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The effect of glenosphere diameter in reverse shoulder arthroplasty on muscle force, joint load, and range of motion

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Background: Little is known about the effects of glenosphere diameter on shoulder joint loads. The purpose of this biomechanical study was to investigate the effects of glenosphere diameter on joint load, load angle, and total deltoid force required for active abduction and range of motion in internal/external rotation and abduction.

Methods: A custom, instrumented reverse shoulder arthroplasty implant system capable of measuring joint load and varying glenosphere diameter (38 and 42 mm) and glenoid offset (neutral and lateral) was implanted in 6 cadaveric shoulders to provide at least 80% power for all variables. A shoulder motion simulator was used to produce active glenohumeral and scapulothoracic motion. All implant configurations were tested with active and passive motion with joint kinematics, loads, and moments recorded.

Results: At neutral and lateralized glenosphere positions, increasing diameter significantly increased joint load ($+12 \pm 21$ N and $+6 \pm 9$ N; $P < .01$) and deltoid load required for active abduction ($+9 \pm 22$ N and $+11 \pm 15$ N; $P < .02$), whereas joint load angle was unaffected ($P > .8$). Passive internal rotation was reduced with increased diameter at both neutral and lateralized glenosphere positions ($-6° \pm 6°$ and $-12° \pm 6°$; $P < .002$); however, external rotation was not affected ($P > .05$). At neutral glenosphere position, increasing diameter increased the maximum angles of both adduction ($+1° \pm 1°$; $P = .03$) and abduction ($+8° \pm 9°$; $P < .05$). Lateralization also increased abduction range of motion compared with neutral ($P < .01$).

Conclusions: Although increasing glenosphere diameter significantly increased joint load and deltoid force, the clinical impact of these changes is presently unclear. Internal rotation, however, was reduced, which contradicts previous bone modeling studies, which we postulate is due to increased posterior capsular tension as it is forced to wrap around a larger 42 mm implant assembly.

Level of evidence: Basic Science, Biomechanics.

Keywords: Reverse total shoulder arthroplasty; shoulder; rotator cuff tear arthropathy; glenosphere; biomechanics; implant size

Institutional Review Board approval was not required (Basic Science study).

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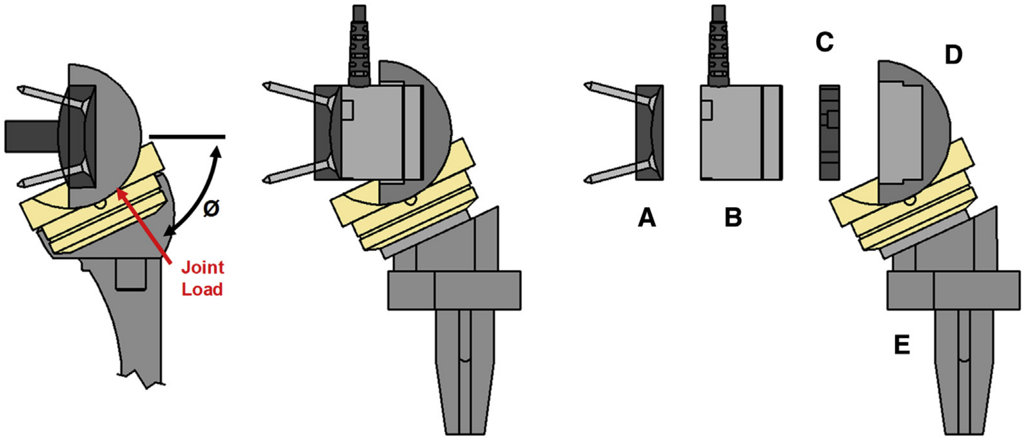

Figure 1 A cross-sectional side view of a typical commercially available reverse shoulder arthroplasty (RSA) system (*left*) with load angle (Ø) shown. Our custom-designed modular RSA implant (*middle*) with exploded view of the glenoid (*right*) showing the custom baseplate (**A**), 6 degree of freedom load cell (**B**), glenosphere lateral offset spacer (**C**), hollow glenosphere (38- and 42-mm sizes) (**D**), and custom humeral component (**E**).

Reverse shoulder arthroplasty (RSA) is an established surgical treatment for severe symptomatic rotator cuff tear arthropathy.[2,5,6,8,16-18,22] As the name implies, RSA reverses the natural geometric anatomy of the glenohumeral joint. As such, selection of optimal implant characteristics and size cannot be directly guided by attempting to replicate the native geometry. The diameter of the glenosphere and articulating polyethylene cup is one such characteristic. Current commercially available RSA implant designs offer sizes ranging from 32 to 53 mm in diameter, with the most widely used offerings providing 2 size options, including either a smaller 36- or 38-mm or a larger 40- to 42-mm-diameter glenosphere/polyethylene insert pairing. The effect of changing RSA glenosphere diameter on shoulder range of motion (ROM) has been investigated by computer models,[4,11,14,19,21] by physical models,[3,12,13] and in an in vitro cadaveric study.[1] The results of solid bone model studies, which do not include soft tissues and use angles of impingement as the outcome variable, report that larger glenospheres provide greater ROM in both abduction[1,3,4,11,13,14,19,21] and internal rotation (IR)/external rotation (ER)[21] and can increase the force required to dislocate the joint.[12] However, there remains a lack of information about the effect of glenosphere diameter on muscle and joint loads, which would provide further insight into the influence of this parameter on the long-term performance of RSA.

The purpose of this in vitro biomechanical cadaveric simulator study was to investigate the effects of RSA glenosphere diameter on the total deltoid force required for active abduction, the resulting articular joint load and load angle, and ROM in IR/ER and abduction for 2 common glenosphere sizes (38 and 42 mm). Our hypothesis was that increased glenosphere diameter would increase ROM in both IR/ER and abduction. In addition, we postulated that the resultant joint loads and muscle forces would not be significantly affected because both sizes share almost identical centers of rotation. Finally, we hypothesized that the joint load angle (or shear component) would increase with the larger glenosphere size owing to the increased stability and ability of the deeper cup to resist applied shear loading.

Materials and methods

Custom instrumented RSA implant

A custom modular implant system was designed for use in this study that included a load sensor, which allowed joint load measurement, and different glenosphere offsets and diameters (Fig. 1). Commercially available polyethylene humeral inserts (Delta Xtend; DePuy, Warsaw, IN, USA) of either 38- or 42-mm size were affixed to the humeral component with the geometry of a neutrally configured clinical RSA. Neutral was defined with the glenoid baseplate placed on the inferior rim of the glenoid, the center of rotation at the glenoid articular surface, a neutral version humeral component with a 155° head-neck angle, and a 12.5-mm lateral offset humeral stem as in a classic Grammont-style implant. The custom glenosphere had either a 38- or 42-mm diameter and was hollowed to allow insertion of a 6 degree of freedom load cell (Nano25, ATI-IA; Apex, NC, USA) before attachment to the glenoid baseplate, which was recessed into the glenoid vault to allow neutral glenosphere positioning. In addition, a 10-mm spacer could be placed between the load cell and the glenosphere to allow 10 mm of lateralization (Fig. 2) to assess for interactions between glenosphere offset and diameter. Following commercial devices, when the glenosphere diameter was increased from 38 to 42 mm, the apparent cup thickness also increased by approximately +2.5 mm (Fig. 2) because of a 2-mm increase in glenosphere radius and a 0.5-mm increase in the distance from the deepest point of the cup to the cup–humeral component mating surface.