Assessing the Contribution of the Central Screw to Glenoid Baseplate Fixation in the Presence of Osteopenic Bone

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Introduction:

Reverse total shoulder arthroplasty (rTSA) has become a widely accepted solution for patients with various shoulder pathologies. Despite its popularity, complications are prevalent in the elderly population due to a limited amount of bone stock that may also be of poor quality.[1] Previous studies on glenoid loosening have extensively followed the established ASTM Standard for Dynamic Evaluation of Glenoid Loosening.[2] Although this approach effectively evaluates glenoid loosening, implants tested in this method are not loaded in clinically relevant positions commonly seen during activities of daily living. In addition, most studies utilize synthetic bones to model implant stability and osteopenic cadaveric specimens are seldom used.[1,3,4] This study introduces a novel cadaveric testing method that simulates physiologically relevant cyclic loads to create implant loosening. The primary goal of the current study was to utilize this model to investigate how the inclusion or exclusion of a central screw changes micromotion, subfailures, and catastrophic failure. We hypothesized that there would be no difference in fixation between implants that utilize the central screws and those without it.

Methods:

Eight matched pairs of cadaveric shoulders from 3 males and 5 females (average age: 80.6 years, range: 73 to 88 years) were confirmed for osteopenia with DEXA scan T-scores that were lower than -1.Scapulae were disarticulated from the shoulder and skeletonized of all soft tissues. Specimens were implanted with Integra Titan rTSA systems and divided into two groups that had a central screw (CS+) and did not have a central screw (CS−).The left and right scapulae of matched pairs were randomly assigned into one of the two test groups. CS+ underwent normal baseplate implantation following manufacturer guidelines, which included the use of the 5.5 mm diameter, 20 mm long central screw. CS- underwent the same procedure but with the exclusion of the central screw. All specimens used 4.5 mm diameter, 25 mm long superior/inferior locking screws and 4.5 mm diameter, 40 mm long anterior/posterior non-locking screws for baseplate fixation. After implantation, each specimen was osteotomized and potted in polycarbonate cylinders with poly methyl methacrylate.To prevent cementing screw tips, beads of dental wax were used to cover screw tips that were protruding from the bone.

Each specimen was tested using a novel custom testing apparatus (Figure 1). In this setup, bi-axial loading was applied by the testing frame actuator and a pneumatic air cylinder to simulate shoulder compressive loads. An adjustable angled vise was used to hold the specimen in a position that represented 30 degrees abduction, similar to that of someone rising from a chair or ambulating with a walker. In addition, each specimen was kept at body temperature via the temperature controlled water bath. 3-D motion tracking was implemented to calculate relative displacement between the scapula and glenosphere. Cyclic fatigue loads were imparted onto each specimen with a monotonically increasing 1 Hz sinusoidal waveform. Specifically, the waveform had a minimum compressive load of 100 N and a first peak of 150 N. The upper limit of the load was increased at a rate of 0.2 N/cycle until failure. To simulate the compressive forces of the muscles squeezing the joint and to prevent the joint from disarticulating, a constant 100 N medial-lateral load was imparted to the horizontal slider through the pneumatic cylinder. The vertical testing frame actuator applied cyclic compressive loads along the axis of the humerus in the superior-inferior direction until catastrophic failure.

Subfailure was defined as permanent creep between the bone-baseplate interface exceeding 1 mm, as determined by actuator displacement and 3-D motion tracking. Groups were

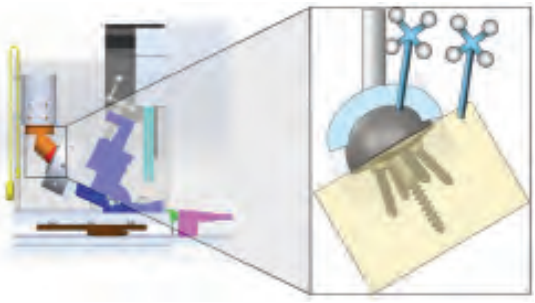

Figure 1. Computer-aided drawing of the testing setup. Horizontal and vertical loads (red arrows) are applied to the implant (orange) in a temperature controlled water bath to simulate physiological loading in the human shoulder.

Figure 2. Photograph of a specimen after catastrophic failure. Implant is separated from the scapula at the bone-baseplate interface.

subsequently compared with 1-tailed paired student t-tests. Axial stiffness, deformation, ultimate load, and survived cycles were measured.

Results:

Use of the central screw improved fatigue life before catastrophic failure, as the average maximum number of cycles survived for CS+ and CS− groups were 7281.88 ± 2517.32 and 5911.63 ± 2686.38 cycles ($p = 0.026$), respectively. The CS+ group sustained 1451.49 ± 465.55 N of compressive load on average, while the CS− group survived an average maximum compressive load of 1213 ± 480.11 N ($p = 0.026$). There were no significant differences found between groups for subfailure, defined as permanent bone-implant construct deformation exceeding 1mm. An analysis of cycle numbers survived as a function of DEXA T-score indicated no strong correlation, with R-squared values of 0.19 and 0.12 for the CS+ and CS- groups, respectively.

Discussion:

This study introduces a novel testing paradigm that effectively elucidated the role the central screw plays in fixation of the glenoid component in rTSA. The screw improved the long-term fatigue life of the implant but did not improve the implant's resistance to 1 mm of creep during monotonically increasing cyclic loading.

Both actuator and 3-D motion capture measurements were used for subfailure analysis in this study, which both have advantages and drawbacks. Actuator-based measurements were recorded for the duration of the test at higher resolutions at 10 microns, however, measurements can only be collected in one dimension. On the other hand, 3-D motion-based measurements have the capacity of three dimensional analysis, but were only recorded every 100 cycles at a lower resolution, about 200 microns.

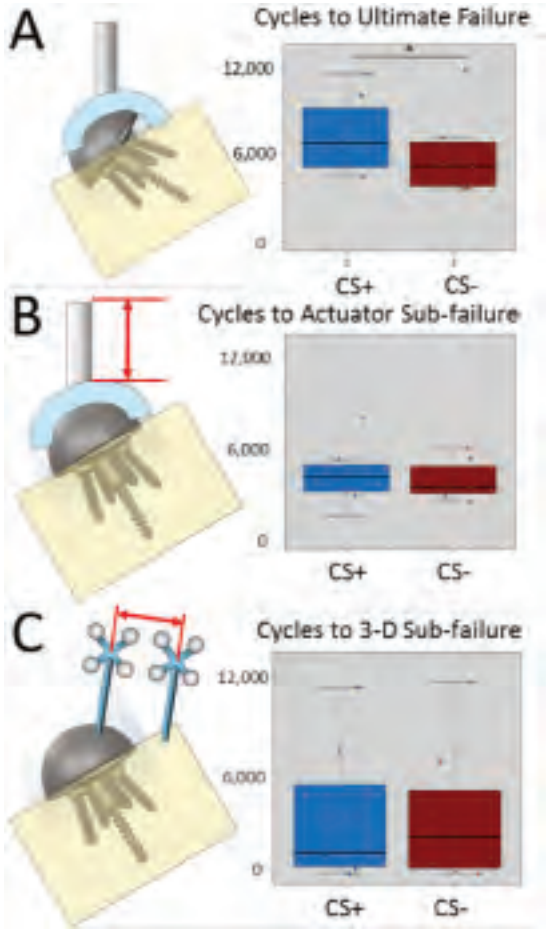

Figure 3. (A) Screw omission significantly decreased the number of cycles to ultimate failure. No significant differences in either subfailure analyses **(B)** measured by actuator movement or **(C)** measured by 3-D motion marker cluster displacement.

Conclusion:

Optimizing screw fixation in poor quality bone is an important clinical issue that requires further research. It is evident the rTSA implants can adequately restore shoulder joint function, but preservation of the already limited bone in the scapula may be beneficial if revision surgery were to be required in the future. Our study suggests that omission of the central screw may provide a reasonable tactic to preserve this bone, but only in a casewhere small external forces are exclusively applied to the joint.

References:

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