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

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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 [2].

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 3 mm in length, 1 mm in width and 0.5 mm 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 palatably 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.

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

<table>
<thead>
<tr>
<th>Material</th>
<th>Elastic modulus (gpa)</th>
<th>Young’s modulus (gpa)</th>
<th>Poisson’s Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enamel</td>
<td>84.1</td>
<td>384.</td>
<td>0.33 [8]</td>
</tr>
<tr>
<td>Dentine</td>
<td>18</td>
<td>18.6</td>
<td>0.31 [9]</td>
</tr>
<tr>
<td>Periodontium</td>
<td>0.05</td>
<td>-</td>
<td>0.45 [8]</td>
</tr>
<tr>
<td>Ni–Cr alloys</td>
<td>93</td>
<td>188</td>
<td>0.28 [9]</td>
</tr>
<tr>
<td>All ceramic IPS Empress</td>
<td>65</td>
<td>45.1</td>
<td>0.26 [8]</td>
</tr>
<tr>
<td>Vita In-Ceram zirconia</td>
<td>258</td>
<td>210</td>
<td>0.30 [10]</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Mesh information</th>
<th>Model I</th>
<th>Model II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesh</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Jacobian points</td>
<td>4 points</td>
<td>4 points</td>
</tr>
<tr>
<td>Minimum element size</td>
<td>0.41 mm</td>
<td>0.399 mm</td>
</tr>
<tr>
<td>Maximum element size</td>
<td>2.1 mm</td>
<td>1.99 mm</td>
</tr>
<tr>
<td>Number of element</td>
<td>46803</td>
<td>11658</td>
</tr>
<tr>
<td>Type of element</td>
<td>Tetrahedral</td>
<td>Tetrahedral</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>71461</td>
<td>19252</td>
</tr>
</tbody>
</table>

**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/mm², distal retainer 147.3 N/mm², mesial connector 253.3 N/mm², distal connector 257.3 N/mm² and for pontic 61.34 N/mm².

Overall stress founded to be Minimum 1.09852e-007 N/mm² on affected 36472 nods and maximum 3016.71 N/mm² on 50011 nods.

**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/mm², mesial connector 144.98N/mm², distal retainer 134.90 N/mm², distal connector 203.28N/mm², and for pontic 48.02N/mm².

Overall stress founded to be minimum 3.00529e-007 N/mm² on affected 38414 nods and maximum 2974.75 N/mm² on 50011 nods.

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

**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/mm², mesial connector 253.87 N/mm², distal retainer 116.60 N/mm², distal connector 274.96 N/mm² and for pontic 63.87 N/mm².

Over all stress founded to be minimum 2.86253e-007 N/mm² on affected 27865 nods and maximum 3485.84 N/mm² 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/mm², mesial retainer 516.74 N/mm², mesial connector 212.28 N/mm², distal connector 1015.6 N/mm² and for pontic 27.13 N/mm².

Over all stress founded to be minimum 1.00412e-005 N/mm² on affected 7932 nods and maximum 2584.93 N/mm² on 10776 nods.

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

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/mm², distal connector 404.2N/mm², mesial retainer 457.03N/mm², and mesial connector 756.13N/mm² and for pontic 27.13 N/mm².

Over all stress founded to be minimum 3.66036e-006 N/mm² on affected 6532 nods and maximum 2664.72 N/mm² 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/mm², distal connector 542.4N/mm², mesial retainer 350.51N/mm², mesial connector 226.19N/mm², distal retainer 414.48N/mm², distal connector 542.4N/mm² and for pontic 81.67 N/mm².

Over all stress founded to be minimum 2.45095e-006 N/mm² on affected 6531 nods and maximum 3143.14 N/mm² on 15767 nods.

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 recorded 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 Uçtaşılı [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

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