A Biomechanical Model of Acetabular Cup Deformation in Metal-on-Metal and Conventional Metal-Backed Component Designs

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Summary: Worst-case evaluation of press-fit cup deformation indicating increased diametral deformation in larger cups with thinner walls and more flexible constructs.

Introduction: Press-fit acetabular components are susceptible to deformation following implantation in an under-reamed socket, with excessive deformation of metal-on-metal (MOM) components potentially leading to increased torsional friction, component micromotion and implant loosening. The purpose of this study was to evaluate the effect of design and material considerations on induced deformation in metal-on-metal as well as conventional metal-backed acetabular components.

Methods: Utilizing an automated reaming and implantation process, metal-on-metal and metal-backed modular acetabular cups were press-fit into a previously validated, worst-case pinching model in polyurethane foam with a 1 mm under-reamed interference fit. Digital image correlation was used to quantify diametral cup deformations caused by press-fit implantation in cups and polyethylene liners from 0 to 120 hours following implantation. Experimental groups (n=6 per group) consisted of 48, 54, 60 and 66 mm MOM cups with a 6 mm wall thickness, 58 mm cups with a 20 mm wall thickness, and both CoCrMo and Ti6Al4V 58 mm metal-backed modular cups.

Results: Increased deformation was correlated with increased cup diameter, thinner wall construction, and Ti6Al4V metal-backed designs (p<0.0001). The greatest diametral deformation within the MOM subset of cups tested was 104 +/- 8 microns, measured in 66 mm diameter thin-walled MOM cups. Significantly higher, yet potentially less clinically significant, deformations were measured up to 267 +/- 14 microns in titanium metal-backed modular cup designs.

Conclusions: The role of clearance in THA lies in the establishment of elastohydrodynamic lubrication between the femoral head and acetabular bearing surface in metal-on-metal device designs. However, too tight of clearance paired with a large component deformation from press-fit implantation and gait loading could potentially increase early component loosening or wear. The results of this study reiterate the need for careful design planning encompassing deformation in thin walled and conventional metal-backed acetabular component designs.

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Introduction: Press-fit acetabular components are susceptible to deformation following implantation in an under-reamed socket. Clinical and cadaveric investigations have described this deformation mechanism as component pinching between the ischial and ilial columns following press-fit implantation. Excessive deformation, particularly in metal-on-metal (MOM) components, may potentially lead to increased torsional friction, component micromotion, degradation of fluid-film lubrication, and implant loosening. The purpose of this study was to evaluate the effect of design and material considerations on induced deformation in metal-on-metal as well as conventional metal-backed acetabular components.

Understanding of the overall effect of implant design on acetabular cup deformation is critical to the prevention of deformation-related clinical complications.

Methods: Utilizing an automated reaming and implantation process, metal-on-metal and metal-backed modular acetabular cups were press-fit into a worst-case pinching model in polyurethane foam with a 1 mm under-reamed interference fit. The experimental setup closely follows a previously validated model from separate investigators which generated acetabular component deformation closely matching those
observed in cadaveric pelvic specimens. Digital image correlation was used to quantify diametral cup deformations caused by press-fit implantation in cups and polyethylene liners from 0 to 120 hours following implantation with an accuracy of +/- 2 microns. Experimental groups (n=6 per group) consisted of 48, 54, 60 and 66 mm MOM cups with a 6 mm wall thickness, 58 mm cups with a 20 mm wall thickness, and both CoCrMo and Ti6Al4V 58 mm metal-backed modular cups. Results: Full results are shown in Table 1. Increased deformation was correlated with increased cup diameter, thinner wall construction, and Ti6Al4V metal-backed designs (p<0.0001). The greatest diametral deformation within the MOM subset of cups tested was 104 +/- 8 microns, measured in 66 mm diameter thin-walled MOM cups. Significantly higher, yet potentially less clinically significant, deformations were measured up to 267 +/- 14 microns in titanium metal-backed modular cup designs. Discussion and Conclusion: The role of clearance in THA lies in the establishment of elastohydrodynamic lubrication between the femoral head and acetabular bearing surface in metal-on-metal device designs. However, too tight of clearance paired with a large component deformation from press-fit implantation and gait loading could potentially increase early component loosening or wear. While the specific designs tested deformed to a magnitude less than the manufacturer-specified diametral clearance, the results of this study reiterate the need for careful design planning encompassing deformation in thin walled and conventional metal-backed acetabular component designs.