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Original Article

Increasing Liner Anteversion Decreases the Interfacial Strength of Polyethylene Liners Cemented Into Titanium-Alloy Acetabular Shells

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ABSTRACT

Background: Acetabular component positioning during revision total hip arthroplasty can be suboptimal. Cementation of an acetabular liner into a well-fixed acetabular shell can allow surgeons to correct component version and inclination without the need for extensive revision surgery and progressive pelvic bone loss. However, to date, it is unknown what degree of version can be corrected without sacrificing fixation strength of the construct. In this study, cemented liners were biomechanically evaluated at increasing degrees of liner anteversion.
Methods: Twenty-five commercially available liners were cemented into acetabular shells at 0°, 10°, 20°, 30°, and 40° of liner anteversion, relative to the acetabular shell (n = 5 per group). Components were then fixed to a materials testing frame and evaluated via an established lever-out testing protocol. Test data were collected via test frame software for calculation of yield and maximum moments during biomechanical testing.
Results: When liners were cemented at 20°, 30°, and 40° of liner anteversion, a significant decrease in maximum fixation moment was found when compared liners cemented at both 0° and 10° ($P < .05$). A significant negative correlation was noted for both yield and maximum moments and increasing liner angle ($r = -0.566$; $P = .011$ and $r = -0.604$; $P = .006$, respectively).
Conclusion: Biomechanical data from our study suggest that a threshold of acceptable anteversion during revision total hip arthroplasty is <20°. However, further studies are warranted to continue evaluation of the potential clinical impact and long-term device performance in this setting.

The rate of revision total hip arthroplasty (THA) continues to rise as patients undergo primary THA at younger and more active stages of life with higher frequency [1,2]. In revision surgeries with a well-fixed acetabular shell, a surgeon may opt to cement a new acetabular liner into the existing shell to preserve pelvic bone [3-5]. This has been shown to be a viable option with successful short- to midterm clinical outcomes [6-13]. Positive long-term outcomes have also been reported in select populations [14-16]; however, the risk of early failure at the cement–liner interface still remains [17,18].

In the setting of revision THA with a well-fixed acetabular shell in suboptimal position, cementing a polyethylene liner into the shell is a method to potentially “correct” the geometry of the femoral head–liner articulation. The correction of component version may reduce the risk of postoperative impingement or dislocation [5,19]. It is unknown what degree of version can be corrected without adversely affecting resultant fixation strength of the acetabular shell–liner construct. Ebramzadeh et al [20] evaluated push-out and torsional strength of cemented acetabular liners at varying degrees of version finding no significant difference between groups. However, the effect of component version was not the main objective of their study, and no attempt was made to find a positioning threshold that may play a role in resulting component fixation.

Little data exist that identifies a potential threshold at which surgeons should consider revising the acetabular shell when

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attempting to correct anteversion via liner cementation during complex revision THA procedures. The purpose of this study was to characterize the fixation strength of cemented acetabular liners in the setting of increasing anteversion relative to the acetabular shell in a lever-out failure model. We hypothesized that fixation strength of the acetabular liners within the shells would decrease as acetabular liner anteversion, relative to the acetabular shell, increases.

Methods and Materials

Components and Test Groups

Twenty-five commercially available acetabular shells (Trilogy Shell with Cluster Holes, 58-mm outside diameter, Zimmer, Inc, Warsaw, IN) and acetabular liners (Longevity Cemented Revision Liner, 28-mm inside diameter, Zimmer, Inc, Warsaw, IN) were used for biomechanical testing. Acetabular liners were cemented into acetabular shells with polymethyl-methacrylate (PMMA) cement (Simplex P, Stryker Orthopaedics, Mahwah, NJ) at the following degrees of anteversion relative to the acetabular shell: 0°, 10°, 20°, 30°, and 40° (n = 5 implants per group). No alteration was made to the cemented surfaces of either the acetabular shell or acetabular liner. However, the backside surface of the acetabular liner is designed for cementation with machined grooves for increased interdigitation with cement.

Component Cementation and Lever-Out Testing Protocol

Based on previously described protocols [21,22], the articulation surface of the acetabular liners were modified to allow for repeatable cementation and lever-out biomechanical testing (Fig. 1). A central, 100-mm threaded rod (1/2-20 thread) was secured to the pole of the acetabular liner and acted as the lever arm during testing. PMMA cement was then prepared and filled within the acetabular liner. Eight holes were machined into the liner articulation surface for increased cement interdigitation. Twelve screws were then positioned circumferentially around the rim of the acetabular liner securing a washer to the outermost surface with a retaining nut fastened against the washer.

A custom fixture using a 3-axis vise was then implemented to control the depth of the liner within the shell resulting in a consistent 2-mm thick cement mantle at the pole of the acetabular liner (Fig. 2A). The shell was held at a specified angle via a 3-axis vise while the liner was lowered into the shell via a linear bearing and shaft secured to the threaded rod at the pole of the liner. A second batch of PMMA cement (Simplex P, Stryker Orthopaedics) was mixed as per manufacturer's instructions in a mixing bowl in air at consistent room temperature and humidity and placed into the acetabular shell before positioning of the liner. The liner was held securely in position for a minimum 24 hours before biomechanical testing.

Components were fixed to a servohydraulic materials testing frame (Mini Bionix 858, MTS Corporation, Eden Prairie, MN), and a load was applied at a constant displacement rate of 1 mm/s to the threaded lever arm until failure (Fig. 2B). For each testing configuration, the plane of the acetabular liner was held perpendicular to the actuator with the shell positioned to create the designated angle of anteversion.

Data and Statistical Analysis

Mechanical testing data (crosshead displacement, force, time) were collected via MTS control software at a rate of 100 Hz. Data were processed with a custom MATLAB program (MathWorks, Inc, Natick, MA) for calculation of 0.2% offset yield moment (N-m) and maximum moment (N-m). Data were reported as mean ± standard deviation and tested for normality using the Shapiro–Wilk Test of Normality. Results were compared with the use of a one-way analysis of variance and post hoc Bonferroni correction for determination of significant relationships. Correlation between liner angle and yield and maximum moments was assessed using the Pearson correlation coefficient. Significance was set at $P < .05$.

Results

Lever-Out Testing

Yield and maximum moments are shown in Figures 3A and B, respectively. Acetabular liners cemented at 20° of anteversion (25.5 ± 2.1 N-m) had a significantly decreased yield moment compared with liners cemented at 10° of anteversion (37.0 ± 6.8 N-m; $P = .034$). Maximum moments calculated for 20° (68.7 ± 1.9 N-m), 30° (74.4 ± 8.2 N-m), and 40° (65.6 ± 4.2 N-m) of liner anteversion had significantly decreased fixation compared with liners cemented to both 0° ($P = .001$, .018, and <.001, respectively) and 10° of liner anteversion ($P < .001$, <.001, and <.001, respectively).

Both yield moment and maximum moment displayed a strong negative relationship with increasing liner angle ($r = -0.566$; $P = .011$ and $r = -0.604$; $P = .006$, respectively). All constructs failed at the acetabular liner–cement interface with an audible crack and fracture of the cement mantle (Fig. 4). This

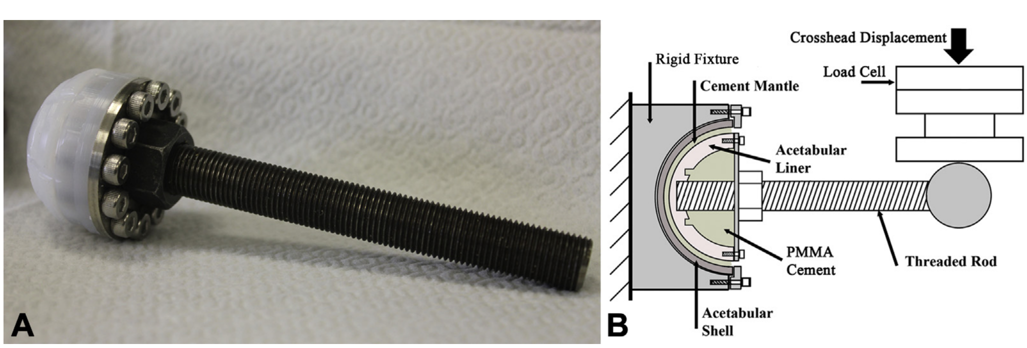

Fig. 1. Modifications were made to the articular surface of commercially available acetabular liners for repeatable cementation and biomechanics testing (A). Biomechanics testing schematic detailing fixation of the acetabular shell and liner construct during the testing protocol (B). The rigid mount was positioned within a 3-axis vise to allow for testing at increasing acetabular liner version, relative to the acetabular shell.