Inlay vs. Onlay: A Comparison of Two Glenoid Systems in Total Shoulder Arthroplasty

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Introduction: Loosening of the glenoid component via a “rocking horse” phenomenon, whereby the glenoid loosens as a result of edge loading of the implant during mild off-axis motion, is a common complication of total shoulder arthroplasties (TSAs). Recently, a partial glenoid resurfacing implant, known as a glenoid inlay, has become available and due to its geometry has the potential to exhibit less rocking-horse loosening 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 this study, n=16 specimens (eight matched pair shoulders) were selected for testing following clinical CT (Philips, Brilliance 64 Slice VCT) 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 parallel to the floor, with the humerus secured for testing in an abduction angle of 60°. Normal biomechanical testing of the specimens was carried out on a custom shoulder testing system, using a materials testing machine and dynamic and fatigue materials testing software that articulated the humerus with respect to the glenoid. A flexible force sensor (K-scan Model 5051, Tekscan, Inc.) was reproducibly positioned in the glenohumeral joint to record the contact pressure distribution and area. A ± 5 mm displacement-controlled anterior/posterior humeral motion was induced to produce glenoid edge loading while an 88.9 N compressive joint load was applied across the joint. TSAs were then performed on all shoulders followed by post implantation CT, with one of each matched pair being implanted with the onlay glenoid implant and the other with the inlay glenoid implant. DJO SurgicalTM provided the TuronTM onlay shoulder system while Arthrosurface, Inc. provided the HemiCAP® inlay shoulder system. Biomechanical testing of the specimens was again carried out under the same conditions as mentioned previously, followed by ± 5 mm of anterior/posterior cyclic fatigue testing with a joint compressive load of 333.6 N was performed to 4000 cycles or until clinical loosening was observed. Following mechanical testing, the specimens were then CT imaged a final time. Differences in measures of contact area, center of pressures, clinical implant
stability and bone patency were statistically assessed between implant designs and over fatigue testing time.

**Results:** Results show that contact area decreased and contact pressure increased after TSA compared to the native joint. Figure 1 shows a sample of the joint pressure mapping data captured during a +/- 5 mm anterior/posterior displacement. The areas of interest for specimens implanted with onlays were exclusively the anterior and posterior edges of the implants whereas the areas of interest for specimens with inlays were the anterior and posterior edges of the implant as well as anterior and posterior edges of the glenoid. The pressures found on the edges of the inlay implant were comparable in magnitude to the edges of the onlay. Of the specimens implanted with the inlay, the glenoid edge, with native tissue still present on the articulating surface, experienced much lower pressures than the respective inlay implant edge. The inlay glenoid edge pressures (which still had native tissue articulating the humeral component) were found to be much lower than the onlay glenoid edge pressures (wherein UHMWPE was articulating against the humeral component). Results of the visible loosening during fatigue testing can be found in Table 1.

**Discussion:** Examining the data collected comparing native tissue to implant surface pressure, all results showed higher pressures on both the inlay and onlay implants than the native tissue examined pre-implantation. As seen in Figure 2, the specimens implanted with onlay implants experienced much higher pressures on the edge of the glenoid than those with inlays. In comparison, pressure on glenoid edges of specimens with the inlay implanted were dissipated by the native tissue still present on the glenoid edge. This is a potential explanation for the dramatic difference in visible loosening of the implants seen during fatigue testing, as shown in Table 1. In Table 1 it can be noted that the inlay implant did not show any evidence of loosening after 4000 cycles of fatigue loading, however all onlays failed and showed visible loosening in under 2000 cycles (Onlay 6 was damaged in handling and was not considered for statistical analysis). This significant difference in loosening (p<0.001) is hypothesized to be the due to the observed load-sharing with the mostly native tissue still present on the glenoid edges of specimens implanted with the inlay, in contrast with specimens implanted with the onlay, where the polyethylene implant edges received all of the load.

**Significance:** An implant that shows less risk of loosening via the rocking horse phenomenon could be better suited for a more active TSA patient.
Figure 1: [A] Specimen tracking showing pre-implantation (left), post-implantation of an onlay implant, pre-fatigue testing (middle), and post-implantation post-fatigue testing (right). [B] Specimen tracking showing pre-implantation (left), post-implantation of an inlay implant, pre-fatigue testing (middle), and post-implantation post-fatigue testing (right).

Figure 2: A comparison glenoid pressure of the anterior and posterior edges of the glenoids of all specimens post-implantation.