Fracture Resistance of 3-Unit Monolithic Zirconia Fixed Restorations Supported by three different substrates: A Comparative Study

Sadeq Al Tayyar, Walid Al-Zordk, Manal Abo Madina, Mohammed H. Ghazy

Abstract
Objectives: To evaluate the fracture resistance of monolithic zirconia fixed dental prostheses (FDPs) supported by implants, combined tooth-implant and teeth.

Materials and methods: Thirty partially edentulous mandibular epoxy resin casts were prepared at their posterior regions and divided into three equal groups (n=10) as the following: (group I) casts received two implants at second premolar and molar regions, (group T) casts with missing lower first molar. All the restorations were constructed from monolithic zirconia. All the samples were underwent thermomechanical load (TCML) (5,000 x 5/55°, 3 x 10⁵ x 98 N). Then subsequently loaded until fracture using universal testing machine. Fracture sites were evaluated macroscopically.

Results: Fracture strength for group I (1893.5±315.3N) significantly differed from group TI (1297.29±222.3N), (P = 0.034) with no significantly difference from group T (1640.56±587.8N), (p = 0.488). Fracture strength of group T was higher than those of group T1 with no statistically significant difference (p = 0.279).

Conclusion: The type of supportive abutments significantly affect the fracture resistance of monolithic zirconia FDPs. Connecting implants rigidly to teeth gives a comparable fracture strength results with those of teeth connected. Monolithic zirconia FDPs have the potential to withstand the occlusal loads applied in the posterior area.

Keywords: Fracture resistance, fixed prostheses, implant, tooth implant, monolithic zirconia.

Introduction
Yttrium-stabilized zirconia (Y-TZP) display outstanding mechanical properties together with high fracture strength as well as fracture toughness due to its transformation toughening phenomenon, it has a flexural strength that mainly varies from 900 to 1200 MPa and a fracture toughness of 9 to 10 MPa. Furthermore, zirconia is regarded as more biocompatible than other materials: ceramics, titanium, or metal alloys, which may enable a healthy as well as aesthetic soft tissue response. Y-TZP has been commonly used as a substitute to other materials for dental applications for instance bilayered crowns, FPDs supported either by natural teeth or dental implants or even a combination of implants and natural teeth, full anatomic monolithic zirconia crowns and FPDs, implant abutments, and screw-retained implant infrastructures.

Numerous studies have presented that zirconia has adequate strength to function as framework for posterior FPDs. This polycrystalline ceramic exhibits superior mechanical properties, biocompatibility, and simplicity of manufacture using CAD/CAM technology. Nevertheless, an early subject takes place was a chipping of the veneering ceramic which was stated in a various researches. It was manifest in the literature that, the zirconia framework infrequently underwent any fracture due to its high strength, its ‘transformation toughening’ phenomenon in addition to its relatively high fracture toughness and flexural strength making zirconia the strongest among all dental ceramics obtainable nowadays.

To evade the problem of ceramic veneer chipping and gaining the benefits of zirconia’s strength, the idea of constructing a prosthesis made of completely zirconia (monolithic zirconia reconstructions) material was approached eliminating the veneering ceramic and depending on stains and glaze layering in different colors for achievement of esthetic appearance. Full contour zirconia applications have been immense in the dental arena, involving single as well as multiple unit restorations, abutments and full arch implant retained restorations. Among the general methods that commonly used to evaluate the mechanical properties of dental ceramic involve; flexural strength, fracture toughness, Vickers hardness and fracture resistance utilizing a universal testing machine.

many in vitro studies were performed to evaluate the fracture resistance of monolithic zirconia single crown. A few data regarding fracture resistance of monolithic zirconia fixed restorations has been reported yet. Thus, this study aimed to evaluate the fracture resistance of implant-supported, tooth implant supported and comparing them with tooth supported fixed monolithic zirconia restorations. The null hypothesis to be tested was that in terms of fracture resistance there are no differences between the treatment options either using implant-supported, tooth-implant supported or teeth-supported fixed monolithic zirconia restorations.

Material and methods
I. Preparation of the models
For the construction of the laboratory models, Nissan typodont cast (Kilgore Nissin Dental Typodont Model India) was used, additional silicon and vacuum formed template indies were taken as a references for the amount of tooth reduction. Then, the teeth were manually prepared using low speed dental hand piece (DMY SKI 301 A, China) according to manufactures guiding principle with chamfer preparation of 1 mm, axial reduction of 1-1.5 mm and occlusal reduction of 2 mm and verified with previously mentioned indices. and from which 30 an epoxy resin cast (Exst 50- Egyptian Swiss For Manufacturing And Egyptian Swiss For Manufacturing And...
Trading 6 October Egypt were duplicated using additional silicon impression material \textsuperscript{17} (Betasil, (heavy-body and light-body) Muller-Omicon GmbH & Co KG Germany) and then prepared to simulate clinical conditions for a three unit FDPs as follows:

- **Group I:** Ten epoxy resin cast with twenty implants of 10 mm length and 4 mm width (Neo Biotech Co., Ltd Korea) were embedded at a distance of 11 mm in both the premolar and molar regions. A load of 10 kg, which is equivalent to 98 N of chewing force was exerted. The test was repeated 30000 times for clinical simulation of 2.6 years chewing condition. All samples were cemented to an epoxy resin casts for further verification. Finally the implants fixtures were screwed into implant abutment represented that, implant supported FDPs group display high fracture strength with statistical significant difference \((P < 0.05)\) than tooth supported FDPs group. The level of significant difference was found, Post Hoc (Tukey HSD) test for comparing between the groups. When a statistical difference was assessed by Kolmogorov-Smirnov test. One way analysis of variance (ANOVA) was used for comparing between the study groups each one to another. The level of significant difference was set at \(\leq 0.05\) for all statistical analysis and confidence interval at 95% (95% CI).

**Results**

All the aged FDPs were survived without any observable defects. The data were collected, tabulated and then analyzed. The mean values and standard deviations of fracture resistance for each group were recorded. One way ANOVA test for fracture resistance between study groups represented statistical significant difference \((P = 0.042, 0.034)\). Post Hoc (Tukey HSD) test for checking the individual variation between FDPs supported by different supportive abutment represented that, implant supported FDPs group display high fracture strength with statistical significant difference \((P = 0.048)\) than teeth supported FDPs group. The specimens were embedded in Teflon housing and fixed to the lower sample holder. A load of 10 kg, which is equivalent to 98 N of chewing force was exerted. The test was repeated 30000 times for clinical simulation of 2.6 years chewing condition. All samples were cemented to an epoxy resin casts for further verification. Finally the implants fixtures were screwed into implant abutment represented that, implant supported FDPs group display high fracture strength with statistical significant difference \((P = 0.042, 0.034)\). Post Hoc (Tukey HSD) test for checking the individual variation between FDPs supported by different supportive abutment represented that, implant supported FDPs group display high fracture strength with statistical significant difference \((P < 0.05)\) than teeth supported FDPs group. The level of significant difference was found, Post Hoc (Tukey HSD) test for comparing between the groups. When a statistical difference was assessed by Kolmogorov-Smirnov test. One way analysis of variance (ANOVA) was used for comparing between the study groups each one to another. The level of significant difference was set at \(\leq 0.05\) for all statistical analysis and confidence interval at 95% (95% CI). The load required to fracture was recorded in Newton.

**Statistical analysis**

By using SPSS software (version 23 SPSS Inc., Chicago, Ill., USA); the normality of the distribution was assessed by Kolmogorov-Smirnov test. One way analysis of variance (ANOVA) was used for comparing between the groups. When a statistical difference was found, Post Hoc (Tukey HSD) Tests were used for multiple comparisons between study groups each one to another. The level of significant difference was set at \(\leq 0.05\) for all statistical analysis and confidence interval at 95% (95% CI). The load required to fracture was recorded in Newton.

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The space between the abutments in the cast model was 1.5 mm as recommended by manufacturer in addition to the bone analog material (approximately 20 GPa). 

In this study, the cast models were constructed from an epoxy resin material and the teeth were prepared as this material has an appropriate modulus of elasticity close to the bone analog material (approximately 20 GPa). 

The fracture mode of the tested FDPs 

Table 1: One way ANOVA test for fracture resistance between study groups

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>1253447.3</td>
<td>2</td>
<td>626723.7</td>
<td>3.8</td>
<td>.042</td>
</tr>
<tr>
<td>Within Groups</td>
<td>2965532.8</td>
<td>18</td>
<td>164751.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4218980.1</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P significant at ≤ 0.05

Fracture mode of the tested FDPs

Most damages occurred near the point of loading and the fracture lines ran buccal or basal to across one of the connectors in all the samples of study groups.

Discussion

In-vitro studies were carried out mostly to overcome the limitations of clinical short term evaluation, difficult of repeatability and standardization of the clinical study.

In this study, the cast models were constructed from an epoxy resin material and the teeth were prepared as this material has an appropriate modulus of elasticity close to the bone analog material (approximately 20 GPa). 

The space between the abutments in the cast model was 11 mm as previous study by Chaa et al who declare that, span length of clinical models representative a missing first molar equal to 11 mm length. 

Posterior edentulous region represent one of the frequent indications for the dental treatment in mandible as well as maxilla.

Though implant retained FDPs are one of the treatment option for posterior free distal extension area, lack of the space or implant failure to integrate may lead to the using of tooth-implant connection.

Monolithic zirconia FDPs were used in this study as they have markedly superior fracture resistance, superior chipping and flexural fracture resistance relative to their veneered counterparts. From both radial cracking and chipping manners, Zirconia-based ceramic monoliths have the greater resistance to failure than those of lithium disilicate glass-ceramics, but still less esthetic.

The thickness of the fabricated monolithic zirconia FDPs was 1-1.5mm as recommended by manufacturer in addition to the bone analog material (approximately 20 GPa).

In the present study, oral environment simulation all the samples were subjected to an artificial aging process. Studies reported that average of the masticatory loads range from 50 to 250 N. 

In this study a cyclic loading force of 98 N with a total number of 300000 cycles were applied to simulate clinical situation for 2.5 years. Thermocycling conventionally used to simulate the thermal changes occurring in the oral cavity during eating, drinking, or breathing. It was performed between 5 and 55°C. This range has already been applied in other studies.

In our study, after the artificial aging process, all tested groups exhibited minimal fracture resistance greater than those of natural maximum biting forces in the posterior area. The fracture resistance that recorded was more than 500 N, which is measured to be the minor level of fracture strength that accepted for FPDs in the posterior area. When comparing the different supportive abutments with the same superstructure zirconia monolithic FDPs we have that the type of supportive abutments exposed a significant effect on the fracture resistance of the zirconia. The maximal fracture strength was recorded for the implants supported followed by teeth supported then interconnected tooth implant retained group.

The results of the current study were settled by Kolbeck and co-workers who tested the impacts of different abutment support on the load-bearing capacity of 3-unit zirconia FPDs and concluded that interconnected tooth implant retained restorations display lower load-bearing capacity than those of tooth-retained prosthesis. In their studies results that performed by Vult von Steyern el al and Sarafidou et al were partially analogous to our current results as they presented that implant retained prosthesis showed the maximal load-bearing capacity, the differences in their studies were that, combined implant-tooth supported restorations exhibited the highest load-bearing capacity than teeth supported restorations. Though there were differences between our study and these two studies, they are in accordance that interconnected tooth implant retained FPDs endure higher loads than the average of biting forces and therefore possibly used for clinical applications.

The results of the current study were also in agreement with Sarafidou et al who found that, implant-supported restorations were exhibited the highest load-bearing capacity than teeth supported and tooth-implant supported fixed restorations. In addition, after ageing process implant-tooth-supported prosthesis display a sufficient load-bearing capacity to be used clinically. results of the present study were also in accordance with Kolbeck et al who demonstrated that, teeth-supported FPDs showed the higher fracture force than tooth-implant supported fixed restorations. However, Fracture strength of tooth-tooth- and implant-tooth retained all-ceramic FDPs showed sufficient fracture resistance for posterior regions.

The current study results were in agreement with Alkhrar et al who declared that. The fracture strength of implant-retained FPDs were however, higher than those of combined tooth-implant retained FPDs, clinical use of their seems to be justified. The results of this study were in contradiction with Al-Wahadheit et al who found that, the bridges supported by mixed implant-tooth abutments showed highest fracture loads than that supported by implant abutments only and than those supported entirely by natural teeth. Our results were also in contradiction with Nothdurft et al who examined 3-unit bridge placed on a combined implant-tooth and free standing implant-supported FPDs.
with all ceramic abutments and presented that the higher of failure strength was recorded for the combined implant-tooth retained FPDs than those for free standing implant-retained group.

Conclusions

Within the limitation of this study, the following conclusions could be drawn

1- Monolithic zirconia FPDs have the potential to resist the occlusal loads applied in the posterior area.
2- The fracture strength of monolithic zirconia FPDs was affected by the type of supportive abutment, through which the implants supported FDPs group display the highest fracture strength followed by teeth supported then interconnected tooth implant supported FDPs.

References


