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ORIGINAL ARTICLE

Reverse total shoulder glenoid baseplate stability with superior glenoid bone loss

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Background: Superior wear of the glenoid bone is common in patients with rotator cuff arthropathy. This can become a treatment challenge for patients who require shoulder arthroplasty. In reverse shoulder arthroplasty (RSA), glenoid bone loss may affect the stability of baseplate fixation. The primary purpose of this biomechanical laboratory study was to assess the initial fixation stability of RSA glenosphere baseplates in the presence of variable amounts of superior glenoid bone loss.

Materials and methods: High-density solid rigid polyurethane foam (30 pounds/cubic foot) was machined to model the glenoid with variable superior defects that provided different levels of support (100%, 90%, 75%, and 50%) for the glenosphere baseplate. The samples were cyclically loaded (0-750 N at 1 Hz for 5000 cycles) at a 60° glenohumeral angle. The micromotion and migration of the baseplate were calculated from displacement data captured during the loading tests with an array of 3 linear variable differential transformers mounted around the baseplate.

Results: Micromotion was significantly greater in samples with 50% defects compared with those with smaller defects. Migration was significantly greater after testing for all defect sizes.

Conclusions: Initial fixation of RSA glenosphere baseplates was significantly reduced in models with 50% bone loss on the superior edge compared with models with less bone loss in this high-density bone foam model.

Level of evidence: Basic Science Study; Biomechanics

Keywords: Glenoid baseplate; reverse total shoulder arthroplasty; superior glenoid defect; rotator cuff tear; biomechanics; micromotion

Reverse shoulder arthroplasty (RSA) is a successful treatment option for patients with rotator cuff tear arthropathy. Since the initial approval of the RSA in the United States in 2004, there has been rapid development of new implant designs and techniques. Clinical results have been favorable; however, long-term follow-up studies have reported complications have in up to 33% of patients.[19] Despite initial concerns regarding glenosphere stability and fixation, component loosening has been reported in less than 7% of patients.[19]

Rotator cuff tear arthropathy results from a chronic massive rotator cuff tear. With the loss of the rotator cuff constraint, the humeral head migrates superiorly, resulting in joint subluxation. The arthritic changes that occur secondary to this superior subluxation are often associated with bone loss of the superior aspect of the glenoid. Glenoid bone loss has been

This is a biomechanical study, which did not require Institutional Review Board approval.

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thought to be a relative contraindication to reverse total shoulder arthroplasty because of concerns about failure of glenosphere fixation. However, a variety of enhanced fixation methods, including increased number and size of screws, use of locking screws, bone ingrowth technology, and use of augments, have led to some surgeons implanting reverse components in patients with glenoid bone loss. How much bone stock is required for successful fixation of a reverse total shoulder arthroplasty is still unknown and may vary with different implant designs.

The primary purpose of this biomechanical laboratory study was to assess the initial fixation stability of RSA glenosphere baseplates in the presence of variable amounts of superior glenoid bone loss. Baseplate stability is assessed by micromotion and migration. Migration is the progressive displacement of the baseplate from its original position measured over time. Micromotion is the movement of the baseplate relative to the bone substrate that occurs within each load cycle. The hypothesis was that increasing the size of the glenoid bone deficiency would result in increased micromotion and migration of the glenosphere baseplate.

Materials and methods

Implant

The Comprehensive Reverse Total Shoulder Prosthesis system (Biomet, Warsaw, IN, USA) was used in this study. A 41-mm glenosphere was attached to the 28-mm-diameter, porous-coated baseplate via the Versa-Dial (Biomet) adapter that was configured to provide maximum inferior offset (4.5 mm) and >6 mm of lateral offset. The humeral component was an ArComXL (Biomet) ultrahigh-molecular-weight polyethylene humeral bearing with a 41-mm diameter of curvature.

Specimen preparation

Forty samples of high-density solid rigid polyurethane bone foam (Sawbones; Pacific Research Laboratories, Inc., Vashon, WA, USA) were machined into cylinders with a diameter of 33 mm and height of 80 mm. This bone foam material had a density of 0.480 g/cm^3 (30 pounds/cubic foot [pcf]), a compressive strength of 18.0 MPa, and a compressive modulus of 0.445 GPa,[24] values that are within the range of mechanical properties reported for cadaveric glenoid cancellous bone.[1,7,14,17,18] The bone foam cylinders were further machined to produce different levels of superior bone defect. A superior wedge of 30° was machined into 30 samples to give varying levels of baseplate contact (90%, 75%, and 50%). Ten samples were prepared for each category of baseplate contact, and the remaining 10 samples were left intact to act as a control where no defect was present.

The glenosphere baseplates were implanted according to the manufacturer's recommended technique. A guide pin was placed down the center of the foam cylinder, and a reamer was used to prepare the foam to accept the baseplate. The baseplates were impacted until fully seated with the superior screw hole aligned with the center of the superior wedge defect. Fixation was performed with a 6.5-mm central screw that was 30 mm long. Four nonlocking 4.75-mm screws that were each 15 mm long were placed in the 4 peripheral holes on the baseplate. The bone foam samples were embedded within polymethylmethacrylate cement so that only 1 cm of bone foam was exposed. Photographs of the prepared baseplates in each to the test configurations are shown in Fig. 1.

The polymethylmethacrylate-embedded samples were secured within an aluminum cylinder that was rigidly mounted to the base of a servohydraulic load frame (mini-Bionix II; MTS Corp., Eden Prairie, MN, USA), such that the superior-inferior axis of the glenoid was oriented at 60° relative to vertical axis of the load frame actuator (Fig. 2, *a* and *b*). An auxiliary mounting ring was placed around and connected to the peripheral edge of the baseplate by 4 setscrews (Fig. 2, *c* and *d*) that extended radially from the baseplate in the approximate superior, inferior, anterior, and posterior directions.

An array of 3 linear variable differential transformers (LVDTs; GCD-121-050, Measurement Specialties Inc., Hampton, VA, USA) was placed about the baseplate (Fig. 2, *e* and *f*). LVDT 1 was placed in line with the head of the inferior setscrew so that it measured the motion on the baseplate along the superior-inferior axis. LVDTs 2 and 3 were mounted perpendicular to the plane of the glenoid and offset anteriorly from the baseplate and auxiliary mounting ring.

A system of frictionless lever arms was used to couple the tip displacements of LVDTs 2 and 3 to measure the medial/lateral displacements of the inferior and superior setscrews just outside of the auxiliary ring (Fig. 2, *e, f, and j*). These displacements were then transformed to determine the medial/lateral motion of the inferior edge and superior edge of the baseplate. The glenosphere was then impacted onto the baseplate (Fig. 2, *g* and *h*), and the humeral tray

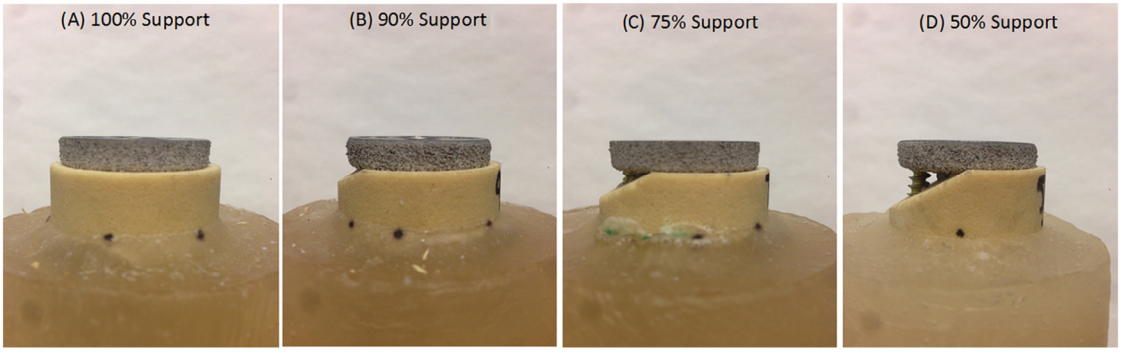

Figure 1 Side views of baseplate/bone foam constructs prepared to provide (**A**)100%, (**B**) 90%, (**C**) 75%, and (**D**) 50% bone foam support of the glenoid baseplate.