10.21608/adjc.2024.326678.1645 Advanced Dental Journal
Volume 7 (2025) | Issue 4| Pages 725-733

Original Article

Fracture Resistance of Maxillary Premolars Restored with Different Dentin Replacement Protocols

Hend Sayed Ahmed[1], Maha El Baz[2], Shadwa Hatem Kabil[1]

[1]Department of Conservative Dentistry, Faculty of Dentistry, The British University in Egypt, Egypt
[2]Department of Conservative Dentistry, Faculty of Dentistry, Cairo University, Egypt

Email: hend.sayed@bue.edu.eg

Submitted: 09-10-2024
Accepted: 20-10-2024

Abstract

Aim: The aim of this research was to investigate the fracture resistance of premolar teeth with standardized mesioocclusodistal (MOD) cavities restored with different dentin replacement protocols.
Subjects and methods: Sixty sound maxillary premolar teeth with standardized MOD cavities were assigned to six groups (n=10): G1: sound teeth (positive control); G2: unrestored premolars with MOD cavities (negative control); G3: restored incrementally with nanohybrid resin composite; G4: restored by bulk fill flowable followed by nanohybrid resin composite; G5: restored with packable fiber-reinforced composite followed by nanohybrid resin composite and G6: restored with flowable fiber-reinforced composite followed by nanohybrid resin composite. After being thermocycled at 37ºC, 4mm diameter steel sphere was used in a universal testing machine to apply stresses on specimens at a cross-head speed of 5mm/min until fracture occurred. The results were statistically analyzed with statistical significance set at ($P \leq 0.05$).
Results: Intergroup comparison has shown statistically significant difference ($P < 0.001$). The highest fracture resistance was in G5 followed by G1 (natural tooth) then G6 with no difference between them. G4 and G3 showed intermediate results, which was statistically lower than G1, G5 and G6. The least fracture resistance was in G2 (unrestored MOD cavity), which was statistically lower than all groups.
Conclusion: Using fiber-reinforced composite (either packable or flowable) as dentin substitute material under resin composite is considered a perfect choice to restore fracture resistance of maxillary premolars with MOD cavities.

Keywords: Fracture Resistance; Bulkfill Resin Composite; fiber-reinforced Composite, dentin substitute material.

Introduction

Over the past ten years, composite restorations have been increasingly popular due to patients’ demands for aesthetics and increased emphasis on maintaining the structural integrity of their teeth. That's why, it is becoming a crucial component of general dental practice. Secondary caries, fracture, and occlusal wear are considered the main reasons behind composite fillings failure ***(Garoushi et al., 2012)***. One of the most crucial aspects of dental materials' properties is their resistance to fractures. It is dependent on the material's ability to withstand internal flaws that cause cracks to spread which may lead to bulk fracture or marginal microscopic fractures ***(Bonilla et al., 2001)***.

Weakening of tooth structure during mesioocclusodistal (MOD) preparations along with the role of restorative materials and approaches in fortifying the remaining tooth structure have been a subject of consideration in recent studies ***(Dalpino et al., 2002; Massa et al., 2010)***. In MOD cavities the prepared tooth is subjected to fatigue and microcracks due the preparation procedure that considerably affect tooth strength due to brittleness of tooth structure and repeated occlusal stresses as well as loss of marginal ridges ***(Bichacho., 1994; Bhardwaj et al., 2002***). Furthermore, repetition of occlusal stresses on extensive MOD cavities pushes the cusps away from each other causing fractures ***(Solomon et al., 2007)***. For this reason, it is essential to restrengthen these teeth to improve the fracture resistance.

Recently, the clinical functioning of the latest dental composites has perfected consistently to offer sufficient strength, permitting a wider application in posterior restorations with good longevity. Nonetheless, a significant disadvantage of contemporary resin composites in stress-bearing posterior restorations is their comparatively high brittleness and low fracture toughness.

Furthermore, many techniques have been proposed to enhance the fracture resistance of composite materials, including the use of incremental filling strategies to reduce the configuration factor (***Lee et al., 2007; Park et al., 2008; Moosavi et al., 2012).*** Moreover, a suggested solution to the aforementioned issue is to employ an intermediary resin that has a low viscosity and elastic modulus to act as an elastic buffer ***(Feilzer et al., 1990; Braga et al., 2004; Sadeghi and Lynch., 2009)***. Thanks to the introduction of flowable composite, it is nowadays among the materials that are available for this application. The early generations' low modulus of elasticity limited its usage to liners. On the other hand, the second generation is designed for bulk-fill flowable bases that are offered as liners in class I and II under conventional resin-composites, with a cure depth that is reportedly greater than 4 mm ***(Campodonico et al., 2011; Ilie and Hickel., 2011; Roggendorf et al., 2011; Salerno et al., 2011)***. Recently, the renovation of glass fibers and its introduction in the resin composite provided a considerable increase in the flexural strength and fracture resistance of composite restorations enhancing its resistance to crack propagation. Thus, the innovation of bulk fill fiber reinforced flowable composites provided a paradigm shift in the fracture toughness of the restorations ***(Alshabib et al., 2023).*** However, limited studies have assessed its performance, particularly when the material is to be placed in stress bearing areas. Accordingly, this study aimed to assess the consequence of different dentin replacement protocols on the fracture resistance of premolar teeth with standardized mesioocclusodistal (MOD) preparations restored with composite restoration. The null hypothesis stated that the different dentin replacement protocols would not reveal any difference in the fracture resistance of the restored premolars.

Subjects and Methods

Sample size calculation*:*

In order to do a statistical test of the null hypothesis, a power analysis was created with sufficient power. With an effect size (f) of (0.786) determined by using the results of a prior study ***(Tsertsidou et al., 2023)***, and alpha (α) and beta (β) values of (0.05) and (0.1), respectively (i.e., power=90%), the total needed sample size (n) was established to be (48) samples (i.e., group=8 samp). In order to account for any procedural errors during testing, the sample size was raised by 20% to equal (60) samples (10 samples each group). For Windows, R statistical analysis S.W. version 4.3.2 was used to calculate the sample size.

Methodology

This in vitro investigation used sixty extracted, undamaged, caries-free maxillary premolar teeth that were devoid of fractures, hypoplastic abnormalities, and cracks. The bucco-palatal dimension of each premolar was measured using digital caliper (ESSENTRA, Ontario, Canada) with a tolerance of 10μm.

Premolars were assigned into six groups (n=10) such that variance of the mean bucco-palatal width between groups was less than 5% ***(Abbas et al., 2003; Fleming et al., 2005; Alshabib et al., 2023; Tsertsidou et al., 2023)***. Premolars were stored in distilled water containing 0.1 % thymol at 4ºC till cavity preparation. Regarding periodontium simulation, root surfaces were covered by 0.2 – 0.3mm layer of melted wax 2mm below the cement enamel junction (C.E.J). Then the teeth were mounted vertically using a chemically activated acrylic resin (Acrostone, Egypt) into a cubic cupper mould. The acrylic resin extended to within 2mm below the C.E.J. The specimens were divided into six groups at random as follows: G1: sound teeth (positive control); G2: unrestored premolars with MOD cavities (negative control); G3: restored incrementally with nanohybrid resin composite; G4: restored by bulk fill flowable followed by nanohybrid resin composite; G5: restored with packable fiber-reinforced composite followed by nanohybrid resin composite and G6: restored with flowable fiber-reinforced composite followed by nanohybrid resin composite. The composition and characteristics of the restorative materials used are listed and described in Table 1.

Cavity preparation

All specimens of group 2 through 6, a standardized MOD cavities were prepared using carbide fissure bur no. 57 size 010 (Brassler, Savannah, Georgia, USA) mounted at high-speed handpiece cooled with air/water. Depth of the cavity was 4 ± 0.2 mm from the tip of the palatal cusp and cavity width was 4 ± 0.2mm. The proximal walls were parallel and the occlusal isthmus width was one-third of the intercuspal distance. All dimensions were measured using single periodontal probe during preparation of all the cavities and no bevel was performed in the margins of the cavities.

Adhesive application

After cavity preparation, selective etch approach was adopted for bonding using universal adhesive (Prime & Bond Universal, DENTSPLY Sirona), Konstanz, Germany). Following manufacturer’s instructions, cavity was air dried gently for 10 seconds, 37% phosphoric acid etching gel (Scotch bond etchant, 3MESPE, St Paul, MN, USA) was applied on enamel margin for 30 seconds, rinsed for 30 seconds with air/water spray and finally dried with gentle air for 5 seconds. The universal adhesive was actively applied with micro brush (Micro brush, USA) for 20 seconds and left for 10 seconds to flow and then light cured for 20 seconds using Elipar™ Deep Cure-LED curing light (3M ESPE, Germany) for 20 seconds at light intensity 1200 mW/cm².

Resin composite build-up protocols:

The used resin composites in this study were nanohybrid composite (NeoSpectra HV Shade A2, DENTSPLY Sirona), flowable bulk fill resin composite (Surefill SDR Flow, universal shade, DENTSPLY Sirona) and flowable (EverX Flow, GC Company, Tokyo, Japan) and packable (EverX Posterior, GC Company, Tokyo, Japan) fiber-reinforced resin composite (Table 1). “Tofflemire” metal matrix bands with its holder were used. All cavities (Group 3 through group 6) were restored according to the assigned group, as follows:

Group 3 (incremental packing): Universal nano-hybrid restorative material (NeoSpectra HV Shade A2, DENTSPLY Sirona) was packed in two horizontal increments with thickness 2mm. Each increment was light cured for 20 seconds.

Group 4: The first layer was flowable bulk fill resin composite (Surefill SDR Flow, universal shade, DENTSPLY Sirona) in 2mm thickness and light cured for 20 seconds followed by one increment of regular nanohybrid resin composite (NeoSpectra HV Shade A2, DENTSPLY Sirona) in 2 mm thickness and light cured for 20 seconds.

Group 5: The first layer was packable fiber-reinforced resin composite (EverX Posterior, GC Company, Tokyo, Japan) in 2mm thickness and light cured for 20 seconds. The second increment (2mm) was of nano-hybrid resin composite (NeoSpectra HV Shade A2, DENTSPLY Sirona) and light cured for 20 seconds.

Group 6: The first layer was flowable fiber-reinforced resin composite (EverX Flow, GC Company, Tokyo, Japan) in 2mm thickness and light cured for 20 seconds. The remaining 2 mm was filled with nano-hybrid resin composite (NeoSpectra HV Shade A2, DENTSPLY Sirona) and light cured for 20 seconds.

All restorations were properly finished and polished followed by specimens' storage for 24 hours in 37°C distilled water.

Thermocycling

Specimens were subjected to 5000 thermocycles to simulate 6 months of clinical performance before testing the fracture resistance. Alternation between 5 and 55 ◦C ± 2 was performed; the dwell time and transfer time was 5 seconds between each bath according to ISO 11405 recommendations. Then specimens were examined for cracks or debonding.

Measurement of fracture resistance:

Using universal testing machine (Model LRX-plus; Lloyd Instruments Ltd., Fareham, UK), fracture resistance test was done. A steel sphere of 4 mm diameter was placed on the inclined planes of the buccal and lingual cusps of the tested teeth at a cross-head speed of 5 mm/min until the fracture occurred. The force was recorded in Newton as the fracture resistance.

Results

Data was analyzed using Medcalc software, version 22 for windows (MedCalc Software Ltd, Ostend, Belgium). Continuous data was explored for normality using Kolmogrov Smirnov test and Shapiro Wilk test. Continuous data showed normal distribution and was described using mean and standard deviation. Intergroup comparison was performed using one-way ANOVA followed by Tukey Kramer post hoc test with statistical significance set at ($P \leq 0.05$). Statistical power of the study was set at 80 % with 95 % confidence level and all tests were two tailed.

Intergroup comparison has shown statistically significant difference ($P < 0.001$). The highest fracture resistance was in G5 followed by G1 (sound tooth) then G6 with no difference between them. G4 and G3 showed intermediate results, which was statistically lower than G1, G5 and G6. The least fracture resistance was in G2 (unrestored MOD cavity), which was statistically lower than all groups.

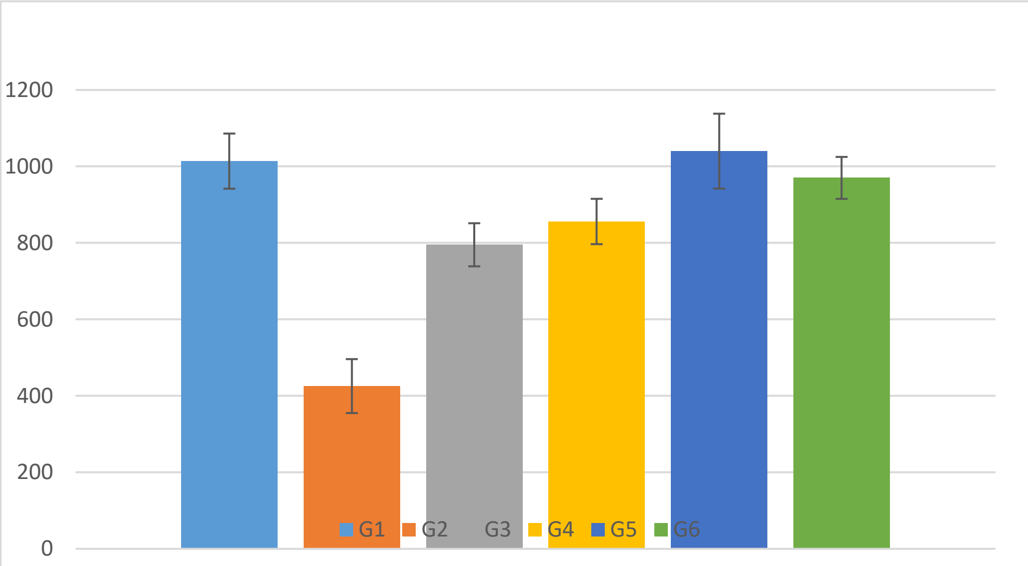
Table 1: Brand names, specifications, chemical composition and manufacturer of the used materials

Material	Specifications	Composition	Manufacturer
NeoSpectra Composite	Nanohybrid composite material	Matrix: (methacrylate-, acid-modified methacrylate-, inorganic polycondensate- or epoxide based) modified version of the polysiloxane. itis combined with a well-established poly-urethane-methacrylate as well asbis-EMA and TEGDMA. Fillers: 77-79 weight	*DENTSPLY sirona, , Konstanz, Germany*
SureFil™ SDR flow [Smart Dentin Replacement] (Universal Shade)	Visible light cured bulk-fill flowable base resin composite	**Matrix:** SDR™ patented UDMA resin, TEGDMA, DMA resin, Di-functional diluents, EBPADMATriethyleneglycol dimethacrylate **Fillers:**Barium and Strontium. Fluoro alumino-silicate glasses. (68% by wt., 45% by vol.)	*DENTSPLY sirona, , Konstanz, Germany*
EverX Posterior	short-fiber reinforced resin composite	**Resin matrix:** Semi-interpenetrating polymer network (semi-IPN): net- poly (methyl methacrylate)-inter-net-poly (bis-glycidyl- A-dimethacrylate): Bis-GMA, TEGDMA, and PMMA **Fillers**: E-glass fiber, barium borosilicate	GC Company, Tokyo, Japan
EverX Flow	short-fiber reinforced flowable resin composite	combination of organic resin matrix and inorganic glass fibres and filler particles. The resin matrix contains Bis-MEPP, TEGDMA and UDMA. The fillers are a mix of short E-glass fibres and particle fillers, mostly barium glass. The total filler rate of everX Flow is 70% in weight.	GC Company, Tokyo, Japan
Prime & Bond Universal	Universal adhesive	Mono, di- trimethacrylae resins,PENTA, diketone, stabilizers, organic phosphine oxide, cetylamine hydrofluoride, acetone,water, self-cure activator. pH: 2.5 Urethane Dimethacrylate, Di-and Tri Methacrylate resins, phosphoric acid, modified acrylate resin, Barium Boron	*DENTSPLY sirona, , Konstanz, Germany*

Table 2: Mean and standard deviation of fracture resistance of all groups:

Group	Mean	SD
G1	1013.84[a]	72.10
G2	425.55[c]	70.54
G3	795.13[b]	56.37
G4	855.99[b]	59.31
G5	1039.99[a]	97.91
G6	970.00[a]	54.86
P value	P < 0.001*	

*Means that do not share the same letter are statistically significant, * denotes statistically significant*



In the

Figure (1): Bar chart showing mean and standard deviation of fracture resistance of all groups

Discussion

In dentistry, direct resin-based restoration solutions are indispensable. Polymerization shrinkage in resin-based composite materials has several detrimental impacts ***(Ilie and Hickel., 2011).*** Furthermore, dentists continue to prioritize technique sensitivity to get positive outcomes. Despite the introduction of a novel class of bulk fill resin-based composites, the effectiveness of these materials has not been well studied in clinical or laboratory settings. When the material is to be employed in stress-bearing areas, these tests are very crucial. Therefore, the purpose of this study was to examine the fracture resistance of maxillary premolars having MOD cavities restored with different composites used as dentin substitute, most of them can be applied in bulk followed by conventional nanohybrid composite as a final layer of the whole restoration.

fracture would be more frequent and the remaining tooth structure would be weakened respectively. The bucco-palatal width of each tooth was standardized to vary no more than 5% amongst teeth to facilitate comparisons both within and between groups. It would be expected that all restored teeth with different packing approaches would present greater fracture resistance values in comparison to the prepared unrestored teeth due to restoration of the fracture resistance of tooth by modulus of elasticity of resin composite ***(Abbas et al., 2003; Fleming et al., 2005; Plain et al., 2005; Cara et al., 2007).*** These results are consistent with the current investigation, which found that the unrestored group had the lowest fracture resistance values.

The current findings validated the importance of using bulk fill fiber reinforced composite and different resin composite dentin substitutes in enhancing fracture resistance of badly broken-down teeth. This study's results, which support those of other investigations, indicate that the fracture resistance of the group restored using bulk fill fiber reinforced packable composite as a base was as high as that of the unprepared teeth ***(Alshabib et al., 2023)***. In the current study, the null hypothesis was rejected as there was significant differences between all tested groups. The highest fracture resistance was in G5 in which the first layer was packable fiber-reinforced resin composite followed by G1 (natural tooth) then G6 in which the first layer was flowable fiber-reinforced resin composite with no difference between them. G4 whereas the first layer was flowable bulk fill resin composite SDR and G3 in which only universal nano-hybrid restorative material showed intermediate results, which was statistically lower than G1 (intact teeth), G5 and G6. The least fracture resistance was in G2 (unrestored MOD cavity), which was statistically lower than all groups. This could be attributed to the increased resilience and high resistance to crack propagation found in the ever x posterior. The favorable characteristics of its fiber and matrix components are responsible for this ***(Attik et al., 2022).*** The ever x posterior and flow has fibers that are longer than the critical fiber length, which allows for more effective stress transmission from the matrix. These results are consistent with the body of knowledge in the literature ***(Kikuti et al., 2012; Alshabib et al., 2019).*** It is important to highlight that, despite this improvement in fracture resistance, research has indicated that the primary cause of the fiber-reinforced composites decreased flexural strength is hydrolytic degradation that takes place between the matrix and the glass fibers. It should be mentioned that, in general, composites reinforced with glass fibers absorb more water than composites reinforced with particle fillers ***(Alshabib et al., 2021)***. Therefore, Following the technique of application used in the current study, it should be noted that, despite the restrictive term bulk fill, the bulk fill flowable resin composite regardless of the filler component, are essentially base layers that should be essentially covered by surface layer of 2mm of methacrylate- based resin-based composite.

The use of SDR in the current study in G4 is considered one of the limitations that could be replaced by the use a conventional nano-hybrid bulk fill composite. A high-molecular-weight monomer (AUDMA) that reduces the number of reactive groups in the resin chain, makes up the resin matrix of nano-hybrid bulk fill composites ***(Moorthy et al., 2012; Eweis et al., 2020)***. During the polymerization process, this property increases the final polymeric matrix's stiffness. Moreover, adding addition-fragmentation chain transfer monomers (AFM) to nano-hybrid composites can increase the polymer network's homogeneity, which may result in improved mechanical properties and this explains the good fracture resistance found in G4. According to recent research, nano-hybrid composites provide better flexural strength. This is explained by the resin matrix's composition as well as the filler content ***(Eweis et al., 2020)***.

Only premolar teeth were used in this investigation, and fracture resistance was assessed soon after the restoration and thermocycling. However, several factors, including aging, fatigue loads, chemical, physical, and thermal changes, might alter the induced fracture in the oral cavity. Furthermore, there are cyclical changes in the pace, magnitude, and orientations of the stresses within the mouth cavity. Therefore, more research is required to assess how these materials and layering strategies with dynamic loading behave in vivo. Low modulus of elasticity values should be avoided when it comes to dental composites because they cause significant distortion. In a comparable manner, excessively flexible materials should be used cautiously while pursuing high flexural strength as this will reduce the material's total strength. Such circumstances result in an unequal distribution of load, which prevents the chewing forces from being distributed horizontally throughout the periodontium. As a result of occlusal pressure, the restoration's surface is subjected to significant tensile loads, which may affect its adherence to the tooth structure. Furthermore, lateral expansion brought on by occlusal stresses on flexible filling materials within the cavity may eventually result in surface fractures of the teeth ***(Manhart et al., 2000; Alomari et al., 2001; Rodrigues et al., 2007; Pick et al., 2011;)***. To guarantee dental composites function at their best, it is imperative to take these things into account.

Conclusion

Within the limits of this study, the following conclusions can be derived:

1. Fiber reinforced either packable or flowable composite as dentin substitute significantly improve fracture resistance.
2. All dentin substitute composites should be covered by conventional nanohybrid resin composite.

Conflict of Interest:
The authors declare no conflict of interest.

Funding:
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethics:
This study protocol was approved by the ethical committee of the faculty of dentistry-The British University in Egypt on: 20/8/2024, approval number: 24-050

Data Availability:
Data will be available upon request

Credit statement:

Author 1: Data curation, Writing - review & editing, Writing - original draft, Methodology, Conceptualization, Supervision, Formal analysis.

Author 2: Data curation, Conceptualization, Project administration, Supervision, Methodology, Writing - review & editing, Writing - original draft.

Author 3: Methodology, Writing - original draft, Writing - review & editing, Investigation, Resources, Data curation.

References

Abbas G, Fleming GJP, Harrington E, Shortall ACC, and Burke FJT. Cuspal movement in premolar teeth restored with a packable composite cured in bulk or incrementally. *Journal of Dentistry*. (**2003**); 31:437–44.

Alomari QD, Reinhardt JW and Boyer DB. Effect of liners on cusp deflection and gap formation in composite restorations. *Operative Dentistry*. (**2001**); 26:406–11.

Alshabib A, Silikas N and Watts DC. Hardness and fracture toughness of resin-composite materials with and without fibers. Dent. Mater. **(2019**);35, 1194–1203.]

Alshabib A, Algamaiah H, Silikas N, and Watts, DC. Material behavior of resin composites with and without fibers after extended water storage. Dent. Mater. J. (**2021**); 40:557–565.

Alshabib A, Silikas N, Algamaiah H, Alayad AS, Alawaji R, Almogbel S, Aldosari A and Alhotan A. Effect of Fibres on Physico-Mechanical Properties of Bulk-Fill Resin Composites. Polymers (**2023**);15,3452.

Attik N, Colon P, Gauthier R, Chevalier C, Grosgogeat B and Abouelleil H. Comparison of physical and biological properties of a flowable fiber reinforced and bulk filling composites. Dent. Mater. (**2022**); 38:19–30.

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

Bichacho N. The centripetal build-up for composite resin posterior restorations. *Practical Periodontics and Aesthetic Dentistry*. **(1994);** 6: 17–24.

Bonilla E, Mardirossian G, and Caputo A. Fracture toughness of posterior resin composites. *Quintessence International*. **(2001**); 32: 206–210.

Braga RR, and Ferracane JL. Alternatives in polymerization contraction stress management. *Critical Reviews in Oral Biology and Medicine*. (**2004**); 15:176–84.

Campodonico C, Tantbirojn D, Olin P, and Versluis A. Cuspal deflection and depth of cure in resin based composite restorations filled by bulk, incremental and transtooth-illumintaion techniques. *Journal of the American Dental Association*. **(2011)**; 142:1176-1182.

Cara RR, Fleming GJP, Palin WM, Walmsley AD, and Burke FJT. Cuspal deflection and microleakage in premolar teeth restored with resin-based composites with and without an intermediary flowable layer. *Journal of Dentistry.* **(2007)**; 35:482–9.

Dalpino PH, Francischone CE, Ishikiriama A, Franco EB. Fracture resistance of teeth directly and indirectly restored with composite resin and indirectly restored with ceramic materials. *Am J Dent*. **(2002)**;15(6):389-94.

Eweis A, Yap A and Yahya N. Comparison of flexural properties of bulk-fill restorative/flowable composites and their conventional counterparts. Oper. Dent. (**2020**); 45:41–51.

Feilzer AJ, De Gee AJ, and Davidson CL. Quantitative determination of stress reduction by flow in composite restorations. *Dental Materials*. **(1990)**; 6:167–71.

Fleming GJP, Hall D, Shortall ACC, and Burke FJT. Cuspal movement and microleakage in premolar teeth restored with posterior filling materials of varying reported volumetric shrinkage values. *Journal of Dentistry.* (**2005**); 33:139–46.

Garoushi S, Tanner J, Vallittu P, and Lassila L. Preliminary clinical evaluation of short fiber-reinforced composite resin in posterior teeth: 12-months report. *The Open Dentistry Journal*. **(2012**); 6: 41–45.

Ilie N, and Hickel R. Investigations on a methacrylate based flowable composite based on the SDR^{TM} technology. *Dental Material*. **(2011)**; 27:348-355.

Kikuti W, Chaves F, Hipolito V, Rorigues F, and Alpino P. Fracture resistance of teeth restored with different resin based restorative systems. *Brazilian Oral Research*. (**2012)**; 26:275-281.

Lee MR, Cho BH, Son HH, Um CM, and Lee IB. Influence of cavity dimension and restoration methods on the cuspal deflection of premolars in composite restoration. *Dental Materials*. **(2007)**; 23:288–95.

Manhart J, Kunzelmann KH, Chen HY, and Hickel R. Mechanical properties and wear behavior of light-cured packable composite resins. *Dental Material*. **(2000)** Jan;16(1):33-40.

Massa F, Dias C and Blos CE. Resistance to fracture of mandibular premolars restored using post-and-core systems. *Quintessence Int*. **(2010)** Jan;41(1):49-57.

Moorthy A, Hogg C, Dowling A, Grufferty B, Benetti A, and Fleming G. Cuspal deflection and microleakage in premolar teeth restored with bulk fill flowable resin based composite base materials. *Journal of Dentistry*. (**2012)**;40: 500-505.

Moosavi H, Zeynali M, and Pour Z. Fracture resistance of premolars restored by various types and placement techniques of resin composites. *International Journal of Dentistry.* **(2012)**; 1-5.

Palin WM, Fleming GJP, Nathwani H, Burke FJT, and Randall RC. In vitro cuspal deflection and microleakage of maxillary premolars restored with novel low-shrink dental composites. *Dental Materials*. (**2005)**; 21:324–35.

Park JK, Chang JH, Ferracane J, and Lee IB. How should composite be layered to reduce shrinkage stress: incremental or bulk filling? *Dental Materials*. **(2008)**; 24:1501–5.

Pick B, Pelka M, Belli R, Braga RR, and Lohbauer U. Tailoring of physical properties in highly filled experimental nanohybrid resin composites. *Dental Materials*. (**2011**); 27:664–9.

Rodrigues Junior SA, Zanchi CH, Carvalho RVD and Demarco FF. Flexural strength and modulus of elasticity of different types of resin-based composites. Braz. Oral Res. (**2007**); 21: 16–21.

Roggendorf M, Kramer N, Appelt A, Naumann M, and Frankenberger R. Marginal quality of folwable 4-mm base vs. conventional layered resin composite. *Journal of Dentistry*. **(2011)**; 39:643-647.

Sadeghi M, and Lynch CD. The effect of flowable materials on the microleakage of class II composite restorations that extend apical to the cemento-enamel junction. *Operative Dentistry*. **(2009)**; 34:306–11.

Salerno M, Derchi G, Cereracciu L, Ruffilli r, and Barone A. Surface morphology and mechanical properties of new generation flowable resin composites for dental restoration. *Dental Material*. **(2011)**; 27:1221-1228.

Solomon P, Krishna G, Parammeswaran A, Pradeep G, and Kandaswamy D. Fracture resistance of premolar teeth with class II preparations restored with light cured composite with beta quartz inserts, light cured composite and silver amalgam in comparison with intact unrestored teeth-An in vitro study. *Journal of Conservative dentistry*. (**2007**); 10:122-128.

Tsertsidou V, Mourouzis P, Dionysopoulos D, Pandoleon P, Tolidis K. Fracture Resistance of Class II MOD Cavities Restored by Direct and Indirect Techniques and Different Materials Combination. Polymers **(2023)**;15(16):3413.