

Review Article

Subscapularis Repair in Reverse Shoulder Arthroplasty: Does Implant Design Matter?

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Reverse total shoulder arthroplasty (rTSA) continues to expand in indications, and modern implant designs have reshaped the biomechanical role of the subscapularis. However, whether subscapularis repair is necessary after rTSA remains controversial, in part, because its contribution to stability and motion is not uniform across implant geometries. This narrative review synthesizes contemporary biomechanical and clinical evidence to define how glenoid and humeral design features including center of rotation, degree of lateralization, neck–shaft angle, and humeral onlay/inlay configuration, modify subscapularis function, repair demands, and postoperative outcomes. Across the literature, medialized constructs demonstrate greater dependence on the subscapularis

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for anterior stability and internal rotation. In these configurations, successful repair may enhance stability and internal rotation, whereas failed healing can magnify functional deficits and compromise outcomes. In contrast, lateralized designs at the glenoid, humerus, or both improve deltoid wrapping and soft tissue tensioning, increase intrinsic constraint, and expand impingement-free range of motion, thereby reducing the functional necessity of subscapularis repair and maintaining low instability rates even when the tendon is not repaired. Dual lateralization may provide the most robust stability and external rotation, but it can increase anterior soft tissue tension, making selective repair and careful intraoperative tension assessment critical. Overall, implant geometry, not repair status alone, most strongly determines the clinical relevance of the subscapularis after rTSA. These findings support a shift from routine repair toward a design-specific, patient-tailored strategy that integrates implant configuration, tendon quality, soft tissue balance, and functional goals to optimize stability, motion, and long-term success.

I. INTRODUCTION

Reverse total shoulder arthroplasty (rTSA) was originally developed to treat cuff tear arthropathy but has since expanded to address massive rotator cuff tears, complex fractures, and revision cases (Georgoulas et al. 2021; Ackland et al. 2008). By reversing the native ball-and-socket configuration, classic Grammont-style rTSA medializes the glenoid center of rotation while distalizing the humerus, thereby increasing deltoid tension and mechanical advantage to compensate for rotator cuff deficiency (Hansen et al. 2015). Despite its success, long-term outcomes remain influenced by implant design and soft tissue management, particularly subscapularis repair. The optimal management of the subscapularis tendon in rTSA remains controversial (King et al. 2019; Werner et al. 2018; Dedy et al. 2018). In a typical deltopectoral approach, the subscapularis must be released to access the joint, commonly via peel, tenotomy, or lesser tuberosity osteotomy, which varies the type of repair techniques at the time of closure. Biomechanical rationales have historically suggested that an unrepaired or deficient subscapularis might contribute to anterior instability and dislocation particularly in the setting of total shoulder arthroplasty (Hyun et al. 2013; Roberson et al. 2018). Early rTSA designs, characterized by a medialized glenoid center of rotation and a 155° humeral neck-shaft angle, likely relied more heavily on subscapularis integrity to augment anterior stability (Bethell et al. 2023). However, while subscapularis repair can contribute to stability, it may also restrict external rotation and increase the force required for forward flexion (Kozak et al. 2021; Schwartz et al. 2015; Routman 2013). This balance between stability and mobility has resulted in diverse surgical approaches and ongoing clinical and biomechanical debate.

Recent advancements in implant design, including lateralized glenoid components, onlay versus inlay humeral implants, and varied neck-shaft angles, may influence the role of the subscapularis (Jawa and Colliton 2021; Collin et al. 2022; Piper and Horneff 2022). Given these considerations, understanding the biomechanical impact of subscapularis repair in rTSA and its interaction with implant design is critical for surgical decision-making. Accordingly, this review synthesizes biomechanical and clinical evidence examining how implant design influences subscapularis func-

tion, stability, and clinical outcomes in reverse shoulder arthroplasty. Specifically, this review examines glenoid-side design factors, including medialization and lateralization of the center of rotation, humeral-side design factors, including neck-shaft angle, humeral lateralization, and distalization, and the combined effects of glenoid and humeral implant configurations, including medialized glenoid-medialized humerus, medialized glenoid-lateralized humerus, and lateralized glenoid-lateralized humerus constructs ([Table 1](#)).

I. GLENOID-SIDE IMPLANT FACTORS

CENTER OF ROTATION

The original Grammont-style reverse total shoulder arthroplasty employs a markedly medialized center of rotation (COR) combined with a humeral inclination of 155 degrees (Oak et al. 2022). This configuration prioritizes constraint and deltoid efficiency but increases reliance on the subscapularis for anterior stability. Clinical series consistently demonstrate stabilizing effect in these scenarios. Edwards et al (Edwards et al. 2009). reported 138 patients treated with a medialized COR (Aequalis Reverse Shoulder System, Tornier, Memphis, TN, USA) and reported a higher dislocation rate in patients with irreparable subscapularis tendons (9%) compared to those with repair (0%). Similarly, Chelli et al (Chelli et al. 2024). demonstrated that subscapularis repair in Grammont-style implants improved active internal rotation at long-term follow-up, with mean scores increasing from 4.2 to 5.9 at 8 years. However, this relationship is not uniform across all series. Vourazeris et al (Vourazeris et al. 2017). found no significant difference in instability between patients with and without subscapularis repair, suggesting that additional factors beyond medialization alone contribute to stability in rTSA.

Despite these advantages, medialized COR constructs have notable limitations. Scapular notching has been reported in up to 96% of cases (Friedman et al. 2017), raising concerns for long-term wear and implant survival. Reduced deltoid wrapping and suboptimal tensioning, particularly in patients with poor soft tissue quality, may further contribute to instability, glenoid loosening, and acromial stress

Table 1. Characteristics of Studies Evaluating Subscapularis Function and Implant Design in Reverse Shoulder Arthroplasty

Study (Year)	Country	Sample Size	Sex Distribution	Implant System(s)
Burnier (2022)	France/USA	6 cadaveric shoulders	N/A	ReUnion (Stryker) and Altivate (DJO)
Eno (2020)	USA	9 subject-specific computational models	N/A	Comprehensive Reverse Total Shoulder Arthroplasty (Zimmer Biomet, Inc.)
Giles (2016)	UK/Canada	6 cadaveric shoulders	N/A	Custom adjustable load-sensing RTSA system (38-mm Delta Xtend humeral cup; DePuy)
Hansen (2015)	USA	5 cadaveric full upper extremity specimens	5 M, 0 F	42-mm Equinox rTSA (Exactech); 42-mm Delta III Grammont rTSA
Oh (2014)	South Korea/USA	6 cadaveric shoulders	3 M, 3 F	Aequalis Reverse Shoulder Prosthesis (Tornier; variable NSA 135°–155°)
Ameziane (2024)	Germany	50 patients	36 F, 14 M	Delta Xtend (DePuy); Univers Revers (Arthrex, 135° NSA, lateralized)
Chelli (2024)	France	280 shoulders (269 patients)	76% F	Aequalis Reverse (Tornier); Delta Xtend (DePuy Synthes)
Clark (2012)	USA	120 shoulders (111 patients)	74% F	Reverse Shoulder Prosthesis (DJO)
Collin (2022)	France/Switzerland	86 patients	51 F, 35 M	Aequalis Reversed II (Tornier–Wright Medical; BIO-RSA technique)
Cueto (2024)	USA	97 patients	19% F	Equinox (Exactech); Integra Titan (Smith + Nephew)
Edwards (2009)	USA	138 patients	94 F, 44 M	Aequalis Reverse Shoulder System (Tornier)
Engel (2023)	Germany	50 randomized; 41 analyzed	12 M, 29 F (analyzed cohort)	Delta XTend (DePuy Synthes); Universe Reverse (Arthrex)
Franceschetti (2019)	Italy	84 patients	21 M, 63 F	Aequalis Ascend Flex (Tornier)
Friedman (2017)	USA/France	591 patients	367 F, 224 M	Equinox (Exactech)
Oak (2022)	USA	143 patients	63 F, 80 M	Univers Revers prosthesis (Arthrex) with a 135° neck-shaft angle.
Werner (2018)	USA	109 patients	43 M, 66 F	Biomet Comprehensive Reverse Shoulder System (Zimmer Biomet; 147° NSA)
Roberson (2018)	USA	99 patients	38 M, 61 F	Reverse Shoulder Prosthesis (DJO); Trabecular Metal Reverse Shoulder (Zimmer Biomet)

Legend: Summary of studies evaluating subscapularis function, biomechanics, and clinical outcomes in reverse shoulder arthroplasty, including cadaveric, biomechanical, and clinical investigations across multiple implant systems. RSA = reverse shoulder arthroplasty; N/A = not available.

fractures. These limitations have driven the evolution toward more lateralized designs.

Modern reverse shoulder arthroplasty systems increasingly incorporate glenoid-sided lateralization (baseplate lateralization, eccentric glenospheres, bone grafting such as Bio-RSA) (Bauer et al. 2021). Lateralization shifts the center of rotation, enhances deltoid tension, reduces impingement, and may decrease reliance on subscapularis repair. Biomechanical studies further illustrate the impact of glenoid lateralization on shoulder kinematics. A computational model demonstrated that inferiorly lateralized, eccentric glenospheres improved impingement-free range of motion, particularly adduction and external rotation, compared to centered or tilted configurations (Lädemann et al. 2018). In this context, an offset glenosphere may reduce

the functional constraint imposed by a tight subscapularis (Friedman et al. 2017). Additionally, increasing glenosphere size has been shown to enhance stability, with cadaveric studies demonstrating greater force required for dislocation with larger implants, further augmented by subscapularis repair (Pastor et al. 2024). These findings suggest that in certain constructs, lateralization and subscapularis repair may have additive effects on joint stability.

Clinical outcomes largely support the ability of lateralized designs to maintain stability without subscapularis repair. Franceschetti et al (Franceschetti et al. 2019). reported low instability rates (<2%) in patients treated without repair using lateralized constructs, while Friedman et al (Friedman et al. 2017). reported similar findings, noting

improved functional outcomes and no increased instability in patients treated with lateralized implants without subscapularis repair. Additionally, a 2021 meta-analysis by Corona et al. concluded that subscapularis repair in lateralized rTSA did not positively or negatively impact functional outcomes for patients (Corona et al. 2021). However, increased lateralization may increase tension in the repaired subscapularis native footprint, which may impair healing and contribute to postoperative stiffness (Eno et al. 2020).

Overall, the relationship between glenoid lateralization, subscapularis repair, and joint stability is complex and multifactorial. Medialized designs may rely more heavily on subscapularis integrity to maintain stability, whereas lateralized constructs may provide sufficient constraint through implant design alone. However, these benefits must be balanced against the potential for increased soft tissue tension and its impact on healing and postoperative function.

II. HUMERAL SIDE DESIGN FACTORS

NECK-SHAFT ANGLE

The neck-shaft angle (NSA) defines the inclination of the humeral component relative to the shaft and directly influences humeral medialization and soft tissue tensioning. A 155 degree NSA, as seen in traditional Grammont-style implants, medializes the humerus, leading to a more constraint which may negatively impact impingement-free motion and require more reliance on soft tissue stabilizers like the subscapularis. A higher subscapularis non-healing rate of 47.4% at 24 months has been reported in 155 degree NSA constructs, although patients with an intact repair demonstrate improved internal rotation (Collin et al. 2022). This makes sense because in a medialized humeral component, the shoulder has less passive stability and may rely more heavily on the subscapularis for internal rotation. (Engel et al. 2021) However if the subscapularis repair fails, the medialization of the center of rotation can exaggerate the deficit, leading to significantly worse internal rotation due to limited compensatory stability.

In contrast, reduced NSAs (typically ranging from 135 degrees to 145 degrees), as incorporated in contemporary systems such as the DJO Reverse Shoulder Prosthesis (DJO Surgical, Vista, CA, USA); Equinox Reverse Shoulder System (Exactech, Gainesville, FL, USA); INHANCE Reverse Shoulder System (DePuy Synthes/Johnson & Johnson MedTech, Warsaw, IN, USA); and the Perform Reverse Shoulder System (Tornier/Wright Medical, Memphis, TN, USA), lateralize the humerus, improve deltoid tensioning, and enhance impingement-free range of motion. Hansen et al (Hansen et al. 2015). showed that decreasing NSA to 135 degrees increased external rotation torque and reduced subscapularis activation demands. Similarly, the findings by Ameziane et al (Ameziane et al. 2024). suggest that implants with a 135° NSA and increased lateral offset are particularly effective in improving internal rotation when combined with subscapularis repair.

HUMERAL LATERALIZATION

Lateralized humeral stems, often achieved through onlay designs, also optimize soft tissue balance by increasing deltoid wrapping and improving the tensioning environment for the subscapularis. Biomechanical studies further support this concept. Hansen et al (Hansen et al. 2015). and King et al (King et al. 2019). demonstrated that humeral lateralization, particularly when combined with lower NSAs, improves deltoid efficiency and offloads the subscapularis during motion. However, Franceschetti et al (Franceschetti et al. 2019). found no significant difference in forward flexion (116° vs. 114°) or external rotation (53° vs. 56°) between groups. However, they noted better internal rotation in the repair cohort. Likewise, Clark et al (Clark et al. 2012). observed that subscapularis repair neither altered dislocation or overall complication rates nor changed postoperative pain or range-of-motion outcomes when compared with leaving the tendon unrepaired. Malahias et al. and Oak et al (Oak et al. 2022; Malahias et al. 2019). also reported no significant differences in functional outcomes or dislocation rates between patients who had a subscapularis repair and those who did not. Collectively, these clinical and biomechanical findings show that humeral onlay lateralization lowers subscapularis demands, permitting a selective approach to tendon repair. While subscapularis repair in the context of humeral lateralization does not significantly affect instability, forward flexion, or external rotation, it is associated with improved internal rotation when the tendon heals, supporting a tailored approach to subscapularis management in these patients (Baek et al. 2025).

DISTALIZATION

When humeral offset is increased in reverse shoulder arthroplasty through changes in neck-shaft angle, humeral lateralization, or implant positioning, the humerus is often translated distally in addition to laterally (Zitnay et al. 2025). Distalization is a fundamental component of reverse shoulder arthroplasty biomechanics and is used to restore deltoid tension by increasing arm length, typically by approximately 1.5–3 cm (Boutsiadis et al. 2018; Hsu et al. 2011). Biomechanical studies have demonstrated that increasing humeral distalization lengthens the rotator cuff and increases both muscle force requirements and joint reaction forces (Zitnay et al. 2025). In addition, changes in humeral position and center of rotation alter rotator cuff resting lengths, moment arms, and muscle function. Hansen et al (Hansen et al. 2015). demonstrated that the inferior-medial position of the humerus in rTSA alters subscapularis mechanics, shifting the muscle toward a predominantly adducting role throughout much of the range of motion. Similarly, Ackland et al (Ackland et al. 2008). demonstrated that the subscapularis contributes to abduction, adduction, and extension after rTSA, highlighting how implant geometry fundamentally alters its biomechanical role. These findings suggest that the functional contribution of a repaired subscapularis may not be uniform across implant configurations and may depend, in part, on the degree of distalization and lateralization achieved.

III. COMBINED DESIGN INTERACTIONS

Although individual glenoid and humeral design choices independently influence shoulder biomechanics, the functional behavior of rTSA is ultimately determined by their combined configuration. The medialized glenoid/medialized humerus (MG/MH), medialized glenoid/lateralized humerus (MG/LH), and lateralized glenoid/lateralized humerus (LG/LH) framework provides a useful construct for understanding how implant design synergy affects subscapularis demands, joint stability, and clinical outcomes.

Medialized glenoid–medialized humerus (MG/MH) constructs, characteristic of traditional Grammont-style designs, offer a highly constrained configuration, but rely more heavily on subscapularis to maintain anterior stability. Following rTSA, altered biomechanics of the subscapularis amplify its role in internal rotation and stability, particularly in medialized systems (Ackland et al. 2008; Hansen et al. 2015; Giles et al. 2016). Collin et al. reported a subscapularis healing rate of 52.6% in this configuration, with improved internal rotation in patients with an intact repairs (Collin et al. 2022). Notably, no dislocations occurred in patients with healed tendons, underscoring the role of a successful repair (Collin et al. 2022). However, this dependence comes at a cost. Cadaveric data from Hansen et al (Hansen et al. 2015). demonstrated increased subscapularis strain, diminished external rotation torque, and reduced overall range of motion with the medialized designs. Clinically, Grammont-style implants– defined by a large neck-shaft angle and medialized center of rotation– have been associated with instability rates as high as 17% and scapular notching rates reaching 72%, highlighting the limitations of this configuration when subscapularis healing is compromised (Huri et al. 2016).

Medialized glenoid–lateralized humerus (MG/LH) constructs offer a biomechanically advantageous configuration that improves deltoid wrapping and reduces reliance on the subscapularis for anterior stability. This design philosophy has been incorporated into contemporary implant systems such as the DJO Reverse and Zimmer Biomet's Comprehensive Reverse Shoulder. Friedman et al (Friedman et al. 2017). reported low instability rates (0–1.2%) regardless of whether the subscapularis was repaired, with comparable functional outcomes, suggesting that repair may not be essential for stability in this configuration. Supporting biomechanical studies show that humeral lateralization combined with a lower neck-shaft angle enhances torque generation and minimizes subscapularis activation demands (Hansen et al. 2015; King et al. 2019; Oh et al. 2014). As a result, MG/LH constructs appear more forgiving in patients with poor subscapularis quality or irreparable tendons, offering reliable stability and motion without mandatory tendon repair.

Lateralized glenoid–lateralized humerus (LG/LH) constructs further reduce subscapularis dependence by optimizing muscle tensioning and joint stability (Oak et al. 2022; Mohan et al. 2024). Systems such as the Exactech Equinox, Arthrex Univers Dual lateralization improve deltoid leverage and are associated with superior forward flex-

ion and external rotation, while maintaining low instability rates. However, excessive lateral offset may over-tension the anterior soft tissues (Fossati et al. 2020; Bigdon et al. 2019). When a tight or degenerated subscapularis is repaired in this setting, the tendon may be subjected to excessive strain, increasing the risk of repair failure or diminished function. Biomechanical studies by Burnier et al (Mohan et al. 2024). and King et al (King et al. 2019). supports both the improved deltoid efficiency and reduced subscapularis dependency offered by LG/LH designs. Clinically, these constructs provide excellent motion but may increase the risk of acromial stress reactions and progressive tendon thinning, emphasizing the importance of selective rather than routine subscapularis repair (Ameziane et al. 2024).

Collectively, these findings demonstrate that healing rates, stability, and functional outcomes are strongly influenced by implant design. MG/MH constructs often require successful subscapularis repair to maintain anterior stability and internal rotation, yet remain vulnerable to stiffness and higher failure rates if healing does not occur (Hansen et al. 2015; Collin et al. 2022). MG/LH designs reduce subscapularis dependence and yield similar outcomes with and without repair (Hansen et al. 2015; King et al. 2019; Friedman et al. 2017). LG/LH constructs offer the greatest stability and range of motion, but require careful tension management if subscapularis repair is performed (King et al. 2019; Burnier et al. 2022). Overall, the MG/LH configurations appears to provide the most favorable balance of biomechanical forgiveness, functional outcomes, and adaptability in the setting of uncertain subscapularis integrity. Accordingly, prosthesis selection and surgical strategy should be individualized based on patient anatomy, functional goals and tendon quality. Recent findings by Cueto et al (Cueto et al. 2024). reinforce the importance of patient-specific subscapularis management, particularly in medialized designs, where selective repair may enhance internal rotation without compromising external rotation.

CONCLUSION

Subscapularis management in reverse shoulder arthroplasty should be guided by implant design rather than applied as a uniform surgical principle. Glenoid-side factors, including medialization and lateralization of the center of rotation, and humeral-side factors, including neck-shaft angle, humeral lateralization, and distalization, collectively influence the functional role of the subscapularis. Medialized constructs, particularly those combining a medialized glenoid, medialized humerus, and traditional 155° neck-shaft angle, appear to rely more heavily on subscapularis integrity to maintain anterior stability and internal rotation. In contrast, contemporary lateralized designs achieved through glenoid lateralization, humeral lateralization or onlay configurations, and lower neck-shaft angles (135°–145°) improve deltoid wrapping, compressive stability, and impingement-free range of motion, thereby reducing reliance on the subscapularis for anterior restraint, supporting a more selective approach to repair. Ultimately, the combined glenoid and humeral configuration,

along with tendon quality, soft-tissue balance, and patient functional goals, should guide decisions regarding subscapularis repair. Future studies should focus on defining these parameters to further refine indications for subscapularis repair.

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