A Pilot Study of Glenoid Loading and Stability of the Inlay versus Onlay Shoulder System

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Introduction: The glenohumeral joint of the shoulder is the most freely moving joint in the body, and subject to a wide range of load and motion induced joint pathology. Innovative technologies to improve the stability of the glenohumeral joint include a total shoulder arthroplasty (TSA), a reverse total shoulder arthroplasty (RSA), a humeral hemiarthroplasty, or a soft-tissue allograft. Recently, a partial glenoid resurfacing implant, known as a glenoid inlay, has been introduced with a design that may potentially exhibit less implant loosening, often seen with the rocking horse phenomenon, during humeral articulation than the standard glenoid onlay systems currently used in TSA. The inlay design is implanted centrally on the glenoid to match the surrounding anatomy with a fit that leaves it flush with the surrounding cartilage and is hypothesized to lessen the risk of rocking-horse loosening during physiologic activity. The purpose of this research study was to examine the contact pressures and implant stability associated with fatigue loading of the glenoid inlay and onlay systems during physiologic loading and motion in a cadaveric model. We hypothesize that the glenoid inlay system will exhibit lower contact pressures, greater implant stability, and less rocking horse motion following fatigue loading than a standard onlay TSA system.

Methods: In a pilot study, n=4 specimens (two matched pair shoulders) were selected for testing following clinical CT (Philips, Brilliance 64 Slice VCT, Netherlands) confirmation of no evidence of glenohumeral arthritis. A direct joint loading experimental model was used whereby the scapula and humerus were dissected free of their musculature and each potted in aluminum alloy fixtures (Alloy 6063, McMaster-Carr, Atlanta, GA). The glenoid was positioned perpendicular to the floor, with the humerus secured for testing in abduction angles of 10° (neutral carrying angle), 30°, and 60°. Normal biomechanical testing of the specimens was carried out on a custom shoulder testing system using a materials testing machine (Model 8874, Instron, Norwood, MA) and dynamic and fatigue materials testing software (WaveMatrixTM, Norwood, MA) that articulated the surrounding anatomy with a fit that leaves it flush with the surrounding cartilage and is hypothesized to lessen the risk of rocking-horse loosening during physiologic activity. The purpose of this research study was to examine the contact pressures and implant stability associated with fatigue loading of the glenoid inlay and onlay systems during physiologic loading and motion in a cadaveric model. We hypothesize that the glenoid inlay system will exhibit lower contact pressures, greater implant stability, and less rocking horse motion following fatigue loading than a standard onlay TSA system.

Results: A sample of the joint pressure mapping data captured during a ± 5 mm anterior/posterior displacement for the two inlay shoulder specimens (Inlay-1 (I-1) and Inlay-2 (I-2)) and two onlay shoulder specimens (Onlay-1 (O-1) and Onlay-2 (O-2)) is shown in Figure 1. The edges of the inlay implant (white outline) and native glenoid (red outline) were mapped and overlayed with the data to provide a spatial reference. The onlay implant covered the entirety of the native glenoid, and as such is its edges are not graphically depicted. In Figure 2, the average contact area and contact pressure was compared between the anterior and posterior edge of the glenoid. From this data, it can be noted that Inlay-1 has the lowest magnitude contact area and inversely, the highest magnitude contact pressure, which correlated clinically to an anterior rim defect identified during anatomical dissection. On average, the Inlay-2 experienced higher contact area and lower contact pressure than the Onlay-2 specimen. All shoulder specimens were evaluated to determine which implant exhibited earlier clinical loosening, and it was found that both Onlay-1 and Onlay-2 saw clinical loosening before both Inlay-1 and Inlay-2.

Discussion: Appropriate methods and testing have been established to test the glenoid loading and stability through contact...
pressures associated with the inlay and onlay shoulder implant system. These preliminary results show greater edge loading in the onlay implant system, and this pilot data and experimental methods are being used to guide a larger cadaveric study (n=8 matched pair shoulders) to establish statistical significance. A larger cadaveric study will establish this significance with additional CT imaging, controlled environments, less exposure to the elements, and an improved method to determine clinical implant loosening. Future research will investigate the impact glenoid concavity has on implant edge loading. This pilot study was conducted to determine effective methods, a conclusive protocol, and preliminary results to further direct the larger cadaveric study.

Significance: Implant stability following total shoulder arthroplasty is a critical variable in determining longevity of these devices. This work demonstrates that there is potential for the inlay glenoid design to promote and increase load-sharing with surrounding native glenoid bone compared to the onlay design, which could result in greater implant-bone clinical fixation stability. This pilot data will inform a larger study in fulfilling the above claims.

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References:
Figure 2: The comparison of contact area and contact pressure between anterior and posterior cyclic loading of all shoulder specimens at 30 degrees abduction shows the Inlay-2 (I-2) experiences higher contact area and lower contact pressure than Onlay-2 (O-2).

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