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Biomechanical comparison of five implants used to treat a supracondylar periprosthetic fracture of ostheoporotic femur

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The goal of the study is to assess the biomechanical properties of several implants used to treat a supracondylar periprosthetic fracture which rarely occurs mainly in ostheoporotic patients after total knee arthroplasty (TKR). The behaviour of ostheoporotic bone and implants under load is analysed by means of the finite element model.

The study extends the previous analysis [1] of four implants: Distal Femoral Nail (DFN), Angled Blade Plate (ABP), Dynamic Compression Screw (DCS), Less Invasive Stabilization System (LISS). Additionally, the Non-Contact Bridging (NCB) implant is considered and the change in the distance between the proximal and the distal surface of the fracture is assessed along with the displacement of the bone and stress distribution in implants under axial load and torque.

Both compact and spongy bone are modelled by 3D elements. The gap between the surfaces in the fracture line is 2 mm wide. The finite element models of femur with total knee replacement (TKR) and the implants are shown in Fig. 1.

Fig. 1. Frontal and lateral view of the model of femur with particular implants: TKR (green), the fracture (black), ABP (violet), DCS (light blue), NCB (dark blue), LISS (orange) and DFN (red)

The material parameters of the bone correspond to the ostheoporotic bone. Titanium alloy or stainless steel is used for the implants according to the manufacturers specifications. The TKR is made from Co-Cr-Mo alloy.

Two types of load were simulated – the uniaxial load and the torque. In case of the uniaxial load, a force of 800 N was applied on the centre of femoral head in the direction of mechanical axis. As for the torque, a moment of 5 Nm was applied on the centre of femoral head about the mechanical axis.

The von Mises stress distribution in the implants, the displacement of bone in all three main directions and the shortest distance in the fracture line were analysed for the five implants and the two loading conditions.

The axial load is the most evident in the sagittal plane. The bone bends ventrally in all implants, the least in case of DFN. The highest stress values are observed in the fracture area in case of DFN and below the most distally placed screw in the diaphysis in the other implants. The screws are loaded mainly in the area of contact with the compact bone.

For torque, the femoral head rotates ventrally and the greater trochanter dorsally in all cases. The femoral diaphysis twists around the mechanical axis with the values being significantly higher in case of NCB and LISS. The plate implants are loaded mainly in the middle area with no screws inserted, the DFN in the fracture area. The highest stress values are observed in LISS implant.

The proximal part of the fractured bone slides under axial load. The movement is mostly in frontal-distal direction in case of DFN. There is also a displacement in lateral direction in case of the other four implants and the overall displacement in the fracture line is almost double of the one observed with DFM implant. The bone rotates around the implant under torque. The way of rotation depends on the placement of the implant plate). The DFN is inserted inside the bone, therefore the bone rotates around its centre and the maximal movement is lower compared to the other implants in which the centre of rotation is placed significantly laterally.

The results show, that the DFN exhibits the best behaviour for the axial load as expected by the orthopaedic surgeons. However, the LISS and NCB implants do not prove to be the most suitable under torque. The analysis of the change in the distance between the proximal and the distal surface of the fracture under the load has revealed that the movement is more complex and should not be considered only as the change in the shortest distance.

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References

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