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A comparative analysis of treatment of a supracondylar periprosthetic femoral fracture under axial load and torque

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A total knee arthroplasty (TKA) is in rare cases followed by an extra-articular fracture of distal femur. One type of fracture is a simple extra-articular fracture (A1 according to Schewring and Meggitt [3]). It can be stabilized only by surgical treatment. Several implant types are used by orthopedic surgeons for its management. In this study we compare a response to axial load and torque for Distal Femoral Nail (DFN) and Locking Compression Plate (LCP).

The model of bone with fracture, TKA and DFN is the same one as in the previous study [2]. Both compact and spongy bone are modelled by 3D elements. The gap of partially healed fracture with a callus is 2 mm wide. LCP geometry is based on a laser scan. The finite element models with the placement of DFN and LCP are shown in Fig. 1.

The material parameters of bone were obtained from available literature, the callus which forms several weeks after the fracture has material properties of a cartilage [4]. The screws, the spiral blade, DFN and LCP are made of titanium alloy.

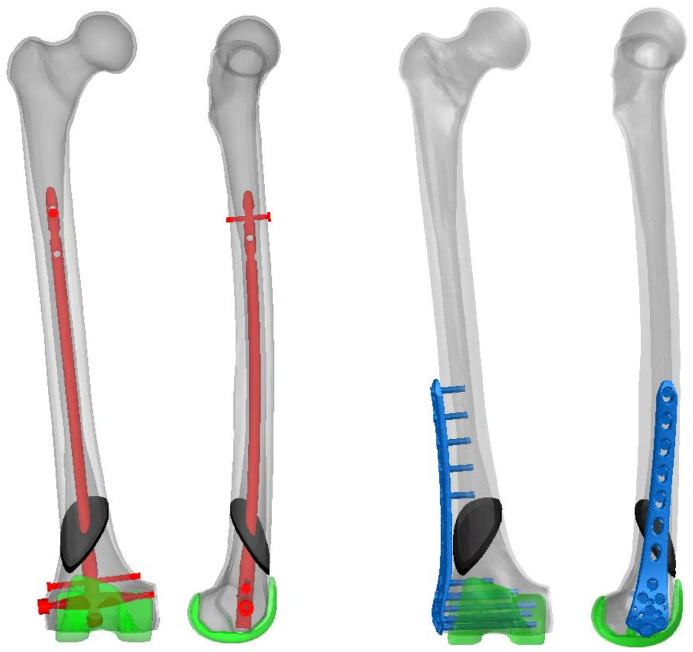

Fig. 1. The frontal (left) and lateral (right) view of model of femur with TKA (green), callus in the area of A1 fracture (black) and implants: DFN (red) and LCP (blue)

Two types of load were used – uniaxial load on the femoral head and torque. The loading conditions correspond to those of Brinkman et al. [1]. For both loads, a rigid body was formed at the surface of the femoral head and the greater trochanter and all degrees of freedom of the distal part of the femoral component were fixed. In case of the uniaxial load, a force corresponding to the body mass of 80 kg was applied on the center of femoral in the direction of mechanical axis and all other degrees of freedom were fixed. For torque, a moment of 5 Nm was applied on the center of femoral head about the mechanical axis and all other degrees of freedom were fixed.

The von Mises stress distribution in the implants and the displacement of femur in all three main directions were analyzed for all cases.

The results of uniaxial load show that in case of DFN there is an increased stress in the middle of the spiral blade in the area in contact with the nail and in the nail in the area around and above the fracture location. The femoral mid-shaft bends laterally and ventrally. Von Mises stress in LCP implant reaches high values also in the area around the fraction location and the screws are loaded mainly in the area of their intersection with compact bone. The femoral mid-shaft and LCP bend medially and ventrally. For both DFN and LCP the whole femur above the fracture moves distally, compressing the callus.

With torque about mechanical axis, the greater trochanter rotates dorsally for both implants. The femoral mid-shaft undergoes larger extension along the mechanical axis in case of LCP. The stress reaches significantly higher values in LCP implant, especially below the level of the screws in the diaphysis and through its whole width at the level of upper three screws on the condyle.

The most significant difference between the model with DFN and the one with LCP is in the displacement in the coronal plane under uniaxial load and markedly higher stress in LPC under torque.

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