Humeral Stem Designs in Reverse Total Shoulder Arthroplasty: A Focus on the Adjustability of Inclination, Torsion, and Version

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Background: While the inclination of the humeral component in reverse total shoulder arthroplasty (rTSA) has been extensively studied, less attention has been given to the parameters of version and torsion. These parameters, which influence outcomes in rTSA, warrant closer examination. This study aims to analyze the designs of humeral stems in rTSA, focusing on their ability to independently adjust inclination (coronal plane), torsion (axial plane), and version (sagittal plane). We hypothesize that while most designs allow for inclination and torsion adjustments, independent version adjustment is rare and may offer unique biomechanical implications.

Purpose: To systematically review currently available rTSA humeral stem designs and assess their capacity for independent adjustment of inclination, torsion, and version based on manufacturer specifications and design features.

Methods: A comprehensive review of commercially available rTSA humeral stem designs was conducted. Humeral stems from various manufacturers were analyzed for their capacity to allow independent adjustment of inclination, torsion, and version. The analysis relied on technical specifications and data provided by manufacturers, supplemented by a critical review of design features.

Results: The review showed that while a few stem designs offer inclination adjustment up to 12.5° via angled liners, there is one implant allowing inclination adjustment within the same stem design, through a modular metaphyseal cup, permitting adjustment from 135° to 155°. Torsion was found to be freely adjustable across all designs, independent of the specific stem configuration. While all systems provide a fixed stem version of 0°, one system offered adjustability of humeral version (0° and 20°) through a modular metaphyseal component.

Conclusions: While torsion can be freely adjusted independent of stem design, the ability to modify inclination is limited to certain systems, mostly relying on angled liners for this purpose. Independent adjustability in the sagittal plane (version) remains rare, with only one system offering this feature through a modular metaphysis. The potential clinical implications of adjustable humeral version in rTSA are yet to be investigated.

What this study adds: This review provides the first comprehensive comparison of rTSA humeral stem designs regarding the independent adjustability of key biomechanical parameters—inclination, torsion, and version. It identifies critical limitations in current implant designs and emphasizes the potential relevance of humeral version adjustment, a largely overlooked variable.

Potential impacts on research, practice, or policy: This review may raise awareness of the variability in humeral stem design with respect to adjustability of inclination, torsion, and version, and highlights areas that warrant further biomechanical and clinical investigation. While the clinical benefit of independent version adjustability remains uncertain, the findings may stimulate future research into whether such modular features influence outcomes following rTSA.

Study design: Manufacturer-Based Review

Level of Evidence: Level V

Keywords: Inclination; Torsion; Version; Humeral stem; Reverse shoulder arthroplasty.

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Introduction

Humeral stem inclination in reverse total shoulder arthroplasty (rTSA) has been the focus of extensive research, consistently emphasizing its biomechanical relevance. The classical Grammont design with a 155° neck-shaft angle (NSA) aimed at improving stability of rTSA with medialized center of rotation [1][2]. Subsequent years saw the introduction of designs with lower NSA combined with lateralized center of rotation in an attempt to improve particularly rotation [3][4][5][6].

Humeral stem torsion—defined as the axial twisting of the humeral component—has recently garnered attention for its hypothesized influence on functional outcomes [7][8]. The study conducted by Oh et al. [9] revealed that implementing humeral component retrotorsion adjusted to the native humeral head retrotorsion yields superior range of motion outcomes compared to the application of a standardized retrotorsion angle of 20°. Moreover, recent investigations have pointed out the importance of adjusting humeral component torsion to individual differences in scapulothoracic orientation and posture in order to improve simulated impingement-free range of motion [7][8].

However, the concept of torsion is frequently conflated with the term 'version' of the humeral component, leading to persistent misconceptions in both clinical practice and academic discourse. This confusion has historical roots; in 1976, Kate [10] highlighted the interchangeable use of these terms in his seminal paper "*Anteversion versus Torsion of the Femur Neck*," emphasizing the significant effort required to delineate their distinct meanings. Nearly half a century later, this terminological ambiguity persists, presenting unique challenges in the context of rTSA, where the anatomy of the shoulder joint is profoundly altered.

Distinguishing between humeral torsion and version is not merely a semantic issue as the ability to adjust version independently of torsion in commercially available humeral stems does indeed exist; this differentiation represents a critical step toward refining implant configurations and improving patient outcomes. To the best of our knowledge, a detailed and systematic evaluation of the adjustability of inclination, torsion, and version across different humeral stem designs has not yet been comprehensively addressed in the scientific literature.

This study aims to provide a comprehensive overview of current commercially available humeral stem systems in rTSA, focusing on their ability to independently adjust humeral inclination, torsion, and version based on manufacturer-provided specifications. We hypothesize that while most designs allow for inclination and torsion adjustments, independent version adjustment is rare and may offer unique biomechanical implications.

Methods

A comprehensive evaluation of commercially available rTSA stem designs was conducted. Included were all systems reported in a similar comparative study by Werthel et al. [11] to ensure broad market representation and facilitate comparability with existing literature. Manufacturer specifications and technical product data sheets were meticulously reviewed to gather detailed information about each implant's design features, focusing on the capacity for independent adjustment of humeral inclination, torsion, and version using predefined criteria, including the range of NSA and modularity of components. Inclination and version were assessed by an experienced shoulder surgeon (P.M.) and an orthopedic surgeon (A.S.) based on the range of NSA provided by the product specifications of the manufacturers. The capacity for independent adjustment of torsion, which is typically not mentioned by the manufacturers (freely adjustable by axial twisting of the humeral component) was confirmed by critical review of design features.

Results

The analysis revealed variability in the range of adjustability for inclination, torsion, and version among the evaluated humeral stem designs (**Table 1**). For inclination, the NSA ranged from 127.5° to 155°, with the majority of designs offering one fixed option and only a subset allowing for customization (**Table 1**). Adjustability of torsion was given by all designs, permitting axial rotation of the stem within the diaphysis and within the confines of the humeral head. One rTSA system was identified that allows to adjust version from 0° to 20° in the sagittal plane (**Table 1**).

Table 1. Overview of the various industrial humeral stem designs.

Stem System	Manufacturer	Inclination adjustment (Yes/No, Range°)	Version adjustment (Yes/No, Range°)	Torsion adjustment (Yes/No, Range°)
Affinis Reverse	Mathys	No, 155°	No, 0°	Yes, Free
Aequalis II	Tornier	No, 155°	No, 0°	Yes, Free
SMR	LimaCorporate	No, 155°	No, 0°	Yes, Free
Delta Xtend	DePuy Synthes	No, 155°	No, 0°	Yes, Free
Trabecular Metal	Zimmer Biomet	No, 150°	No, 0°	Yes, Free
Univers Revers	Arthrex	Yes, 135° or 155° (via metaphyseal cup)	No, 0°	Yes, Free
Altivate	Enovis	No, 135°	No, 0°	Yes, Free
Identity Shoulder System 135°	Zimmer Biomet	Yes, 147° (via 12° angled liner)	No, 0°	Yes, Free
Ascend Flex 127.5°, 132.5° or 137.5°	Wright Medical	Yes, 140°, 145° or 150° (via 12.5° angled liner)	No, 0°	Yes, Free
Humeralock Reverse	FX Shoulder	No, 135°	No, 0°	Yes, Free
TESS	Zimmer Biomet	No, 145°	No, 0°	Yes, Free
Equinoxe132.5°	Exactech	Yes, 145° (via 12.5° angled liner)	No, 0°	Yes, Free
Easytech	Evolutis	No, 135°	No, 0°	Yes, Free
Duocentric	Evolutis	No, 135°	No, 0°	Yes, Free
ReUnion RSA	Stryker	No, 135°	No, 0°	Yes, Free
Comprehensive Shoulder System 135°	Zimmer Biomet	Yes, 147° (via 12° angled liner)	No, 0°	Yes, Free
Inverse Reverse	Wright Medical	No, 135°	No, 0°	Yes, Free
Arrow II	FH Orthopedics	No, 135°	No, 0°	Yes, Free
Medacta Reverse Shoulder System	Medacta	Yes, 145° or 155° (based on liner orientation)	Yes, 0° or 20°	Yes, Free
Tornier Perform	Stryker	Yes, 135° or 145° (via 10° reversed inserts)	No, 0°	Yes, Free

Discussion

This study analyzes three critical stem parameters that shape the biomechanics of rTSA, emphasizing how their adjustability is inherently dictated by the design of the humeral component. Our findings offer valuable insights into the design variability of humeral stems in rTSA. While independent adjustability of inclination and torsion is relatively common, the capacity to modify humeral version independently remains rare, with only one implant system currently providing this feature.

Clinically, the humeral stem inclination in rTSA was proven to impact postoperative range of motion [4][12], stability [1][2], and scapular notching rates [12][13]. Our comprehensive review of commercially available rTSA systems revealed that some stem designs allow variable inclination angles using angled liners (**Table 1**). In contrast, one design allows inclination adjustment within a single stem design via a modular metaphyseal cup from 135° to 155° (**Table 1**). From a 3-dimensional perspective, the relationship of inclination with version becomes apparent, as a tilt in the coronal plane (inclination) transforms into a tilt in the sagittal plane (version) at 90° torsion (**Figure 1**).

The selection of the humeral-sided implant in rTSA is largely at the discretion of the surgeon and is primarily guided by patient-specific factors. Previous research established that humeral head torsion plays a crucial role in total shoulder arthroplasty and directly impacts the joint

center of rotation, subsequently affecting rotational movements and shoulder stability [14][15][16]. Commercially available systems widely recommend a jig aligned with the forearm, a method that was found to be inaccurate in a retrospective study [17]. In this context, Lädermann and colleagues recommended the addition of a 10° to 15° carrying angle to the reported measurements to achieve optimal humeral component torsion [18]. However, this recommendation is based on expert opinion, grounded in the anatomical significance of the carrying angle.

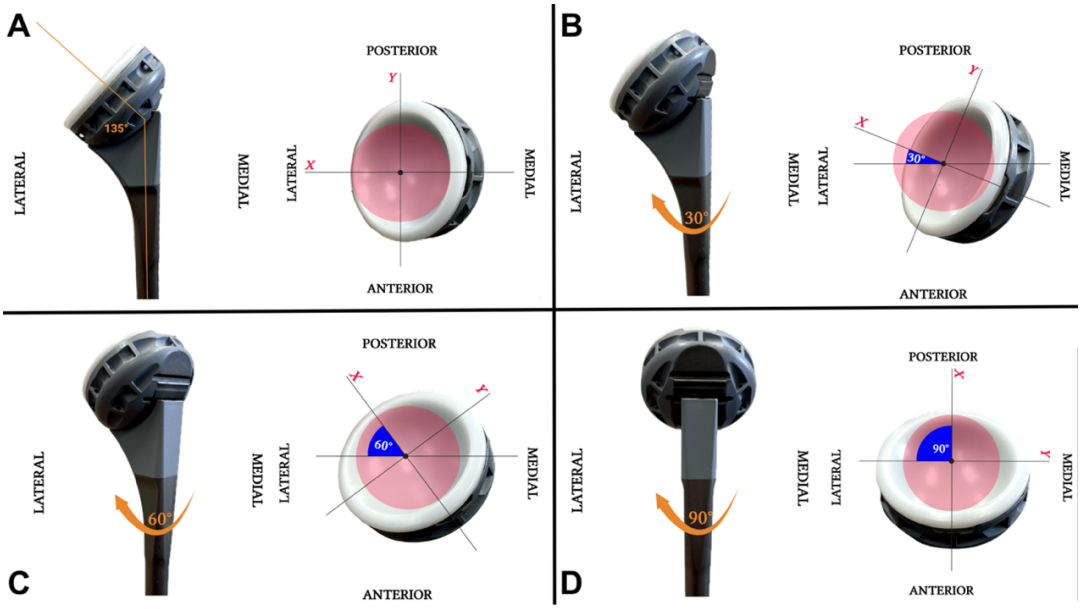


Figure 1. Relationship between torsion and inclination in a modular humeral stem design. Initial torsion of 0° results in 135° inclination in the coronal plane and 0° version (A). With increasing torsion, the inclination in the coronal plane shifts into the sagittal plane (B and C) and reaches its maximum at 90° torsion (D).

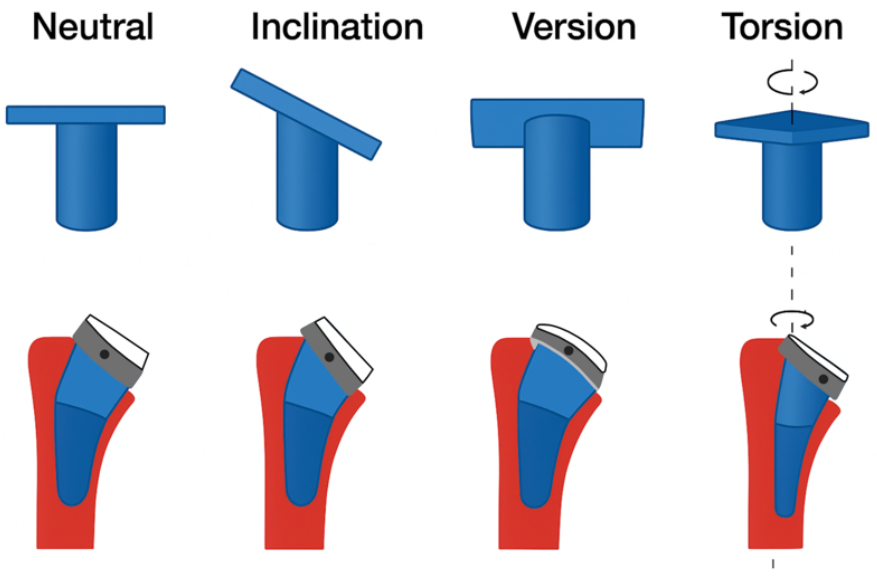


Figure 2: Illustration depicts variations in the alignment of the humeral component relative to the proximal humeral metaphysis. Torsion refers to the rotational positioning of the component along its own axis, while inclination and version describe the angular tilt of the component's tray or cup in relation to its shaft axis, oriented 90° apart.

In addition to the ongoing mislabeling of stem 'torsion' as 'version', there have been conflicting findings regarding the influence of humeral stem torsion on clinical outcomes. Recently, Wiater et al. [19], in double-blinded, prospective randomized control study compared the outcomes in two groups with 0° and 30° humeral component 'retroversion' and found that the 'version' -referring to torsion- does not affect functional outcomes following rTSA. One noteworthy limitation, however, is that the authors did not report the impact of scapulothoracic orientation and different posture types on optimal implant opposition.

Conversely, Berhouet et al. [20] proved in a cadaveric study that rotational range of motion following rTSA is affected by the humeral component torsion, recommending that it should be adapted to patient's 'native retroversion'. By retrospectively evaluating computed tomography scans of 30 patients with arthritic shoulders using a computer surgery model, Kontaxis et al. [21] found in their study that the humeral component torsion affects the impingement free range of motion.

In 1993, Grammont and Baulot [22] suggested that placing the humeral component in 'antetorsion' would improve internal rotation, a movement that is significant in daily life activities (buttoning up a shirt, performing perineal hygiene). This theory depended on the extended distance between the humeral component and scapular neck before scapular impingement ensues. Subsequent biomechanical studies have consistently supported these findings [23][24][25].

In the context of rTSA, the study by Moroder et al. [7] is, to our knowledge, the only paper that briefly pointed out the difference between the two terms torsion and version (**Figure 2**). It is crucial for surgeons to first

understand the biomechanical impact of each component in rTSA. Equally important is familiarity with the various humeral stem designs, particularly those that allow independent adjustment of version without affecting torsion, and those that provide no such flexibility, as they come in a single fixed configuration (**Table 1**).

Our analysis of the available humeral stem designs on the market revealed that only one modular humeral component that allows for independent adjustment of version (0° to 20°) and torsion (**Table 1**). In contrast, other stems achieve version adjustments via torsion adjustments (**Figure 1**). Both approaches have the potential to influence joint compressive forces, joint stability, and impingement-free range of motion.

In an interesting computerized experimental study, Schroeder et al. [26] proved that adjusting the geometry of the humeral tray and polyethylene components could improve internal rotation and maintain the range of motion in other planes, but it may also lead to greater construct instability. A finite element analysis conducted by Permeswaran et al. [27] showed that retroversion of radially asymmetric humeral polyethylene liners can decrease the risk of subluxation and simultaneously improve the range of external rotation.

Based on these findings, it might be advisable to handle both version and torsion (given its effect on version) with caution to prevent postoperative instability after rTSA, which can be particularly challenging to address. For instance, Chalmers et al. [28] reported that only 44% of early dislocations remained stable following revision surgery, while Frankle and colleagues[29] observed similarly poor outcomes with both closed reduction and revision procedures [29].

Although there is currently no consensus or general recommendation regarding the optimal combination of inclination, torsion and version in rTSA, evidence in the literature indicates that these parameters impact functional outcomes and implant stability [7][30]. Properly differentiating these terms, and understanding their roles and interactive relationship in various humeral component designs, is essential for refining implant configurations and ensuring accurate communication in clinical practice.

A key limitation of this study is its reliance on manufacturer-provided data, which may not fully capture all design intricacies or intraoperative adaptability of humeral stems in rTSA. Further, this review does not include biomechanical testing or clinical outcomes, limiting its applicability to direct patient care. Variability in reporting standards among manufacturers may also affect the comparability of different designs. Future studies should integrate experimental validation and clinical data to further assess how the adjustment of each stem parameter (particularly independent humeral version adjustment) affects implant performance and clinical outcomes.

Conclusion

In all rTSA systems, torsion can be adjusted regardless of the stem design, whereas inclination adjustments are restricted to specific systems, mostly achieved with angled liners. Independent adjustability in the sagittal plane (version), however, is uncommon, with only one system currently incorporating this capability.

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Contributions

Abdelkader Shekhbihi: Writing, Analysis, Review, Revision. Philipp Moroder: Conceptualization, Review, Revision

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