Dissertationsanzeige zum Dr. rer. biol. hum.

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Thema der geplanten Dissertation (Dr. rer. biol. hum.) / Topic of the planned dissertation:
„Fatigue Analysis of Dental Implants via the Finite Element Method
Considering Bone Remodeling and Peri-Implantitis "

Dental implants are used to support replacements for lost teeth. They exist in different configurations (support of single crowns, bridges, etc.) and materials (mainly titanium and ceramics). Their use has been increasing in the general population, but especially among the elderly.

Due to the typical functional load expected for its application (mainly nonuniform varying load due, among others, to mastication), fatigue is one of the main concerns for the long-term reliability of dental implants.

Another issue regarding its reliability is the bone loss in the region of the implant. This damage to the bone tissue can occur either as a reaction to mechanical loads (remodeling), as also as consequence of an inflammatory process (peri-implantitis). In either case it can lead to a reduced structural support of the implant.

Therefore, it is of interest to investigate the interaction between these two mechanisms of failure, as both effects (fatigue of implant and loss of support due to bone damage) are of the long-term cumulative damage type. It is expected that a progressing bone loss will reduce the support of a dental implant (either as a single implant or as support for a bridge), leading to higher stresses for the same functional loads, which in turn can lead to a premature fatigue failure of the dental implant.

Zielsetzung / Objective:
The objective of the proposed dissertation is to elaborate a fatigue model for dental implants. This model shall consider not only the long-term effect of the functional loads (e.g., mastication), but also the adverse effect on the support of the implant due to bone loss caused by remodeling and peri-implantitis.

Geplante Untersuchungen / Planned Investigations:

Due to the nature of the planned work, the investigations performed will be mostly "In-silico", i.e., based on computer models created to represent the actual phenomena of interest.

The base case for the initial investigations will be a geometry considering one implant anchored in the jaw bone and supporting a single crown. The material for the implant will be titanium and for the crown zirconium dioxide (a typical dental ceramic) is going to be used.

Occlusal loads during the mastication will be obtained from current literature. These loads will be used both to calculate the fatigue damage accumulation of the titanium implant as also to calculate the bone remodeling rate as per different models.

As for the bone loss due to peri-implantitis, available data of image diagnostics will be used to create curves of the evolution of the geometry around the implant along the time.

Erwartete neue Erkenntnisse / Expected new Knowledge:
The main hypothesis for the proposed dissertation is that there is a quantifiable interaction mechanism between these two effects (fatigue damage accumulation and bone loss due to remodeling and peri-implantitis).

An expected new knowledge is the creation of a model where all these factors are considered and their respective influences can be calculated for a typical dental implant.

This would allow to answer when and under which circumstances (e.g., cracking of the implant material or loosening of base support) the mechanical failure of the dental implant will occur.

Methodik der Arbeit / Methodology:

At first, a simplified analytic model of the bone-dental implant system will be developed. This model will be used as a base case for calculation of fatigue damage using S-N (stress-number of cycles) fatigue curves from the literature and for verification of a FE model for a simplified geometry of the bone-dental implant system. The FE model will be created using the structural module of the software Ansys Workbench.

Once the initial FE model is verified, successively more complex and realistic models will be created considering different factors of influence, as for example: preload, type of support, type of force application, etc. This initial model will at this stage consider only single static loads.

With a verified FE model, the next step is its further development to include structural fatigue effects. It will, based on an input list of load-cycles, automatically drive the simulation of all load cases and calculate the cumulative damage on pre-defined points based on the S-N curves.

As a further development of the FE model, a damage routine for the jaw bone will be implemented (using the Python programming language), to include the effect of bone loss due to remodeling and periimplantitis. This damage routine will progressively reduce the base support of the implant via elimination of mesh elements representing the bone around the base of the implant.

In a final step, all the mentioned factors will be considered concurrently and, under the assumptions taken, the mechanical failure of the dental implant will be able to be assessed and predicted.

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Datum, Unterschrift des Kandidaten

Mit meiner Unterschrift bestätige ich die Anmeldung der o. g. Dissertation und erkläre, dass ich das wissenschaftliche Vorhaben betreue und ein Votum informativum zur Dissertation erstellen werde.

Datum, Unterschrift der Erstbetreuerin

Datum, Unterschrift des Juniorbetreuers

Mit meiner Unterschrift erkläre ich, dass ich das wissenschaftliche Vorhaben betreuen und die Dissertation begutachten werde.

Datum, Unterschrift des Zweitbetreuers