PREDICTION OF IMPLANT STABILITY: AN *IN VITRO* EVALUATION

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Endosseous dental implantology is now a successful treatment for oral rehabilitation. Among other factors, primary implant stability is a prerequisite for successful long-term outcome and has been shown to be related to bone mineral density. Several methods exist which are said to provide quantitative assessment of primary implant stability following surgery. However, these techniques only provide assessment of implant stability after placement. Therefore, a tool which could provide the primary implant stability before surgery would be of great clinical value, particularly when intending to employ immediate loading.

The aim of the present work is to introduce and to validate a method which allows for planning implant position and provides, in near real-time, an assessment of implant stability.

A tool has been developed that combines a planning software for dental implant placement with finite element analysis (FEA). The position of the implant is first planned on the CT scan of the patient. Once the implant position has been decided upon, the bone mineral density is extracted from the voxels surrounding the implant and converted to Young's modulus. These values are then automatically assigned to the elements of a generic 3D mesh representing an implant surrounded by bone. An in-house finite element solver was developed to allow for a fully automated analysis. Loads are applied to the model and the finite element solver is invoked to calculate and display micromotions, stresses and strains for individual cases.

To validate the method, an in vitro evaluation of the tool was performed. 75 implants of four different diameters were placed in 11 human cadaver maxillae. Peak insertion torque of each implant was measured during placement. Then, resonance frequency analysis of the implant was performed. To test for the correlation between FEA and experiments, a torque of 25Ncm was applied to the implant in FE model and its rotation was measured. Additionally, the implant in FE model was subjected to radial load and the displacement of the upper surface of the implant recorded. The bone mineral density around the implant was obtained from a pre-implantation CT.

Correlation between the implant rotation predicted by the FE model and insertion torque measured in the experiment was found to be low ($r2$=.0933, .006, .3045, .1433 for implant diameters of 3.4, 3.8, 4.5, 5.5mm respectively). Further, the insertion torque measured experimentally and the resonance frequency did not show any correlation either ($r2$=.0439, .0049, .0394, .1095). However, when correlating the amount of hard bone around the implant (not considering soft bone or fatty tissues) with the measured torque better prediction was achieved ($r2$=.7240, .7638, .8387, .8366 with $p<0.002$).

Primary implant stability is assessed routinely when deciding if an implant is suitable for immediate loading. The in vitro validation of the FEA planning tool showed no correlation to the insertion torque measured. This may be because measures of implant torque would be very sensitive to areas of local high bone density whilst the finite element analysis considers the full distribution around the implant.

The results did not show any correlation between the experimental torque and RFA4, but good correlation between torque and local bone density.

The in vitro study performed in this study suggests that neither experimental methods (torque and RFA) nor the computational planning tool presented gives concordant results. The ability to predict long-term implant performance pre-operatively is very appealing. Further clinical follow-up studies will determine which measure of implant stability is indicative of patient outcome.