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Efficacy and safety of xenograft augmentation in rotator cuff repair: a systematic review and meta-analysis

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Rotator cuff tears are common disorders that can significantly impact patientś shoulder function and quality of life. Incomplete or failed healing is relatively common following repair of large tendon tears. Xenograft materials are increasingly used for augmentation of repairs, but their efficacy and safety remain under debate. This systematic review and meta-analysis aimed to evaluate the outcomes of xenograft-augmented rotator cuff repair in comparison to standard repair techniques. A detailed literature search was conducted across PubMed, Embase, Cochrane Library, and Web of Science databases on September 2, 2023, focusing on studies that utilized xenograft materials in rotator cuff repair. We included randomized controlled trials (RCTs) and cohort studies (CHS) that reported on dichotomous and continuous outcome measures. Risk of bias was assessed using the Cochrane Risk of Bias tool 2 (RoB2) for RCTs and the Risk of Bias assessment for non-RCT studies-I tool for nonrandomized studies. Data synthesis was performed using random-effects models to compute odds ratios (ORs) and standardized mean differences. Eight studies met the inclusion criteria, including three RCTs and five CHS evaluating xenograft materials, including porcine dermis and small intestine submucosa patches. Meta-analysis of RCT data revealed no statistically significant difference in failure rates between xenograft-augmented and standard repair groups (OR 0.48, 95% CI 0.08-2.90; $P = .42$), as did CHS (OR 1.08, 95% CI 0.49-2.38; $P = .85$). Similarly, the radiological healing rates showed no significant benefit for xenograft use (OR 1.41, 95% CI 0.23-8.56; $P = .71$). However, xenograft use was associated with a statistically significant higher complication rate (OR 3.65, 95% CI 1.28-10.4; $P = .02$). No significant differences were observed in strength measurements and range of motion. Xenograft-augmented repair of rotator cuff tears does not significantly improve radiological healing nor reduce failure rates compared to standard repair. However, it is associated with a higher complication rate. These findings suggest that while xenograft materials may be safe for clinical use, their benefits over traditional repair techniques are not conclusively supported by current evidence. Further high-quality, multicenter RCTs are needed to confirm these results and to explore alternative xenograft implants as well as the role of patient-intrinsic factors, such as tear size, tendon and muscle quality, and medical comorbidities on outcome.

Rotator cuff tears, the most prevalent upper extremity disorder among individuals over 50 years of age, present a significant clinical challenge in our increasingly aging population.[25] The incidence of these injuries ranges broadly from 5% to 40%.[24] This concern is further magnified when considering that approximately 54% of the people over the age of 60 are affected by either partial or complete rotator cuff tears.[30] Massive rotator cuff tears (MRCT) are defined as full-thickness tears of at least two tendons or lesions more than five centimeters in the coronal plane. These tears make up around 20% of all rotator cuff injuries and a significant 80% of recurrent tears.[5,14,21] The prognosis for MRCT is challenging since large tears are associated with worse outcomes and increased rates of structural failure

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

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after surgery. The literature suggests retear rates of up to 78% following repair of MRCT.[5,19,27] Alternatives to surgical repair include reverse shoulder arthroplasty and lower trapezius transfer. Repairing tears that cannot be reattached to their anatomical footprint due to retraction or insufficient tendon length is a surgical challenge.[23,38] Although there have been advancements in repair techniques and postoperative therapy protocols, many patients still experience discomfort, dysfunction, and even pseudoparalysis due to MRCT.[28]

Augmentation of rotator cuff tendon repair with allograft or xenograft materials has been used in an effort to improve tendon strength and to decrease failure rates. Graft choice, healing rates, and functional outcomes in severe irreparable rotator cuff tears are interconnected.[11,12,37] The advantage of xenograft materials is availability and biomechanical strength of the material. Xenografts also have drawbacks, including slow or delayed graft healing, remodeling, incorporation,[20] graft resorption,[16] and the risk of progressive osteoarthritis requiring conversion to reverse total shoulder arthroplasty in a significant number of patients.

The primary aim of this systematic review and meta-analysis is to rigorously evaluate the comparative effectiveness and safety of xenograft-augmented rotator cuff repair (RCR) vs. standard non-augmented repair techniques. Specifically, we seek to determine whether xenograft materials improve the rates of anatomical and functional recovery while assessing the incidence of associated complications. This study will contribute to the existing literature by providing updated, evidence-based insights into the utility of xenografts in the management of large to MRCT.

Material and methods

A comprehensive literature search was conducted on September 2, 2023, across the electronic databases PubMed, Embase, Cochrane Library, and Web of Science. The search string was tailored to each database's syntax, with the PubMed version being as follows: (((((tissue scaffold*) OR tissue scaffold)) OR (((xenograft*[tw]) OR dermal[tw] OR “Bioprosthesis”[All Fields] OR ((((xenogenic) OR (“dermal xenograft patch”[All Fields] OR (“small intestine mucosa”[All Fields]) AND (graft* OR transplant* OR bioprostheses[MeSH Terms] OR homograft*))))) OR “Transplantation, Homologous”[Mesh] OR (“dermal xenograft patch”[All Fields] OR (“small intestine mucosa”[All Fields])))))) AND ((musculotendinous cuff[tw] OR (“tendons”[MeSH Terms] OR (“superior capsule”[All Fields]) OR repair[All Fields] OR reconstruction [All Fields] AND (“shoulder”[MeSH Terms] OR “shoulder”[All Fields]) OR (“superior capsule”[All Fields])))) OR (rotator cuff[All Fields] OR rotator cuffs[All Fields])). Three independent reviewers (F.C.O., M.M.D., and T.L.T.) conducted the screening process. Initially, the articles underwent title and abstract screening, considering the following inclusion criteria: (1) randomized controlled trials (RCTs), retrospective or prospective studies, involving human subjects; (2) publications in the English language; (3) articles published in indexed journals; and (4) studies analyzing the utility of xenograft materials in the management of RCR. The exclusion criteria were as follows: (1) studies involving a pediatric population, (2) articles published in languages other than English, (3) preclinical studies, (4) case series, and (5) review articles and meta-analyses. Upon concluding the initial screening phase, the full texts of the included articles were evaluated, and the reference lists of all the retrieved articles were further screened to identify potentially relevant studies. A Preferred Reporting Items for Systematic Reviews and Meta-Analysesflowchart of the selection process is reported in Figure 1. Senior investigators were responsible for reaching a consensus when discrepancies arose between the two reviewers. The included full texts underwent data extraction and subsequent collection for the purposes of the present manuscript. The methodological quality of the included RCT was appraised using the Cochrane Risk of Bias tool 2 (RoB2) for RCTs.[34] For prospective and retrospective studies, the RoB assessment was conducted by employing the Risk of Bias assessment for non RCT studies-I tool.[33]

Meta-analysis was performed separately for RCTs and cohort studies (CHS) utilizing Cochrane RevMan Web (The Cochrane Collaboration, London, United Kingdom). For Dichotomous variables, the Mantel-Haenszel method with a random-effects model was employed to calculate odds ratio (OR). For continuous variables, the inverse variance method in a random-effects model was employed.

Results

The included studies compared the outcome of xenografts with the outcome of standard of care treatment of large to MRCT. The xenografts utilized included an acellular porcine dermis-derived collagen membrane (Conexa Reconstructive Tissue Matrix; Tornier Inc., Bloomington, MN, USA), a porcine small intestine submucosa (SIS) (SIS, Restore Orthobiologic Implant; DePuy, Warsaw, IN, USA), a collagen bovine pericardium patch (TUTOPATCH; Tutogen Medical GmbH, Neunkirchen am Brand, Germany), and a xenologous porcine dermal patch (DX Reinforcement matrix-patch; Arthrex Inc., Naples, FL, USA).

Risk of bias assessment

In evaluating the RoB for RCTs, the Cochrane RoB 2 was employed.[34] Each of the seven distinct types of bias was categorized as either “low risk,” “high risk,” or “unclear risk.” Subsequently, the findings of this assessment were translated into the Agency for Healthcare Research and Quality standards, which ranked the RCTs as “low risk,” “some concerns”, or “high risk” (Table I). For non-RCTs, quality assessment was conducted using the Risk of Bias assessment for non RCT studies-I tool, which evaluates the potential benefits or harms of an intervention in studies that did not utilize randomization to allocate interventions (Table II).[33]

Acellular porcine dermal patch (Conexa Reconstructive Tissue Matrix; Tornier Inc., MN, USA)

Avanzis double-blind, RCT evaluated the efficacy of augmenting RCRs with a porcine dermal patch (Conexa Reconstructive Tissue Matrix; Tornier Inc., Bloomington, MN, USA) compared to standard medialized single-row repair. The study randomized 92 patients undergoing RCR with a porcine dermal patch augmentation or standard repair. Preoperatively, there were no significant differences between the groups. At the final 24-month follow-up, 69 patients were available for evaluation. The xenograft group (group A) achieved a higher healing rate of 97.6% compared to 59.6% ($P < .001$) in the control group without augmentation (group B) based on imaging analysis. When considering only tendons graded as completely “healed”,” group A (graft augmentation) demonstrated a 78% healing rate vs. 24.3% in group B ($P < .001$). The subgroup analysis based on preoperative tendon retraction severity showed that group A achieved 100% healing for early retracted tendons, compared to a 64% rate in group B ($P = .003$). For late or massive tendon retraction cases, group A maintained healing rates of 92.3% and 69.2% (healed only) vs. 50% and 16.7%, respectively, in group B ($P = .015$ and .004). Clinical outcome scores, including Constant score, disabilities of arm, shoulder and hand, simple shoulder test, and EQ-visual analog scale (VAS) improved significantly in both groups postoperatively compared to baseline, with no significant differences between the two groups at 24 months.

Castagna et al included 35 patients in their prospective cohort study with large or MRCT, which underwent arthroscopic repair

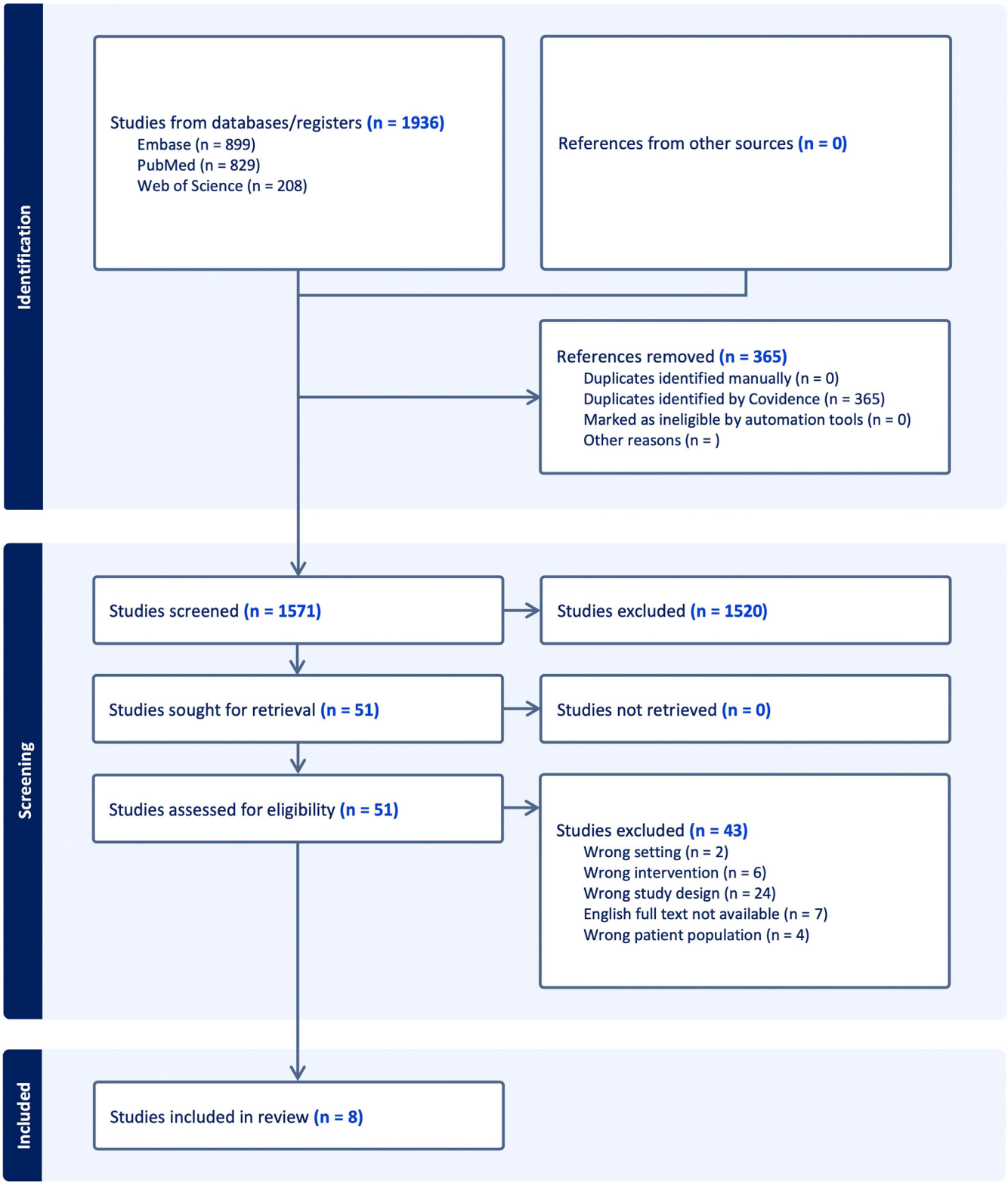

Figure 1 Preferred reporting items for systematic reviews and meta-analyses flowchart.

augmented with a porcine dermis-derived collagen membrane (Conexa Reconstructive Tissue Matrix, Wright Medical Group, Memphis, TN, USA) vs. standard arthroscopic repair without augmentation. A statistically significant difference in the Constant score in favor of the treatment group was documented at the final evaluation, with 71.4 ± 11.8 vs. 63.9 ± 11.9 in the control group ($P = .036$). Subgroup analysis showed that patients undergoing augmented rotator cuff repair (RCR) and presenting retears in magnetic resonance imaging (MRI) had a significantly higher functional outcome with a Constant score of 65.3 ± 10.8 than patients in the control group with MRI

Table I
RoB2 – Risk of bias assessment for RCT studies.

Risk of bias domain Study	D1	D2	D3	D4	D5	Overall
Avanzi 2019[1]	+	+	+	!	+	+
Bryant 2019[4]	+	+	+	+	+	+
Iannotti 2006[17]	+	+	+	!	+	!

RCT, randomized controlled trial.
D1, randomization process.
D2, deviations from the intended interventions.
D3, missing outcome data.
D4, measurement of the outcome.
D5, selection of the reported result.

+ Low risk.
! Some concerns.
- High risk.

evidence of retears and a Constant score of 53.4 ± 9.7 ($P = .0136$). Postoperative MRI at the final 24-month follow-up showed that 21.9% of shoulders in the treatment group presented retears of the supraspinatus tendon vs. 33.3% in the controls.

The prospective cohort study of Maillot et al compared the outcomes of the following three different treatments in 32 patients for large and MRCT: arthroscopic complete repair, open repair with xenograft patch augmentation (Conexa Reconstructive Tissue Matrix; Tornier, Inc., Bloomington, MN, USA), and arthroscopic débridement with biceps tenotomy. The mean improvement in the Constant-Murley score was +29.0 from 45.7 ± 11.6 to 74.7 ± 4.3 in the repair group and +32.2 from 43.6 ± 11.0 to 75.8 ± 8.6 in the patch group at the final follow-up examination. There were no significant differences between the repair and patch group. The VAS score also improved significantly for all the groups in the postoperative evaluation with 6.9 ± 1.2 to 0.7 ± 0.8 in the repair group and 7.1 ± 1.2 to 0.6 ± 0.7 in the patch. The patch group was the only one with significant improvement in active anterior elevation and active external rotation from 109° ± 30° to 144° ± 32° ($P = .015$) and 32° ± 11° to 52° ± 11° ($P = .001$), respectively. Complications arose in 5 out of 11 patients in the patch group and in one patient in the repair group.

Porcine small intestine sub-mucosa (SIS, Restore Orthobiologic Implant; DePuy, Warsaw, IN, USA)

The double-blind RCT of Bryant et al aimed to evaluate if augmenting RCRs with porcine SIS (Restore Orthobiologic Implant; DePuy Synthes, Raynham, MA, USA) could improve outcomes compared to repair alone. 62 patients with moderate to large rotator cuff tears were randomized into two groups as follows: SIS graft (Restore Orthobiologic Implant) augmentation or standard repair. Demographics, tear characteristics, and repair details were comparable between the two groups preoperatively. The primary outcome was repair failure assessed by magnetic resonance arthrography at 1 year. The overall failure rate was high at nearly 60% across both groups. In the SIS augmentation group, the failure risk was 52.9% compared to 65.4% in the control group. The relative risk was 0.81 (95% CI 0.53-1.24, $P = .33$), suggesting a potential reduction in risk with SIS, but the difference was not statistically significant. At 1 year, patient-reported outcomes like Western Ontario Rotator Cuff Index exhibited similar trajectories postoperatively in both groups as did range of motion and strength measurements. Preoperative MRI revealed that 38 patients had isolated supraspinatus tears, of which 17 had intact tendons and 18 had persistent full-thickness defects at 1-year postoperative MRI, irrespective of SIS augmentation. For combined supraspinatus-infraspinatus tears, only 5 out of 18 had healed tendons at 1 year. Adverse events were minor, including one deep infection requiring washout in the SIS group and one repair revision in the control group by 24 months.

Iannotti et al utilized the same implant, evaluating the effectiveness of augmenting repairs of chronic two-tendon rotator cuff tears. 30 patients with repairable large or massive two-tendon rotator cuff tears were randomized into two groups as follows: SIS augmentation (Restore Orthobiologic Implant; DePuy Synthes, Raynham, MA, USA) or repair without augmentation. MRI with intra-articular gadolinium at 1 year assessed cuff healing status. The rotator cuff healing rate was lower in the SIS augmentation group at 27% (4/15), compared to 60% (9/15) in the nonaugmented control group ($P = .11$). After adjusting for tear size, repairs without SIS augmentation had a modest 7% higher likelihood of healing (OR 1.07, $P = .07$). The median postoperative Penn total score also trended lower in the augmentation group at 83 vs. 91 in controls ($P = .07$). Subgroup analysis revealed that large tears healed nearly twice as often as massive tears (OR 1.9, $P = .007$). The SIS augmentation group had lower median postoperative function scores ($P = .03$). No other Penn subscores differed meaningfully between the groups. Three adverse events occurred in the SIS group as follows: one required irrigation or débridement for wound drainage or disruption, one developed subacromial effusion treated with antibiotics, and one had self-limited erythema.

Walton et al performed a retrospective cohort study comparing xenograft augmentation (Restore Orthobiologic Implant; DePuy Synthes, Raynham, MA, USA), with standard repair at two-year follow-up in 30 patients. At three months, the reported pain was higher in the xenograft group with a mean activity pain score of 9.9 ± 1.6 points in the xenograft group compared to 4.0 ± 1.3 points in the control group ($P < .01$). At the two-year mark, participation in sports activities was significantly lower in the xenograft group compared to the control group ($P < .01$). Additionally, individuals in the xenograft group reported more difficulty with hand-behind-

Table II
ROBINS-I – Risk of bias assessment for non RCT studies.

Author and citation (y pub)	Baseline confounding	Selection of participants	Classification of intervention	Deviation from intended intervention	Missing data	Measurement of outcomes	Selection of reported results	Overall risk of bias
Flury 2018[13]	Low	Low	Low	Low	Low	Moderate	Low	Low
Walton 2007[36]	Low	Moderate	Low	Low	Low	Moderate	Low	Moderate
Castagna 2018[6]	Low	Moderate	Low	Low	No information	Moderate	Low	Moderate
Ciampi 2014[9]	Low	Moderate	Low	Low	Low	Moderate	Moderate	Moderate
Maillot 2018[22]	Low	Moderate	Low	Low	No information	Moderate	Low	Moderate

RCT, randomized controlled trial.

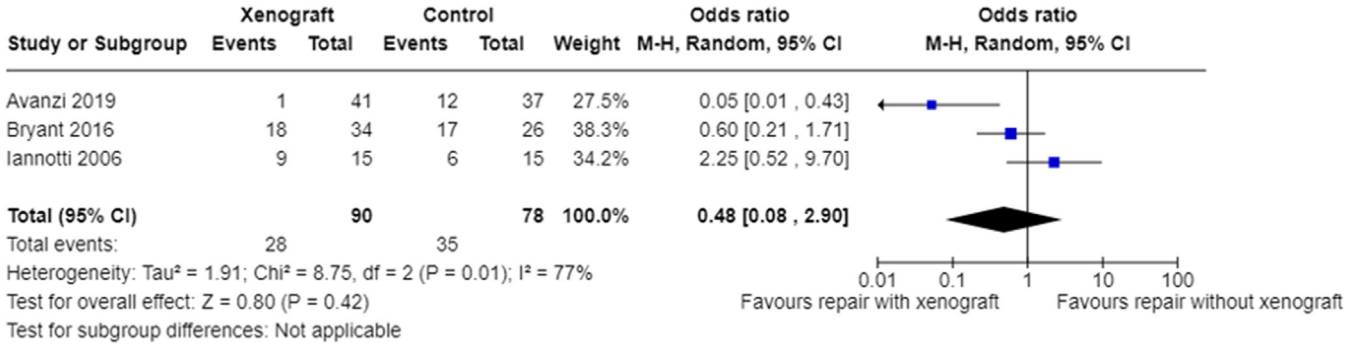

Figure 2 Meta-analysis comparing rate of radiological healing between xenograft and control group in RCTs. *RCT*, randomized control trials.

the-back activities ($P < .05$). The overall satisfaction with shoulder condition was similar between the groups ($P = .43$). Strength in external rotation did not significantly differ, but the xenograft group exhibited significantly less strength in internal rotation (63 ± 6 N and 99 ± 11 N; $P < .01$), lift-off strength (28 ± 4 N compared with 61 ± 11 N; $P < .01$), and adduction strength (70 ± 7 N compared with 100 ± 12 N; $P < .05$) compared to the control group. Moreover, the xenograft group showed higher impingement scores in external rotation (1.0 compared with 0.0; $P < .05$, Mann-Whitney rank-sum test). MRI indicated comparable retear rates between the groups at two years postsurgery (60% in xenograft group and 58% in control group), and the mean tendon thickness did not significantly differ (1.50 mm in xenograft group and 1.58 mm in control group).

Bovine collagen pericardium patch (TUTOPATCH; Tutogen Medical GmbH, Neunkirchen am Brand, Germany)

Ciampi et al compared the outcomes of 152 open repair of MRCT augmented with a biological (collagen) and a synthetic polypropylene patch in their retrospective cohort study. The mean pain scores (VAS) at the 36-month follow-up were 3.66 ± 1.05, 4.06 ± 1.02, and 3.28 ± 1.10 ($P < .001$), and the UCLA scores were 14.88 ± 1.98, 14.69 ± 1.99, and 24.61 ± 3.22 ($P < .001$), respectively. Importantly, the polypropylene group demonstrated significantly higher UCLA scores at 36 months ($P < .001$). Similarly, mean elevation and strength at the 36-month mark differed significantly among the groups, with values of 140.68° ± 9.84° and 8.73 ± 0.54 kg for the control group, 140.61° ± 12.48° and 9.03 ± 0.60 kg for the collagen group, and 174.71° ± 8.18° ($P < .001$) and 13.79 ± 0.64 kg ($P < .001$) for the polypropylene group. Elevation and strength in the polypropylene group surpassed those in the other groups ($P < .001$). No significant difference was observed between the control and collagen group at 36 months. Ultrasound assessments at the 1-year mark revealed the following retear rates: 41% in the control group, 51% in the collagen group, and 17% in the polypropylene group ($P = .001$). No major complications or adverse events related to patch application were reported.

Porcine dermal patch (DX reinforcement matrix-patch; Arthrex Inc., Naples, FL, USA)

Flury et al investigated clinical and subjective outcomes after arthroscopic RCR with xenograft porcine dermal patch augmentation compared with RCR alone in their retrospective cohort study of 40 patients. Prior to surgery, patients allocated to the patch group exhibited slightly higher levels of subscapularis fatty infiltration compared to those in the control group. Surgical procedures involving the application of patches took on average 22 minutes longer than standard interventions ($P = .003$). At the 24-month follow-up, 4 patients in the control group and 9 patients in the patch group were diagnosed with recurrent subscapularis tendon defects ($P = .096$), with 8 of the 11 identified medial cuff failures occurring in the patch group. There were 8 patients in the control group and 12 patients in the patch group who experienced local complications, including recurrent defects ($P = .343$). The presence of recurrent defects did not substantially impact functional outcomes.

Meta-analysis

Due to the heterogeneity of the reported variables in the RCTs, only failure rate and rate of radiological healing could be included in the meta-analysis. Both failure rate and rate of radiological healing were extracted at the latest available follow-up time point (Avanzi 2019[1] 24 months, Bryant 2016[4] 24 months, and Ianotti 2006[17] 12 months). Meta-analysis did show a trend in failure rate favoring xenografts in more recent studies (less failures); however, it failed to reach statistical significance with an OR of 0.48 (95% CI 0.08, 2.90), $P = .42$ (Fig. 2).

A similar, although weaker trend, can be seen in the comparison of radiologically healed RCRs, favoring the xenograft group with an OR of 1.41 (95% CI 0.23, 8.56), $P = .71$ (Fig. 3).

Comparing CHS, we were able to perform meta-analysis on failure rate, complications, Constant score, strength (abduction), and anterior shoulder motion. All variables were extracted at the latest available timepoint reported in the respective studies. Examining failure rate in CHS, we did not find a continuation of the trend displayed in the RCTs, with an OR of 1.08 (95% CI 0.49, 2.38), $P = .85$) (Fig. 4).

Examining complication rate, 2 of the included CHS did not report any complications in either group (Castagna 2018[6] and Ciampi 2014[9]) and could therefore not contribute to the statistical model employed. The included individual studies showed a trend towards a higher complication rate in the xenograft cohort; however, none of them showed a statistically significantly higher rate. By integrating the aforementioned data into our model, we discovered a statistically significant increase in the risk of complications in the xenograft group, as shown by an OR 3.65 (95% CI 1.28, 10.4), $P = .02$) (Fig. 5).

Three of the included CHS report on Constant score, with only Castagna 2018[6] reporting a statistically significant higher Constant score individually. After combination of the 3 respective studies, a statistically significant higher Constant score is associated with the xenograft cohort, with a mean difference of 4.8 (95% CI 0.4, 9.21), $P = .03$) (Fig. 6).

Strength measurements following RCR are reported in 3 of the included studies, with Ciampi 2014[9] reporting abduction strength in kg measured with a dynamometer, Flury 2018[13] reporting

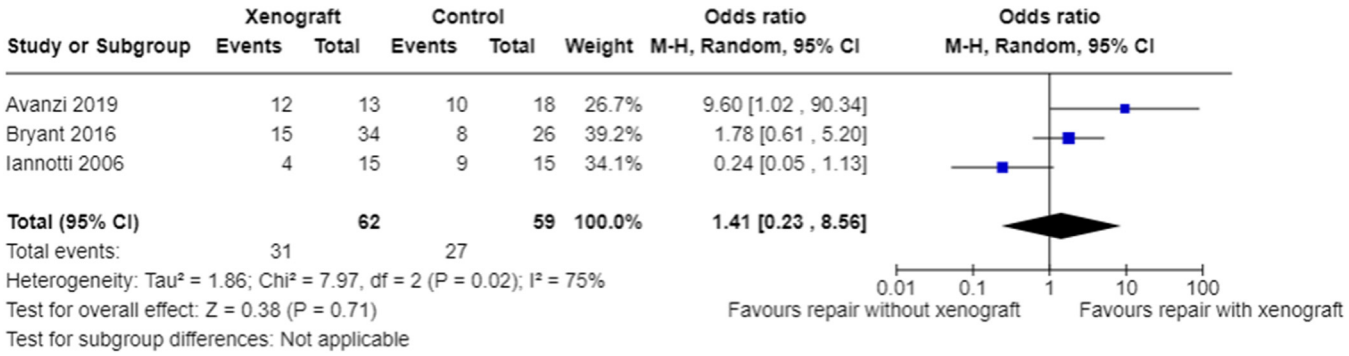

Figure 3 Meta-analysis comparing failure rate between xenograft and control group in CHS. *CHS*, cohort studies.

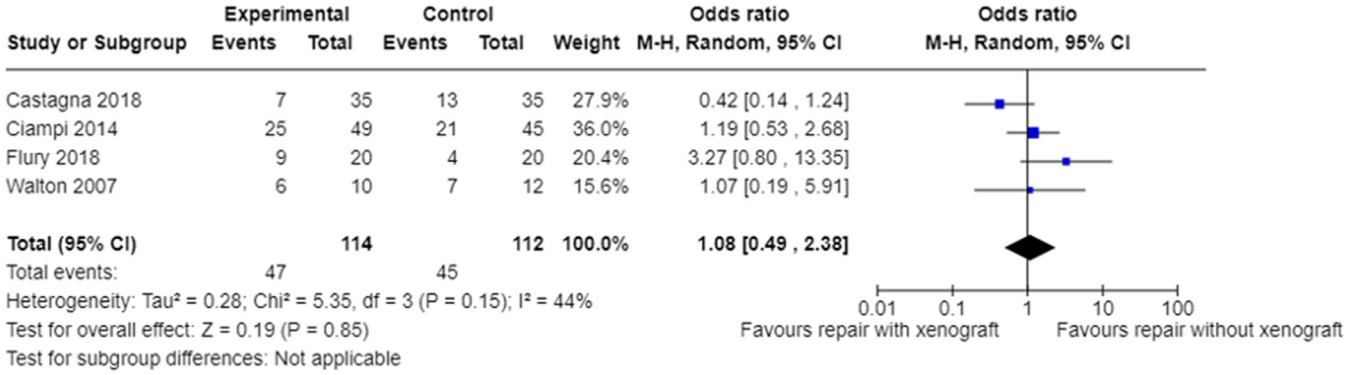

Figure 4 Meta-analysis comparing failure rate between xenograft and control group in RCTs. *RCT*, randomized control trials.

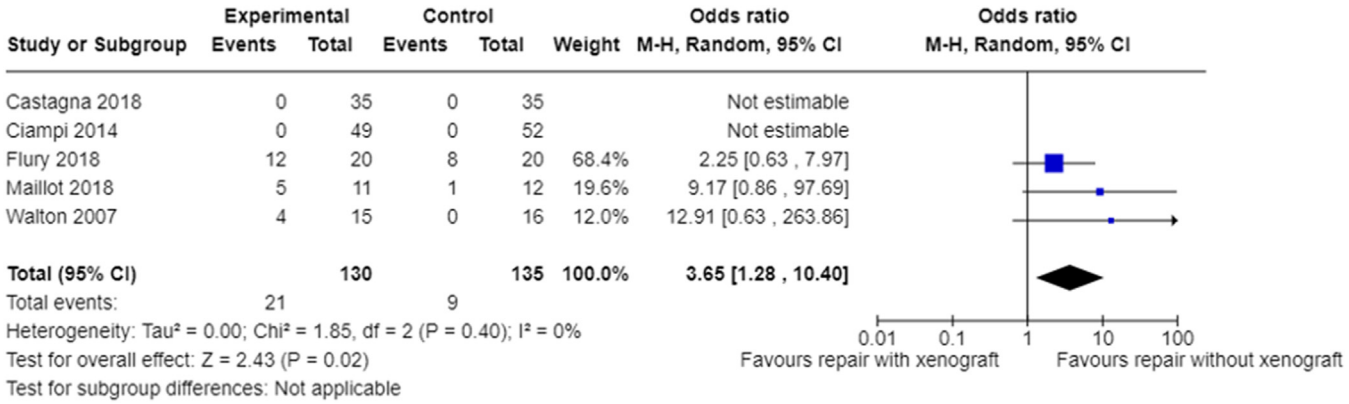

Figure 5 Meta-analysis comparing complication rate between xenograft and control group in CHS. *CHS*, cohort studies.

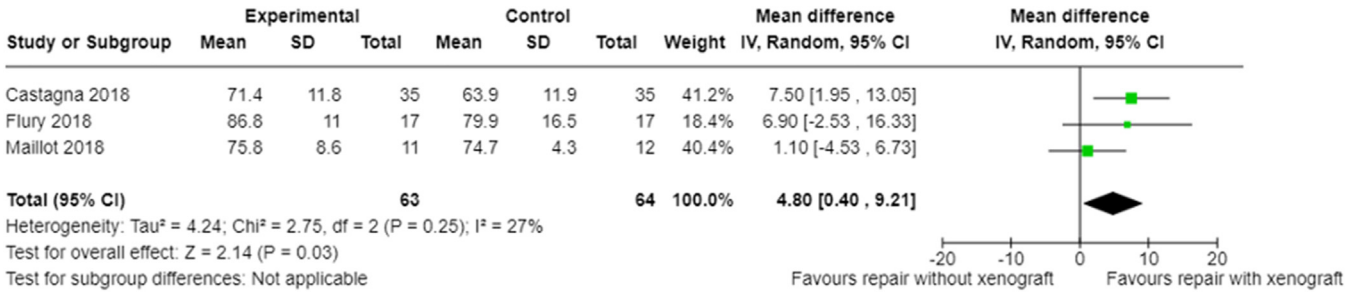

Figure 6 Meta-analysis comparing constant score between xenograft and control group in CHS. *CHS*, cohort studies.

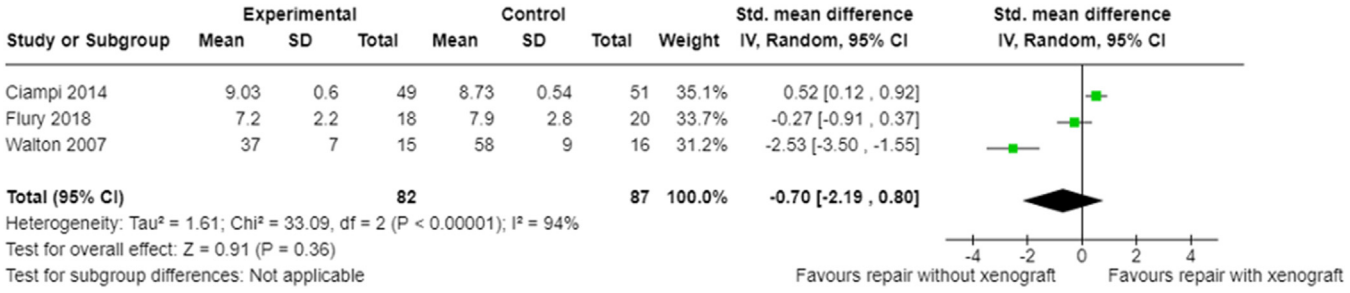

Figure 7 Meta-analysis comparing abduction strength between xenograft and control group in CHS. *CHS*, cohort studies.

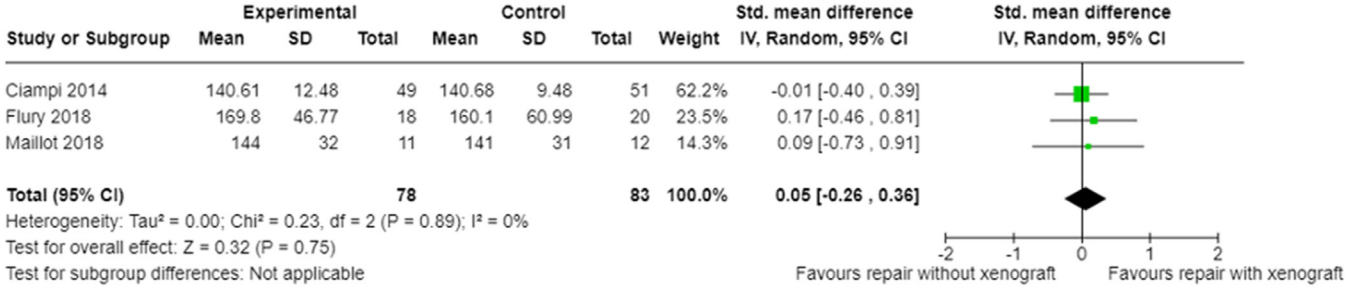

Figure 8 Meta-analysis comparing elevation between xenograft and control group in CHS. *CHS*, cohort studies.

abduction strength in kg measured with a spring scale, and Walton 2007[36] reporting abduction strength ("supraspinatus strength") in N measured with a dynamometer. Due to the heterogeneity in methods and units, we decided to report the standardized mean difference (SMD) for this variable. After combination of the respective studies, a trend favoring repair without xenograft is exhibited with a SMD of −0.7 (95% CI -2.19, 0.8), $P = .36$ (Fig. 7).

Range of motion in comparable planes is reported in 3 studies. We did not find a statistically significant difference between xenograft and control groups after combination, with an SMD of 0.05 (95% CI -0.26, 0.36), $P = .75$ (Fig. 8).

Discussion

This systematic review and meta-analysis aimed to critically evaluate the effectiveness and safety of using xenograft materials for augmenting RCRs compared to standard repair techniques. The findings from the meta-analysis of RCTs suggest lower failure rates and higher radiological healing rates with xenograft augmentation, though these differences did not reach statistical significance. The analysis of cohort studies revealed conflicting results, with no clear advantage of xenografts over controls in terms of failure rates but a significantly higher risk of complications associated with xenograft use. On the other hand, xenograft augmentation was associated with improved Constant scores postoperatively, indicating better functional outcomes, while no significant differences were observed in strength measurements or range of motion.

The significantly higher complication rate observed with xenograft augmentation highlights the need for careful patient selection and counseling. Flury et al discuss some complications more extensively, such as 3 patients in the augmented group having persistent postoperative pain and 2 presenting with subacromial bursitis, potentially as an effect of xenograft augmentation.[13] Maillot et al report on 1 deep joint infection and postoperative stiffness in 4 patients in the augmentation group.[22] The study of Walton et al reports that all 4 patients with complications had severe inflammatory reactions to the xenograft.[36] These potential complications underscore the importance of meticulous surgical technique, appropriate perioperative management, and close patient monitoring. Noticeably, all studies report different complications, demonstrating the need for further research.

While meta-analysis did not demonstrate a statistically significant advantage of xenograft augmentation in reducing failure rates or improving radiological healing, the suggestions of clinical outcome scores suggest a potential role for xenografts in certain clinical scenarios.[7] Xenograft augmentation may be considered for large or MRCT, where the risk of failure is higher, and the potential benefits of improved structural integrity and joint stability may outweigh the added risks and costs associated with xenograft use.[35] The significantly higher complication rate observed with xenograft augmentation highlights the need for careful patient selection and counseling.[13,22,36] Additionally, the choice of graft material and surgical technique should be guided by the available evidence and the surgeon's experience, as variations in these factors may influence outcomes.[10] Finally, further insight may be gained by comparison of xenograft materials with alternatives for rotator cuff augmentation (ie, human dermal allograft or collagen scaffold).

The utilization of graft augmentation has gained traction in RCR procedures due to its potential to enhance initial biomechanical strength and reduce retear rates.[2,18] These grafts can potentially augment tendon-bone healing by serving as a scaffold and delivery vehicle for biological agents. Various graft materials have been explored in addition to xenografts, including various autografts, as well as synthetic grafts

While xenograft augmentation has yielded conflicting results, with some studies reporting a high incidence of complications, including hypersensitivity reactions, more recent investigations have demonstrated promising outcomes with bovine collagen patches.[17,35] These patches have exhibited healing rates ranging from 89% to 96%, with no evidence of adverse reactions.[35] Histopathological analyses in animal models have suggested that dermal allografts and amnion augmentation may more closely resemble native tendon tissue compared to débridement or bovine patch augmentation.[31]

Currently, acellular dermal human-derived allografts represent the most widely used augmentation option.[18] These allografts demonstrate the ability to revascularize and remodel into tendon-like tissue without eliciting an excessive inflammatory response.[32] Cadaveric studies have revealed increased biomechanical load to failure and reduced failure rates when augmenting repairs with dermal allografts compared to standard repairs alone.[26]

Numerous clinical studies have reported improved postoperative healing and functional outcomes of rotator cuff tears with allograft augmentation.[2,15,29] RCTs have shown higher healing rates, lower retear incidence, and better functional scores (eg, American Shoulder and Elbow Surgeons, Constant-Murley) with dermal allograft augmentation compared to standard repairs, particularly for large and massive tears.[3] A systematic review found allograft augmentation to have an 82% integrity or repair rate, outperforming xenograft augmentation (68%) and standard repairs (49%).[8] Moreover, allograft augmentation has demonstrated superior functional outcomes and range of motion compared to xenograft augmentation.[2]

Shared decision-making with patients is crucial, as the potential benefits of xenograft augmentation, such as improved functional outcomes as indicated by higher Constant scores, must be weighed against the increased risk of complications. Patients should be informed about the potential risks, benefits, and uncertainties associated with xenograft use, allowing them to make an informed decision aligned with their individual preferences and goals. Appropriate postoperative management, including physical therapy and activity modification, remains essential for optimizing functional recovery and long-term outcomes.

The authors acknowledge the limitations of this systematic review. Regardless of systematic search methodology, the potential for publication bias remains a concern, as studies with negative or null findings may be less likely to be published. Additionally, heterogeneity in study designs, surgical techniques, outcome assessment methods, and patient populations across the included studies poses challenges in directly comparing and pooling the results, potentially introducing biases and limiting the generalizability of the findings. Moreover, the relatively small number of included studies, particularly RCTs, may have limited the statistical power to detect significant differences between the groups. Meta-analysis was restricted to a subset of outcome measures due to the inconsistent reporting of various outcomes across studies. It is essential to interpret the findings of this study in the context of these limitations, acknowledging the need for further well-designed, high-quality RCTs to address the remaining uncertainties and strengthen the evidence base for the use of xenografts in RCR.

The role of xenografts in challenging scenarios, such as revision surgeries and massive irreparable tears, warrants further investigation to inform surgical decision-making. Economic analyses assessing the cost-effectiveness of xenograft augmentation are essential for healthcare resource allocation and reimbursement policies. Prioritizing comprehensive patient-reported outcomes and quality of life measures is vital to understanding the impact on patient-centered outcomes and overall well-being. Addressing these areas through collaborative, well-designed research efforts can strengthen the evidence base for the judicious use of xenografts in RCR.

Conclusion

This study found no statistically significant advantages of xenograft augmentation over standard RCR. Xenograft use was associated with significantly higher complication rates and improved functional scores. Overall, the evidence highlights xenografts as a potentially promising but complex adjunct requiring further research to optimize graft materials, techniques, and identify ideal indications for improving outcomes.

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Supplementary Data

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