PATIENT SPECIFIC 3D FINITE ELEMENT MODELLING, ANALYSIS AND VERIFICATION OF DENTAL IMPLANT NAVIGATION AND INSERTION SYSTEM

Valerio Taraschi

School of Mathematical and Physical Sciences

University of Technology - Sydney

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Declaration

This thesis is the result of a research candidature conducted jointly with another University as part of a collaborative Doctoral degree. I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative doctoral degree and/or fully acknowledged within the text.
I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Valerio Taraschi

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Abstract

The use of a biomechanically correct finite element model (FEM) for simulating the behaviour of the human mandible during functional movements can be improved by including patient-specific anatomical data and real bone density data derived from a tomographic scan.

A model produced through this approach could be more realistic than the ones reported in literature over the last decades which lack subject-specificity in terms of morphological features and local material properties. Most of the published models over-constrain the mandible and do not include the action of facial muscles leading to what this study proves being simplistic or even erroneous interpretations of crucial implant osseointegration processes.

By interpreting tomographic data, in this research work the author developed advanced FEMs of the human mandible applied to realistic clinical scenarios and which can therefore be used to guide treatment plans.

Finite element simulations were also created to validate the design and the mechanical stability of a dimensionally reduced implant-supported patient reference tool used with an innovative and minimally invasive image-guided surgery system.

The author developed such novel navigation system for oral implantology to allow surgical approaches which otherwise could be not pursued using traditional techniques. This task required the design and prototype of software and hardware components which are now being clinically tested.

This thesis shows the application of the navigation system to the insertion of long angled implants for posterior support of full-arch prostheses. From the results of the FEM and by taking into account the micro-motions of the inserts generated by the full set of muscular

forces acting on a mandible in mechanical equilibrium under functional loading, this configuration showed superior osseointegration potential as opposed to what is reported in literature.

The author also applied the FEM to evaluate the osseointegration potential of implants with deep cortical anchorage, as opposed to shorter mono-cortical implants.

Moreover, a novel procedure for their safe insertion was designed by combining the benefits of ultrasonic bone socketing (piezoelectric osteotomy) with the dynamic guidance offered by the developed navigation system.

In force of its clinical potential, the surgical approach proposed in this study is currently being validated through in vivo trials approved by the independent ethical committee of University of Bologna. Preliminary results from Clinical Trials, as presented in this work, reported an average accuracy for implant insertion of 0.90+/-0.07 mm.

It is reasonable to state that the ultimate conclusion of this investigation is that the developed image-guided surgery system can be used safely and for significant outcomes on a routine basis for orthodontic or maxillofacial surgical procedures.

On the other hand the simulation designed to investigate its safe use on a patient is potentially suitable to determine the impact of patient-specific treatment procedures for ideal prosthetic restorations and to simulate the behaviour of other implantable components.

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