Splinted and Unsplinted Dental Implants: A QCT/FEA Study

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Abstract: To properly assess the stress distributions at the peri-implant area of a human maxilla, two variants of implant-supported overdentures (IODs) were evaluated using the Quantitative Computed Tomography-Based Finite Element Analysis (QCT/FEA). The used CT data were acquired from a 76-year-old edentulous male who was predetermined for an anterior maxillary replacement. Between the splinted and unsplinted variant, the bar-supported splinted variant showed favorable stress distributions both in bone and in the bodies of implants.

Keywords: Splinted; QCT/FEA; Implant; Dental; Stress

1 Introduction

Implant-supported overdentures (IODs) are a treatment option that is often used when the patient's bone quality is not sufficient, the lip line is not adequate for good phonetics and aesthetics or there is a buccolingual inclination of the alveolar ridge [1]. The system of connection between the overdenture and the implants includes the unsplinted attachments, such as various balls, locators and double crowns, or splinted attachments with many variants of bar and clip designs [2,3]. In literature, however, there is no clear consensus on which variant is better [4].

2 Materials and Methods

2.1 Data acquisition

We analyzed the maxilla of a 76-year-old male with sufficient dexterity. First, we checked the extraoral and intraoral requirements for an IOD were met [1]. Straumann SLA RN SP Roxolid implants were implanted in the most suitable sites of the patient's maxilla and a 3D X-ray was performed (Fig. 1). Then, a QCT/FEA (Fig. 2, Quantitative Computed Tomography-Based Finite Element Analysis) was performed in Mechanical Finder.

Fig. 1 The 3D X-ray scan of the patient that was obtained with the Planmeca ProMax ®3D Classic.

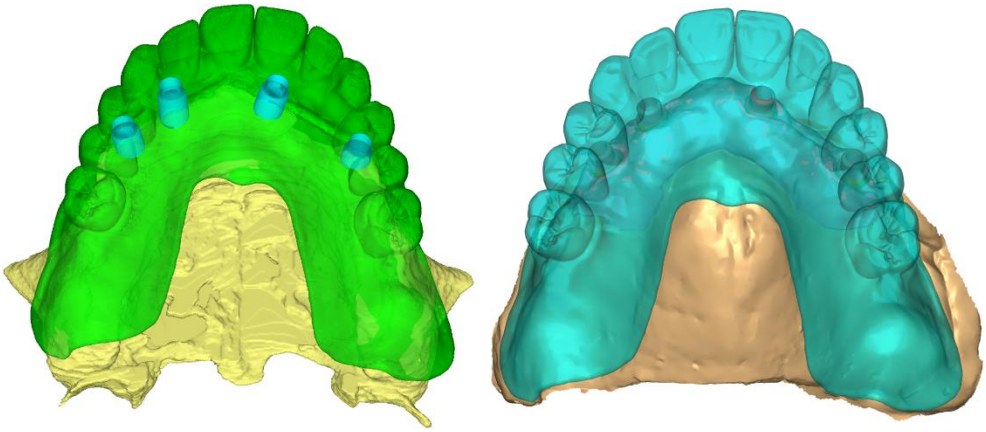

Fig. 2 Left—The QCT/FEA reconstruction with prosthetics, right—the laboratory X-ray model.

2.2 Analyzed implant variants

After the reconstruction of the maxillary model, we modelled two variants of the implant assemblies—a splinted and an unsplinted variant, shown on Fig. 3. The model also contained the overdenture made from PEEK (polyetheretherketone) (Fig 4).

Fig. 3 Left—The splinted design chosen for analysis, right—the unsplinted locator design.

2.3 Boundary Conditions

Simulations were performed in three load cases. The load was always represented by a force slanted in the buccolingual direction. The first load case was loading of both maxillary central incisors by 150 N in the frontal region with the force being slanted by 35°, the second by 600 N in the distal region on both molars and slanted only by 5° and the third by 600 N in the distal region on the first premolar with force components only in the direction of the implant axis. The model was constrained by fixing a section of the cut-off, as shown on Fig. 4.

3 Results

The results shown on Fig. 5 are comparisons of equivalent stress between the splinted and unsplinted variant in bodies of implants. Aside from the first load case (150 N, 35° slanted on incisors), the splints show great contribution towards the overall stiffness of the structure and redistribute stress into the whole assembly—unlike the unsplined variant, where stresses concentrate into individual implants and create large concentrations of stress.

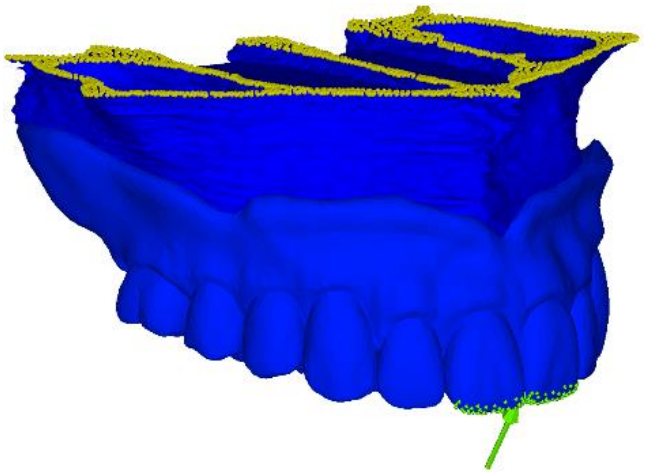

Fig. 4 The complete model with the force from the first load case. Yellow color represents constrained nodes. Green color represents loaded nodes. The model now also contains the prosthetic from PEEK.

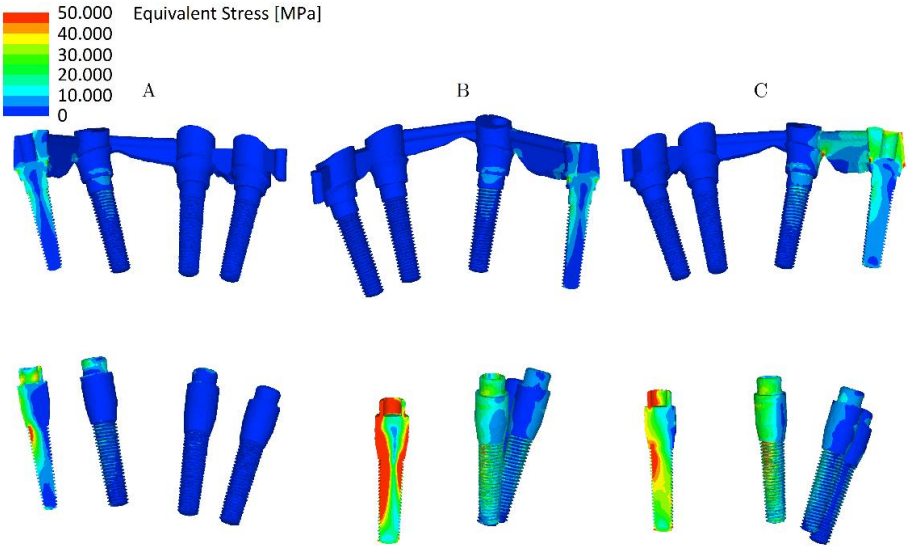

Fig. 5 Isolines of Equivalent (Von-Mises) stress in bodies of implants of both analyzed variants. Column A—1st load case, column B—2nd load case, column C—3rd load case. Top row is the splinted variant, bottom row the unsplinted variant.

The splinting effect also prevents excessive displacements of the implants, which in turn has a positive effect on concentrations of stress in bone (Fig. 6). The splinted variant shows only small areas with concentrations of minimum principal stress. The unsplinted variant, where the stiff implants were displaced into bone, shows large concentrations of stress at the implants' apices. The isolines on Fig. 6 also show the positive effect of splinting on reducing the stresses from flexion (bending).

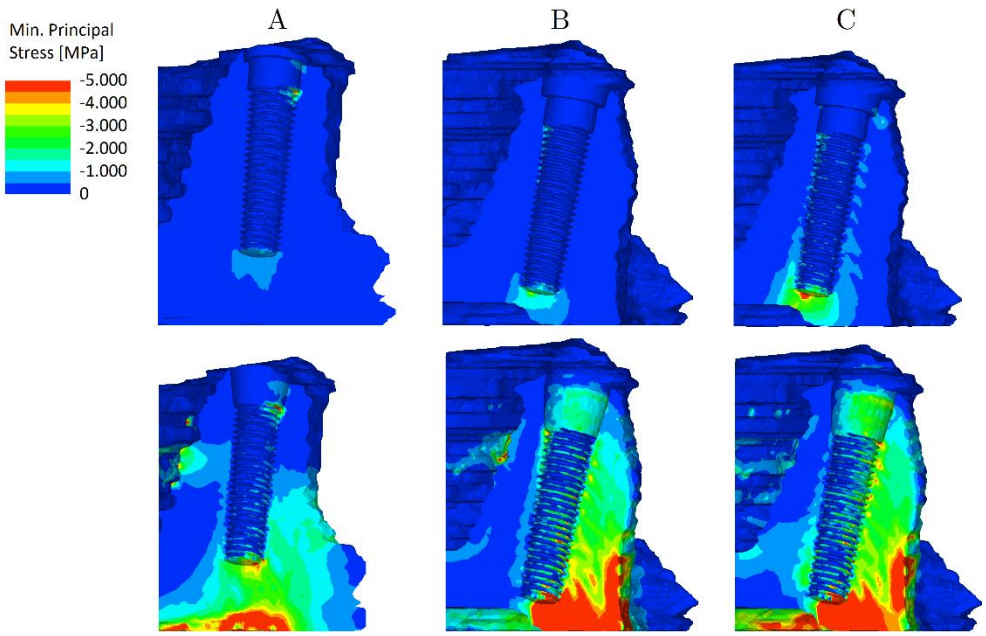

Fig. 6 Isolines of Minimum Principal Stress in bone for both analyzed variants. Column A—1st load case, column B—2nd load case, column C—3rd load case. Top row is the splinted variant, bottom row the unsplinted variant.

Conclusion/Summary

According to the results from the QCT/FEA analyses, the splinted variant shows smaller concentrations of stress in implants and more favorable stress distributions among all load cases. The splinting effect seems to have a positive effect in fixed implant-supported solutions for edentulous patients. This simulation was performed on an X-ray scan, which is arguably harder to work with (weaker imaging capabilities) than a CT scan but can still result in acceptable results if reconstructed properly. Models like these should always include the prosthesis as it provides additional stiffness and load redistribution which helps the unsplinted variant.

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