Numerical Evaluation of the Application of High Performance Polymers as a Framework Material in Dental Prosthetics

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Abstract. In the recent past, new high performance polymers have been introduced in dentistry as an alternative framework material for dental prosthetics. It was the aim of the presented numerical study to compare the loading behaviour of such a polymer with typical, classical materials with special respect to realistic biomechanical loading conditions. Finite-Element models of two different bridges - one placed on teeth, the other placed on implants - were created using different framework materials. Both models were created in two variations, a veneered bridge and a full anatomical bridge. These models were loaded with occlusal forces of up to 500 N, and resulting distribution of stresses and strains within the different models were compared. The restorations with polymer framework showed an increased deflection upon loading with on the same time decreased stresses. The veneered polymer frameworks showed areas of increased stresses in the veneering in the inter-dental regions. The determined loading behaviour of the full anatomical polymer bridges showed to be suitable for clinical application.

Introduction

In dentistry, there is currently a wide range of different framework materials available for creating dental bridges. Typically, materials like ceramics, precious and non-precious alloys are used for such frameworks of dental restorations. New advances in high performance polymers have led to the introduction of such materials as an alternative framework material. To analyse the potential benefit from such new materials and to predict their possible clinical outcome, it is necessary to compare these new materials with well-established and proven materials. Numerical methods offer one way to perform such an investigation and allow focusing on a small set of parameters in this comparison.

Aim

It was the aim of the presented study to determine the mechanical and biomechanical behaviour of dental bridges made of a recently introduced high performance polymer (polyether-ketone-ketone, Pekkton®, Cendres + Métaux SA, Switzerland) using numerical methods (finite element methods, FEM) and to compare these results with different well-established framework materials that are used for manufacturing dental bridges.

Material and Method

The FE models created were based on the 3D optical scans of two different bridges taken from clinical cases. The first bridge was a tooth-anchored three-unit bridge (second premolar to second molar), the second bridge was an implant-anchored four-unit bridge (first premolar to second molar). Separate scans were available for the tooth stumps (the abutments), the framework, and the veneered bridge. As the clinical root geometry for the teeth of the three-unit bridge was not available, it was instead placed on two teeth taken from a commercial 3D model of an idealised dental arch ("teeth with roots and gum", Viewpoint Data Labs [now Digimation], USA). The four-unit bridge was placed on the CAD data of the corresponding abutments and implants. The models consisted on the following components: framework, veneering, tooth (abutment), and cement layer between tooth (abutment) and framework. Additionally, a 0.2 mm thick layer of periodontal ligament was modelled around the roots of the teeth. The resulting models are shown in Fig. 1. Loads of up to 500 N [1] were applied on the central unit(s) of the bridges in an angle of 30° to the tooth (implant) axes using a spherical indenter.

The Framework material was varied to investigate the influence of the material on the loading behaviour. Following materials were simulated: Gold alloy (Young's Modulus 136 GPa), Titanium (110 GPa), two different Pekkton variants (4.4 and 10 GPa).

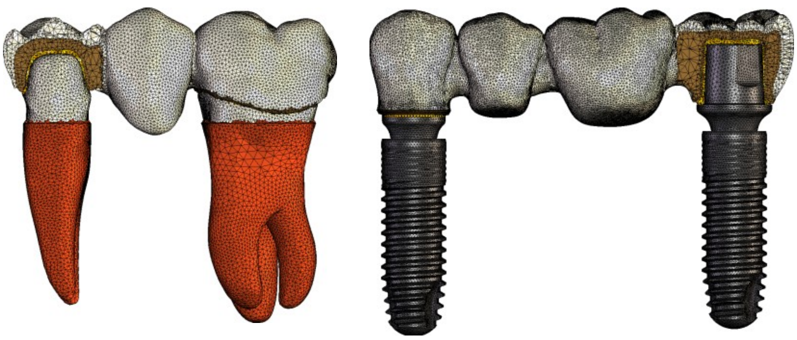

Fig. 1: FE models of the three-unit (left) and four-unit bridge (right). Part of the model is cut away to show the inner composition of cement, framework and veneering.

Results

Stresses in the frameworks were concentrated in the connections between the units (see Fig. 2). They decreased from about 200 MPa in the metal framework to 40 MPa in the polymer framework. At the same time, the deflection within the bridge (measured at the central unit) increased for the polymer framework (25 µm for a load of 500 N) compared to the metal frameworks (both 10 µm with 500 N). Due to the larger deformation in the polymer framework, stresses in the veneering increased as well compared to the veneering for the metal frameworks (70 and 10 MPa in the three-unit bridge, respectively; see Fig. 3). The variation of the framework material only had a minor influence on the load distribution in the surrounding biological tissue. Even higher stresses were determined in the veneering of the four-unit bridge (see Fig. 4).

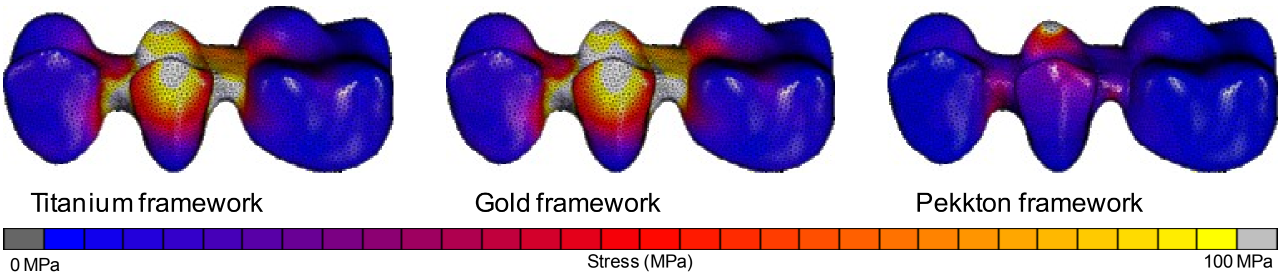

Fig. 2: Computed stresses in the framework of the three-unit bridges for a load of 500 N depending on the framework material.

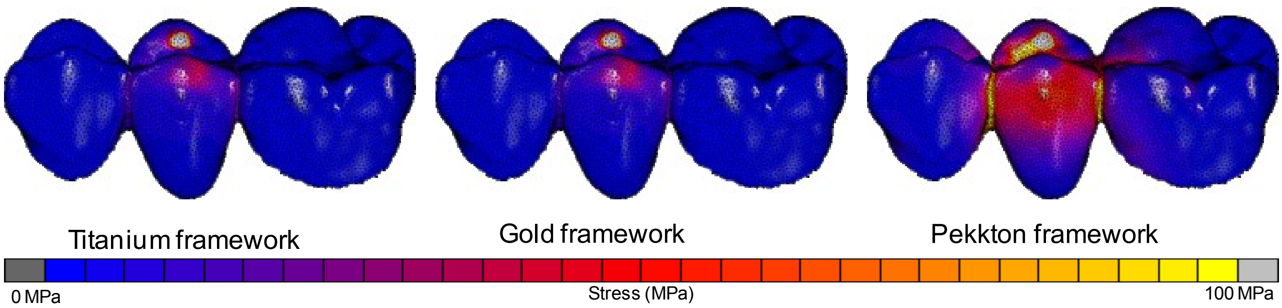

Fig. 3: Stresses in the veneering of the three-unit bridges for a load of 500 N depending on the framework material.

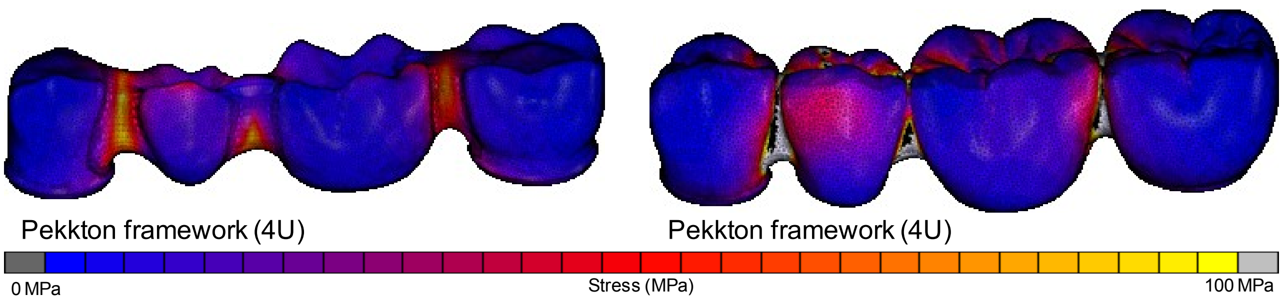

Fig. 4: Computed stresses in the framework (left) and the veneering (right) of the four-unit bridges with polymer framework for a load of 500 N.

Conclusions

The FE simulations show a prominent influence of the framework material on the distribution of stresses in the bridge. The polymer framework reduced the stresses in the framework itself, while the stresses in the veneering increased. In dental application this can be avoided by a reduced veneering placed only on the the lateral sides of the teeth. The framework material did not influence magnitude or distribution of stresses and strains in the surrounding biological tissues. Following this, the mechanical behaviour of this polymer allows its use as an alternative to the classic metal framework materials.

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References

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