STRONGER IMPLANTS DO NOT CAUSE STRESS-SHIELDING IN THE FIXATION OF HIP FRACTURES – VALIDATED FINITE ELEMENT ANALYSIS AND CADAVER TESTS

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INTRODUCTION

A stable fixation by osteosynthesis is essential to allow an early mobilization of patients with hip fractures. However, there are cases of implant failure. The reason for these failures can be amongst others pseudarthrosises or high bodyweights of the patients.

When these patients are supplied with stronger implants to improve the fracture stability, it is feared that stress-shielding occurs. Stress-shielding is the effect when the load on the bone decreases and the load on the implant increases, because of the high stiffness of the implant. Especially reinforced intramedullary nails bear the risk of a shift of the failure mode from the nail to the lag screw in the case of overloading.

It was hypothesized that a reinforced intramedullary nail does not cause stress-shielding but results in lower strains and stresses within the implant during loading. The risk for fatigue failure would therefore be lower for a stronger implant than for a current nail design.

METHODS

Two intramedullary nails were compared, a Gamma3 long and a reinforced prototype with a larger diameter of the proximal shaft.

Initially the von Mises stress distribution on the implants was calculated by finite element (FE) models. These models simulated the implant in the standardized femur [3] and were validated by strain measurements on the nail in a previous study [2]. The implants were analyzed in two fractures (AO 31A3.1/A3.3) and two load cases. The two load cases simulated the maximum hip joint force with and without an additional muscle force, which acted on the lateral side of the femur. The forces were calculated based on the findings of Bergmann et al [1].

To check the results by the FE models, analog experiments in human cadaver bones were carried out. Six pairs of human femurs (age 67±7) were osteomized and fixated with the two implants in a paired cross-over design. The specimens were tested in a servo electric testing machine to measure the construct stiffness and the strains on the nail by two strain gauges during maximum load.

An unpaired t-test was used to determine statistical significant differences between the two implants ($p<0.05$).

RESULTS AND DISCUSSION

The finite element simulations resulted in 11-28% lower stresses on the nail, 22-71% lower stresses on the lag screw and a similar construct stiffness (-7-12% difference) for the stronger implant in both fractures and load cases.

In the cadaver tests the stronger implant resulted in significant lower strains at the two strain gauges ($p<0.001$; $p=0.016$) and a comparable stiffness ($p=0.446$) albeit the fracture type and the load case.

The enhanced stability and stiffness of the implant by the reinforced proximal part of the nail shaft did not cause stress-shielding. The risk of fatigue failure was lower for the stronger implant because of the lower stresses and strains within the osteosynthesis. This was true for the nail shaft and the lag screw. Thus, obese patients or patients with expected delays of fracture healing may potentially benefit from the application of stronger implants.

REFERENCES

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