**Evaluation of Custom-Designed Posterior-step Glenoid Prostheses for Treatment of Biconcave Glenoid Defects in Shoulder Osteoarthritis**

1. Biomechanics Laboratory, The Pennsylvania State University (UP), PA, USA
2. Department of Orthopaedics and Rehabilitation, Milton S. Hershey Medical Center, Hershey, PA, USA

**INTRODUCTION**

Loosening of the glenoid component continues to compromise the outcome of total shoulder arthroplasty (TSA), a commonly performed procedure for advanced shoulder osteoarthritis. The risk for glenoid component loosening is greatly increased with pre-existing posterior glenoid erosion that is routinely encountered in osteoarthritis. Treatment options for posterior glenoid erosion are currently limited and have inconsistent success rates. The goal of the present project was to employ a cadaver model to evaluate the mechanical efficacy of two novel posterior-step glenoid prostheses (Poly-step and Ti-step), that were custom-designed to compensate for typical biconcave (type B2) posterior glenoid defects. Our first hypothesis was that TSA using a standard (STD) glenoid prosthesis, in the absence of a defect, will not significantly alter joint stability, as measured by gleno-humeral translations, but will increase loading of the glenoid at most locations, as measured by the peri-glenoid principal bone strains. The second hypothesis was that implantation of custom Poly-step and Ti-step prostheses in the presence of a defect will be mechanically equivalent to STD prosthesis implantation in the absence of such a defect.

**METHODS**

**Specimen Preparation:** Fifteen non-embalmed, fresh frozen human shoulders with intact joint capsule and rotator cuff were procured from human donor bodies, and were tested in a custom-built loading apparatus. Fluoroscopic guidance was used to recreate the in vivo glenoid orientation as the scapulae were fixed in mounting jigs in 10° of anterior tilt, with the glenoid articular surface being perpendicular to the scapular plane and inclined 25° superiorly. Reflective marker clusters were rigidly fixed on to the acromion and the humeral shaft, while three triaxial strain gauge rosettes (Kyowa, Japan) were anchored around the perimeter of the glenoid.

**Operative Protocol:** TSA was performed by an experienced shoulder surgeon using modular Bigliani/Flatow® system (Zimmer Inc., IN) in all specimens in a consistent manner. A STD glenoid prosthesis was implanted in five specimens, while a 20° biconcave defect, as measured at the glenoid center, was surgically created in the posterior glenoid of the remaining ten specimens. Subsequently, custom Polyethylene-step (Poly-step) and Titanium-step (Ti-step) glenoid prostheses were implanted in five specimens each. Custom prototypes were manufactured by attaching polyethylene and titanium step-blocks, onto the back of STD implants using cyanoacrylate and two screws. The step-blocks were in turn manufactured based on the geometry of the created defect and the STD glenoid implant.

**Experimental Loading Protocol:** Physiological shoulder loading was simulated by applying 30 to 50N static forces to the rotator cuff muscles through cryogenic clamps, and up to 200N of axial forces to the distal humerus using a linear actuator (IDC/Danaher Motion). The axial forces were recorded using a force transducer (Omega Corp.) that was interfaced with the distal humerus. The arm was placed in 90° of abduction in the scapular plane, and in horizontal flexion and horizontal extension 30° anterior and posterior to the scapular plane respectively. Peri-glenoid bone strains, marker-motion, and axial forces were simultaneously recorded during loading.

**Data Processing Protocol:** Maximum (E_max) and minimum (E_min) principal strains were derived from strains, while the motion of the humeral head center with respect to the glenoid center was derived from the marker motion by global-to-anatomical coordinate system transformation. For consistency across specimens, the variables were zeroed at 20N of axial pre-loads, and the respective measurements at 200N axial forces were compared across experimental conditions, arm positions using a general linear model ANOVA followed by Tukey pairwise comparisons. The significance was set at 0.05 alpha. Subsequently, the change in variables as a consequence of TSA was compared across the three implant types.

**RESULTS**

EMax, E_min and principal strain angles at 200N of axial loading, and gleno-humeral translations from 20 to 200N of axial loading following TSA using a standard glenoid prosthesis were not significantly different from those in the native joints (p > 0.05). In the presence of a 20° biconcave posterior glenoid defect, the E_max (i.e. compressive principal strains) on the superior aspect of the glenoid were significantly lower than those in intact specimens (p = 0.007). Following implantation of the Poly-step glenoid prosthesis, all the variables were similar to those measured in the native joints. In contrast Ti-step prosthesis implantation resulted in statistically greater anterior E_min (p = 0.003) and posterior E_max (i.e. tensile principal strains) (p = 0.001), and more anterior humeral head translations (p = 0.021), as compared to the respective measurements in the native joints. Comparison of the alterations in E_max, E_min and joint translations (Fig 1a, b and c resp.) across implants also revealed significant differences for the Ti-step implant as compared to the STD and Poly-step prostheses at 200N of loading. Overall, significant inter-specimen variability was observed.

**DISCUSSION**

We successfully employed a cadaver shoulder loading model for mechanical testing of standard and Posterior-step glenoid implants, as custom-designed for treating biconcave posterior glenoid defects. In past experiments, similar translations and higher strains have been observed after TSA as compared to the native joints. Our observations of similar peri-glenoid strains and gleno-humeral translations before and after TSA using STD and Poly-step implants suggest that the joint loading pattern and stability are not significantly altered with either of these implant types. However this may not be true for the metal-backed Ti-step implant as the anterior E_min and posterior E_max were significantly increased and the translations were more anterior as compared to the native joints. Furthermore, analysis of the change in the variables as a consequence of TSA using a Ti-step implant revealed significant differences as compared to those for the STD and Poly-step implants, which probably reflects a stress-shielding effect by the metal-backed Ti-step prostheses. Therefore, we conclude that the Poly-step glenoid prosthesis may be a viable option for treating posterior glenoid deficiencies, and therefore, this novel prosthesis warrants further mechanical investigations, such as fatigue loading and testing for loosening performance etc. If successful, this prosthesis may become an important treatment avenue for surgeons treating arthritic shoulders with posterior glenoid deficiency, and may potentially reduce the incidence of glenoid component loosening and failure.