The effect of Uncertainty of dental implant morphology on osseointegration

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Dental implants have attracted significant attention and been well accepted as the most effective treatment to partially or fully edentulous patients, among which osseointegrated dental implants have a great potential to achieve desirable and predictable outcomes [1]. In order to further increase success rate of implantation and reduce healing time, an improved osseointegration quality is believed to be achieved by porous-coated morphology. A 18 month trial has been conducted on a partially porous-coated endosseous dental implant with traditional threads, and the histological data clearly indicated a shortened stabilizing time of implantation and dramatically increased contact area over all porous-coated samples to threaded ones [2]. To model such a scenario, we applied multi-scale finite element analysis technique to a 2D dental implant model over a 48 month remodelling process, where the displacement responses from a macro-scale model was transferred to the localized micro-scale model with detailed porous surface morphology characteristics [3, 4]. However, this piece of work was based upon a deterministic model of coating and particles/beads in the micro model and did not capture the random feature of coating process.

This paper aims to apply a multi-scale analysis to multiple sets of 2D fully porous-coated dental implant models with randomized morphologies. These models’ morphologies are generated by the design parameters, including numbers, sizes, and locations of particles/beads, some of which is selected to be randomized by computer while the rest are given as the constant parameters in the modelling algorithm. From these two scales of models, the remodelling stimuli (i.e. strain energy density) and stress are determined for assessing the performance of different morphologies.

Specifically, a single macro-scale model is used to obtain kinematical boundary conditions for all micro-scale models [3, 4], and combinations of porous diameters of 30, 50, and 100 µm and different volume fractions at 5%, 15%, and 55%, are considered, respectively. In each set of combination, 10 models are created when the locations of pores are assigned randomly by computer within the blood region specified in the model. The only rule applied to location assignment is that no overlapping allowed to keep volume fractions constant in each set of models. The boundary conditions are applied to every model at the same locations with the results from the macro-scale model at corresponding remodelling iterations. The distributions of mechanical stimuli along the blood-implant and blood-bone interfaces are plotted against their true distances along these interfaces, to examine its relation to the density change along interfaces. This study provides us with a statistical understanding in characterization of porous implants and will be of significance for design optimization of implant morphology.

References