18 Strategies to Improve Function in Reverse Total Shoulder Arthroplasty (RTSA): Glenoid-Shaft Angle and Lateralization

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As discussed throughout this edition, the shoulder relies on a careful balance of stability and mobility, and while an anatomic total shoulder arthroplasty aims to reproduce normal shoulder kinematics, the reverse total shoulder arthroplasty (RTSA) is a non-anatomic procedure. It draws on a partially constrained design to empower the deltoid and the intact elements of the shoulder girdle to move the humerus around a fixed point, the glenosphere. When the treatment of rotator cuff tear arthropathy was revolutionized by Grammont's design, the mechanical effect of his design increased the deltoid's moment arm by 42% [1]. In time, modern reverse designs have maintained the essential elements of his approach to maintain the joint's stability, while simultaneously seeking a more anatomic position for the resulting shoulder joint to minimize complications and maximize range of motion (external rotation).

The normal inclination of the proximal humerus, or neck-shaft angle (NSA), is approximately 135°. However, person-to-person variability can range from 115 to 148°. When studied, approximately 22% of patients will have a NSA less than 130° or greater than 140°, so careful consideration needs to address the native anatomy and the intended surgical result [2]. The Grammont design had a fixed, 155-degree NSA and enhanced the deltoid moment arm by moving the humerus inferior or distal [3]. This change in position made the deltoid more powerful in forward elevation and abduction, while shifting the center of rotation medially [4]. Grammont achieved success in his design by moving the center of rotation (COR) medial to the interface between the baseplate and glenoid [5].

This change in the COR created a stable foundation for the reverse total shoulder by minimizing sheer and promoting the compression necessary for osteointegration. When combined with a 155-degree angle on the humeral prostheses, these technical considerations addressed the intrinsic disability of rotator cuff arthropathy as long as the glenosphere was placed inferior on the glenoid face and the humeral implant did not impinge.

However, these design choices also result in significant changes to the physiologic function of the shoulder's muscular supports. The anterior deltoid, the posterior deltoid, and the pectoralis major are more easily recruited as flexors and abductors, improving a patient's ability to lift the arm. The latissimus dorsi, teres major, and lower part of the pectoralis major have an increased ability to serve in adduction and extension. This change results in a corresponding decrease in their effect on both internal and external rotation [6, 7]. In patients with Grammont-style RSA, the anterior and posterior rotator cuff are weakened by medialization, limiting their active internal and external rotation [8, 9].

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A. D. Mazzocca et al. (eds.), *Shoulder Arthritis across the Life Span*,
https://doi.org/10.1007/978-3-031-33298-2_18

In time, the medialization intrinsic to the traditional Grammont design was associated with high rates of scapular notching and concern for baseplate micro-motion, osteolysis, and potential glenoid loosening [10, 11]. This concern combined with the observation that more notching was associated with worse clinical outcomes [12–15]. To address the concerns associated with the traditional design, lateralized implants have been developed to improve the characteristics of the glenoid component, the humeral stem, or both [16].

Lateralized glenoid components employ modern materials to create a stable implant-bone interface with a COR that is lateral to the surface of the glenoid. This modification preserves rotational moment arms of the subscapularis and teres minor and enhances the active range of motion in the axial plane [17]. While the joint's COR needs to be more medial than the native, lateralization of the glenosphere from the glenoid enhances the compressive forces at the bone-implant interface and may overcome the shear forces that result from lateralization [18].

As a result, lateralized components have been shown to decrease the impingement between the scapular neck and the humeral prosthesis that results in notching. In a systematic review of 13 studies, the incidence of scapular notching was 5.4% in a lateralized glenoid group compared to 44.9% in a traditional group ($p < 0.001$) [19]. At the same time, patients with a lateralized prosthesis demonstrated more active external rotation (46° vs. 24°, $p < 0.001$). In contrast, clinically significant glenoid loosening was found in 1.8% of the traditional compared to 8.8% in the lateralized group ($p = 0.003$), raising questions of the sheer stress associated with lateralization. When one lateralized design was compared to a Grammont-style prosthesis, the same disparity was confirmed; glenoid loosening occurred in 5.8% of lateralized implants compared to 2.5% [20]. In the lab, lateralized implants have increased micro-motion with a lateralized design, acknowledging that lateralization can be achieved through the implant's design or with bone grafting and/or bone augmentation of the glenoid [18].

With the ongoing evolution of reverse total shoulder designs, there may be a lag in the maturation of the data available regarding implant behavior. In a 2019 systematic review that included 103 studies, there was no difference in the rate of aseptic loosening for lateralized and medialized glenoids (1.84% vs. 1.15%, respectively) [21]. Correspondingly, patient outcomes were similar for the two designs in a 2018 review, despite a difference in external rotation (lateralized greater than Grammont) and a difference in scapular notching (Grammont greater than lateralized) [22].

In considering the relevant equivalence of the two designs' results, the debate remains unresolved. The Grammont design medializes the center of rotation, creating a compressive force at the implant-bone interface that may improve the glenoid fixation and implant longevity. Conversely, lateralized designs decrease the incidence of scapular notching and may improve external rotation.

Changes to the humeral component have been introduced to maximize the compression on the glenoid component while increasing the mechanical advantage of a lateralized center of rotation. While 155° is the most common humeral shaft angle, the horizontal cut may increase the impingement [23–26]. A reduced neck-shaft angle aims to reduce scapular notching, but it may increase the rate of dislocation [3].

In biomechanical studies, a decreased shaft angle will increase the range of motion, while decreasing the potential for contact with the inferior angle of the glenoid [27]. A recent meta-analysis of 2222 shoulders undergoing RTSA compared the rate of scapula notching and dislocation between implants with different neck-shaft angles [28]. While only 20% of the implants included had a neck-shaft angle of 135°, scapular notching was found to be more common with a 155-degree implant (16.80%) than a 135-degree prosthesis (2.83%) ($p < 0.01$). There was no significant difference in dislocation rate between the two groups (2.33% and 1.74%, respectively). However, lateralization alone has been shown to decrease scapular notching, even with a 155-degree prosthesis, so the neck-shaft angle may not be the salient implant characteristic [29].

When the impact of neck-shaft angle on range of motion was examined, a similar meta-analysis revealed that a 135-degree prosthesis achieved greater external rotation (33°) than the 155-degree alternative (25°) ($p < 0.01$) [30]. In this way, modification to the humeral designs that lower the neck-shaft angle may reduce scapula notching and increase external rotation. How this adjustment should be combined with the lateralization of the glenoid component and the risk of loosening warrants further investigation, particularly if the risk of scapula fracture is included in the broader analysis of a patient's expected clinical result (Figs. 18.1 and 18.2; Table 18.1).

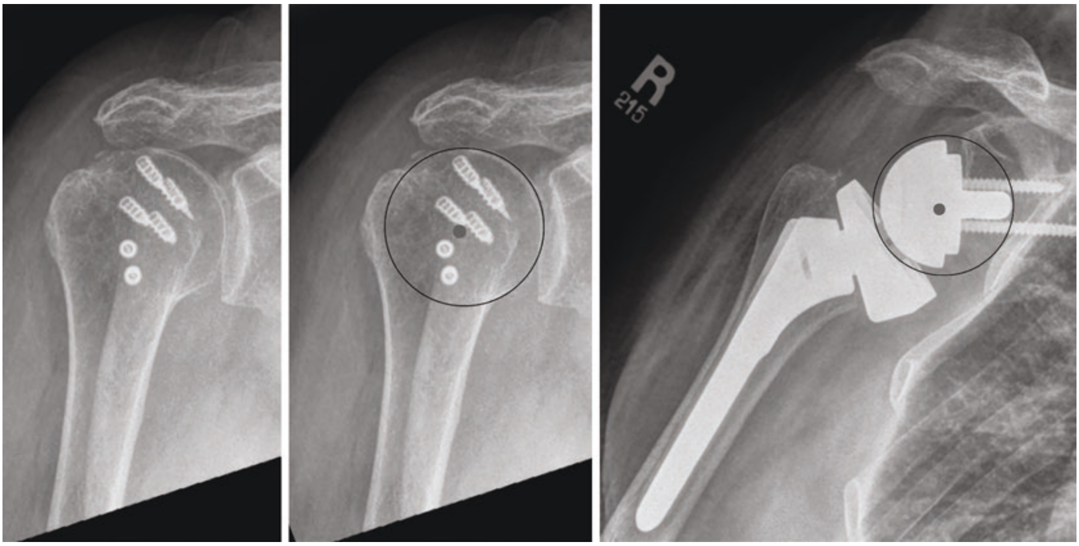

Fig. 18.1 Grammont-style prosthesis. Left—AP radiograph of a right shoulder in a patient with rotator cuff arthropathy. Center—The center of rotation relative lies in the center of the humeral head. Right—After a Grammont-style reverse total shoulder, the center of rotation is offset medially and distally

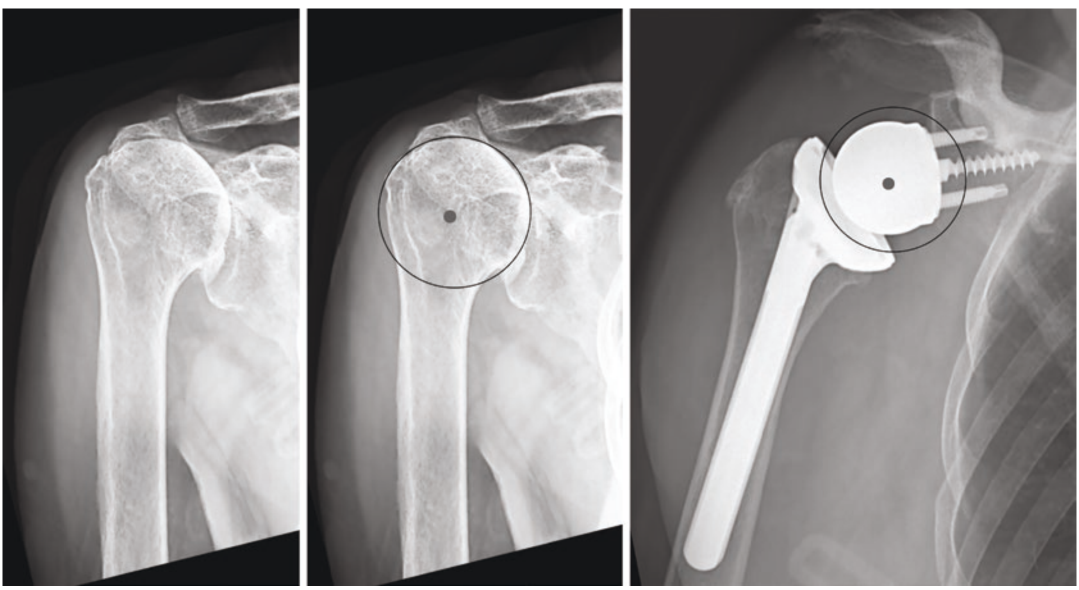

Fig. 18.2 Lateralized prosthesis. Left—AP radiograph of a right shoulder in a patient with rotator cuff arthropathy. Center—The center of rotation relative lies in the center of the humeral head. Right—After a lateralized reverse total shoulder, the center of rotation is moved laterally

Table 18.1 Methods for affecting lateralization in a reverse total shoulder arthroplasty

Glenoid	
Frankle-style glenosphere	Non-hemispherical design moves the center of rotation lateral
Bone grafting/bone augmentation of glenoid	Increased bone stock places the baseplate more lateral
Augmented-metal baseplates	Metal augment lateralizes the position of the baseplate
Lateralized baseplate	Thickness of the baseplate increases the lateral offset
Humerus	
Decreased neck-shaft angle	Moves the humeral shaft lateral rather than distal
Humeral tray/adaptor	Increases the offset of the humeral component
Humeral stem design	Curved and onlay stems

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