calcific deposits and none of the 24 articles addressed the topic of surgical interventions in relation to the location of the CDs. All studies examined adults of both sexes. Duration of preoperative symptoms ranged from 3 months to 10 years, and the length of follow-up ranged from 4 weeks to 6 years, with most studies having either a 6-month or >1-year follow-up. Three studies were RCTs, and 21 studies used a quasiexperimental design. Many of the quasiexperimental studies were incorrectly labelled with another study design in the original publication.

Supplementary File Sheet S2 and S3 in the supplement show the results of the risk-of-bias and quality assessment. In general, the quality of evidence for the different shoulder functions and pain outcomes was very low.

Overall meta-analysis findings for individual surgical interventions

All surgical interventions resulted in statistically significant improvements in shoulder function and pain with Hedge's g values that imply a very large effect size. For example, the Hedge's g (95% CI) values for the CMS were 2.62 (1. 85-3.40) for CD removal, 3.21 (2. 93-3.50) for CD removal with SAD, and 2.59 (1. 27-3.92) for CD removal with tendon repair (Supplementary File Sheet S4 and S7). Results for other functions and pain outcomes are provided in the supplementary materials. Note the overall Hedge's g effect size estimates for the different surgical outcomes that are presented in this paragraph were based on different patients and studies; therefore, they should not be directly compared.

Meta-analysis findings comparing different surgical techniques

Pairwise meta-analyses of studies that examined multiple surgery types were made to compare effect sizes of different types of surgery. These results are illustrated in SupplementaryFigures S4-S14 and described below.

Calcification removal vs. calcification removal and subacromial decompression

There was no significant difference between CD removal vs. CD removal with SAD for the CMS (Hedges'g = 0.10; 95% CI, −0.13 to 0.34), DASH (Hedges'g = −0.01; 95% CI, −0.44 to 0.42), and VAS scores (Hedges'g = −0.15; 95% CI, −0.40 to 0.10). However, only four studies contributed to this comparison, and there was a trend in the direction that favoured CD with SAD as having better CMS and pain control scores than CD removal alone, as the confidence interval was close to zero (Supplementary File Sheet S6 and S9).

Calcification removal vs. calcification removal and tendon repair

There was no significant difference between CD removal vs. CD removal with tendon repair for the CMS (Hedges'g = −0.41; 95% CI, −0.85 to 0.03), VAS (Hedges'g = 0.22; 95% CI, −0.14 to 0.58), ASES (Hedges'g = −0.02; 95% CI, −0. 85 to 0.81), and DASH scores (Hedges'g = −0.01; 95% CI, −0. 44 to 0.42) (Supplementary File Sheet S6, S9, S12, and S14). Despite the limited number of studies available for comparison (3 studies), there was a tendency toward improved CMS and VAS in the group that only received CD removal, with modest and small effect sizes for the difference and confidence intervals that were close to zero.

Subgroup analysis

Supplementary File Sheet S5 in the supplementary file presents the forest plot for subgroup meta-analyses and their weighted effects sizes for CMS scores based on patient's position during the surgery (beach chair: Hedges'g = 2.01, 95% CI = 0.87-3.14; lateral decubitus: Hedges'g = 3.84, 95% CI = 2.10-5.57), timing of the use of physiotherapy (delayed: Hedges'g = 2.34, 95% CI = 1.27-3.41; immediate: Hedges'g = 2.34, 95% CI = 1.67-3.01), and follow-up time (<12 months: Hedges'g = 2.38, 95% CI = 1.38-3.38; ≥ 12 months: Hedges'g = 2.23, 95% CI = 1.68-2.79). Supplementary File Sheet S8 presents the subgroup meta-analyses for VAS score based on follow-up time (<12 months: Hedges'g = −3.10, 95% CI = −4.22 to −1.99; ≥12 months: Hedges'g = −4.31, 95% CI = −6.57 to −2.04). Subgroups meta-analyses could not be performed for other outcomes because there were an insufficient number of studies.

Other findings and observations

Nine articles in this systematic review measured the size of CDs before the surgical interventions. The surgical interventions of these nine articles were not driven by the size of CDs and were not different in the different treatment groups.[3,5,11,15,17,19,35,43,47]

Overall, eight studies reported that complete vs. partial removal of tendon calcification did not result in a difference in functional outcome scores across all surgical interventions.[3,13,15-17,28,29,31] In addition, six studies found that the average time of partial CD resorption after surgery was 16 months (6 months-36 months).[3,16,17,35,43,47]

The most frequent adverse event following surgery was adhesive capsulitis. Its prevalence ranged from 3% to 16% with CD removal alone or CD removal with SAD and ranged from 8% to 28%, with CD removal with tendon repair.[5,6,13,17-20,22,26,35,43,47]

Recovery time ranged from 6 weeks to 4 months for CD removal and CD removal with SAD and took about 6 months for CD removal with tendon repair.[6,12,17,19,22,30,35,47,48] Finally, several studies noted that coracoacromial ligaments were preserved using the CD combined with SAD approach.[1,5,11,13,19,42,48] Others performed arthroscopic or open coracoacromial ligaments resections, with no differences in the rate of complications, both groups reported a considerable improvement in postoperative functional scores.[29,31,36]

Discussion

To our knowledge, this is the first meta-analysis to examine the differences between different surgical intervention methods for calcific tendonitis. We found that all surgical intervention methods resulted in a substantial improvement in all shoulder functions and pain control measures, with no statistically significant differences between the surgical intervention methods. The lack of statistical significance may reflect the limited number of studies available for comparison (3-4 studies), and there was a trend in the direction that favored the CD removal alone and CD with SAD approaches vs. the CD removal with tendon repair approach. Furthermore, qualitative findings showed that the CD removal alone and CD removal with SAD approaches had a lower rate of complications and a shorter recovery time than CD removal with tendon repair. Also, we found that there was no difference in the outcomes scores based on the patient's position during the surgery, physiotherapy, or follow-up time duration.

The previously published systematic review on CD surgical treatment compared SAD alone, CD removal with SAD, and CD removal alone.[42] Based on a narrative synthesis of results, they concluded that there was no difference between the 3 techniques in terms of functional outcome, pain control, and complication rate. Our study, which included a greater number of studies (24 vs. 6 studies), patients (1401 vs. 294 patients), and meta-analysis calculations, confirms these narrative findings. However, the meta-

analysis suggested that there was a trend toward a better pain control and shoulder function in CD removal with SAD compared with CD removal alone. In our review, there were not enough studies to compare patient's functional outcome scores in SAD alone with other techniques.

Another limitation to the previous systematic review is that it did not include the technique of CD removal with tendon repair as an option for the surgical treatment of CD. The present investigation revealed that the inclusion of tendon repair in conjunction with CD removal may lead to heightened shoulder pain, prolonged rehabilitation, and an increased likelihood of postoperative complications, particularly adhesive capsulitis. Hence, a few authors have proposed that prioritizing the preservation of tendon integrity at the expense of leaving some calcification deposits may result in improved pain management and functional outcomes.[3,15,47]

The present study observed a lack of a link between surgical procedures and the process of calcification resorption. In their study, Lee et al conducted a comparison between the removal of CD alone and the combination of CD removal with tendon repair. They observed that there was no significant difference in the final outcomes between complete and partial CD removal in both groups.[15] Similarly, Jacobs et al and Rubenthaler et al conducted a comparative analysis of CD removal vs. CD with SAD, yielding consistent results.[13,31]

In addition, the current study did not find a connection between the size of the CDs and the surgical interventions, as the measurement of the deposit size before the surgical interventions was only mentioned in nine out of 24 articles.[3,5,11,15,17,19,35,43,47] Across these nine studies, the surgical interventions were not influenced by the size of CDs and were not different in the different treatment groups. For example, Castangna et al (2015) had two groups: CD removal vs. CD removal with tendon repair.[3] The size of the calcification in the CD removal group was 9 (4.1) mm and in the CD removal with tendon repair was 11.3 (2.7) mm, with no significant difference between the deposits size ($P = .14$) and surgical outcome in the two groups.[3] Maier et al (2013) conducted a comparison between the complete removal of CD on lesions with an average size of 220 (149) mm^2 and partial removal on lesions, with an average size of 186 (116) mm^2 with no significant difference in lesion sizes between the two groups. The study found that the removal of CDs, while maintaining the integrity of the rotator cuff, led to good to excellent results in 90% of the participants and prevented iatrogenic rotator cuff injury. Also, minor calcium remnants did not impair clinical outcomes and got naturally resolved within 1 year in all instances, except in 3 patients with 7.7 mm^2 remaining CD.[17] Marder et al (2011) compared CD removal vs. CD removal with SAD with a lesion size >10 mm^2 in both groups. They found better short-term results in the CD removal group at 6 weeks, with a faster recovery at 11 weeks compared to the group that had CD with SAD (18 weeks). They concluded that adding SAD to CD removal does not provide more benefits compared to CD alone.[19]

Adhesive capsulitis emerged as the prevailing complication subsequent to the excision of CD, irrespective of the specific surgical approach employed.[5,6,13,17-21,35,42] However, there was a greater level of complication observed in the groups that underwent CD excision with tendon repair.[26,47] No additional surgical intervention was required for the treatment of this problem, as the majority of patients showed improvement with physical therapy. However, it is worth noting that two patients required further surgical intervention and were brought back to the operating room for SAD after having CD removal alone.[35]

The duration of recovery following CD removal exhibits considerable variation, ranging from a minimum of 6 weeks to a maximum of 6 months across all surgical approaches. CD removal and CD removal with SAD groups had shorter recovery time than CD removal with tendon repair.

The utilization of intraoperative ultrasound facilitates the identification and localization of tendon calcifications, but at the expense of prolonging the duration of the surgical procedure. For example, Martinel et al (2022) concluded that using ultrasound increases operative time and enables the removal of more calcification, but that this technique has more adhesive capsulitis than doing CD removal without ultrasound.[20] Also, Medancic et al (2021) used ultrasound and found that it helped locate and manage complex arch-shaped calcification.[22] Therefore, it is advisable to employ this approach in instances of complex tendon calcifications.

This analysis was limited by a lack of high-quality research that directly compared various surgical treatments for calcific tendonitis. Nevertheless, we implemented a rigorous selection criterion that included studies that possess a meticulously structured technique for assessing the effectiveness of surgical interventions. A key feature of our review is its inclusion of several surgical approaches for managing CD and the use of quantitative methods to compare them. Future research might explore the potential impact of CD sizes on the surgical management of resistant calcific tendonitis.

Conclusion

All surgical interventions that were studied in this meta-analysis resulted in large and significant improvements in shoulder function and pain. There was a positive trend toward either CD removal alone or CD removal with SAD in terms of superior shoulder function and pain scores. Further high-quality studies, such as RCTs, are needed to increase the number of studies for comparison between these techniques and thus confirm or contradict whether these trends are important.

Disclaimers:

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Conflicts of interest: Ryan Bicknell has consulting agreement with DePuy-Synthes and Zimmer-Biomet and receives research funding from Zimmer-Biomet. All the other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Availability of data and materials

Group-level data were obtained from the published results of the studies included in the systematic review and are provided in the supplemental file.

Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.xrrt.2024.03.013.

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