Research Article

Oral Health & Dental Science

# Finite Element Study of Fracture Strength of Two Different Resin Bonded Bridge Designs

**Amr Touny Abbas[1*], Enas Fateh Elbab[1], Manal Rafie[1] and Mohamed Eldenary[2]**

*[1]Department of Fixed Prosthodontics, Minia University, Minia, Egypt.*

*[2]Department of Mechatronics, Faculty of Engineering, Minia University, Minia, Egypt.*

**[*]Correspondence:**
Amr Touny Abbas, Department of Fixed Prosthodontics, Minia University, Minia, Egypt, Tel: +1(979)422-2171; E-mail: dramrtouny@gmail.com.

**Received:** 20 October 2017; **Accepted:** 15 November 2017

**Citation:** Amr Touny Abbas, Enas Fateh Elbab, Manal Rafie, et al. Finite Element Study of Fracture Strength of Two Different Resin Bonded Bridge Designs. Oral Health Dental Sci. 2017; 1(1): 1-6.

## ABSTRACT

*Resin-bonded fixed dental prostheses had variable popularity since the technique for splinting mandibular anterior teeth with a perforated metal casting was described by Rochette. His work was then suggested as an alternative to conventional metal-ceramic fixed FDPs and its substantial removal of tooth structure needed to create strong, anatomically contoured, and esthetic restorations.*

*The most accepted design for resin bonded bridge is covering the maximum area of palatal or lingual surface of the abutment which give moderate fracture strength in low stress area like lateral incisor, in this research we tried to compare that conventional design for restoring upper lateral incisor with other more conservative one (by reducing the retainer size) that was proposed to enhance esthetic and fracture strength.*

*Finite element analysis (using solid work software) was used to compare fracture strength of three different restorative material used (PFM, IPS Empress &Vita In-Ceram zirconium) simulation of occlusal load on the pontic portion of the restoration (solid work was fed by all the individual properties to predict the behavior of the actual object).*

*This study proved that the fracture strength of the proposed conservative design may exceed that of the conventional design.*

## Keywords

Resin bonded bridge, Adhesive bridges, Modified resin bonded bridge.

## Introduction

In the past three decades, interest in resin-bonded fixed partial denture with partial coverage retainers has increased. This may be due to the fact that these prostheses are more conservative, require minimal tooth reduction, and preserve healthy tooth structure and the integrity of periodontal tissues, also for superior esthetic than some types of complete coverage restoration. This prosthesis may be preferable in restoring missing teeth in a young patient with large pulp for the reasons of pulpal and periodontal health preservations [1].

The most accepted design for resin bonded bridge is covering the maximum area of palatal or lingual surface of the abutment which gives moderate fracture strength in low stress area like lateral incisor [2].

During and since that period, design parameters have been enumerated and tested clinically, such designs, combined with new technologies for adhesive bonding of resin to most alloys, which have led to a simpler, more reliable prosthetic procedure that complements the dentist's prosthodontic armamentarium [3-5].

This paper aimed to compare that conventional design for restoring upper lateral with other more conservative one (by reducing the retainer size) that was proposed to enhance esthetic and fracture strength. Using Finite element analysis program to compare between the two designs Predicting how the bridge will react to real stresses with different materials of construction reducing the laboratory cost and time, the program works by breaking down the real object into large numbers of cubes. A used mathematic equation helped in the behavior prediction of such element [6].

## Methodology

Three-dimensional finite element models were constructed using Solid work office premium 2013, each model was restored by three materials; NiCr, All ceramic IPS Empress and Vita In-Ceram zirconia. The analysis was performed on laptop dell vostro, Intel Core I 3, processor 2.35 GHz, 4.0 GB RAM. Using the following steps with solid-work 2013.

### 1-3D drawing of the model component

Drawing the tooth was done in cylindrical manner from root portion to crown portion by drawing multiple nearly oval shapes arranged in parallel way spitted by top planes. then by lofting properties in solid program the 3D sketch was lofted to create the final 3D image of the desired tooth periodontal ligament was modeled around the tooth root. After creation of the upper canine and upper central using the extrude cut properties, cut the retainer shape on the abutment and recreate the lost part at the same time.

The retainer shape one was cut corresponding

**Model I:**

Preparation was confined to enamel only extending above the cervical line with 1 mm and below the incisal edge with 2 mm following the anatomical contour of the incisal edge 0.5 mm depth, for upper central the preparations extended from the middle third of distal surface to the palatal third of the mesial surface, while for upper canine extended from the middle third of mesial surface to the palatal third of the distal surface. One vertical proximal groove was placed parallel to the planned path of insertion in the distal surface of the upper central (1 mm incisally from the palatal cervical finishing line 3mm in length, 1mm in width and 0.5mm in depth) and mesial of upper canine (2 mm incisally from the palatal cervical finishing lines 3 mm in length, 2 mm in width and 0.5 mm in depth) [7].

**Model II:**

Preparation was just confined to the cingulum area above the cervical line with 1 mm for both upper central and upper canine0.7 mm in depth Two vertical proximal grooves were placed parallel to the planned path of insertion in the mesial and distal surfaces of the upper central and upper canine for upper central these grooves were positioned 2 mm incisally from the palatal cervical finishing lines and palatally from the most facial extent of the proximal tooth preparations 1 mm in length, 2 mm in width and 1 mm in depth, while for upper canine these grooves were positioned 3 mm incisally from the palatal cervical finishing lines 2 mm in length, 2 mm in width and 1 mm in depth. The cervical margins had definite chamfer finish line 0.7 mm in depth with no undercuts each model was exported as SLDASM files and imported into solid work simulation package to be meshed and analyzed.

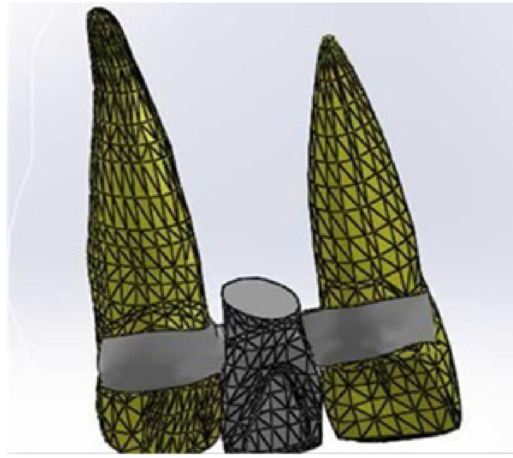

**Figure 1:** Model 1.

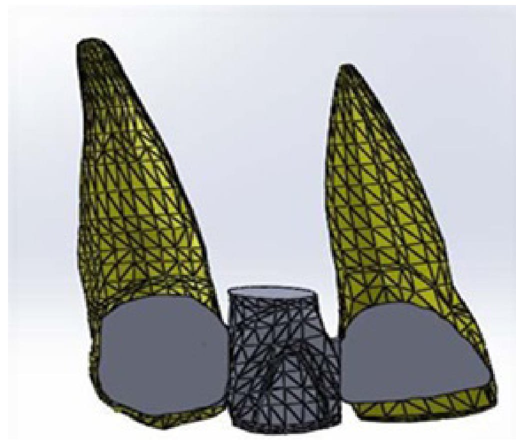

**Figure 2:** Model 2.

### Assembling of the component

Parts (retainers, pontic and abutments) of each model were joined into a solid part for model I and II.

| Material | Elastic modulus (gpa) | Young`s modulus (gpa) | Poisson's Ratio |
|---|---|---|---|
| Enamel | 84.1 | 384. | 0.33 [8] |
| Dentine | 18 | 18,6 | 0.31 [9] |
| Periodontium | 0.05 | - | 0.45 [8] |
| Ni–Cr alloys | 93 | 188 | 0.28 [9] |
| All ceramic IPS Empress | 65 | 45.1 | 0.26 [8] |
| Vita In-Ceram zirconia | 258 | 210 | 0.30 [10] |

**Table 1:** Defining of the material properties of each component.

### Defining the load

A Load of 200 N was applied to the palatal surface of the pontic subjecting the samples to compressive action [11].

### Meshing of the models

Meshing was completed in order to detect that no interferences between the 3D images are present (interferences affect the result) with help of interferences detector tool in the program, after that complete mesh was done and the information for the two models are presented in table 2.

| Mesh information | Model I | Model II |
|---|---|---|
| Mesh | High | High |
| Jacobian points | 4 points | 4 points |
| Minimum element size | 0.41 mm | 0.399 mm |
| Maximum element size | 2.1 mm | 1.99 mm |
| Number of element | 46803 | 11658 |
| Type of element | Tetrahedral | Tetrahedral |
| Number of nodes | 71461 | 19252 |

**Figure 3:** Roots as fixation point for model II.

# Results

## NiCr alloy Model I

Studying specific stress of von mises stress with displacement of NiCr model I (conventional design) which recorded for mesial retainer 92.04 N/mm$^2$, distal retainer 147.3 N/mm$^2$, mesial connector 253.3 N/mm$^2$, distal connector 257.3 N/mm$^2$ and for pontic 61.34 N/mm$^2$.

Overall stress founded to be Minimum 1.09852e-007 N/mm$^2$ on affected 36472 nods and maximum 3016.71 N/mm$^2$ on 50011 nods.

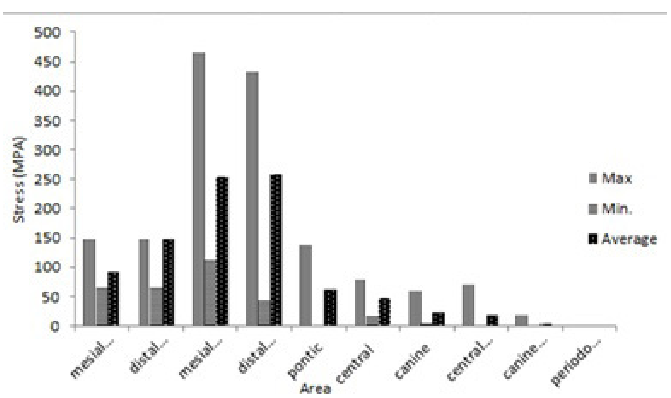


**Figure 4:** Comparison of von mises stress on each bridge components of NiCr model I.

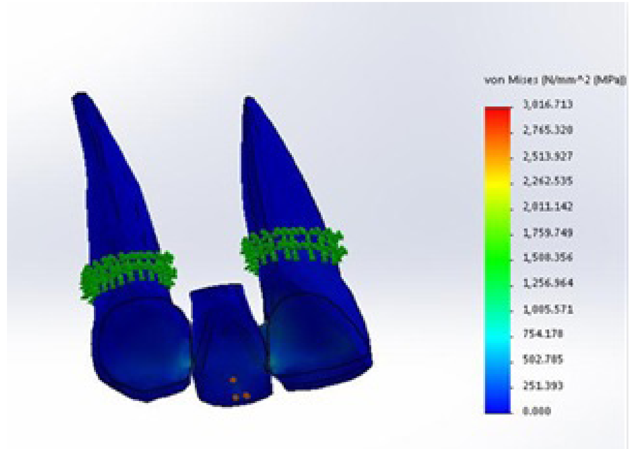


**Figure 5:** Model I Von mises stress of NiCr.

## IPS Empress Model I

Studying specific stress of von mises stress with displacement of IPS Empress Model I (conventional design) which recorded for mesial retainer 173.70 N/mm$^2$, mesial connector 144.98N/mm$^2$, distal retainer 134.90 N/mm$^2$, distal connector 203.28N/mm$^2$, and for pontic 48.02N/mm$^2$.

Over all stress founded to be minimum 3.00529e-007 N/mm$^2$ on affected 38414 nods and maximum 2974.75 N/mm$^2$ on 50011 nods.

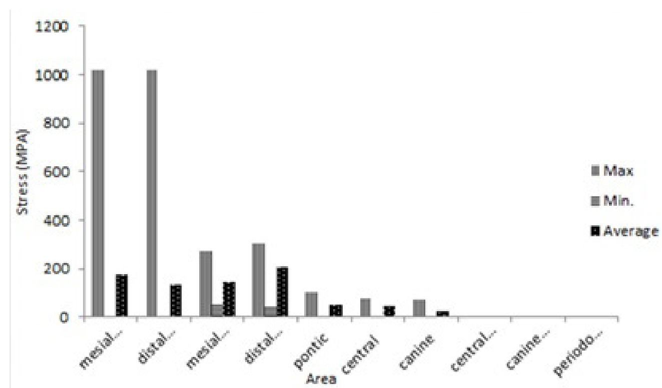


**Figure 6:** Comparison of von mises stress on each bridge components OF IPS Empress model I.

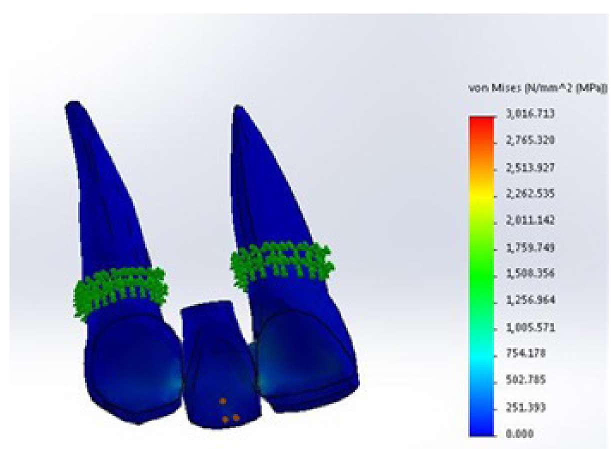


**Figure 7:** Von mises stress of IPS Empress Model I.

## In-Ceram zirconia model I

Studying specific stress of von mises stress with displacement of In-Ceram zirconia model I (conventional design) which recorded for mesial retainer 151.91 N/mm$^2$, mesial connector 253.87 N/mm$^2$, distal retainer 116.60 N/mm$^2$, distal connector 274.96 N/mm$^2$ and for pontic 63.87 N/mm$^2$.

Over all stress founded to be minimum 2.86253e-007 N/mm$^2$ on affected 27865 nods and maximum 3485.84 N/mm$^2$ on 50011 nods.

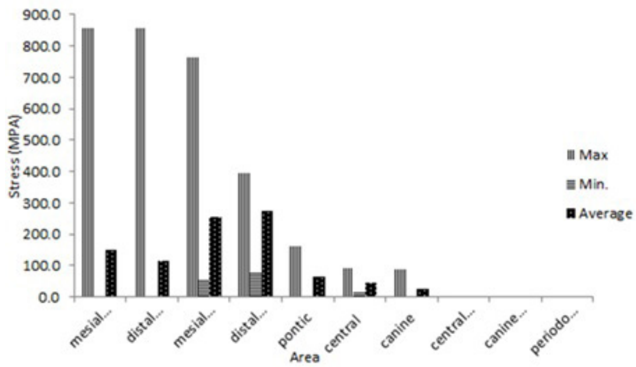


**Figure 8:** Comparison of von mises stress on each bridge components of In-Ceram zirconia model I.

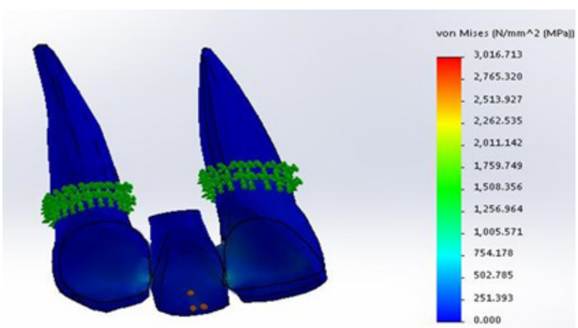


**Figure 9:** Von mises stress of In-Ceram zirconia model I.

## NiCr alloy model II

Studying specific stress of von mises stress with displacement of NiCr model II (conservative design) which recorded for distal retainer 474.98N/mm$^2$, mesial retainer 516.74 N/mm$^2$, mesial connector 212.28 N/mm$^2$, distal connector 1015.6 N/mm$^2$ and for pontic 59.71N/mm$^2$.

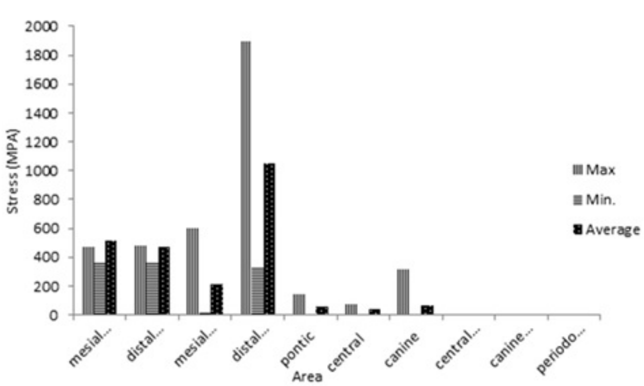


**Figure 10:** Comparison of von mises stress on each bridge components of NiCr model II.

Overall stress founded to be minimum 1.00412e-005 N/mm$^2$ on affected 7932 nods and maximum 2584.93 N/mm$^2$ on 10776 nods.

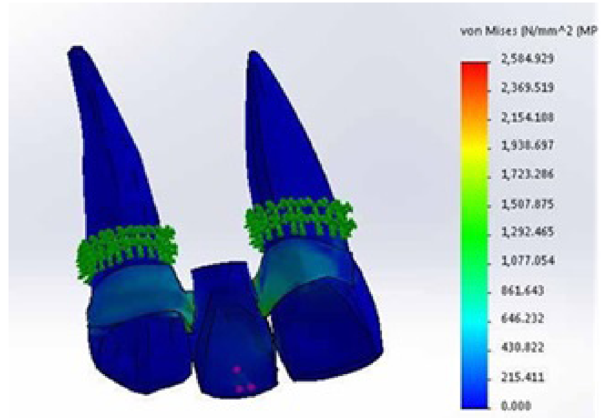


**Figure 11:** Von mises stress of NiCr model II.

## IPS Empress Model II

Studying specific stress of von mises stress with displacement IPS Empress of model II (conservative design) which recorded for distal retainer 504.80N/mm$^2$, distal connector 404.2N/mm$^2$, mesial retainer 457.03N/mm$^2$, and mesial connector 756.13N/mm$^2$ and for pontic 27.13 N/mm$^2$.

Over all stress founded to be minimum 3.66036e-006 N/mm$^2$ on affected 6532 nods and maximum 2664.72 N/mm$^2$ on 15767 nods.

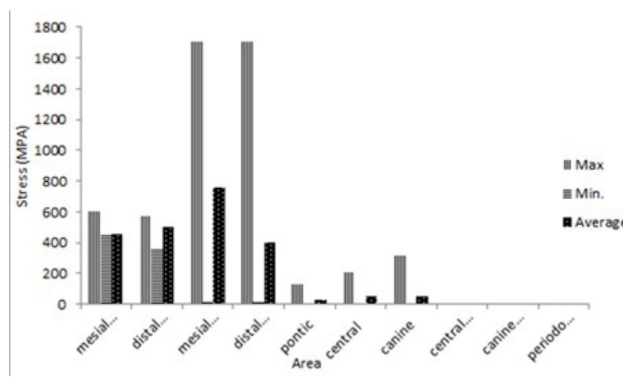


**Figure 12:** Comparison of von mises stress on each bridge components of IPS Empress model II.

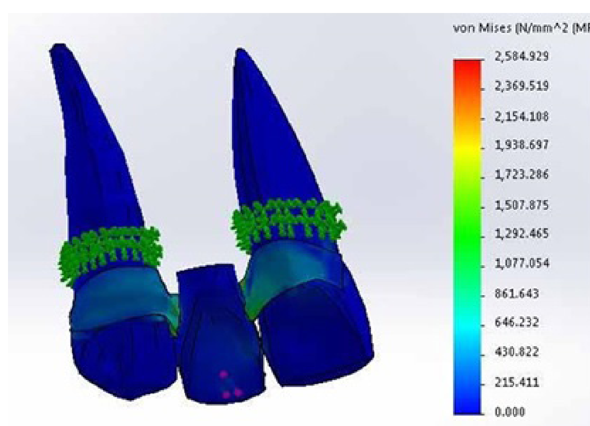


**Figure 13:** Von mises stress of IPS Empress model II.

### In-Ceram zirconia model II

Studying specific stress of von mises stress with displacement of In-Ceram zirconia model II (conservative design) which recorded for distal retainer 414.48N/mm$^2$, distal connector 542.4N/mm$^2$, mesial retainer 350.51N/mm$^2$, mesial connector 226.19N/mm$^2$, distal retainer 414.48N/mm$^2$, distal connector 542.4N/mm$^2$and for pontic 81.67 N/mm$^2$.

Over all stress founded to be minimum 2.45095e-006 N/mm$^2$ on affected 6531 nods and maximum 3143.14 N/mm$^2$ on 15767 nods.

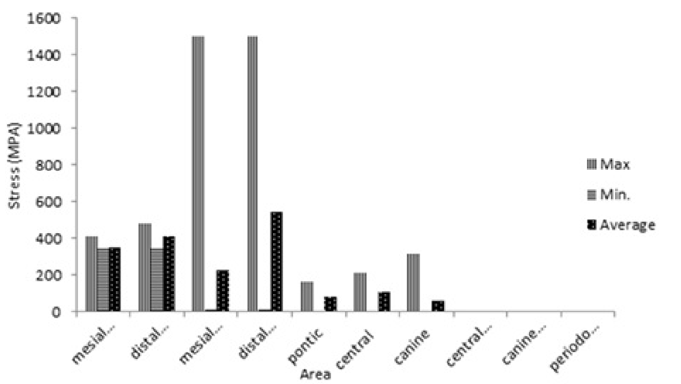


**Figure 14:** Comparison of von mises stress on each bridge components of In-Ceram.

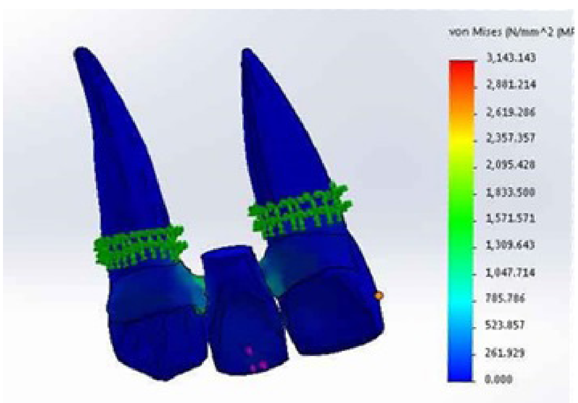


**Figure 15:** Von mises stress of In-Ceram zirconWia model II.

## Discussion

Results of IPS Empress showed increased stresses around mesial retainer and mesial connector in model II than model I also increase of stresses around distal retainer and distal connector than model I and decreased stress falling on the pontic in model II than model I Whereas In-ceram zirconia findings showed increased in stresses concentration around mesial retainer in model II than model I while mesial connector nearly the same in both models also increase of stresses around distal retainer and distal connector in model II than model I and decreased stress falling on the pontic in model I than model II.

Model I results showed increased stresses concentration on the mesial retainer in IPS Empress than zirconia and recorded lower stresses in NiCr, on mesial connector IPS Empress recorded lower value than zirconia and NiCr, distal retainer nearly the same in the three materials but in distal connector zirconia had higher stress concentration than NiCr while IPS Empress recorded the lower value and for pontic IPS Empress recorded the lowest value than zirconia and NiCr. Whereas model II recoded increase in stresses concentration on the mesial retainer in NiCr than IPS Empress and recorded lower stresses in zirconia, on mesial connector IPS Empress recorded much higher value than zirconia and NiCr, distal retainer nearly the same in the three materials but in distal connector NiCr had higher stress concentration than zirconia while IPS Empress recorded the lower value and for pontic IPS Empress recorded the lowest value than zirconia and NiCr. Abutments recorded nearly the same stress with the three materials excluding that stress increased on the central abutment in case of zirconia and root portion of IPS Empress retainers had higher stress than the other two materials with the same stress concentration on the periodontium.

Resin bonded fixed partial dentures using zirconia are assumed to improve the rigidity of all ceramic Resin bonded fixed partial dentures and allow them to reduce the distortion under functional load. In other words, a zirconia framework currently has the potential to reduce the amount of tooth reduction required to secure its rigidity, compared to a metal framework designed according to the traditional standard. The fact of reducing the amount of tooth preparation is considered to have high clinical significance for the application of zirconia resin bonded fixed partial dentures [12].

Study advisor in the solid work program gave solution to decrease stress falling on model II by increasing the depth of the retentive grooves and move its location to be more labially which was calculated to lower stress concentration to the half on the retainers.

From these results we noticed that decreases retainer size increase the stress concentration on the retainer near the connector area in model II than for model I and nearly stress falling on the pontic area equal.

This was in agreement with Ziada et al. [13], who reported that stresses concentrated on proximolingual areas, connector and near the connector, Ziada H. et al. [14] illustrated that stress magnitude at the proximolingual areas of the pontic in the 3-unit resin-bonded fixed partial denture. Also in agreement with Seto and Capeto [12], who clarified that adding grooves in horizontal matter related to the cingulum improves the retention and distribute the stresses to be concentrated on connector area.

However these findings were against Bhakta et al. [6] who reported that all the stress concentrated on the adhesive layer and The difference of the current study and these studies due to different experimental design as he studied cantilevered design, Fillip et al. [11] who concluded that all stress concentrated on tooth restoration complex and also disagree with Yurdukoru and Uçtaşli [16], who illustrated that increase force exerted on the supporting structure with reducing the preparation depth and this was due to different experimental conditions.

## Conclusions

Stress analysis result showed that all the stress the stresses concentrated on proximolingual areas connector, near the connector. Increase stress in model II within the retainer than model I while stress fallen on the abutments nearly the same

Within the limitation of this study;

- Conservative design had higher fracture strength than conventional one.
- Analysis result showed that all stress was concentrated on proximo- lingual areas, connector and near the connector.

## Recommendation

Retention Evaluation of the conservative design should be investigated before it`s clinical application.

## References


1. Chun li Lin, Kuang-Wei Hsu, Chun-Hsien Wu. Multi-factorial retainer design analysis of posterior resin-bonded fixed partial dentures: finite element study. Journal of Dentistry. 2005; 33: 611-620.
2. Klaus W Boening. Clinical performance of resin-bonded fixed partial dentures. J Prosthet Dent. 1996; 76: 39-44.
3. Rochette AL. Attachment of a splint to enamel of lower anterior teeth. The Journal of Prosthetic Dentistry. 2005; 30: 418-423.
4. Howe DF, Denehy GE. Anterior fixed partial dentures utilizing the acidetch technique and a cast metal framework. The Journal of Prosthetic Dentistry. 1977; 37: 28-31.
5. Livaditis GJ. Cast metal resin-bonded retainers for posterior teeth. The Journal of the American Dental Association. 1980; 101: 926-929.
6. Shashwat Bhakta, Richard van Noort George Cardew. Improved retention of anterior cantilever resin-bonded prostheses by design alteration: An experimental and finite element study. The Journal of Prosthetic Dentistry. 2006; 95: 209-217.
7. Shillingburg HT, Hobo S, Whitsett LD, et al. Fundamentals of Fixed Prosthodontics Third Edition chapter 23 Resin-Bonded Fixed Partial Dentures. Denial Prosthesis Design. WU 515 F331 1336.536-546.
8. Paul H DeHoff, Kenneth J, Anusavice Nils Götzen. Viscoelastic finite element analysis of an all-ceramic fixed partial denture. Journal of Biomechanics. 2006; 33: 40-43.
9. Lin CL, Hsu K, Wu CH. Multi-factorial retainer design analysis of posterior resin-bonded fixed partial dentures: a finite element study. Journal of Dentistry. 2005; 33: 611-620.
10. Salma M Fathy, Mohamed I El-Anwar, Abeer A El-Fallal, et al. Three-Dimensional Finite Element Analysis of Lower Molar Tooth Restored with Fully Milled and Layered Zirconia Crowns. Journal of Dental Health Oral Disorders & Therapy. 2014; 1.
11. Filip K, Niek DJ, Cornelis JK, et al. Influence of Retainer Design on Two-unit Cantilever Resin-bonded Glass Fiber Reinforced Composite Fixed Dental Prostheses: An In Vitro and Finite Element Analysis Study. Journal of Adhesive Dentistry. 2003; 10: 355- 364.
12. Zohra N, Gasmi IN, D Hadyaoui, et al. Resin-Bonded Fixed Partial Dentures: from Metal-Ceramic to Zirconia What Concerns?. Iraqi Dental Journal. 2014; 36.
13. Ziada HM, Benington IC, OrrJ F. Photoelastic stress analysis in resin bonded bridge design. European Journal of Prosthodontics and Restorative Dentistry. 1995; 3: 217-222.
14. Ziada HM, John F Orr, Benington IC. Photoelastic stress analysis in a pier retainer of an anterior resin-bonded fixed partial denture. The Journal of Prosthetic Dentistry. 1998; 80: 661-665.
15. Seto BG, Caputo AA. Photo elastic analysis of stresses in resin-bonded cingulum rest seats. The Journal of Prosthetic Dentistry. 1986; 56: 460-465.
16. Yurdukoru B, Uçtaşli S. Analysis of stresses in modified resin-bonded cast fixed partial dentures. Ankara Univ Hekim Fak Derg. 1990; 17: 91-98.