

A Finite Element Model for investigating cementless tibial component micromotion of the Oxford Unicompartmental Knee Replacement

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INTRODUCTION:

The cementless Oxford Unicompartmental Knee Replacement (OUKR) tibial component relies on osseointegration to achieve long-term stability. For this to occur, micromotion must remain below the upper limit of 150µm. Finite element (FE) modelling allows us to quantify the probability that osseointegration will occur by assessing micromotion when the implant is loaded. The aim of this study is to compare micromotion for two variants of OUKR tibial components under physiological loads using the finite element method.

METHODS:

Two tibial component variants with different methods of fixation were investigated in this study: a standard keel, and two pegs. FE models of these variants were created and implanted in a previously validated tibia model. Implants were modelled using an analytical rigid definition. The tibia was segmented from a CT scan with material properties assigned based on CT intensities. The interference due to press-fit of the implant was adjusted from the surgical specifications, and the bone-implant interface was modelled using non-linear friction. The combination of these parameters was based on previous research modelling implant pull-out force. Three loading cases for each implant design were considered: functional, eccentric, and lateral loading. These loading cases correspond to the bearing position at the point of peak force in the gait cycle, deep lunge, and peak force in the gait cycle with the bearing impacting the lateral wall of the implant, respectively (Figure 1). Micromotion was measured by finding the displacement of nodes on the bone surface relative to the implant surface. This was done for both the bottom of the implant tray and the surface of the keel or pegs, hereafter referred to as the tray and keel surfaces respectively.

RESULTS SECTION:

Modelling showed that greater micromotion occurred using the standard keel compared to peg fixation for all loading conditions, across both the tray and keel. Eccentric loading resulted in the highest levels of micromotion for both methods of fixation. These large values of displacement during eccentric loading occurred at the anterior aspect of the implant, due to lift-off of the implant from the resected tibia.

Median micromotion remained below 150µm for all loading conditions for the peg design. Functional and lateral loading of the standard keel resulted in median micromotion below 150µm, but eccentric loading resulted in median micromotion of over 300µm (Table 1 & Figure 2).

DISCUSSION:

The new fixation method of two pegs performed better than the standard keel for all loading cases, with both a lower median micromotion and range of micromotion for the tray and keel areas. As bone ingrowth has been demonstrated in the current design (standard keel), it is reasonable to infer that bone ingrowth will occur when pegs are used for fixation.

As bone ingrowth occurs in the keel of the current cementless OUKR, it follows that micromotion for the current keel is below 150µm. This is reflected in the current study, which reports micromotion in the keel area as below 150µm for a functional load. As the median micromotion is above the 150µm threshold for an eccentric loading, such as during a deep lunge, it is advisable that this movement is discouraged in the postoperative period.

Analysis of the distribution of micromotion reveals that the majority is due to anterior lift-off of the implant. The peg design experiences less anterior lift-off than the standard keel, and future designs should aim to minimise this behaviour.

SIGNIFICANCE/CLINICAL RELEVANCE:

The Oxford Knee is the most widely used partial knee replacement in the world. This study has applied a method for quantifying micromotion and hence assessing the likelihood of achieving long-term stability of alternative implant designs, paving the way for designs which maximise successful fixation while minimising the risk of fracture.

IMAGES AND TABLES:

Table 1 - Tray median micromotion (µm)

	Functional Load	Lateral Load	Eccentric Load
Standard Keel	92	88	311
Peg	53	61	72

Figure 1– Finite element model showing locations of:

- 1 – Lateral load,
- 2 – Functional load,
- 3 – Eccentric load



Figure 2 – Distribution of keel area node micromotion. Graph inset shows a standard keel (L) and pegs (R).

