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Research Article

Finite Element Study on: Cantilever Bridge Material Selection

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Abstract

Objectives: In this study, a cantilever bridge material selection was numerically investigated, by comparing total deformation and Von Mises stress maximum values and distributions on bone and bridge body.

Methods: One three-dimensional finite element model was created for the studied bridge by using 3D contact scanner. A model bridge with missing upper first bicuspid with a cantilever design where upper second bicuspid and first molar served as abutments was scanned. Porcelain Fused to Metal (PFM), Emax and Poly-Ether- Ketone-Ketone (PEKK) were tested as bridge materials. The cement layer of 40 micron was applied. The model was subjected to compressive vertical load of 100N applied at the central fossa of the pontic.

Results: Within the limitations of this research, the results showed acceptable deformation values except the case of PEKK Bridge. Emax bridge showed better performance than PFM one, that its higher elasticity enable absorb more energy from load.

Conclusion: PEKK as a pure material is not suitable for such cantilever bridge. Less rigid bridge material (within limits) may transfer less load to its beneath structures.

Keywords: *Cantilever; Bridge; Porcelain Fused to Metal; Emax; PEKK*

Introduction

The cantilever fixed dental prosthesis is defined as a prosthesis supported by retainer on an abutment from one end and the other end is extended freely without support [1-3]. They are indicated when there is contraindication to implant placement as in case of anatomical considerations regarding bone or other vital structures or due to cost or patient concerns. Retrospective studies for survival of cantilever fixed prostheses showed 93% survival after 5 years, 84.5% after 8 years and this was comparable to those of traditional fixed prostheses [4]. A meta-analysis stated that the survival rates were 82% over 10 years for cantilever fixed dental prostheses [3]. Only 63% were free from complications through the observation period. Metal ceramic cantilever fixed dental prostheses have proved its efficiency in the literature [5]. Lithium disilicate prostheses were tested before and produced less Von Misses stresses than metal ceramic ones [6].

However, PEEK might not be the optimal choice for dental applications where aesthetic and long-term structural properties are of primary importance. Because of its crystalline structure, PEEK's performance is limited and the complex manufacturing process needs fingertip accuracy. However, Pekkton, based on another member of the polyaryletherketone family, polyetherketoneketone (PEKK), has been specifically developed for dental applications. As a chameleon can adapt to its environment, Pekkton can be adapted to the different structural and processing requirements needed by dental laboratories.

Unlike PEEK, the Pekkton line offers crystalline as well as amorphous structures, which means a wider range of products can be offered. With the crystalline versions of Pekkton, products with improved mechanical properties, stiffness and chemical resistance can be obtained. Products made out of amorphous Pekkton, on the other hand, reach a higher flexibility and are easier to process. As a result, it is of great interest to dental technicians, who can now produce crown and bridge frameworks more simply.

Due to the ideal viscosity of the material and its large working temperature range, geometrically complex forms can be produced through casting and compressing the pieces under high temperatures. Thanks to lower shrinking rates during the cool-down process, it is possible to reach higher degrees of accuracy with Pekkton. In addition, when using crystalline Pekkton, crowns and bridges with a high chemical and mechanical resistance can be produced. However, the most important mechanical properties can be reached through reinforcing Pekkton with a large amount of fibres [2,13].

Aim of the Study

The aim of this study was to evaluate the effect of different manufacturing materials on the stress distribution in posterior three-unit cantilever dental prosthesis.

Materials and Methods

A 3D finite element model was constructed by 3D scanning a sample bridge (simulating fixed-free or cantilever partial denture). The bridge geometry was acquired by using 3D scanner (Roland Modela - model MDX-15 - Roland DG Corporation of Hamamatsu, Japan) and computer graphics program (Roland´s Dr. PICZA 3™ software), utilizing Roland Active Piezoelectric Sensor. Such scanner produced data file containing a cloud of points coordinates (See figure 1).

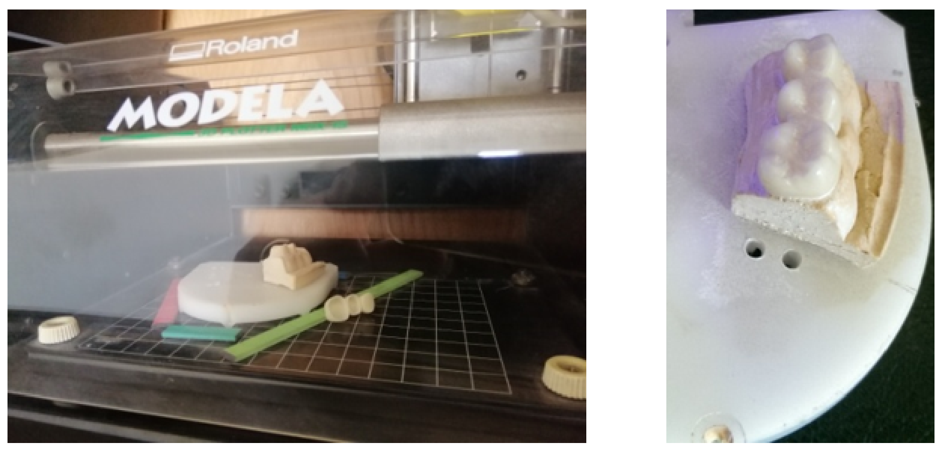

Figure 1: *Cantilever (Fixed-Free) tooth retained partial denture during scanning.*

An intermediate, software was required (Rhino 3.0 - McNeel inc., Seattle, WA, USA) to trim a newly created surface by the acquired points. Finally, the bridge outer surface was closed and filled from its bottom to generate volume representing solid bridge. Then, the solid bridge geometry was exported to finite element program as STEP file format. The same process was repeated for supporting bone and prepared teeth (abutments). Cement layer of 40 μm was created by scaling bone and abutments prior to using set of Boolean operations (subtract, cut, etc.) to keep the cement layer only [1,13].

All materials that used in this study were assumed to be homogenous, isotropic and to possess linear elasticity and its properties were listed in table 1. All the components (base, cement layer, partial denture) of the model were exported as STEP files and imported into finite element package ANSYS Workbench version 16 (ANSYS Inc., Canonsburg, PA, USA) to be assembled and analyzed.

Material	Young's modulus [MPa]	Poisson's ratio
Base: Dentin	18,600	0.31
Resin cement (Glass Ionomer)(40 μm Cement Layer)	12,000	0.25
Bridge Materials		
Porcelain Fused to Metal (PFM)EMax PEKK	149,450 91,000 5,100	0.34 0.23 0.40

***Table 1:** Material properties imported to the finite element program.*

The parabolic tetrahedral element was used meshing the model. The mesh density of model components is listed in table 2. Figure 2 illustrate the model of partial denture on ANSYS screen, while figure 3 showed meshed component.

	Nodes	Elements
Base: Dentin (Cortical and Spongy)	49,781	33,087
Cement layer (40 μm)	17,286	6,214
Bridge	599,207	416,126
Total	666,274	455,427

***Table 2:** The used mesh density.*

***Figure 2:** Partial denture component during assembly (ANSYS screen shots).*

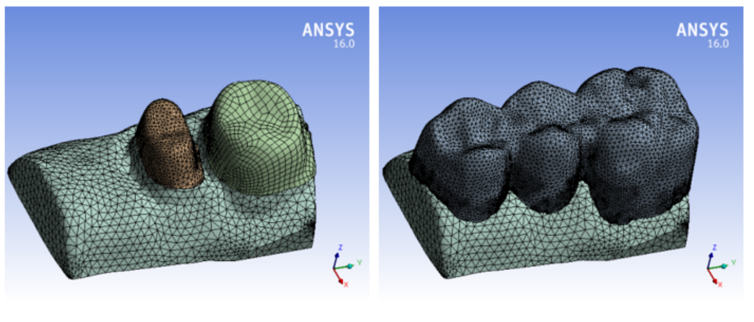

Figure 3: *Meshed Partial denture after assembly (ANSYS screen shots).*

The solid modeling and finite element analysis (linear static analysis) were performed on Workstation HP Z820, with Dual Intel Xeon E5-2660, 2.2 GHz processors, 64GB RAM. Three runs were performed, using three different bridge materials. A compressive load of 100 N was applied on the central fossa of the pontic, while the models base was fixed as a boundary condition.

Results

Total deformation locations did not change whatever the bridge material, while the values were altered. Pontic deformed downward showing maximum deformation on bridge, while maximum deformation appeared on cement layer and on the prepared tooth next to and towards pontic as illustrated in figure 4.

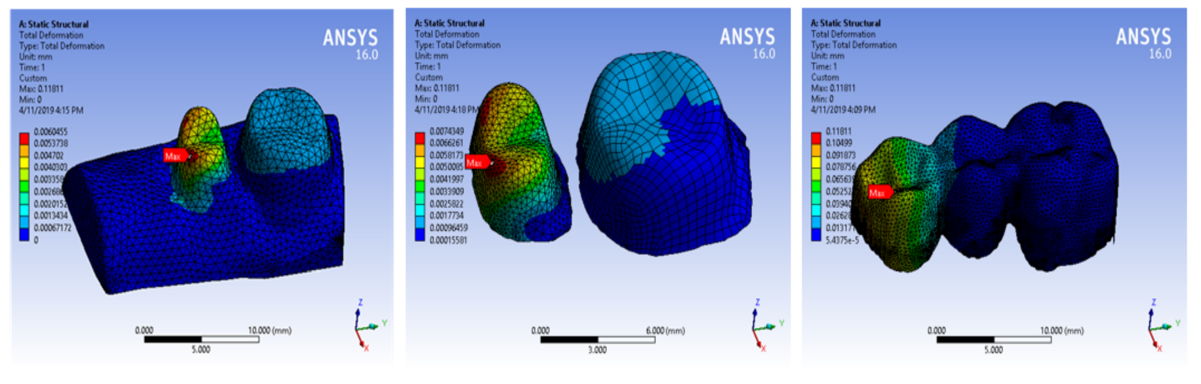

Figure 4: *Sample of total deformation distribution with PEKK bridge.*

The locations and values of maximum Von Mises stress in the three studied cases indicated that the most critical location is the finish line towards the pontic. Where bone and cement received maximum Von Mises stress (Figure 5), then the pontic connector to the other units of the bridge showed high stress values due to load bending effect.

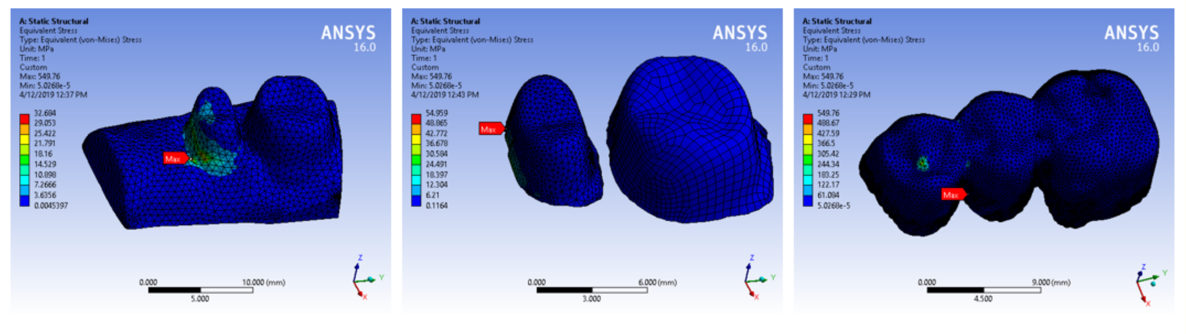

Figure 5: *Sample of Von Mises Stress distribution with Emax bridge.*

Comparing the obtained results with the three tested materials (Figure 6) showed that Emax bridge exert 5% less Von Mises stress on bone on bone in comparison to PFM bridge. On the other hand, cement layer received about 18% more Von Mises stress on bone on bone in comparison to PFM bridge. The highest stresses and deformation appeared with PEKK bridge.

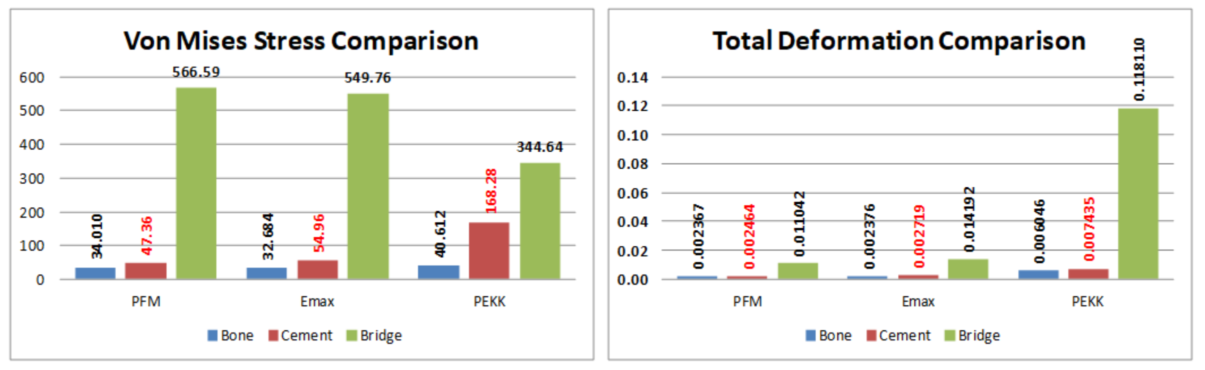

Figure 6: *Comparison between the three materials.*

Discussion

Cantilever fixed dental prostheses are considered now a predictable treatment option after clinical and radiographic assessment as stated by Roccuzzo., *et al.* in 2019, even if supported on dental implants [7].

For improving esthetics and longevity of fixed prostheses metal ceramic prostheses were developed as an alternative of resin veneered gold crowns [8]. Although wear of the opposing is a problem in this type of prostheses due to the hardness of the veneering ceramic.

To solve the problems of metal ceramic prostheses regarding esthetics, biocompatibility and other drawbacks, all ceramic materials were used.

Lithium disilicate all ceramic materials was used as an alternative all ceramic material for fixed dental prostheses, but in a study by Garling., *et al*. in 2019 it was found that the survival reached 48.6% after 10 years of use and 30.% after 15 years of use [9].

The results of this study showed that PEKK as a pure material is not suitable for such bridge [15]. While reinforce it with fiberglass or carbon fiber may improve its behavior. The fracture resistance of PEEK fixed dentures is more than those of lithium disilicate ones [10].

PFM and Emax results were within physiological limits, pointing out to recommending them for manufacturing this type of bridges. For lithium disilicate crowns a 15 year, survival rate of 81.9% has been reported [11].

Emax bridge is less rigid than PFM one, that indicated more load energy absorption and more deformation as appeared in figure 6. The percentage of stress reduction and the slight increase in deformation indicated the superiority of using Emax in such bridge design. Leucite ceramic cause more tooth deformation than lithium disilicate ceramic, the modulus of elasticity of lithium disilicate is more than leucite ceramic. The stiff material concentrate the stress inside itself so decreasing the transfer to the underlying structure [12].

Finish line (the facing part to pontic) should be carefully prepared to avoid stress concentration and failure [14].

Conclusion

Within the limitations of this in vitro study, it may be concluded that;

- PEKK as a pure material is not suitable for such cantilever bridge.
- Less rigid bridge material (within limits) may transfer less load to its beneath structures.
- Special care should be taken to finish line especially at the facing part to pontic.

Acknowledgement

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Ethical Approval

This research does not require ethical approval and followed the Helsinki declaration.

Conflict of Interest

The authors declare that they have no conflict of interest.

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