

Polyethylene stresses in Unicompartmental knee replacements during a step-up activity.

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INTRODUCTION

The use of a thin bearing in Unicompartmental knee replacements is advantageous because more bone is preserved. However, very thin bearings can be associated with bulk failure and increased wear.

Osteolysis, resulting from a foreign body response to particulate debris, is a significant failure mechanism with knee arthroplasty [1]. The primary cause of osteolysis around knee replacements is from wear debris produced at the articulating surfaces. Wear rate of polyethylene can increase exponentially with increasing contact pressure [2] therefore contact stress analysis of knee arthroplasty designs can be used to predict performance.

Finite Element (FE) analysis is usually carried out at discrete points of an activity. The aim of this study was to compare the peak contact stress in a fully congruent mobile polyethylene (PE) bearing and a fixed flat PE bearing throughout the entire step-up activity, using a validated FE model.

METHODS

A validated FE model of a cadaver tibia implanted with a cemented tibial tray was used in this study [3].

Two implanted tibia models were used with a common spherical femoral component. A mobile, fully congruent, Oxford Unicompartmental bearing, (Biomet, Swindon, UK), and a generic flat bearing

were inserted into the FE models. In both cases the minimum thickness was 3.5mm.

The tibial tray and femoral component were modelled as cobalt chromium, linear elastic and isotropic. The cement layer was modelled as linear isotropic. A nonlinear material model was used for the PE bearing [4].

Kinematic data from fluoroscopy measurements during a step-up activity was used to determine the relative tibial-femoral positioning for each model; this was a function of knee flexion angle.

The load data was adapted from in-vivo measured loads using an instrumented implant during a step-up activity [5]. Separate loads were applied to the medial and lateral compartment and these were scaled to a subject of mass 74kg (mass of tibia donor).

A Coulomb friction contact model was used to simulate the PE / metal bearing surfaces; for the fixed bearing the PE was fully bonded to the tibia. A coefficient of friction was taken from literature [6].

The peak stresses in the fixed flat bearing were assessed as a function of bearing thickness. The thickness of the flat fixed bearing was varied from 2.5mm to 6.5mm.

RESULTS AND DISCUSSION

Fully congruent articulating surfaces between the femoral component and the PE bearing significantly reduce the peak contact stress and peak von Mises stress in the bearing over the entire step-up activity (Figures 1 and 2).

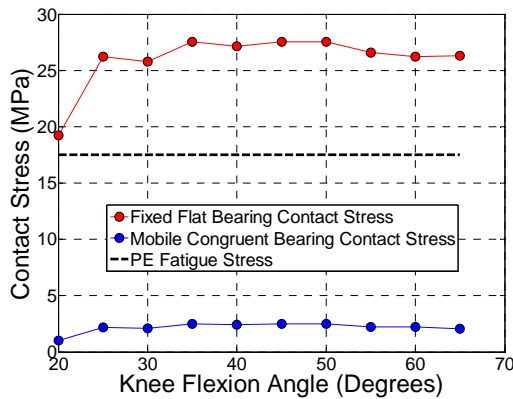


Figure 1 – Peak contact stress on the bearing surface over entire step-up activity.

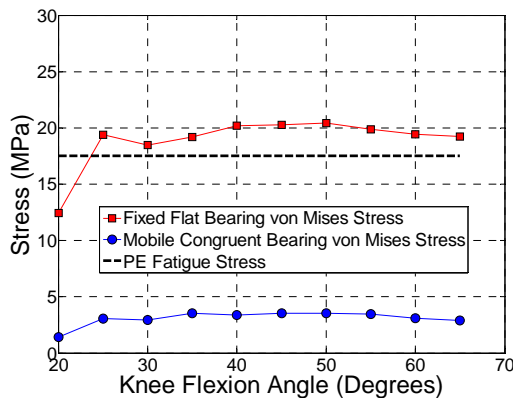


Figure 2 - Peak von Mises stress in the bearing over entire step-up activity.

A bearing thickness greater than 4mm ameliorates the stresses in the flat fixed bearing to below the fatigue limit. A minimum thickness of 6.5mm is required to achieve the lowest von Mises stress in the fixed flat bearing (Figure 3).

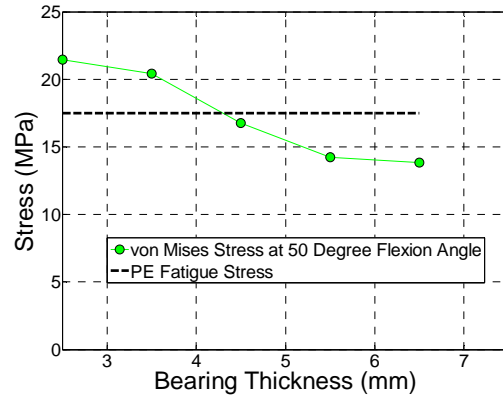


Figure 3 – Peak von Mises stress in the flat fixed bearing for 50° flexion angle.

This study has compared the stresses on a fixed flat and mobile congruent bearing for a Unicompartmental knee arthroplasty over an entire step-up activity. The danger with thin fixed bearings is the stresses are close to the fatigue limit. The results of the model raise concerns about using relatively thin, fixed PE bearings and demonstrate that congruent designs can be markedly thinner without approaching the material limit.

Mobile congruent bearings have a greater potential for being bone conserving. A minimum potential saving of 3mm is possible with a mobile congruent bearing.

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