INTRODUCTION:

A significant source of failure for external fixation devices is loosening/infection of the fixation implant [1-3]. It has been noted that mechanical damage can pre-empt infection of the implant-tract or, conversely, infection can lead to loosening [1]. As bone stiffness and strength drops with ageing or disease such as osteoporosis, the risk of loosening is likely to increase. However it is not clear how fixator configuration should be adapted to minimise loosening in weaker bone.

In this study, finite element analysis of half-pin and Ilizarov fixation of a midshaft tibial fracture were conducted for a range of age groups. These were used to assess the effect of bone competence on the yielding of tissue surrounding fixation implants, with the aim of informing the selection of fixator configuration to minimise loosening.

MATERIALS AND METHODS:

External fixation of the tibial midshaft using half-pins and Ilizarov wires was modeled using finite element analysis. Half-pin configurations of two and three stainless steel and titanium pins were modeled. The Ilizarov wire configurations consisted of two and four wires over a range of wire tensions.

Bone competence was varied to approximate three groups: a) healthy/young bone; b) osteoporotic/middle-aged bone and c) osteoporotic/old-aged bone. The tibial cross-sections were varied to match reported age-related variations [4]. Orthotropic elastic constants of bone were assigned, including the variation of elastic constants with age/porosity and periosteal-endosteal position based on a recent study by the authors [5]. Implant-bone interactions were modeled with contact analysis, enabling realistic separation in regions of tension and slippage in shear.

Bone damage was simulated using a bone-specific, strain-based yield criterion. To the knowledge of the authors this is the first time that all these key features of bone-implant interaction and bone properties have been included in a computational model.

RESULTS:

The volume of yielded bone (indicating loosening) at pin entrance sites for two-pin fixation for a single legged stance is shown in Fig. 1. The volume of yielded bone increased with ageing, approximately three times greater in old-aged bone than in young bone. In the young and middle-aged cases yielded bone never penetrated the full cortical thickness. Contrastingly, the full cortex thickness yielded in the old-aged bone for pin fixation. The volume of yielded bone increased with proximity to the fracture gap; the lower pins in each case. The use of titanium pins (not shown) increased the volume of yielded bone around half-pins by approximately 1.7 times.

The volume of yielded bone around Ilizarov wire tracts is plotted in Fig. 2. The volume of yielded bone increased with ageing by a factor of approximately two times from young to old bone. Considerable variation in yielded bone volume was predicted between different wire insertion sites (A-D, see figure caption). The yielded bone volume was five times greater at a site near the wire end support, than one distant from the support. Increasing wire tension reduced the volume of yielded bone. It was observed that reduced wire sagging at the entrance sites led to less ‘pinching’ of the bone and the consequent reduction in yielding.

REFERENCES: