NUMERICAL INVESTIGATION ON THE PRIMARY AND SECONDARY STABILITY OF ROOT-ANALOGUE-IMPLANTS

Mostafa Aldesoki (1), Ludger Keilig (1,2), Istabrak Dörsam (1,2), Christoph Bourauel (1)

1. Oral Technology, University Hospital Bonn, Germany; 2. Department of Prosthetic Dentistry, Preclinical Education and Materials Science, University Hospital Bonn, Germany

Introduction and Aim

The use of dental implants is a well-established approach for the restoration of chewing function after the loss of single or multiple teeth. Typically, threaded implants (TI) of different designs are used to anchor single tooth replacements or bridges in the mouth of the patient.

In cases where treatment requires the extraction of an existing, but severely damaged tooth, the shape the existing alveolus has to be considered. Such an existing alveolus might impede with the placement of a treaded implant. Either the cavity needs to be filled with bone substitute material, increasing the healing time until the implant can receive full function al loading, or diameter and/or length of the implant need to be chosen overly large to assure stability of the implant. This holds especially for multi-rooted teeth.

In such cases, custom root-analog implants (RAI) can offer an alternative, as they can be directly fitted to the geometry of the existing alveolus [1,2]. In this study, we compare a RAI with a TI in different bone blocks with respect to the the primary and secondary stability of using the finite elements method (FEM).

Materials and Methods

The geometry of tooth 47 (lower right 3rd molar) was extracted from an existing CBCT, and a RAI was designed based on this geometry. In a previous part of this study, two different RAIs (milled titanium, 3D printed titanium) were manufactured, and the surfaces were again scanned optically to determine manufacturing precision. In the current part of the study, the digital models of the RAIs were inserted into two different bone bocks (idealized rectangular sawbone block, and realistic bone segment taken from the same CBCT scan as the molar). FE models of a conventional TI inserted into the same bone configurations were used as reference. Material parameters are listed in Table 1.

Material	Young's Modulus	Poisson Ratio
Titanium	110 000 MPa	0.35
Cortical bone	13 700 MPa	0.30
Spongious bone	1 370 MPa	0.30

Table 1: Material properties used in the simulations.

In a first simulation series, we assumed sliding contact at the bone/implant interface to simulate early loading condition. In a second series, we used glued contact instead at the bone/implant interface to simulate the osseointegrated state. We applied a force of up to 200 N to the top of the implant in all simulations.

Results

There were only minor differences between the two RAIs in the numerical investigations. In the FE simulations, the induced equivalent stresses on the TI were drastically higher than the stresses induced on the RAI. Furthermore, the healing status positively affected the RAI model, reducing the stresses from 23.7 MPa in the immediate loading to 13.2 MPa in complete osseointegration (see Figure 1).

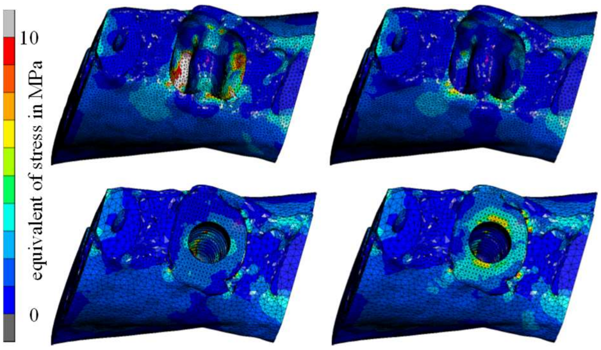

Figure 1: Calculated stresses in the anatomical bone model for a RAI (top row) and the TI (bottom row) under immediate loading (left column) and after osseointegration (right column).

Conclusions

The investigated RAIs showed a promising biomechanical behavior in the numerical studies. Especially after osseointegration, the custom shape of the RAIs might offer might offer a suitable alternative for the TI.

References

1. Chen et al, J Prosthet Dent, 112:1088-1095, 2014.
2. Mangano et al, Lasers Med Sci, 29:1321-1328, 2014.

Acknowledgements

We thank University of Applied Science Bonn-Rhein-Sieg for their help in the optical scanning. This work was supported by a grant from the German academic exchange service (DAAD, 2019/20, 57440921).