GENERIC DESIGN OF THE HIP RESURFACING PROSTHESIS

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INTRODUCTION

Aseptic loosening and femoral neck fractures resulted in unpredictable survival of resurfacing arthroplasty in the past. Introduction of metal-on-metal bearing couples reduced aseptic loosening drastically. Improving prosthesis design in order to optimize load transfer can be an additional means to reduce implant failure. We tested various parametric design changes to explore their influence on the stress pattern in the anatomical and 'resurfaced' proximal femur.

METHODS

Finite element analysis of the proximal femur was performed with a generic, hemispherical deign. Parametric tests were performed for implant stiffness, stem length and shell size. Modeled elastic moduli were 110,000 MPa (titanium), 200,000 MPa (CoCr) and 350,000 MPa (ceramic). Stem length variations were: a) *conventional stem*, as currently is use, b) *half stem*, reaching till the neck, c) *short stem*, reaching till the center of the femoral head and d) *no stem*. Shell sizes, expressed as an angle, included 260°, 220° and 180°.

RESULTS

Cortex. Peak stress concentration at the cortex was at the posterior-medial cortex of the neck, just under the posterior rim of the prosthesis. Surface replacement did not alter the cortical stress pattern of the cortex, independent of design.

Cancellous bone. Resurfacing caused stress concentration at the medial side of the neck. The antero-posterior part of the proximal half of the neck was slightly stress shielded, whereas a slight increase in stress was found at the distal half of the neck. In the femoral head especially the area of the primary trabecular system and the circumference were shielded. This shielding was profound even with the least stiff implants. The stiffer the prosthesis, the more distal the area of stress concentration extended distally. The shielding was independent on prosthesis stiffness. The *short stem* and *no stem* designs did not influence the stress pattern in the femoral neck. The length of the stem has no influence on the stress pattern in the femoral head. With decreasing shell size, the area of stress concentration at the medial neck extended more distally. The antero-posterior shielding slightly decreased, however that change was very small. In the femoral head a smaller prosthesis reduced stress shielding slightly.

DISCUSSION

The shielding of the femoral head in our model showed a pattern similar to the resorption pattern found by Huiskes *et al*. [1]. They suggested prosthetic failure to result from a combination of progressive mechanical effects and interface bone resorption due to micromotion. Possibly, shielding

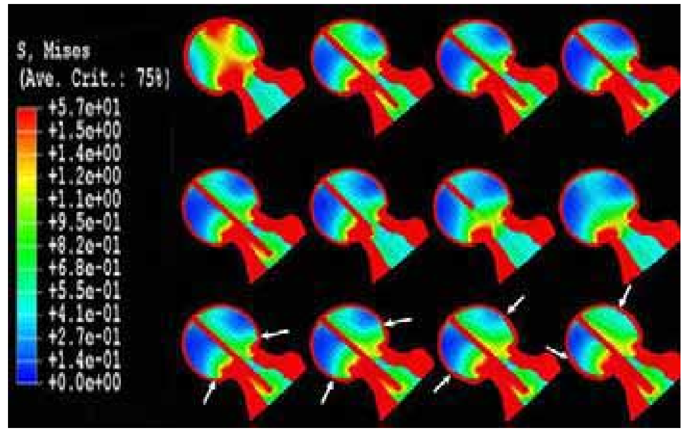

Figure 1: Stress pattern at the proximal femur showing the effect of implants stiffness (top, left to right: anatomical hip, Ti, CoCr, ceramic), stem length (middle, left to right: conventional stem, half stem, short stem, no stem) and shell size (bottom, left to right: 260°, 220°, 180° and 140°). Arrows indicate the edge of the prosthesis. Stresses are Von Mises stresses.

compromises bone quality, to make the femoral head more susceptible to these processes.

Watanabe *et al*. [3] related early fractures to stress shielding of the femoral neck in their finite element analysis. However, using DEXA scans, Kishida *et al*. [2] found bone mineral density in the femoral neck to be preserved after surface replacement. It likely is the stress concentration in the cancellous bone of the medial femoral neck that puts the neck at a greater risk for fractures.

CONCLUSIONS

1. As yet reported, resurfacing arthroplasty leads to stress concentration at the cancellous bone of the femoral neck and stress resorption at the circumference of the femoral head.
2. Less stiff implants reduce stress shielding of the femoral head but lead to higher stress concentration at the neck.
3. Designs with a short stem preserve the stress pattern of the anatomical hip joint at the level of the femoral neck.
4. A smaller shell slightly reduces stress shielding in the femoral head.
5. Thus, designs with a short stem could possibly reduce the risk on stress fractures, while small shells could possible be beneficial in preserving bone quality of the femoral head.

BIBLIOGRAPHY

R. Huiskes: *Acta Orthop Scan*, **56(6)**, 1985
Y. Kishida: *JBJS*, **86-B(2)**, 2004
Y. Watanabe: *J Arthropl*, **15(4)**, 2000