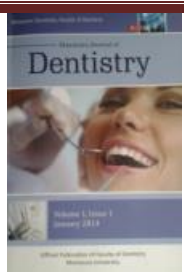
Fracture Resistance of Maxillary Premolar Teeth Restored with Bulk Fill Resin Composite: In-vitro Study



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Abstract:

Aim of the study: To evaluate the fracture resistance of maxillary premolar teeth with MOD cavities restored with different bulk fill resin composite systems *In-vitro*.

Materials and methods: Seventy maxillary premolars were selected and divided into seven groups n=10. The first group was left intact and considered as positive control group (In). Class II MOD cavities were prepared in the remaining groups. The second group was left prepared unrestored and considered as negative control group (Un). Five different resin composite systems were to restore the cavities. The first one was incremental fill resin composite Z350 XT (ZX) and the third group was considered as control group. The remaining resin composite systems were of bulk fill type and were as follow: Tetric® N Ceram Bulk-Fill (TB), Filtek Bulk Fill (FB), SonicFill2™ (SF) and Reveal® HD Bulk (RV). All the groups were thermocycled (Robota, Egypt) for 5000 cycles. Fracture resistance test was performed immediately after thermal aging process by (Instron 3345, Canton, MA, USA). Fracture patterns were examined under stereomicroscope and recorded. Samples for each fracture pattern were examined under SEM. Data was tabulated then analyzed using One-way analysis of variance (ANOVA) followed by t-test in order to determine significant differences among groups (P= 0.05).

Results: There was no statistical significant difference (P≤ 0.05) between FB, SF groups. On the other hand, there was a significant difference between In, Un, ZX, TB, RV groups (p= 0.0001). Additionally, there was a significant difference between (FB, SF) groups and the remaining groups (p= 0.0001).

Conclusion: Based on the current study, both incremental-fill and bulk-fill resin composite systems did not restore the fracture resistance of the sound teeth. However, the use of bulk fill resin composite (Tetric N Ceram) has a positive effect on the fracture resistance of the maxillary premolar. On the other hand, the other bulk fill resin composites showed comparable fracture resistance values with incremental-fill resin composite systems.

Keywords: Fracture resistance, bulk fill resin composite, class II, maxillary premolars.

Introduction

Over the last years, the improvements of the restorative materials and techniques in adhesive dentistry results in reinforcement of weakened dental tissue.[8] Mesioocclusodistal (MOD) cavity preparation reduces the tooth resistance to fracture as a result of the loss of marginal ridges and microfractures caused by applied occlusal loads.[3] Occlusally applied loads may force cusps apart and in teeth with wide Class II cavities, a fracture of the cusps occurs as a result of fatigue of the brittle tooth structure by propagation of microcracks under repeated loading.[9]

Teeth with wide class II cavities restored with dental amalgam have frequently shown cuspal fracture as a result of the inability of this material to reinforce the weakened cusps.[16] Bell and others[2] showed that large MOD cavities filled with dental amalgam usually develops cuspal fracture because cracks are propagated under functional occlusal forces. Thus, teeth with large cavities are usually restored with onlays instead of inlays, because when a significant amount of the tooth structure is lost, there is an increased susceptibility to cuspal fracture. Although the onlay restoration procedure provides a tooth-strengthening effect but at the same time it results in additional sacrificing of the tooth structure during its preparation and therefore loss of conservation.[8]

Resin composite have been used in posterior teeth since the 1960s. The fracture resistance of teeth had been improved greatly after the introduction of resin composites because it has the ability to strengthen the remaining dental tissue as a result of bonding to the tooth structure.[23] The clinical performance of the recently introduced dental composites has been significantly inhanced over the last few years to gain adequate strength and resistance in order to withstand the forces of mastication and provide less polymerization shrinkage and better curing depth. Nevertheless, the relatively increased brittleness and decreased fracture strength of the recent dental composites still a major problem in stress-bearing posterior restorations.[14]

Polymerization shrinkage of dental composite materials can result in deformability of the surrounding tooth structure resulting in microcracks which predispose the tooth to fracture.[12] In contrast to incremental filling technique, if the preparation is bulk-filled with a single composite increment, the resulting high C-factor can further increase shrinkage stress.[17] However, the manufacturers have introduced these new bulk fill resin composite technologies to overcome the complexity and time consuming procedure of incrementally fill resin composite. They made a lot of modifications in composition of bulk fill resin composites. The introduction of stress relievers results in reduction of the polymerization

shrinkage stresses to 1.13 MPa and shrinkage volume to 1.9%.[25] Bulk fill resin composites can achieve high internal adaptation to the cavity walls and floor due to its smooth and creamy consistency eliminating the need for a liner. The good internal adaptation, marginal integrity, and low polymerization shrinkage can affect and reduce the tooth deformation, postoperative sensitivity, and microleakage.[24]

Fracture resistance is one of the most important characteristics of dental materials. It depends on material resistance to crack propagation from its internal defects. These cracks can result in microscopic fractures of the restoration margins or bulk fracture of the filling.[5] Some authors[1, 15, 19, 20] reported no significant differences in fracture resistance between teeth restored with bulk fill resin composite or incremental fill resin composite. However, others[21] have contrasting opinions.

Several factors could affect the durability of the restorations in the oral cavity; mechanical factor, pH, bacteria, moisture, fracture resistance and loading factor. Tooth fracture has been appeared as a huge problem in dentistry and is one of the most common causes of tooth loss.[10] For the aforementioned reasons, this study is conducted to compare the fracture resistance of maxillary premolars when restored with bulk fill and incremental fill resin composites.

Materials and Methods:

Five different resin composite restorative systems were used in the current study. Each resin composite restorative material was used with its manufacture recommended etchant and adhesive. The resin composite restorative systems which used in this study were as follow: an incremental-fill resin composite;Z350 XT/ Single Bond Universal (ZX), Four different bulk-fill resin composite systems; Filtek Bulk Fill/ Single Bond Universal (FB), Tetric® N Ceram Bulk-Fill/Tetric® N Bond Universal (TB), SonicFill2™ /Opti Bond™ Universal (SF) and Reveal® HD Bulk/ All Bond Universal® (RV). Two devices were used in this study. The first one was Demi™ Ultra LED Curing Light System /Kerr; Orange, CA, the second device was SonicFill™ Handpeice/ Kerr; CA, USA.

1-Cavity preparation:

The mounted teeth were divided into seven groups (n=10). The first group was left intact and considered a positive control group (In). Silicon indices were taken to the occlusal surfaces of the remaining teeth. The second group were left prepared unrestored and considered a negative control group (Un). For the remaining 50 teeth, an occlusal stamp was taken using flowable resin composite. A standardized MOD cavity were prepared in groups from 2 to 7 using straight fissure diamond with copious air-water cooling. The cavity preparation dimensions were as follow: the pulpal depth was 2.5mm and the buccoligual width was one third of the cuspid distance. No proximal axial steps were prepared for accurate standardization. The same periodontal probe was used to measure the occlusal depth and buccolingual width.

2-Teeth grouping and Restorative procedure:

Group In: Intact teeth (positive control)
Group Un: Prepared unrestored teeth (negative control)
Group ZX: Prepared teeth and restored with ZX (control)
Group TB: Prepared teeth and restored with TB
Group FB: Prepared teeth and restored with FB
Group SF: Prepared teeth and restored with SF
Group RV: Prepared teeth and restored with RV

After completing all the cavity preparations, the prepared teeth were divided randomly into six groups (n=10). Group Un was left without any restorations. Selective etching for the enamel was done for 15 seconds then copious rinsing with air/water spray for 30 seconds. After that, drying was performed with oil free air. The adhesive was applied to the cavities then cured for 10 seconds. The restorative procedure was performed using pre-contoured Tofflemire matrices. The cavities were filled by bulk fill technique. Before curing, a piece of Teflon tap was applied over the occlusal surface and the occlusal stamp was reseated over the occlusal surface to reproduce the exact occlusal anatomy of the tooth that were existing before cavity preparation. The occlusal stamp was removed, and initial curing was done for 5 seconds before removal of the Teflon tap. After that, curing was completed for 15 seconds.

3- Fracture resistance test:

All the teeth were stored in distilled water at room temperature for 5 days until the time of testing. All the specimens were subjected to thermal cycling treatment in a thermal cycling machine for 5000 cycles between 5°C ±2 and 55°C ±2, with a dwell time of 20 second and transfer time of 5 seconds to simulate six months aging.[13] The fracture resistance test was performed within 24 hours after thermal cycling by a universal testing machine which makes a compressive axial loading delivered by a metal sphere of 8mm diameter which comes in contact with the palatal slopes of the buccal cusp and buccal slopes of the palatal cusp at a crosshead speed of 0.5mm/min. This compressive axial loading was increased until the specimen fractures and the load required to fracture the specimens were recorded in Newton(N).

4-Statistical analysis:

The collected data were tabulated and then analyzed statistically by using IBM SPSS software program (SPSS™ Software, V.20, IBM, NY, USA). Quantitative data were described using mean, standard deviation after testing normality using Kolmogorov-Smirnov test. Significance of the obtained results was judged at 5% level. One-way ANOVA test: for normally quantitative variables, to compare between more than two groups with t test to detect within groups significance.

Results

Means and standard deviations of fracture resistance for all groups are shown in table 4. A graphical presentation of these results presented in figure 21. One-way ANOVA test: for normally quantitative values, to compare between more than two groups with t test to detect within groups significance ($p \leq 0.05$).

The one-way ANOVA test showed that cavity preparation significantly affects the fracture resistance of premolar teeth (p=0.0001). Restoration of prepared teeth with resin composite significantly increase the fracture

resistance of maxillary premolar teeth (*p=0.0001*) .Fracture resistance of the prepared maxillary premolar teeth greatly improved by resin composite restorations (*p=0.0001*). Comparing means of fracture resistance of all the restored groups with different resin composite systems, the one-way ANOVA test showed that there were statistically significant differences between all the restored groups (*p=0.0001*).

Regarding the bulk fill groups, there were statistically significant differences between their means of fracture resistance (*p=0.0001*). TB group had the highest mean fracture resistance value (704.58 ±174.04 N) among the restored groups while RV recorded the lowest mean fracture resistance value (442.78 ± 120.17 N). On the other hand, no statistically significant difference was found between FB and SF (*p≤0.05*). The sequence of fracture resistance records as follow: In > TB > ZX > SF > FB > RV > Un at level of significance (*p= 0.0001)*.

Groups	N	Mean (Newton)	SD
In	10	1510.35[a]	52.13
Un	10	205.41[e]	16.13
ZX	10	575.79[c]	112.44
TB	10	704.58[b]	174.04
FB	10	508.81[cd]	121.75
SF	10	521.42[cd]	144.68
RV	10	442.78[d]	120.17
LSD	104.72		
P value	0.0001		

Means and standard deviations of fracture resistance for different Gs

The final state after completing finishing and polishing procedure after 24 hours.

The final state after completing finishing and polishing procedure after 24 hours.

Discussion:

In the current *in-vitro* study, we compared the fracture resistance of maxillary premolar teeth restored with different bulk fill resin composite systems TB, FB, SF and RV and one incremental composite resin system ZX. The null hypothesis which stated that there is no significant difference in fracture resistance of maxillary premolar teeth with MOD cavities restored with bulk fill or incremental fill resin composite systems was partially accepted since there are a Bulk fill group showing higher fracture resistance value than incremental fill group and other groups showing lower fracture resistance value compared with incremental fill resin composite.

The results also showed that the fracture resistance of sound teeth was higher than all the restored groups indicating the impossibility of the direct resin composite restorations to regain the fracture resistance of sound teeth. This may be due to the large MOD cavity preparations used in this study. This result is with the agreement of Atalay et al.[1] and Santos et al.[7] who verified partial reinforcement of teeth restored with resin composite compared with intact teeth. On the other hand, Dalpino and others[8] and de Freitas and others[6] reported no significant difference in fracture resistance between intact teeth and teeth restored with composite resin. The discrepancy between the results of our study and those of Dalpino and others[8] and de Freitas and others[6] probably lies

in differences in experimental conditions. In their other, smaller preparations and more conservative restorative procedures were used. In our study, diverse factors with potential to weaken the remaining dental structure were employed, i.e., large MOD cavities and no axial walls.

The results of fracture resistance test revealed that TB composite group had significantly higher fracture resistance value compared with all the remaining groups restored with bulk fill and incremental fill resin composite and this may be contributed to the minimal polymerization shrinkage stresses due to the presence of shrinkage stress relivers which is a filler functionalized with saline. These stress relivers acts as a microscopic spring which neutralizes the forces generated during shrinkage. It also contains pre-polymerized fillers which results in decrease its modulus of elasticity[4] and increases its fracture resistance. In addition, the presence of Ivocerin which is described as germanium-based photo initiator increases the depth of cure of TB to 4.5mm and therefore results in sufficient polymerization and degree of conversion with increased mechanical properties.[11] A study conducted by Rauber et al.[20] agreed with results of the current study which stated that TB is characterized by particles with a low modulus of elasticity, which act neutralizing the forces of contraction during polymerization, ensuring a proper adaptation of the restoration material to cavity walls even in 4 mm increments and increase its fatigue resistance. De Asis et al.[22] disagreed with the current study results and they stated that the fracture resistance will not be affected by the type of resin composite either bulk fill or incremental fill.

The results of fracture resistance test showed that there is no significant difference found between FB and SF composite group and this may be due to the low polymerization shrinkage stresses of FB due to the presence of new monomers called 1,12-dodecane dimethacrylate (DDDMA) that relief the stresses and reduce it to a valuable degree. In addition, DDDMA provides flexibility, fast cure, and improved surface characteristics to the polymer matrix, which are suitable properties for bulk fill resin composites. A study conducted by Atalay et al.[1] agreed with the current study where they found that the fracture resistance of FB was high and they explained that by the lower polymerization shrinkage of FB compared with conventional resin composite. Another study by Rosatto et al. [21] agreed with the current study where he stated that bulk-fill filling techniques resulted in lower cusp strain, shrinkage stress and higher fracture resistance. The fracture resistance of FB was lower than that of ZX which may be due to the increased level of thermal expansion for FB during thermal cycling. Despite the higher inorganic filler content and the reduction in the amount of resin matrix of FB, they exhibited significantly higher thermal expansion compared with the other conventional resin composites which may be related to the type of matrix resin, surface treatment of the fillers and the size of filler particles.

SF group showed lower fracture resistance values compared with ZX group and this result might be due to the lower mechanical properties of SF compared with ZX. This result is with the agreement of Leprince et al.[18] who stated that the mechanical properties of the bulk-fill composites mostly lower compared with the conventional high viscosity material. Another reason for the low fracture resistance of SF compared with ZX may be due to the void formation during placement of SF which occurs as a result of changes in resin composite rheological properties (reduced viscosity under sonication) from that originally provided by the manufacturers. These voids are potential loci of stress concentration and may act as initiation points for fracture and crack propagation, reducing mechanical strength and fracture resistance. This also might explain the predominant adhesive failure within the SF group where these voids were present at the interface which results in reduction of the bond strength between composite and an adhesive system.

Conclusions

Based on the results of the present study and within its limitations, the following conclusions can be assumed:

- Extensive MOD cavity preparations greatly deteriorate the fracture resistance of maxillary premolars.
- Tetric N Ceram Bulk fill resin composite showed the highest fracture resistance value among all the other resin composite systems.
- The other types of bulk fill resin composites showed comparable fracture resistance values with incremental-fill resin composite systems.
- Both incremental-fill and bulk-fill resin composite systems doesn't provide fracture resistance near that of sound teeth.

References

1. Atalay C, Yazici A, Horuztepe A, Nagas E, Ertan A, Ozgunaltay G. Fracture resistance of endodontically treated teeth restored with bulk fill, bulk fill flowable, fiber-reinforced, and conventional resin composite. Operative dentistry. 2016;41(5):E131-E40.

2. Bell J, Smith M, De Pont J. Cuspal failures of MOD restored teeth. Australian Dental Journal. 1982;27(5):283-7.

3. Bhardwaj T, Solmon P, Parameswaran A. Tooth restored with composite resin-a comparative analysis. Trends in Biomaterials and Artificial Organs. 2002;15(2):57-60.

4. Blackham J, Vandewalle K, Lien W. Properties of hybrid resin composite systems containing prepolymerized filler particles. Operative dentistry. 2009;34(6):697-702.

5. Bonilla ED, Mardirossian G, Caputo AA. Fracture toughness of posterior resin composites. Quintessence international. 2001;32(3).

6. Buainain de Freitas CR, Serra Miranda MI, Ferrarezi de Andrade M, Flores O, Humberto V, Geraldo Vaz L, et al. Resistance to maxillary premolar fractures after restoration of Class II preparations with resin composite or ceromer. Quintessence international. 2002;33(8).

7. Coelho Santos MJM, Bezerra RB. Fracture resistance of maxillary premolars restored with direct and indirect adhesive techniques. Journal of the Canadian Dental Association. 2005;71(8).
8. Dalpino P, Francischone CE, Ishikiriama A, Franco EB. Fracture resistance of teeth directly and indirectly restored with composite resin and indirectly restored with ceramic materials. American Journal of Dentistry. 2002;15(6):389-94.
9. Eakle W. Fracture resistance of teeth restored with class II bonded composite resin. Journal of Dental Research. 1986;65(2):149-53.
10. Ellis S, McCord J, Burke F. Predisposing and contributing factors for complete and incomplete tooth fractures. Dental update. 1999;26(4):150-8.
11. Fabio Antonio Piola RIZZANTE JAD, Marco Antônio Húngaro DUARTE,, Rafael Francisco Lia MONDELLI GMaSKI. Polymerization shrinkage, microhardness and depth of cure of bulk fill resin composites. Dental Materials Journal. 2019.
12. Franca F, Worschech CC, Paulillo L, Martins L, Lovadino J. Fracture resistance of premolar teeth restored with different filling techniques. J Contemp Dent Pract. 2005;6(3):62-9.
13. Gale M, Darvell B. Thermal cycling procedures for laboratory testing of dental restorations. Journal of dentistry. 1999;27(2):89-99.
14. Garoushi S, Tanner J, Vallittu P, Lassila L. Preliminary clinical evaluation of short fiber-reinforced composite resin in posterior teeth: 12-months report. The open dentistry journal. 2012;6:41.
15. Hegde V, Sali A. Fracture resistance of posterior teeth restored with high-viscosity bulk-fill resin composites in comparison to the incremental placement technique. Journal of Conservative Dentistry. 2017;20(5):360-4.
16. Hürmüzlü F, Kİremİtçİ A, Serper A, Altundaşar E, Sİso ŞH. Fracture resistance of endodontically treated premolars restored with ormocer and packable composite. Journal of Endodontics. 2003;29(12):838-40.
17. Jackson RD, Morgan M. THE NEW POSTERIOR RESINS AND: A SIMPLIFIED PLACEMENT TECHNIQUE. The Journal of the American Dental Association. 2000;131(3):375-83.
18. Leprince JG, Palin WM, Vanacker J, Sabbagh J, Devaux J, Leloup G. Physico-mechanical characteristics of commercially available bulk-fill composites. Journal of dentistry. 2014;42(8):993-1000.
19. Mincik J, Urban D, Timkova S, Urban R. Fracture Resistance of Endodontically Treated Maxillary Premolars Restored by Various Direct Filling Materials: An In Vitro Study. International Journal of Biomaterials. 2016;2016:5.
20. Rauber GB, Bernardon JK, Vieira LCC, Maia HP, Horn F, Roesler CRdM. In vitro fatigue resistance of teeth restored with bulk fill versus conventional composite resin. Brazilian dental journal. 2016;27(4):452-7.
21. Rosatto C, Bicalho A, Veríssimo C, Bragança G, Rodrigues M, Tantbirojn D, et al. Mechanical properties, shrinkage stress, cuspal strain and fracture resistance of molars restored with bulk-fill composites and incremental filling technique. Journal of dentistry. 2015;43(12):1519-28.
22. Silva de Assis F, Lima L, Nogueira S, Rodrigues Tonetto M, Bhandi SH, Souza Pinto SC, et al. Evaluation of Bond Strength, Marginal Integrity, and Fracture Strength of Bulk-vs Incrementally-filled Restorations. Journal of Adhesive Dentistry. 2016;18(4).
23. Siso Ş, Hürmüzlü F, Turgut M, Altundaşar E, Serper A, Er K. Fracture resistance of the buccal cusps of root filled maxillary premolar teeth restored with various techniques. International Endodontic Journal. 2007;40(3):161-8.
24. Vasquez D. A New-Generation Bulk-Fill composite for Direct Posterior Restorations. Inside dentistry. 2012;8(5):1-4.
25. Vivadent I. TetricEvoCeram® Bulk Fill: The bulk composite without compromises. Scientific Documentation Schaan, Liechtenstein. 2013.