Relationship between interfacial micromotion and bone density around a cementless hip implant

Motivation & Objectives

The hip is one of the most injured joint in the body with ageing. Osteoarthritis and degenerative diseases often lead to the necessity of a total hip arthroplasty in order to reduce pain and increase mobility. The advantage of cementless implants resides in the natural stem anchorage by osseointegration instead of the cement use. Nevertheless, the related stability is highly dependent on the micromotion amplitude between the implant and the bone. The origins of the micromotion variation are not well understood, but an explanation may be linked with density. Therefore, in order to help the surgeon to reduce the risk of implant loosening, the following question has to be answered:

Is there a correlation between bone density and micromotion?

Experiment and Post-processing

A cadaveric study is performed. Before the implantation of two cadaveric femurs, beads made of stainless steel (⌀ 600 μm) are dropped off in the bone cavity. Six beads composed of Tantalum (⌀ 800 μm) are fixed on the implant and serve to detect the implant in the space. The region of interest begins at the osteotomy and ends forty millimeters lower (Gorthcaw et al., 2012).

Two tests are performed on the femur in a micro-CT. For the compression, the femur is kept fixed and a force of 1800 [N] is applied on the implant. Then, the torsion test is performed. A torque of 14 [Nm] is applied on the bone and the implant remains fixed. These tests model walking and stair climbing average loads for a person of 75 [kg] (Bergmann et al., 2001 & 2010). Three scans are done: initially without load, during the loading and after the test without load.

The position of the beads are visible in the scans thanks to their radio-opacity. By an image-processing operation, their center of mass is detected as well as the implant surface. By expressing the coordinates from the three scans in the same referential, it is possible to measure the displacement of the beads, as well as the distance between beads and implant surface. The last scan is defined as referential. Thus, three measurements are performed:

- The subsidence corresponds to the driving in effect that occurs at the first loading in reality. It is the displacement between before and after loading.
- The micromotion is the displacement between during and after loading. It directly acts on the cells differentiation.

The gap is the distance between the implant and the beads that is similar to the distance between implant and bone.

Results

The micromotion amplitudes distribution is plotted on the implant region of interest. In compression, the mean value is 80 [μm]. The minimal and maximal values are 17 and 151 [μm] respectively. In torsion, the mean value is 49 [μm], and the minimal and maximal values 9 and 100 [μm]. The values remain below the critical threshold of 150 [μm] that leads to fibrous tissue formation.

The density representation on the implant surface allows highlighting some high density regions on the medial face.

A statistical approach, based on correlation graph and coefficients, to define any correlation between micromotion and density leads to no relation. Nevertheless, based on visual approach, some similarities are observed between low micromotion in compression on the medial upper face and the high density parts that correspond to a support zone.

Discussion and Conclusion

Some limitations have been observed regarding the accuracy and relevance of this study:

- Bone conservation in formalin during 4 years and temperature variation can alter the bone quality.
- Applied loads are not adapted to donor weight and can be higher than the real ones.

These limitations can be bypassed by further studies on the effects of conservation and the use of donor weights to adapt the loads.

This study has allowed answering to the question of the existence of any correlation between density and micromotion. Based on this experiment on two femurs, no correlation has been found. Nevertheless, some similarities have been observed between low micromotion values and high density support zones. Because of a lack of markers near these zones, it is not possible to conclude to a relation between support zones and low micromotion.

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