EC DENTAL SCIENCE
Research Article

Finite Element Study on Posterior Three-Unit Fixed Dental Prosthesis Made from Different Materials

Salah A Yousief[1,2]*, Jumanah Ateeq A Alsubhi[3], Wurayf Hassan A Tulbah[3], Maram Turky Abbas[3], Nusaybah Abbas Yamani[3], Haila Majed aljuhani[3], Suha saud alshammari[3], Manar Ghazi Almohnna[3], Njoud fahad almeniei[3], Ebtisam, Alghamdi[3], Ibrahim Alqurashi[3], Madawi Badr Alshalhoub[3], Yousef Jayar[3], Rami M Galal[4,5] and Mahmoud A Mekky[6]

[1]*Restorative Dentistry Department, AL-Farabi Dental College, Jeddah, Saudi Arabia*

[2]*Crown and Bridge Department, Faculty of Oral and Dental Medicine, Al Azhar University, Assuit Branch, Egypt*

[3]*Restorative Dentistry Department, King Khallid University, Abha, Saudi Arabia*

[4]*Fixed and Removable Prosthodontics Department, National Research Centre, Egypt*

[5]*Fixed Prosthodontics Department, Al Nahda University (NUB), Egypt*

[6]*Lecturer, Fixed Prosthodontics Department, Faculty of Oral and Dental Medicine, South Valley University, Egypt*

***Corresponding Author**: Salah A Yousief, Crown and Bridge Department, Faculty of Oral and Dental Medicine, Al Azhar University, Assuit Branch, Egypt.

Received: April 04, 2020; **Published:** May 14, 2020

Abstract

Objective: Numerically investigating different restorative materials effect on fixed dental prostheses stresses and deformation distributions on bone, cement, and prosthesis body.

Materials and Methods: Four different restorative materials; Porcelain Fused to Metal (PFM), Emax, Feldspathic porcelain and Poly-Ether-Ketone-Ketone (PEKK) were tested. A 3D finite element model was created by scanning plaster Model Bridge with missing maxillary first premolar. Mandibular bone augmented by two prepared abutments representing maxillary canine and second premolar. Compressive vertical load of 200N was applied at the central fossa of the pontic, while model base was fixed in place as boundary condition.

Results: Four linear static analyses were performed. Regardless the prosthesis material, maximum Von Mises stress was located on the abutment finishline towards the pontic. On the other hand maximum total deformation was found on abutment top towards the pontic.

Conclusion: Carful preparation of the finishline contact with fixed partial denture is a must to avoid stress concentration. Bone deformation and stresses were within physiological limits, while increasing fixed prosthesis material has slightly decreased bone stresses. Pure PEKK as fixed prosthesis material is not recommended due its high flexibility and deformation.

Keywords: *Finite Element Analysis; Fixed Dental Prosthesis; Porcelain Fused to Metal; Emax; Feldspathic Porcelain; PEKK*

Introduction

In cases where the patient is complaining from missing tooth with adjacent teeth with large fillings or crowns, it is a proper treatment option to use fixed dental prosthesis supported on these adjacent teeth [1]. There are different materials that can be used for the fabrication of tree-units fixed dental prosthesis. Till now, the most common is the porcelain fused to metal with 94% survival rate over 5 years [2]. However, many other options are available as monolithic zirconia, PEEK and glass infiltrated zirconia veneered with feldspathic porcelain [17]. PEEK has the advantage of less attrition to the opposing teeth [6]. Other options have lower survival rates as compared to traditional porcelain fused to metal as stated in a meta-analysis [2]. All ceramic materials can be prone to connector failure or chipping of the veneering material if it is veneered. Clinical studies have shown that veneered zirconia restorations are more prone to chipping than porcelain fused to metal ones [2,3]. As stated by recent review it was found that chipping decreased with some changes in the way of processing and design of substructure [4]. Now, there is monolithic zirconia, but accused to have more wear to the opposing natural tooth. But this has not been fully proven yet [5]. It is not enough to depend on parameters as the flexural strength and fracture toughness to judge a material survival rate or success.

Aim of the Study

The aim of this study is to numerically evaluate and compare, the fracture resistance of fixed dental prosthesis to recommend the most suitable material category.

Materials and Methods

3D scanning of a sample plaster bridge (simulating fixed dental prosthesis (FDP)) was used to build finite element model. 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).

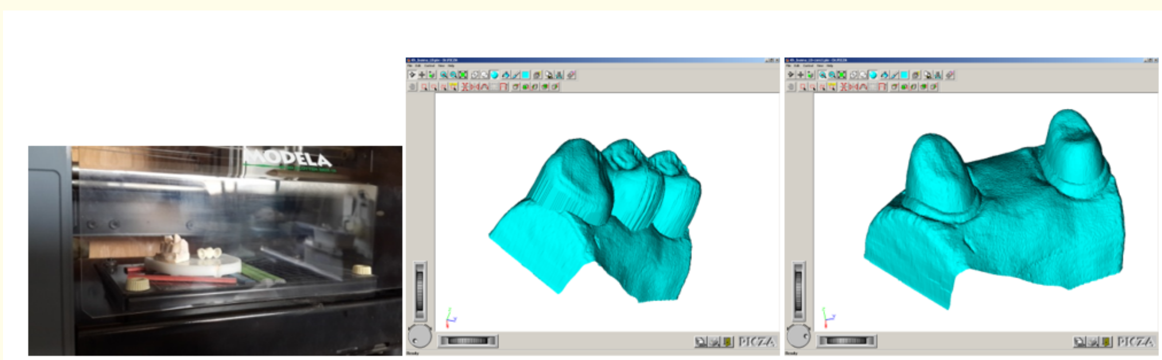

Figure 1: *Fixed-Fixed tooth retained partial denture during scanning.*

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 [16]. The same process was repeated for supporting bone and prepared teeth. Set of Boolean operations (subtract, cut... etc.) to keep prepared teeth cavity in bridge, while the cement layer was ignored.

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
Bone	18,600	0.31
Resin cement (Glass Ionomer) (40 µm Cement Layer)	12,000	0.25
Bridge Materials		
Porcelain Fused to Metal (PFM) Emax Feldspathic porcelain PEKK	149,450 91,000 69,000 5,100	0.34 0.23 0.30 0.40

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

The parabolic tetrahedral element was used for meshing the model, that mesh density of all model components is presented in table 2. Figure 2 illustrate the model components (meshed) on ANSYS screen.

	Nodes	Elements
Bone (Cortical and Spongy)	160,908	93,785
Cement	93,591	54,503
Bridge	58,240	28,971
Total	312,739	177,259

Table 2: *The used mesh density.*

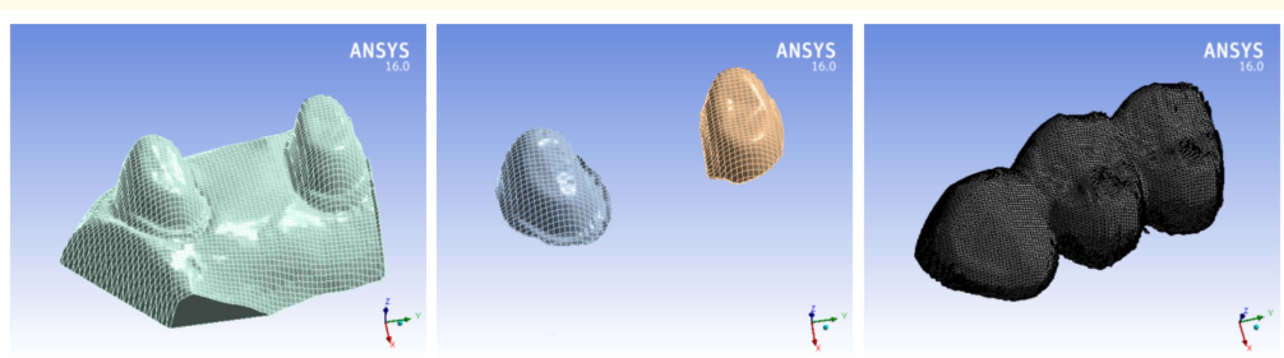

Figure 2: *Partial denture components and mesh (ANSYS screen shots).*

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 200 N was applied on the central fossa of the pontic, while the models base was fixed as a boundary condition.

Results

Feldspathic Porcelain bridge showed highest Von Mises stress on bone, while PEKK showed about 7% less value as the lowest case. Figure 3 and 4 illustrate the obtained results as; Von Mises stress distributions and total deformation distributions on model components in case of porcelain fused to metal and Feldspathic Porcelain bridge respectively. Von Mises stress and total deformation distributions did not show great differ between one bridge material to another, while the values slightly differed.

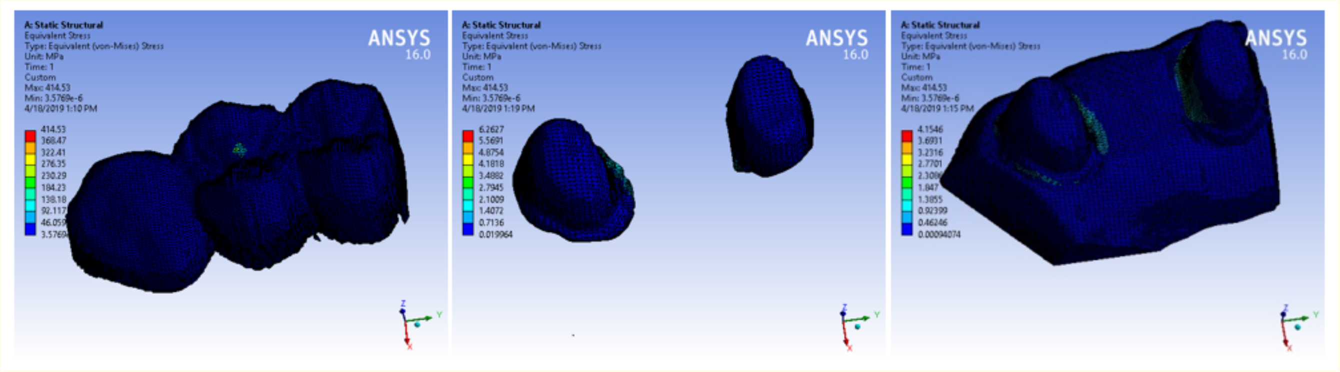

Figure 3: *Porcelain Fused to Metal bridge results (Von Mises stress).*

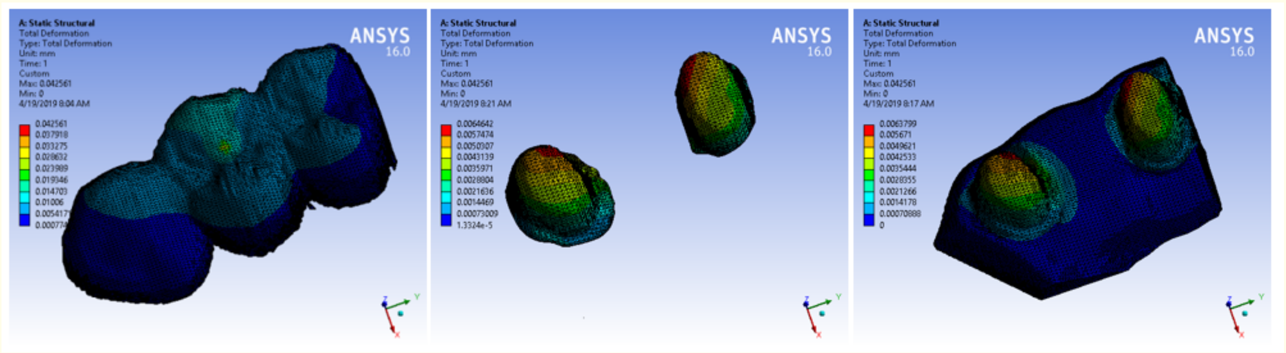

Figure 4: *Feldspathic Porcelain bridge results (total deformation).*

Moderate rigidity bridge materials (as Emax) showed best behavior with cement layer, as appear in results comparison in figure 5.

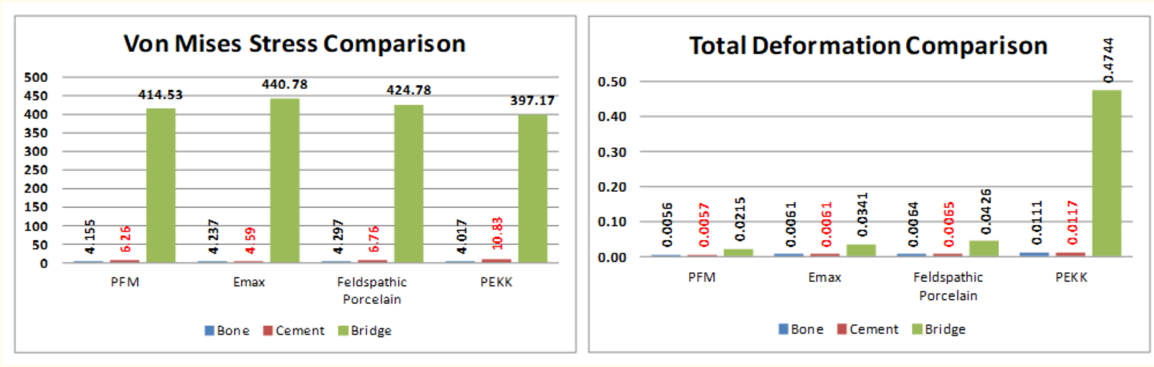

Figure 5: *Results comparison (maximum values of Von Mises stress and total deformation).*

The best behavior of bridge material was appeared with Porcelain Fused to Metal (PFM), followed by Emax, then Feldspathic porcelain. While, pure PEKK may not suitable for this application. Finishline towards pontic received the highest stresses on bone and cement layer, while zone under load showed maximum stress value on bridge body.

Discussion

Within this section PEKK was excluded from comparison as it receive very high Von Mises stress that indicating low life time. PEEK modified with nanometer zirconia has shown more wear resistance than PEEK. In contrary, Beuer., *et al*. stated that the fracture resistance of PEEK is more than that of zirconia and ceramics and that it can be easily modified by incorporating other constituents [9]. CAD CAM fabricated fixed dental prostheses showed more fracture resistance than conventional methods [10]. In another study it was found that frameworks made of PEEK showed very high patient acceptance [11].

Bone stresses were within physiological limits under all the tested bridge materials under the compressive load of 200 N. Bone was slightly affected to bridge materials, that extreme Von Mises stress difference did not exceed 7% and total deformation 20%. Porcelain Fused to Metal (highest rigidity) indicated the best behavior for bone. Some researchers found that the zirconia is less conductive to mechanical failure than metal ceramic [12]. No differences were observed between all ceramic and metal ceramic prostheses in terms of survival and bone loss as stated by Lemos., *et al*. in a systematic review in 2019 [18].

Where reducing bridge material rigidity increase bone deformation up to certain limit. More reduction of bridge material stiffness will completely change the deformation distribution and increase in bone deformation. Although it was found by Datte., *et al*. [13] in a finite element analysis and strain gauge study that increasing the elastic modulus of the prosthesis material reduces the stress concentration for bone.

Maximum Von Mises stress values appeared on bone finishline towards the pontic. This result matching El-Banna., *et al*. [8] that in two cases of missing tooth bridge restoration as cantilever or fixed-fixed bridge the finish line received the maximum stresses towards the missing tooth. Also Miura., *et al*. [14] in a finite element analysis found that the finish line has an effect on reducing the stresses, where they found that the deep chamfer finish line with curved internal angle showed less stresses than shoulder finishline when used with monolithic zirconia crowns.

Conclusion

Within the limitations of this study, the following conclusions can be drawn:

- Maximum values of Von Mises stress appeared at finish line towards pontic. Therefore, the highest possible care should be taken in preparing finishline for improving bridge performance.
- Bone deformation and stresses were within physiological limits, while increasing partial denture material has slightly decrease bone stresses.
- Pure PEKK as partial denture material is not recommended due its high flexibility and deformation.

Acknowledgement

Acknowledge is due to the Scientific Research Center of King Khalid University.

Ethical Approval

This research doesn't require ethical approval and followed the Helsinki declaration.

Conflict of Interest

There is no conflict of interest.

Bibliography

1. Da Silva JD., *et al*. "Outcomes of implants and restorations placed in general dental practices: a retrospective study by the Practitioners Engaged in Applied Research and Learning (PEARL) Network". *Journal of the American Dental Association* 145 (2014): 704-713.

2. Pjetursson BE., *et al*. "All-ceramic or metal-ceramic tooth-supported fixed dental prostheses (FDPs) a systematic review of the survival and complication rates. Part II: Multiple-unit FDPs". *Dental Materials* 31 (2015): 624-639.

3. Heintze SD and Rousson V. "Survival of zirconia- and metal-supported fixed dental prostheses: a systematic review". *The International Journal of Prosthodontics* 23 (2010): 493-502.

4. Anusavice KJ. "Standardizing failure, success, and survival decisions in clinical studies of ceramic and metal-ceramic fixed dental prostheses". *Dental Materials* 28 (2012): 102-111.

5. Stober T., *et al*. "Clinical assessment of enamel wear caused by monolithic zirconia crowns". *Journal of Oral Rehabilitation* 43 (2016): 621-629.

6. Lakshmana Bathala., *et al*. "The Role of Polyether Ether Ketone (Peek) in Dentistry - A Review". *Journal of Medicine and Life* 12.1 (2019): 5-9.

7. Heimer S., *et al*. "Surface properties of polyether ether ketone after different laboratory and chair side polishing protocols". *The Journal of Prosthetic Dentistry* 117 (2017): 419-425.

8. El-Banna KA., *et al*. "Fracture resistance of two all ceramic posterior fixed partial dentures designs: a finite element analysis". *Egyptian Dental Journal* 60.3 (2014): 3303-3312.

9. Beuer F., *et al*. "Load-bearing capacity of all-ceramic three-unit fixed partial dentures with different computer-aided design (CAD)/computer-aided manufacturing (CAM) fabricated framework materials". *European Journal of Oral Sciences* 116 (2008): 381-386.

10. Stawarczyk B., *et al*. "Three-unit reinforced polyetheretherketone composite FDPs: influence of fabrication method on load-bearing capacity and failure types". *Dental Materials Journal* 34 (2015): 7-12.

11. Sinha N., *et al*. "Versatility of PEEK as a fixed partial denture frame work". *The Journal of Indian Prosthodontic Society* 17 (2017): 80-83.

12. Tribst Joã PM., *et al*. "Short communication: Influence of restorative material and cement on the stress distribution of posterior resin-bonded fixed dental prostheses: 3D finite element analysis". *Journal of the Mechanical Behavior of Biomedical Materials* (2019).

13. Datte CE., *et al*. "Influence of different restorative materials on the stress distribution in dental implants". *Journal of Clinical and Experimental Dentistry* 10.5 (2018): e439-e444.

14. Miura S., *et al*. "Three dimensional finite element analysis of zirconia all ceramic cantilevered fixed partial dentures with different framework designs". *European Journal of Oral Sciences* 125 (2017): 208-214.

15. Attia MA. "Effect of Material Type on the Stress Distribution in Posterior Three-Unit Fixed Dental Prosthesis: A Three-Dimensional Finite Element Analysis". *Egyptian Dental Journal* 64.4 (2018).

16. Al Qahtani WMS and El-Anwar MI. "Advanced computational methods in Bio-Mechanics". *Open Access Macedonian Journal of Medical Sciences (OAMJMS).* 6.4 (2018): 742-746.

17. Al Qahtani WMS., *et al*. "Recent Advances in Material and Geometrical Modelling in Dental Applications". *Open Access Macedonian Journal of Medical Sciences* 6.6 (2018): 1138-1144.

18. Cleidiel Aparecido Araújo Lemos., *et al*. "Ceramic versus metal-ceramic implant-supported prostheses: A systematic review and meta-analysis". *Journal of Prosthetic Dentistry* 121 (2019): 879-86.

Volume 19 Issue 6 June 2020