Stability in Reverse Shoulder Arthroplasty
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Introduction: Stability, the hallmark of reverse shoulder arthroplasty (RSA), is determined by a congruent glenosphere/humerosocket joint (Figure 1).

Figure 1. A typical reverse shoulder implant (DePuy Delta 36 mm Glenosphere and standard polyethylene socket).

Because of this unique feature, RSA has been used in the management of patients who have an irreparable rotator cuff tear in the presence of glenohumeral arthritis. However, recent clinical studies demonstrated unexpected subluxation and dislocation in RSA devices,1 suggesting the need to have a thorough understanding of this important issue. As a first step toward this goal, the present study aimed to clarify two critical concerns related to RSA stability: What is the hierarchy of factors identified clinically (socket depth, glenosphere size and joint compressive force) associated with the inherent stability of RSA devices and whether or not this hierarchy can be predicted by a simple rigid body model?

Materials and Methods: Biomechanical testing of RSA stability was performed on a custom biaxial loading fixture (Figure 2).

Figure 2. Schematic illustration of the custom, bi-axial test apparatus used to measure RSA stability.

Eight currently available RSA devices, 6 Encore Medical RSP's and 2 Depuy Delta III's, were used. The humerosocket was attached to a horizontal sled that could translate freely in the x-axis, whereas the glenosphere was attached to a vertical sled that could translate only in the y-axis. Weights, placed on the vertical sled, were used to apply a compressive forces $F_N$ (up to 200 N) to each RSA device. The $F_N$ corresponded to the range of unresisted physiological shoulder joint forces.2 A motor translated the horizontal sled at a constant speed of 5 cm/min, and a 2200 N load cell (Omega Engineering Inc.) was used to measure the dislocation force $F_S$. The mathematical model of RSA stability was modified from a previous model for studying conventional total shoulder arthroplasty.3

A one way analysis of variance (ANOVA) with post-hoc Tukey's test was used to detect differences in dislocation force among prostheses. All differences were considered significant at a probability level of 95% ($p<0.05$).

Results: A hierarchy of stability factors was found in RSA. Implant stability as defined by dislocation force was most affected by the compressive force with differences found among the four compressive force conditions (66 N, 110 N, 155 N and 200 N) ($p<0.05$). The socket depth had a significant effect on the stability of RSAs but to a lesser extent than the compressive force. The ball and socket size had the least effect on RSA stability.

The rigid body model was found to be reasonably accurate in predicting the hierarchy of these factors associated with RSA stability. Considering all of the RSA devices tested, a significant positive linear correlation ($R^2= 0.973$, absolute average error of 7.98%) between the analytical and experimentally measured $F_S$ was obtained.

Discussion: Glenosphere-humerosocket stability is an important variable in selecting the appropriate RSA and is closely correlated to compressive force, humerosocket depth, and to a lesser extent on implant size. Theoretical simulation further suggests that this hierarchy of biomechanical factors is primarily defined by rigid body contact characteristics. The model offers a more rigorous and systematic approach to understanding issues in RSA instability. This is extremely important in the design of RSA devices which can potentially save experimental cost and time. RSA devices offer substantially greater inherent stability in comparison to the normal shoulder and TSA devices, but further research is needed to more fully understand the biomechanical nature of RSA to improve long-term clinical outcomes.


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