INTRODUCTION
In the normal hip, stress is distributed over the entire crosssection of the femur. Bending and axial compression are the major modes of loading. Following THA, the stress in the bone is significantly different mainly due to the manner in which the load is transferred to the femur (Huiskes, 1990, Huiskes, 1995). In this case, the load is primarily transferred through shear across the bone-cement-prostheses interfaces.

In addition, the bending displacement in the bone surrounding the stem are reduced because of the relatively high flexural stiffness of the prosthesis. This reduced bending unloads the outer fibers of femur leading to a state of stress shielding. The medial calcar, which experiences a significant reduction in stresses (stress shielding) has been commonly seen to atrophy in in-vivo radiological studies.

An apparent solution to this problem would be a prosthesis which loads the proximal end of the femur in a manner similar to the natural state. Recently, a stemless prosthesis design using proximal fixation was developed by Munting and Verhelpen, (1995) and has shown promising initial results. This design is fixed to the lateral side of the proximal femur by means of a bolt. Their in-vitro experiments showed minimal micromotion and the short-term clinical studies have shown low initial failure rates.

The motivating hypothesis for the current study, is that it is possible to develop a new femoral prosthesis component designed specifically to reduce the levels of stress shielding and interfacial shear stress in the femur following total hip arthroplasty.

PROCEDURES
The first stage of the current design was the development of a general geometry that restores, as much as possible, the natural load-transfer mechanism through the proximal femur. A detailed finite element model of the femur was used to calculate the stresses in the bone. The change in stress, caused by the introduction of the prosthesis, was used as a standard for comparison. The initial study indicated a significant benefit from the use of a short stem verses a long stem in terms of the interfacial shear stresses in the bone.

As a further modification, a proximal plate was added to distribute the contact load over the entire crosssection of the femur and reduce stress shielding in the cortical bone. The combination of a shortened stem and a proximal plate resulted in a major reduction in both stress shielding and interfacial shear stress. Reducing stem length however, made it necessary to devise an alternate method of fixation. One example of proximal fixation is the design by Munting and Verhelpen, (1995) described in the previous section. However, to avoid the use of a stiff metal bolt through the relatively brittle lateral cortex, a cabling system was developed. The cables not only anchor the prosthesis to the bone, but they also help produce a more natural bending-load transfer over the crosssection of the femur by fixing the trochanter to the implant. In the following sections, we present results of the stress analysis and discuss the preliminary in-vitro study of the new design.

RESULTS AND DISCUSSION
To estimate the effect of the prosthesis on the stress distribution in the bone, the stress difference for each element was calculated. Positive stress difference values indicate an increase in overall stress level due to the introduction of the prosthesis and negative values indicate a decrease. The proximal femur below the neck and above the shaft was divided into five medial (regions 3-7) and five lateral (regions 8-12) regions numbered
starting distally. Region 1 represents the proximal diaphysis and region 2 the greater trochanter. In all the regions, except region 2 (greater trochanter), the conventional prosthesis produces significant stress shielding. In region 2, the conventional prosthesis causes a 100% overstress due to the loss of bone mass in this region during surgery. Both the current design and the Munting and Verhelpen, (1995) design show far less stress shielding everywhere except region 12. In addition, both proximally fixed designs cause no noticeable change in the stresses in the diaphysis. Figure 1 compares the stress differences for the Munting et. al. and current designs. As shown, the current design produces lower magnitude stress differences in all regions.

As a preliminary test of the new design, human cadaver femora were tested in static loading before and after implantation of a prototype new prosthesis. The bone was dried, cleaned and potted in a metal cup. Strain gages were attached to the proximal femur, three around the stem on the medial calcar and one on the lateral surface below the anchoring cable. The gages were placed in locations where a conventional intramedullary prosthesis often causes significant stress shielding (see for example the summary in Huiskes and Verdonschot, 1997), but the numerical analyses predicted that the new design would not.

Load was applied to the femoral head in the axial direction through a displacement controlled Instron loading frame. These results showed that the current prosthesis produces little or no stress shielding in at least several critical areas of the proximal femur. Qualitatively therefore, the experimental results were consistent with the analytical predictions.

SUMMARY
This study presents a new design aimed at reducing stress shielding. In the numerical studies, the proposed design consistently performs better than the traditional intramedullary design and the Munting and Verhelpen, (1995) design in the context of femoral stress differences.

The preliminary in-vitro study showed that the new fixation method is viable from a surgical and initial post-surgery perspective. Results show that in several critical areas of the proximal femur, the new design produces little or no stress shielding. This is consistent with the numerical models and lends evidence that the analyses can be used to give an estimate of the overall behavior for the loadings considered.

REFERENCES


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Figure 1: Stress comparison for Munting et. al. and the current design