A Comparison of Rocking Horse Loosening of Metal-Backed Versus All Polyethylene Glenoid Components

Introduction: Glenoid component looseness is a common mechanism for failure of total shoulder arthroplasty. The metal-backed glenoid of the Lima SMR Modular Shoulder Prosthesis has shown encouraging mid-term clinical outcomes and the implant design and fixation strategy may offer a rationale for the improved performance of cementless MB glenoid components. The primary purpose of this study was to utilize a standardized laboratory test of rocking horse loading to evaluate the initial loosening of the SMR glenoid implant in three clinically relevant configurations.

Methods: Thirty blocks of solid rigid polyurethane bone foam (20pcf foam, Sawbones, Vashon, WA) were machined to match the footprints of the glenoid implants and then potted within polymethylmethacrylate (PMMA) cement such that 15mm of the bone foam protruded from the PMMA. The glenoid component of the SMR Modular Shoulder Prosthesis (Lima Corporate, Villanova di San Daniel, Italy) was tested in the following configurations: (1) SMR, cemented, all polyethylene, 3 peg glenoid (PE), (2) SMR cemented metal-backed glenoid (cemented MB), and (3) SMR screwed metal-back gelenoid (screwed MB) with a 20mm superior screw and a 25mm inferior screw. All glenoid components were implanted according to the manufacturer's protocol and then mounted within a custom mechanical testing system that was based upon ASTM F 2028-08. As shown in Figure 1, the PMMA embedded bone foam (B) and glenoid component (A) construct was rigidly secured within a metal box (C). This metal box was secured to a rail system (D) that only allowed for horizontal (±) x-direction motion. The humeral head component (F) was mounted to a second rail system (G) that only allowed vertical (±) z-direction motion. This second rail was connected to the actuator (H) of a load frame system (Mini-Bionix II, MTS Corp, Eden Prairie, MN). A simulated joint reactive force of 750N was applied by a weight/pulley/cable system (E). The external housing of two spring-loaded linear variable differential transducers (LVDT-GCD-121-050, Schaevitz, Hampton, VA) were also fixed to the metal box (C) via a mounting plate (K). The tip displacements of the superior (LVDT I) and inferior (LVDT J) were coupled to the displacements of the superior and inferior edge of the glenoid component relative to the bone foam through a system of frictionless lever arms (L &M) and threaded pins (N &O) attached to the glenoid component. Rocking-horse displacement tests were performed by cyclically translating the humeral head to 90% of the superior and inferior subluxation distance (4.5mm), as described, for 5000 cycles at 1 Hz. A custom data acquisition program synchronized collection of displacement data from the MTS actuator and the LVDTs such that the displacements of the superior and inferior glenoid component edges were tracked with respect to the humeral head off-center translation. A total of 10 cycles of data were collected after 10 cycles, after 100 cycles, then at intervals of every 100 cycles, and finally at intervals of every 1000 cycles until 5,000 cycles. The micromotion of the glenoid component edges was computed by subtracting the averaged position of the superior and inferior glenoid edges when the humeral head was at the neutral position from the averaged positions of the glenoid edges when the humeral head was at the maximum off-center locations, respectively. The micromotions at each implant edge were compared across the implant types at each cycle count with one-way ANOVAs followed by Tukey post-hoc analysis where appropriate. Student’s t-test individually to compare each component’s inferior vs. superior compression and inferior vs. superior distraction. All statistical analysis was performed using SPSS statistical software (IBM, Armonk, NY) with a significance level defined as P<0.05.

Results: Figure 2 shows the compressive micromotion on the superior (2A) and inferior (2B) implant edges and the distraction micromotion on the superior (2C) and inferior (2D) implant edges for all three implant types. The cemented MB implant had the highest micromotion in all categories and will not be discussed further. The screw MB component and PE component exhibited similar distraction micromotion at all cycle counts and at the superior edge until 2,000 cycles. At this point, the PE component had significantly less micromotion than the screw component for the rest of the cycles. The PE and cemented MB components, both of which are asymmetrical implants, showed no statistical differences when comparing their compression and distraction performance at the superior versus the inferior edges. The screw MB component showed greater compression on the inferior edge than the superior edge starting at cycle 1,000 (Inferior =262±40µm, Superior =213±22µm, p=0.044) and continuing to cycle 5,000 (Inferior =298±43µm, Superior =245±33µm, p=0.006). The screw MB component also showed smaller distraction at the inferior edge than the superior edge starting at cycle 10 (Inferior =79±21µm, Superior =130±40µm, p=0.001). The cemented MB component also showed greater micromotion throughout the rocking horse testing as compared to the other implant types. However, the screw MB showed similar micromotion performance as compared to the PE glenoid during the first 1000 cycles. At 2000 cycles and beyond the only difference between the implant types was that the superior edge of the screw MB showed significantly higher distraction as compared to the PE glenoid. Notably, the superior screw was 5mm shorter than the inferior screw. Therefore this study suggests that the longest screw possible, given patient anatomy, should be considered for fixation of screw MB glenoids. A limitation of this time zero study is that it does not account for bony ingrowth which enhances MB implant stability. Clinically the goal is to limit micromotion to less than 150µm during the 6-8 week post-op period to allow bony ingrowth. The screwed MB loosening was within this threshold during the first 1000 cycles, which is consistent with the relevant post-op bonying data for this implant.

Discussion: The cemented MB exhibited the greatest micromotion throughout the rocking horse testing as compared to the other implant types. However, the screw MB showed similar micromotion performance as compared to the PE glenoid during the first 1000 cycles. At 2000 cycles and beyond the only difference between the implant types was that the superior edge of the screw MB showed significantly higher distraction as compared to the PE glenoid. Notably, the superior screw was 5mm shorter than the inferior screw. Therefore this study suggests that the longest screw possible, given patient anatomy, should be considered for fixation of screw MB glenoids. A limitation of this time zero study is that it does not account for bony ingrowth which enhances MB implant stability. Clinically the goal is to limit micromotion to less than 150µm during the 6-8 week post-op period to allow bony ingrowth. The screwed MB loosening was within this threshold during the first 1000 cycles, which is consistent with the relevant post-op bonying data for this implant.

Significance: The screw MB glenoid provides for initial implant stability that is comparable with the PE glenoid. The initial stability provided by this fixation strategy may, in part, be a contributing factor in the bony ingrowth and good mid-term clinical outcomes with this implant.