Loadshift – numerical evaluation of a new design philosophy for uncemented hip prosthesis.

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Hip prostheses alter the load transfer and stress state within the treated femur. This can lead to stress shielding in the proximal femur and subsequent overloading of the diaphysis. We hypothesized that a prosthesis capable of altering its mechanical behavior during the postoperative stage could avoid these problems. Therefore, a new design concept was introduced: the Loadshift Prosthesis. Its shaft is slit along the length into four legs. A biodegradable PE-pin is inserted at the distal shaft-end thereby straddling the legs apart (Figure 1), which come in contact with the interior femur surface. This guarantees a stable post-operative fixation and the shaft transfers part of the hip load. When the pin later degrades contact of the implant shaft with the diaphysis is reduced and the ingrown proximal implant component transfers most of the applied loads, i.e. the load transfer is shifted.

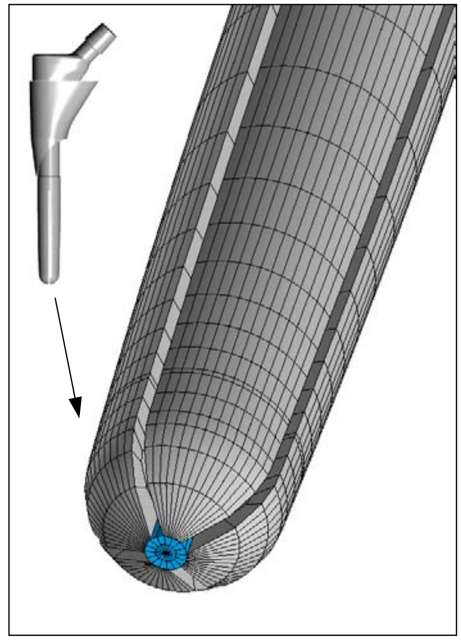

Figure 1: Loadshift prosthesis with detailed tip display

Key objective of this study was the numerical evaluation of this concept. The prosthesis was analyzed in two configurations: with pin inserted and without. Major interest was focused on interface conditions and load-transfer. A three-dimensional finite element model was generated from CAD data of the 3rd generation Sawbone femur (Istituti Ortopedici Rizzoli, Bologna, Italy) and CAD data of the implant [3]. Cortical and cancellous bone was modeled as orthothropic and isotropic material, respectively. Interface conditions between the bone, proximal implant component, and distal implant shaft were simulated with contact elements (stick-slip condition). Dynamic implant loads (Bergmann et. al) and muscle loads (Duda et. al) were applied to simulate normal walking.

The obtained results demonstrate the feasibility of the Loadshift-concept. With the pin inserted the implant shaft contributes significantly to the load-transfer. Lateral forces and bending moments are transferred but no axial load and torsion moment. Maximum relative micromotion between proximal implant component and surrounding bone is about 53 μm and relative sliding distance per cycle is about 180 μm. With the pin not inserted the load-carrying function of the implant shaft vanish almost entirely. Micromotion and sliding distance are significantly higher. Only minor influence on the interface normal motion and stress distribution was found.

This concept supports the ingrowth of the implant cone, allowing a more physiological load-transfer within the proximal femur. A balanced degradation time of the pin with respect to the bone ingrowth could contribute to a successful application of this design.