Factorial Analysis of Glenoid Baseplate Maximum Micromotion in Reverse Shoulder Arthroplasty

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Introduction:

Reverse shoulder arthroplasty (RSA) is commonly used to treat patients with rotator cuff tear arthropathy. Loosening of the glenoid component remains one of the principal modes of failure and is the main complication leading to revision. For optimal RSA implant osseointegration to occur, the micromotion between the baseplate and the bone must not exceed 150 µm. Excess micromotion contributes to glenoid loosening. The purpose of this study was to test the effects of four factors on glenoid baseplate maximum micromotion.

Methods:

A half-fractional factorial design of experiment (2^{k-1}) was used to assess four factors at two levels: central element type (peg or screw), central cortical engagement according to length (13.5 or 23.5 mm), anterior-posterior (A-P) peripheral screw type (nonlocking or locking), and cancellous bone surrogate density (10 or 25 pcf). This created eight unique conditions, where each was repeated five times for a total sample size of 40 (N = 40). Glenoid baseplates were implanted into high- or low-density Sawbones™ rigid polyurethane foam blocks and cyclically loaded at 60° for 1000 cycles (500 N compressive force range) using a custom-designed loading apparatus. Micromotion at the four peripheral screw positions was recorded using linear variable displacement transducers (LVDTs). Micromotion was quantified as the displacement range at the implant-PU interface, averaged over the last 10 cycles of loading. From the factorial analysis, a predictive model was determined for the glenoid baseplate maximum micromotion ($\hat{y}$).

$$\hat{y} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_{12} X_1 X_2$$

Where, X_i (Central element length, central element type, bone density, peripheral screw type) are coded variables and β_i and β_{ij} are regression coefficients.

Results:

The predictive model for baseplate maximum micromotion was β_0 = 94.4 µm, β_1 = -108.9 µm, β_2 = -106.6 µm, β_3 = -40.1 µm, β_4 = -43.3 µm, $\beta_{1,2}$ = 89.3 µm, and $R^2 = 0.92$. No significant effects were observed when varying A-P peripheral screw type or bone surrogate density. There were significant interactions between central element type and length ($p < 0.001$). Baseplates with short central elements lacking cortical bone engagement generated 373% greater maximum micromotion at all peripheral screw positions compared to those with long central elements ($p < 0.001$). Central peg fixation generated 360% greater maximum micromotion than central screw fixation ($p < 0.001$).

Discussion:

A central screw and long central element that engaged cortical bone reduced RSA baseplate primary fixation. These results partially confirmed the hypothesis, that a central compression screw and cortical bone engagement via a longer central element would result in decreased micromotion of the baseplate relative to the PU foam, and that an interaction would exist between central element type and the length required to achieve purchase with the cortex. An interaction existed between central element type and level of cortical engagement, which suggests that a central screw that cortically engages with the scapula may reduce post-operative micromotion. These findings can inform surgical decision-making regarding baseplate fixation elements to minimize the risk of glenoid loosening and thus, the need for revision surgery.