ISSN: 2573-8224

Research Article

Journal of Oral & Dental Health

Evaluation of Fracture Resistance in Maxillary Premolar Teeth Restored with Different Direct Composite Restorative Materials

Ahmed Adel Abdelaziz[1]* and Hebatallah Ahmed Saleh[2]

[1]Associate Professor, Conservative Dentistry Department, Faculty of Oral and Dental Medicine, Badr University in Cairo (BUC), Egypt

[2]Lecturer, Conservative Dentistry Department, Faculty of Dentistry, Cairo University, Egypt

***Corresponding author**
Ahmed Adel Abdelaziz, Associate Professor, Conservative Dentistry Department, Faculty of Oral and Dental Medicine, Badr University in Cairo (BUC), Egypt.

Submitted: 2023 Jan 02; **Accepted:** 2023 Jan 26; **Published:** 2023 Jan 31

Citation: Abdelaziz, A.A., Saleh, H.A. (2023). Evaluation of Fracture Resistance in Maxillary Premolar Teeth Restored with Different Direct Composite Restorative Materials. *J Oral Dent Health, 7*(1), 01-07.

Abstract

Purpose: *This study was conducted to evaluate the effect of three direct resin composite restorative materials on fracture resistance in mesio-occluso-distal (MOD) cavities prepared in maxillary premolars.*

Materials and Methods: *A total of 25 maxillary premolars were collected and then divided into five main groups (n=5). Group 1 (positive control group): sound teeth with no cavity preparation. Group 2 (negative control group): MOD cavities with no restoration. Group 3: MOD cavities restored with nanocomposite FILTEK™ Z350 XT Group 4: MOD cavities restored with simplified universal composite OptiShade™ and Group 5: MOD cavities restored with universal nano-filled composite Estelite® Sigma Quick.*

Results: *Group 5 showed the maximum fracture strength value (ranged from 1170-1355 N) followed by Group 4 (998.1-1158 N) then Group 3 (900.9-1097 N) followed by Group 1 (positive control) with fracture strength value ranging from 836.1 to 1059 N. Group 2 (negative control) showed the minimum fracture strength value ranged (380.6-631.6 N). For the significance evaluation of different groups, One-Way ANOVA was performed followed by Tukey`s post hoc test for multiple comparisons which revealed all significant differences between different groups as P-value < 0.05 except for (group 1 # group 3), (group 1 # group 4) and (group 3 # group 4) respectively which were insignificantly different as P-value > 0.05.*

Conclusion: *Reinforcement of the teeth could be achieved after MOD cavity preparation in maxillary premolars through proper restorative procedures.*

Keywords: Fracture resistance, MOD cavities, supra-nano fillers, Universal adhesive

Introduction

Restoring MOD cavities in premolars is a challenging procedure due to the loss of both marginal ridges causes weakening of the remaining tooth structure significantly decreases its resistance to fracture and increases the risk of cuspal deflection, therefore MOD cavities need a restoration that is capable of reinforce the remaining tooth structure and withstand fracture when subjected to high occlusal load [1,2,3].

Composite resin is considered nowadays alternative restorative material for posterior teeth and significantly increases the resistance of the remaining tooth structure to fracture. However, polymerization shrinkage remains the most important intrinsic weakness in resin composite [4,5,6].

The layering concept was developed to provide satisfactory esthetic properties however it requires more restorative skills and more chairside time [7,8,9]. Single-shade universal composites have recently introduced to simplify shade selection and restorative procedures. OptiShade™ is a highly filled nano-hybrid universal composite developed to simplify inventory management and save clinicians time on shade selection while providing excellent material properties, it features high strength, low shrinkage, and durability for posterior restorations together with outstanding color match, polishability for anterior restorations [10,11].

A recently introduced resin composite Estelite® Sigma Quick which possesses high filler content and spherical supra nano-filler particles of silica and zirconia improved its mechanical

and esthetic properties with reduced curing time and increasing polymerization conversion rates [12].

Since there is a Limitation in research and information available on the mechanical properties of such materials, our study aimed to evaluate fracture resistance in maxillary premolar teeth directly restored with different resin composite restorative materials.

Materials and Methods

Ethical Approval

Our present study has been reviewed and then approved by Badr University in Cairo BUC Institutional Ethical Committee with approval number: BUC-IACUC-230827-34.

Sample Size Calculation

Sample size was calculated depending on a continuous response variable from matched pairs in a previous study [13]. According to this study, matched pairs were normally distributed with a standard deviation (112.44). If the true difference in the mean response of matched pairs was (370.38), we need to study (3) samples for each group to be able to reject the null hypothesis that this response difference is zero with probability (power 0.8 = 80%). The sample size was increased by 20% to compensate for processing and laboratory failures during the assessment. The Type I error probability associated with this test of this null hypothesis is (0.05). Final sample size for each group will be (n=5), total sample size for all groups (n=25).

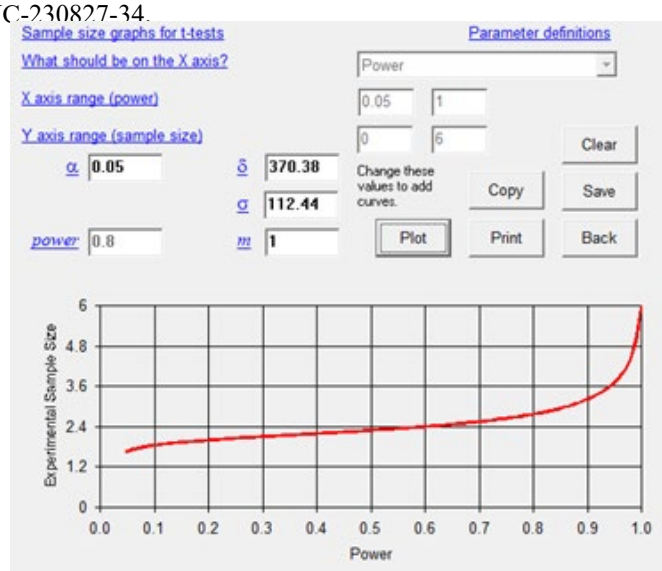

Figure 1: Power Graph revealing the Power of the Study corresponding to the Estimated Sample Size using SP Power Analysis

Grouping of Teeth

A total number of 25 Maxillary premolar teeth were collected to perform this in-vitro study. Extracted teeth were selected for periodontal purposes. After teeth have been cleaned and disinfected, they are divided into 5 main groups according to the restorative protocol used. (n= 5)

Group 1: Intact teeth (positive control)

Group 2: Prepared unrestored MOD cavities (negative control)

Group 3: (control) MOD cavities were restored with universal nanocomposite (Filtek FILTEK™ Z350 XT universal composite, 3M)

Group 4: MOD cavities were restored with simplified universal composite with adaptive response technology (OptiShade™, Kerr)

Group 5: MOD cavities were restored with universal composite with Radical Amplified Photo polymerization (Estelite® Sigma Quick, Tokoyama).

To simulate periodontal ligaments, a light body polyvinyl siloxane impression material was applied to cover the root of each tooth and then fixed perpendicularly using self-cured acrylic resin. To facilitate restoring the original anatomy, occlusal surface impression for each tooth was taken to make an occlusal stamp.

Material	Manufacturer	Organic Matrix Composition	Inorganic Filler Composition
OptiShade™	Kerr, CA, USA	• BisGMA • BisDMA • TEGDMA	• Percentage of spherical silica and zirconia particles 81% by weight and 64 % by volume with an average particle size of 5 – 400 nanometers in addition to 400 nm barium glass particles.

FILTEK™ Z350 XT	3M/ESPE, St Paul MN, USA	• BisGMA • UDMA • TEGDMA • PEGDMA • Bis-EMA(6) resins.	• Filler percentage 78.5% by weight and 63.3% by volume of silica fillers (20 nm) and zirconia fillers (4 – 11 nm) with average cluster particle size is 0.6 - 10 microns
Estelite® Sigma Quick	Tokuyama, Dental Co. Tokyo	• Bis-GMA • TEGDMA	• Filler percentage 78% by weight (63% by volume) of SiO2, ZrO2 (200 nm), PFSC (average 0.2 μm).
All bond universal	Bisco, chaumburg, USA	• HEMA • MDP • Bis-GMA • Ethanol	

Table 1: Materials composition as described by manufacturers

Cavity Preparation

Standardized MOD cavities were prepared for all groups except for teeth in group 1 (+ve control group) using high-speed handpiece and flat end parallel-sided diamond fissure bur. The cavity preparation dimensions were performed as follows: Cavo-surface angle was 900, roundation of all line and point angles and the axio-pulpal line angle, the pulpal depth was 2 mm from the cavo-surface margin to the pulpal floor and 4 mm to the gingival seat, the bucco-lingual dimension was 3 mm. No bevel was performed. The occlusal depth and the bucco-lingual width were measured with the same periodontal probe. Storage of Teeth in distilled water for all groups was done until the time of the restorative procedure.

Restorative Procedure

After completing all cavity preparations, selective acid etching was performed on the enamel margin using phosphoric acid etchant (37%) for 15 seconds then rinsed with water for 15 seconds, and then dryness was done using cotton pellet to remove excess water without dentin dehydration. After that, universal adhesive (All-bond universal, Bisco, USA) was applied to all cavity walls and margins with a micro-brush then light cured for 20 seconds with an LED light curing device (3M Elipar DeepCure-S LED Curing Light, 3M, USA).

The restorative material was applied using a circumferential tofflemire matrix. After the bonding procedure, teeth in each group were restored with the correspondent resin composite material. After the composite was applied into the cavity, Teflon tap piece was applied between the composite and the stamp to reproduce the original anatomy before curing of composite. After initial curing for 5 seconds, removal of stamp was done and curing was completed.

Fracture Resistance Testing

Storage of all specimens were performed in distilled water for five days at room temperature until testing time. A universal testing machine was used to test the fracture resistance. All data were collected, tabulated, and statistically analyzed.

Statistical Analysis

IBM SPSS software package version 24.0. (Armonk, NY: IBM Corp) and Graph Pad Prism 18 was used for statistical analysis of the obtained results.

One Way ANOVA followed by Tukey`s post hoc test were used for multiple comparisons of data which revealed as means and standard deviations for all groups.

Results

As a descriptive study, group 5 showed the maximum fracture strength value (1170-1355 N) with a mean ± standard deviation (1276±68.52 N) followed by group 4 with a maximum fracture strength value (998.1-1158 N) with a mean ± standard deviation (1076±67.09 N), as listed in Table (2) and showed in Figure (2). Group 2 showed the minimum fracture strength value (380.6-631.6 N) with a mean ± standard deviation (486.4±84.81 N) followed by group 1 with fracture strength value ranged (836.1-1059 N) with a mean ± standard deviation (953.5±91.81 N) and finally group 3 (900.9-1097 N) with a mean ± standard deviation (1016±79.59 N), as listed in Table (2) and showed in Figure (2).

For the significance evaluation of different groups, One Way ANOVA was performed followed by Tukey`s post hoc test for multiple comparisons which revealed all significant differences between different groups as P-value < 0.05 except for (group 1 # group 3), (group 1 # group 4) and (group 3 # group 4) respectively which were insignificantly different as P-value > 0.05, as listed in Table (3).

	Gp 1	Gp 2	Gp 3	Gp 4	Gp 5
N	5	5	5	5	5
Min	836.1	380.6	900.9	998.1	1170
Med	940.7	491.0	1029	1063	1298
Max	1059	613.6	1097	1158	1355
M	953.5	486.4	1016	1076	1276
SD	91.81	84.81	79.59	67.09	68.52
SEM	41.06	37.93	35.59	30.01	30.64
Lower 95% CI	839.5	381.1	917.6	992.6	1191
Upper 95% CI	1068	591.7	1115	1159	1361

Table 2: Descriptive Statistics of Fracture Resistance (N) of Different Groups

N; Number, Min; Minimum, Med; Median, Max; Maximum, M; Mean, SD; Standard Deviation, SEM, Standard Error of Mean, CI; Confidence Interval
Gp 1; +ve control
Gp 2; -ve control
Gp 3; FILTEK™ Z350 XT
Gp 4; OptiShade™
Gp 5; Estelite® Sigma Quick

Groups	MD	95.00% CI of diff.	Sig	P-value
Gp 1 # Gp 2	467.1	317.7 to 616.5	*	<0.0001
Gp 1 # Gp 3	-62.90	-212.3 to 86.49	Ns	0.7175
Gp 1 # Gp 4	-122.4	-271.8 to 27.00	Ns	0.1424
Gp 1 # Gp 5	-322.9	-472.3 to -173.5	*	<0.0001
Gp 2 # Gp 3	-530.0	-679.4 to -380.6	*	<0.0001
Gp 2 # Gp 4	-589.5	-738.9 to -440.1	*	<0.0001
Gp 2 # Gp 5	-790.0	-939.4 to -640.6	*	<0.0001
Gp 3 # Gp 4	-59.49	-208.9 to 89.90	ns	0.7560
Gp 3 # Gp5	-260.0	-409.4 to -110.6	*	0.0004
Gp 4 # Gp 5	-200.5	-349.9 to -51.11	*	0.0054

Table 3: Tukey's Post Hoc Test Showing Multiple Comparisons Between Different Groups
MD; Mean Difference, Sig; Significance, CI; Confidence Interval, P; Probability Level

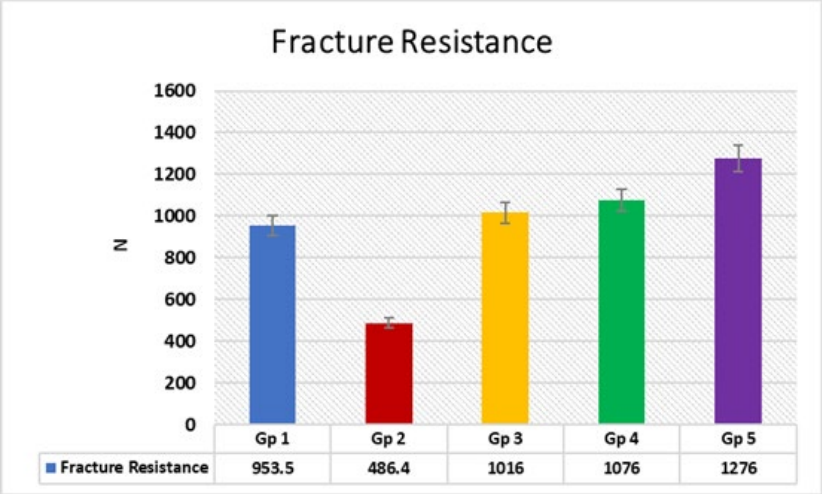

Figure 2: Bar Chart revealing Descriptive Statistics of Fracture Resistance (N) of Different Groups

Discussion

In the present study, comparison of fracture resistance of maxillary premolar teeth restored with different resin composite materials FILTEK™ Z350 XT, OptiShade™ and Estelite® Sigma Quick the null hypothesis stated that there are no statistically significance differences in fracture resistance between different resin composites were rejected since Estelite® Sigma Quick showed high fracture resistance that was statistically significant than other two composite groups.

In our present study, the prepared untreated group (negative control) showed the minimum fracture resistance value (380.6-631.6 N), this could be attributed to that the amount of lost tooth structure in the prepared cavity is strongly correlated to its fracture resistance after restoration. Also, in the present study, performing MOD cavities in premolar teeth reduced the structural integrity of the tooth with more susceptibility to fracture which explains the lowest fracture resistance of the negative control group [14,15].

In our study, regardless the type of the resin composite material used, all restored groups revealed significant differences regarding fracture resistance than the negative group. This could be attributed to the use of innovative adhesive material single bond a universal which is considered universal adhesive system that acts as internal splinting to reinforce the weekend tooth structure due to the chemico-mechanical bonding which occurs between hybrid layer, bonding agent, and tooth structure which reinforces tooth structure making restoration to the tooth as one single unit and so increasing fracture resistance [16].

Also, in our present study, it was found that regardless of resin composite materials used, all restored groups showed high fracture resistance value than intact positive control group with insignificant differences between the 3rd and 4th groups FILTEK™ Z350 XT and OptiShade™ respectively, and significant difference with group 5 Estelite® Sigma Quick [17]. The literatures have always reported that new resin composite materials together with the introduction of nanocomposite beside innovations in bonding have resulted in obtaining mechanical properties comparable to that of sound tooth. Also, these results might be due to performing a conservative standardized cavity preparation which in turn maximizes the remaining sound tooth structure and increases resistance of restored teeth to fracture [18].

Our findings are in accordance with many studies which revealed that fracture resistance of maxillary premolar teeth depends upon the amount of remaining tooth structure preserved after cavity preparation, and so following the concept of minimal intervention dentistry to preserve the maximum amount of tooth structure has been applied in our study to maintain function and mechanics that increase the fracture resistance of premolar teeth and increase its longevity after restoration [19,20].

However, our results contradicted with that of Megahed et al., 2020, Atalay et al., 2016 and Santos et al., 2005 whom revealed that resin composite partially reinforce cavitated teeth compared to sound teeth [21,22,23]. Also, our findings were in contrast with Ahmed et al., 2020 stated that highest significant fracture resistance value was presented by sound teeth due to preservation of marginal ridges mesially and distally moreover presence of intact buccal and palatal cusps results in reinforcing the tooth maintaining its integrity and increasing fracture resistance [24]. Moreover, the available restorative materials are unable to fully restore lost mechanical properties due to cavity preparation which results from the multiple interfaces between resin composite, bonding and tooth structure which represent different challenges during adhesion [25,26].

On the other hand, Dalpino et al., 2002 and others showed no significant difference in fracture resistance between sound teeth and that restored with resin composite [27]. According to the monoblock concept which means bonding different interfaces and tooth structures to behave as a single unit [14]. This successful bonding helps in obtaining a more favorable stress distribution and a higher fracture resistance. Also, selection of appropriate adhesive can provide monoblock restoration which successfully behaves functionally as a homogenous unit and can finally be comparable with sound tooth structure.

In this study, the reason for selecting maxillary premolar teeth for the evaluation of fracture resistance was done as it was found that it is the most susceptible teeth for vertical fracture clinically owing to their complex anatomy [28]. Also, the reason for performing MOD cavities in premolar was considered as a challenging procedure since premolar teeth become weakened with the loss of marginal ridges which in turn dramatically influences fracture resistance related to the occlusal stresses resulting during mastication [29].

In our study, OptiShade™ resin composite was selected as it is considered and belongs to a group of composites named Single shade universal resin composites also known as SsURCs which are nowadays clinically preferred to facilitate shade selection. In addition, they have the cost savings by reducing the amount of waste associated with expired products [30]. Majority of the studies focus on the esthetic properties and shade matching of OptiShade™ simplified composite regardless their mechanical or physical properties.

In the present study Group 5 Estelite® Sigma Quick showed the highest fracture resistance (1191-1361) that was statistically significant than other resin composite groups which are group 3 FILTEK™ Z350 XT and group 4 OptiShade™ and also than group 2 positive control. This variation in fracture resistance among different resin composites may be attributed to the difference in the chemical composition of the organic matrix, filler content, filler size and filler loading [31,32].

Our results were in accordance with those of Hada and Panwar, in 2019, whom attributed their results to that Estelite® Sigma Quick provides high polymerization activity based on the improvements in matrix conversion from monomer to polymer and its stability in ambient light provided by Radical amplified photo-polymerization initiator which known as RAP technology

[33]. Also, the outstanding mechanical and esthetic aspects provided by its supra-nano monodispersing spherical filler particles [34,35].

As a major feature in the catalyst technology known as RAP technology adopted for Estelite® Sigma Quick, the initiator balances the high polymerization activity with short curing times and these radicals significantly decrease residual monomers in comparison to conventional comforquinon amine photo polymerization resulting in increasing in polymerization rates. Also, Estelite® Sigma Quick contains supra-nano monodispersing spherical filler particles (silica and zirconia) of diameter 0.2 um which produce best balance between material properties and esthetics [36]. This may explain the higher fracture resistance obtained for Estelite® Sigma Quick than other composite groups.

Conclusion

Reinforcement of the teeth after MOD cavity preparation in maxillary premolars could be achieved through restorative procedures and it is correlated to application of minimal intervention dentistry concept together with quality of bonding and type of restorative material used.

References

1. Ahmed, R., Haridy, M., & Gallab, O. (2020). Influence of different cavity designs and induced strain of weakened thermos-cycled maxillary premolar teeth. An in-vitro study. Ain Shams Med J, 23(4), 65-71.
2. Rosatto, C.M.P., Bicalho, A.A., Veríssimo, C., Bragança, G.F., & Rodrigues, M.P., et al. (2015). Mechanical properties, shrinkage stress, cuspal strain and fracture resistance of molars restored with bulk- fill composites and incremental filling technique. J Dent, 43(12), 1519-1528.
3. Farahanny, W., Dennis, D., & Sihombing, D.L. (2019). Fracture resistance of various bulk-fill composite resins in class II MOD cavity on premolars: An in vitro study. World J Dent, 10(3), 166-169.
4. Habib, E., Wang, R., & Zhu, X.X. (2018). Correlation of resin viscosity and monomer conversion to filler particle size in dental composites. Dent Mater, 34(10), 1501-1508.
5. Ahmed, R., & Ahmed, H.S. (2022). Fracture resistance of MOD cavities in maxillary premolar teeth restored with different restorative protocols: An in-vitro study. Egypt Dent J, 68, 1907-1916.
6. Wang, W.J., Grymak, A., Waddell, J.N., & Choi, J.J.E. (2021). The effect of light curing intensity on bulk-fill composite resins: heat generation and chemomechanical properties. Biomater Investig Dent, 8(1), 137-151.
7. Ebaya, M.M., Ali, A.I., El-Haliem, H.A., & Mahmoud, S.H. (2022). Color stability and surface roughness of ormocer- versus methacrylate-based single shade composite in anterior restoration. BMC Oral Health, 22(1), 430.
8. Abouelleil, H., Pradelle, N., Villat, C., Attik, N., & Colon, P., et al. (2015). Comparison of mechanical properties of a new fiber reinforced composite and bulk filling composites. Restor Dent Endod, 40(4), 262-270.
9. Hada, Y.S., & Panwar, S. (2019). Comparison of the fracture resistance of three different recent composite systems in large Class II mesio-occlusal distal cavities: An in vitro study. J Conserv Dent, 22(3), 287-291.
10. Sidhu, S.K., Ikeda, T., Omata, Y., Fujita, M., & Sano, H. (2006). Change of color and translucency by light curing in resin composites. Oper Dent, 31(5), 598-603.
11. Morsy, A., Gamal, W., & Riad, M. (2020). Color matching of a single shade structurally colored universal resin composites with the surrounding hard dental tissues. Egypt Dent J 66, 2721-2727.
12. Jain, A., Sonkusre, S., Tavane, P.N., Singh, A., & Gupta, P., et al. (2015). Evaluation of microleakage between silorane based and supra nanofill composite in class II cavities: An in-vitro study. Int J Curr Microbiol App Sci, 4(4), 321-327.
13. Megahed, M.S.M., Ali, A.I., & Zaghloul, N.M. (2020). Fracture resistance of maxillary premolar teeth restored with bulk fill resin composite: In-vitro study. Mansoura J Dent, 7(26), 56-60.
14. Bassir, M.M., Labibzadeh, A., & Mollaverdi, F. (2013). The effect of amount of lost tooth structure and restorative technique on fracture resistance of endodontically treated premolars. J Conserv Dent, 16(5), 413-417.
15. Ibrahim, A.M., Richards, L.C., & Berekally, T.L. (2016). Effect of remaining tooth structure on the fracture resistance of endodontically-treated maxillary premolars: An in vitro study. J Prosthet Dent, 115(3), 290-295.
16. Fahad, F., & Majeed, M. (2014). Fracture Resistance of weakened premolars restored with sonically - activated composite, bulk - filled and incrementally - filled composites: A comparative in vitro study. J Baghdad Coll Dent, 26(4), 22-27.
17. Vianna, A.L.S.V., Prado, C.J.D., Bicalho, A.A., Pereira, R.A.D.S., & Neves, F.D.D., et al. (2018). Effect of cavity preparation design and ceramic type on the stress distribution, strain and fracture resistance of CAD/CAM onlays in molars. J Appl Oral Sci, 26, 1-10.
18. Nazari, A., Bajaj, D., Zhang, D., Romberg, E., & Arola, D. (2009). Aging and the reduction in fracture toughness of human dentin. J Mech Behav Biomed Mater, 2(5), 550-559.
19. Mergulhão, V.A., de Mendonça, L.S., de Albuquerque, M.S, & Braz, R. (2019). Fracture Resistance of Endodontically Treated Maxillary Premolars Restored with Different Methods. Oper Dent, 44(1), E1-E11.
20. Bilal, H., & Ibrahim, H.J.A. (2017). Fracture resistance of endodontically treated premolar teeth with extensive MOD cavities restored with different bulk fill composite restorations (An in vitro study). J Bagh Coll Dent, 29(2), 26-32.
21. Atalay, C., Yazici, A., Horuztepe, A., Nagas, E., & Ertan, A., et al. (2016). Fracture resistance of endodontically treated teeth restored with bulk fill, bulk fill flowable, fiber-reinforced, and conventional resin composite. Operative dentistry, 41(5), E131-E40.
22. Santos, M.J., & Bezerra, R.B. (2005). Fracture resistance of maxillary premolars restored with direct and indirect adhesive techniques. J Can Dent Assoc, 71(8), 585.
23. Ahmed, R., & Ahmed, H. (2022). Fracture resistance of MOD cavities in maxillary premolar teeth restored with

different restorative protocols: An in-vitro study. Egypt Dent J, 68(2), 1907-1916.
24. Wu, W., Lin, T., Liu, P., Ramp, L.C., & Pan, Y. (2014). In vitro compressive fracture resistance of human maxillary first premolar with different mesial occlusal distal cavity. J Dent Sci, 9(3), 221-228.
25. Suksaphar, W., Banomyong, D., Jirathanyanatt, T., & Ngoenwiwatkul, Y. (2017). Survival rates against fracture of endodontically treated posterior teeth restored with full-coverage crowns or resin composite restorations: a systematic review. Restor Dent Endod, 42(3), 157-167.
26. Ástvaldsdóttir, Á., Dagerhamn, J., van Dijken, J.W., Naimi-Akbar, A., & Sandborgh-Englund, G., et al. (2015). Longevity of posterior resin composite restorations in adults – A systematic review. J Dent, 43(8), 934-954.
27. Dalpino, P.H., Francischone, C.E., Ishikiriama, A., & Franco, E.B. (2002). Fracture resistance of teeth directly and indirectly restored with composite resin and indirectly restored with ceramic materials. Am J Dent, 15(6), 389-394.
28. Emamieh, S., Hojati, P., Ghasemi, A., & Torabzadeh, H. (2018). Effect of cusp coverage and water storage on compressive strength of composite restorations of premolars. J Clin Exp Dent, 10(4), 2-6.
29. Politano, G., Fabianelli, A., Papacchini, F., & Cerutti, A. (2016). The use of bonded partial ceramic restorations to recover heavily compromised teeth. Int J Esthet Dent, 11(3), 314-336.
30. Hasanain, F.A. (2021). Flexural strength and depth of cure of single shade dental composites. JPRI, 33(49), 110-118.
31. Bagheri, R., Fani, M., Barfi Ghasrodashti, A., Nouri Yadkouri, N., & Mousavi, S. (2014). Effect of a home bleaching agent on the fracture toughness of resin composites, using short rod design. J Dent (Shiraz), 15(2), 74-80.
32. Ferooz, M., Azadeh, N., Barahman, N., & Azar, M. (2014). The role of home bleaching agent on the fracture toughness of resin composites using four-point bending test. J Dent Biomater, 1: 9-15.
33. Hada, Y.S., & Panwar, S. (2019). Comparison of the fracture resistance of three different recent composite systems in large Class II mesio-occlusal distal cavities: An in vitro study. J Conserv Dent, 22(3), 287-291.
34. Ilie, N., & Stark, K. (2014). (2014). Curing behaviour of high-viscosity bulk-fill composites. J Dent, 42: 977-985.
35. Estelite® Sigma Quick 5-year Clinical Performance Report. The Dental Advisor. 2014.
36. Tokuyama Sigma Estellite Quick. Technical Product Profile.