Bone Remodelling Around Uncemented Acetabular Prostheses

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Despite the generally inferior clinical performance of acetabular prostheses as compared to the femoral implants, the causes of acetabular component loosening and the extent to which mechanical factors play a role in the failure mechanism are not clearly understood yet. The study was aimed at investigating the load transfer and bone remodelling around the uncemented acetabular prosthesis.

The 3-D FE model of a natural right hemi-pelvis was developed using CT-scan data. The same bone was implanted with two uncemented hemispherical acetabular components, one metallic (CoCrMo alloy) and the other ceramic (Biolox delta), with 54 mm outer diameter and 48 mm bearing diameter. The FE models of the implanted pelvis (containing ~116000 quadratic tetrahedrals) were generated using a submodelling approach, which were based on an overall full model of implanted pelvis (containing ~217600 quadratic tetrahedrals) acted upon by hip joint force and twenty one muscle forces. The apparent density ($\rho$ in g cm$^{-3}$) of each cancellous bone element was calculated using linear calibration of CT numbers of bone, from which the Young’s modulus (E in MPa) was determined using the relationship, $E = 2017.3\rho^{2.46}$ [1].

Implant-bone interface conditions, fully bonded and debonded with friction coefficient $\mu = 0.5$, were simulated using contact elements. Applied loading conditions consist of two load cases during a gait cycle, corresponding to 13% and 52% of the walking cycle. Fixed constraints were prescribed at the pubis and at the sacroiliac joint. The bone remodelling algorithm was based on strain energy based site-specific formulation [2]. The FE analysis, in combination with the bone remodelling simulation, was performed using ANSYS FE software.

The predicted changes in peri-prosthetic bone density were similar for the metallic and the ceramic implant. For debonded implant-bone interface, stress shielding led to ~20% reductions in bone density at supero-anterior, infero-anterior and posterior part of the acetabulum (Fig. 1). However, bone apposition was observed at the supero-posterior part of the acetabulum, where implantation led to ~60% increase in bone density (Fig. 1). The effect of bone resorption was higher for the fully bonded implant-bone interface, wherein bone density reductions of 20 – 50% were observed in the cancellous bone underlying the implant (Fig. 1), which is indicative of implant loosening over time. However, implantation led to an increase in bone density around the acetabular rim for both the interface conditions (Fig. 1). These results are well corroborated by the earlier studies [3,4]. Implantation with a ceramic component resulted in 2 – 7% increase in bone density at supero-posterior part of the acetabulum as compared to the metallic component, for the debonded interface condition. Considering better wear resistant properties and absence of metal ion release, results of this study suggest that the ceramic component might be a viable alternative to the metallic prosthesis.


Figures

Figure 1