BIOMECHANICAL ANALYSIS OF HIP CEMENTLESS FEMORAL STEM DESIGNS IN PHYSIOLOGICAL AND OSTEOPOROTIC BONE DURING DIFFERENT STATIC LOADS

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Introduction

Total Hip Arthroplasty (THA) is a highly successful surgical procedure. However, Periprosthetic Femoral Fractures (PFF) are a common cause of implant failure[1]. Cementless femoral components have a higher incidence of PFF compared to cemented implants, but the trend towards using cementless implants is increasing due to the advantages it offers. The contribution of different cementless stem designs to PFF risk is still a debated topic in the literature. This study compares the stress and strain distributions on physiological and osteoporotic femoral bones for different cementless hip stem designs under different loading conditions. The focus is on the perioperative period before osteointegration occurs. A biomechanical study using finite element analysis was performed to achieve the highest comparative value.

Methods

The study developed 4 finite element models and analyzed each one for healthy and osteoporotic bones; in detail 1 native control and 3 implanted femurs: one short anatomical stem with femoral neck preservation, one double-wedged press fit stem (Type 2) and one anatomical standard stem (Type 6). The bone geometry was reconstructed from CT images and three THA stem designs were implanted in the femoral bone. The material models used linear elasticity and different Young's moduli and Poisson's ratios were assigned to healthy and osteoporotic bones [2]. The stems were made of titanium alloy. The models were tested under 3 load conditions: gait, sideways falling, and four-point bending [2]. The gait test analyzed maximum force during daily activities, the sideways falling test simulated common clinical injuries, and the four-point bending test simulated the boundary conditions of the standard experimental test used to measure the resistance of the bone.

Results

<u>Gait</u>: Similar stress distribution found in anatomical stem (Type 6) and short anatomical stem with femoral neck preservation in native model. Type 2 stem reduced stress in proximal femoral area (Figure 1) and showed non-homogeneous stress with concentrations in small areas. In osteoporotic bone, increases of 5% in average von Mises stress were found in native, Type 6 and short anatomical stem; 10% increase was found in Type 2 stem.

<u>Side-way falling</u>: Native model had the highest stress in femoral neck, while prosthetic stems reduced stress, with higher stresses found in stem tip areas for Type 6 and short anatomical stems. Type 2 stem showed no remarkable stress concentrations. Stress overall increased in osteoporotic bone in all models, with the highest rise in Type 2 stem.

<u>Four-Point Bending:</u> All configurations in physiological bone models showed comparable stress distributions. Type 6 had higher stress in trochanteric area, Type 2 had high stress in distal part of stem. No significant difference in average stress in osteoporotic bone in any studied model.

Discussion

The critical phase of the press-fit THA is before stem osteointegration, as most fractures occur within the first six months after surgery: analyzing the prosthesis behavior can therefore be beneficial to understand the eventual consequences of a design over the other. The results of this study showed that anatomical stems with femoral neck preservation performed similarly to native models, while double wedge stems demonstrated a reduction in stress in the proximal femoral area and a theoretical higher risk of PFF. Type 6 stems confirmed the clinical evidence that the anatomic stem design represents a protective factor against stress-shielding. Therefore eventual resorption in anatomical stems, and mainly in neck preservation stems, could then be explained mainly by errors during surgical planning and surgical technique.

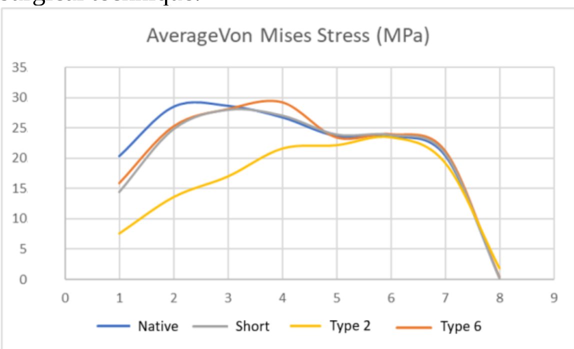

Figure 1: A graph of the Average von Mises Stress in different regions of the femur (1=proximal, 9=distal) during the Gait test

References

1. Patsiogiannis N. et al. EFORT Open Rev. 2021
2. Soenen M. et al. The Journal of Arthroplasty. 2013