

THE SCLEROTIC LINE: WHY IT APPEARS UNDER KNEE REPLACEMENTS (A STUDY BASED ON THE OXFORD KNEE)

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INTRODUCTION

Radiolucent lines and sclerotic margins are often seen on knee radiographs taken a year or longer after Oxford Unicompartamental Knee Replacement (OUKR) surgery [1]. Histology of material from beneath OUKRs shows that the radiolucent zone is predominantly fibrocartilage and the sclerotic margin is lamellar bone [2]. The reasons for the existence of these types of tissue are not clearly understood although several speculations exist [2].

The aim of this study was to apply known rules for bone remodelling to a finite element (FE) model of the tibia, to use an iterative process to simulate the in vivo remodelling that occurs during the first year of post OUKR surgery, and thus to investigate if and why the model predicts the sclerotic line.

METHODS

A 3D FE model of the medial half of the proximal 75 mm of a tibia implanted with a cemented OUKR was created and run over 365 iterations linked with known remodelling rules. The model was based on an experimentally validated FE model of a complete human cadaveric tibia with an OUKR tibial component [3]. The model was run under a load of 1157 N perpendicular to the implant, the peak load seen by the medial plateau of the tibia of an 82 kg (mass of cadaveric tibia donor) person during normal gait [4].

After each iteration, new material properties were calculated for elements in a 2 mm thick area which was adjoining the bone cement. An element's new material property was a function of the stress-strain condition [5] at its centre of gravity, its current material property, and a rate of change. The rate of change was set so that an iteration represented roughly a day of in vivo remodelling. It was assumed that these elements represented granulation tissue before the first iteration with Young's modulus and Poisson's ratio assumed to be 0.2 MPa and 0.47 respectively.

The material properties of the elements which represented the rest of the bone were changed based on a set of established bone remodelling rules [6]. The initial properties of these elements were calculated from radiographic density values from CT scans [7].

"Synthetic AP radiographs" were generated by reverse calculating radiographic densities from material properties for the model after 365 iterations. Comparisons were made between these plots and patient AP radiographs.

Von Mises stress at the centres of gravity of elements in the bone where the sclerotic line is usually seen (immediately neighbouring the 2 mm soft tissue remodelling zone) were calculated after 365 iterations. The same entities were also calculated assuming the same load and bone material

properties derived from CT data (i.e. putting in a tibial implant had no effect on the bone and the initial 2 mm layer of granulation tissue did not form). The two groups of results (with remodelling and without any remodelling) were compared using 'boxplots'.

RESULTS AND DISCUSSION

The model was able to predict the radiolucent lines and the sclerotic lines observed on radiographs (Figure 1). The mean von Mises stress in the sclerotic region was higher when remodelling was assumed than when no remodelling was assumed (Figure 2). This indicated that the presence of the soft tissue (radiolucent line) increased the stress in the underlying bone. This was expected because, once a layer of soft tissue is formed, it causes shear stresses to be imparted to the underlying bone in addition to the compressive stresses that are a direct result of the load on the implant. The additional stress taken up by this bone causes it to increase in density in keeping with Wolff's law. This bone of increased density causes the sclerotic line observed on radiographs.

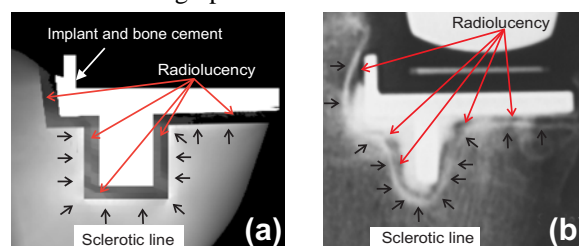


Figure 1: (a) synthetic radiograph and (b) patient radiograph both showing radiolucencies and sclerotic lines.

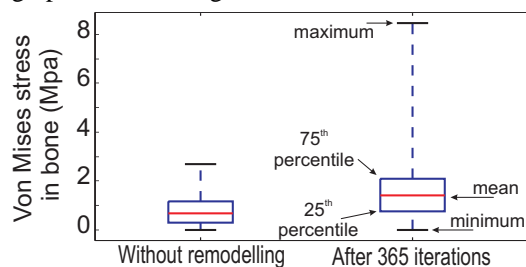


Figure 2: 'Boxplots' of von Mises stresses in bone in the region where the sclerotic line is seen.

CONCLUSIONS

The sclerotic line is caused by the stiffening of bone due to the relatively larger loads seen by the bone just beneath the soft tissue layer (radiolucent line) surrounding the bone cement of an OUKR.

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