

Deformation of Metal-Backed Acetabular Components and the Impact of Liner Thickness in a Cadaveric Model

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Introduction: Compressive forces experienced during 1-2 mm press-fit implantation of cementless acetabular components may cause cup deformation from rim loading against dense cortical bone along the anterior-superior and posterior-inferior margins of the acetabulum [1,2]. This may have potential clinical consequences, especially when thinner cup assemblies are used. The extent of shell deformation in conventional metal-backed cups with polyethylene (PE) liners is not presently known. It is also unclear if shell deformation results in PE liner deformation and if PE thickness affects the overall cup deformation. We used a cadaveric model to evaluate the deformation of Trident acetabular components (Stryker Orthopaedics) with historical and recently introduced thinner PE inserts during implantation and subsequent gait loading. Interaction between liner and shell deformation was also examined.

Materials and Methods: Six cadaver pelvises (3 male and 3 female donors - 30 to 50 y.o.) underwent bilateral total hip arthroplasty (Trident I PSL system) by a trained surgeon (DCM)(IRB-approved). For each specimen, a thin PE insert was implanted in a randomly selected side, and a historical thick PE insert was used on the contralateral side as a paired control. Each acetabulum was reamed to its clinically appropriate size (1.8 mm nominal diametral press-fit). Matched shell sizes were used for the contralateral side of each hip for paired-comparison of the effect of liner thickness. A total of three shell sizes (50, 54, and 58 mm) were implanted in the six bilateral hips, with two pelvises per shell size.

Each hip was mounted on a MTS Mini-Bionics system in anatomic orientation [3] and then lowered onto a rigidly fixed femoral head. Passive cables were mounted through the pelvis at the abductor attachment points to provide stability. Vertical compressive loading of 2.2 kN was applied and then cycled 10 times between 0.1 and 1.2 kN. Shell and liner diameters were measured at specified locations around the main anterosuperior (A-S) and anteroinferior (A-I) axes using a digital caliper. These were measured three times and averaged at each of the following time-points: 1) pre implantation; 2) post shell implantation; 3) post liner insertion; 4) ≥ 30 min. post implantation (creep); 5) pre mechanical loading; and 6) post mechanical loading.

Results: One pelvis (thick liner group) cracked during implantation and was excluded from the statistical analysis. Upon initial insertion, all shells experienced some degree of deformation, with an average initial pinch of 0.31 mm [range 0.16 to 0.43 mm]. Shell pinch decreased after insertion of the liner and loading (final average: 0.18 mm [range 0.04 to 0.34 mm]). Average shell pinch for the thin and thick liner groups decreased significantly from 0.32 to 0.22 mm ($p = 0.019$) and from 0.29 to 0.13 mm ($p=0.003$), respectively, between initial and final states (Fig. 1). There was no significant difference between the liner groups ($p>0.106$). Although the same shell sizes were used between each paired thin-thick liner cup, greater final shell deformations, though not significant, were observed for those in the thin liner group. The initial thin and thick liner pinch averaged 0.17 mm [range 0 to 0.40 mm] and 0.06 mm [range -0.07 to 0.16 mm], respectively. After loading, the average liner pinch decreased to 0.04 mm for the thin liner group ($p=0.031$) and 0 mm for the thick liner group ($p=0.103$). There was no significant difference in the initial and final liner pinch between the thick and thin liner groups ($p>0.348$), though the largest deformations were recorded for the thin liners. Final shell and liner deformation was reasonably correlated to the initial shell deformation (Fig. 2). A greater amount of shell pinch was also associated with patients with higher BMD.

Discussion: We used a cadaveric model to determine the degree of shell and liner deformation for Trident acetabular components with both historical and thin PE inserts. Young donor cadavers, with 1.8 mm under-reaming, provided a conservative worst-case scenario for testing. The shell pinch measured in the present

study was comparable to those measured in previous experiments [1,2]. Pinch deformation of the shell decreased between shell insertion and the final time point, which suggests a "settling in" effect where the combined effects of liner insertion, visco-elastic creep, and plastic deformation of the bone under loading led to cup opening. The thin liners also experienced a similar behavior. We also found no significant differences in shell or liner pinch deformations between the historical thick and thinner liner groups. Although the liner pinch deformations were slightly greater for the thin liner group, the correspondingly greater (not significant) initial and final shell deformations compared to the thick liner group suggests that the shell deformation may play a more important role than liner thickness. Though cup deformation was observed, we do not predict that the increased stresses will result in unreasonably elevated wear in thin highly crosslinked PE liners based on corresponding finite element analyses. However, the amount of in vivo deformation is likely dependent on the extent of bony support (e.g. bone quality, reamed bone geometry [4-6]), surgical variables (e.g. cup positioning), and implant design (e.g. diameter, thickness, amount of intended press-fit, type of locking mechanism).

References: 1. Jin ZM et al., Proc Inst Mech Eng [H], 2006; 2. Squire M et al., J Arthroplasty, 2006; 3. Widmer et al., J Arthroplasty, 2002; 4. Kim YS et al., J Arthroplasty, 1995; 5. MacKenzie JR et al., CORR, 1994; 6. Schwartz JT, Jr. et al., CORR, 1993

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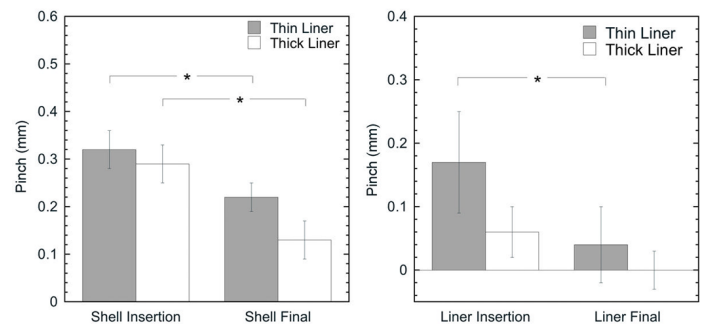


Fig. 1. Measured shell (left) and liner (right) pinch

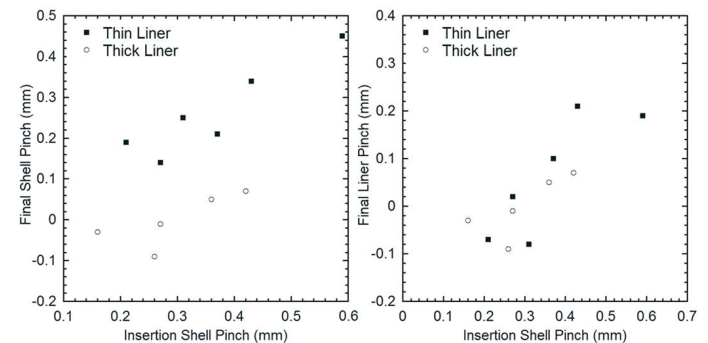


Fig. 2. Final shell (left) and liner (right) pinch vs. initial shell pinch ($r^2 = 0.50$ and 0.67 , respectively)