EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 69, 731:740, January, 2023

Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 13-10-2022 • Accept Date : 12-12-2022 • Available online: 1-1-2023 • DOI : 10.21608/edj.2022.168156.2287

EFFECT OF CAVITY DISINFECTANTS ON GINGIVAL MARGIN SEALING OF RESINOUS AND NON-RESINOUS SELF-ADHESIVE RESTORATIVE MATERIALS: AN IN VITRO STUDY

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ABSTRACT

Objectives: To assess the impact of using two types of cavity disinfectants on dentin margin sealing of resinous and non-resinous self-adhesive restorative materials.

Materials and Methods: Standardized box-form Class V cavities were prepared on the buccal surfaces of 72 sound premolars. The teeth were divided into three groups (n=24) according to dentin pretreatment method; no pretreatment, 2% Doxycycline pretreatment and 2% Chlorhexidine pretreatment Each group was subdivided into two subgroups (n=12) according to restorative material used; non-resinous Glass ionomer restorative material and self-adhesive resin composite. After artificial aging through thermocycling in water baths at 5°C and 55°C, with a dwell time of 30 seconds in each bath and a transfer time of 15 seconds, the teeth were soaked in methylene blue dye for 24 h. The dye leakage was examined under stereomicroscope at X40 magnification.

Results: No significant differences in the microleakage score median were found between group I, II and group III ($P > 0.05$) for both restorative materials used. However, there was a significant difference between the two subgroups A & B ($P < 0.05$) for CHX pretreated cavities where Glass ionomer restored specimens showed lesser degree of dye-leakage compared to self-adhesive composite restored specimens.

Conclusion: The current study's findings indicate that using of cavity disinfectants has no effect on gingival marginal seal of both resinous and non-resinous restorative materials.

KEYWORDS: Cavity disinfectants, margin sealing, self-adhesive resin composite, conventional glass ionomer.

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INTRODUCTION

The evolution of bonding systems from first to seventh generation was aimed to simplify bonding procedure and decrease the number of clinical steps. Bonding procedure is considered to be technique sensitive and time-consuming process; the cavity should be kept uncontaminated throughout the multiple stages of adhesive application. By simplifying the bonding procedure there will be less chances of mistakes. Etching and priming steps are eliminated in sixth & seventh generations for easier manipulation. [1]

The development of adhesive-free self-adhesive resin composite restorative materials further simplified the procedure by reducing the time that contamination by oral fluids could jeopardize the restoration. Adding of acidic moieties to reactive diluents is the utmost popular method for facilitating the dental bonding. [2,3]

For a long time, glass ionomer was considered as the only self-adhesive restorative material that chemically bond to tooth structure. [4] Due to the lower physical and mechanical properties of conventional glass ionomer [5], hybrid glass-ionomer materials have been formulated to withstand such limitations including short working time, long-setting time and water sensitivity. [6]

Self-adhesive composites claimed to decrease operating time and technique sensitivity during application. [7] Most of self-adhesive composites possess an acid functional monomer that conditions enamel and dentin and forms chemical bond with inorganic components of the tooth structure. They also have a chemical composition comparable to conventional composites. [8]

Dentin is a complex tissue organized in the 3-dimensional framework consisting of 50% minerals and 30% of the collagen and 20% water by volume. Due to this complexity, biological makeup and moisture content, bonding to dentin is challenging. [10] Perfect seal at the cervical margins is still a significant issue. [9] Studies conducted over an extended period of time have revealed a gradual loss of resin to dentin bond strength. [11] Many factors affecting the dentin sealing ability of resin such as mechanical stresses, changes in the oral cavity's temperature and pH, water sorption, resin shrinkage. [12]

Resin infiltration of recently developed self-adhesive resin composite is point of controversies. A number of studies have questioned whether self-adhesive resin composites are effective alternative to conventional composites with separate application of adhesives. [2,3]

Failure of the restorative material to seal the dentin margin results in marginal gap and subsequent microleakage and secondary caries that represent the primary reason for replacement of different types of restorations. [13]

Using of antibacterial cavity disinfectants after cavity preparation seem to reduce the risk of recurrent caries and pulpal inflammation caused by microorganisms that may remain in the cavity. According to the literature, there are both merits and demerits of using cavity disinfectants. According to some researchers, applying a cavity disinfectant may cause microleakage between the tooth tissue and the restoration. Others, however, have reported that the disinfections have no effect on restoration microleakage. [14,15]

As microleakage is reversely proportional to margin sealing and there are limited data available on the consequence of using cavity disinfectants on dentinal margin microleakage of self-adhesive restorative materials, therefore the aim of the current study was to assess the impact of using two types of dentin disinfectants on dentinal margin sealing of resinous and non-resinous self-adhesive restorative materials.

The null hypothesis was that using of cavity disinfectants would not affect the sealing ability of self-adhesive resin composite and conventional glass ionomer to dentin.

MATERIALS AND METHODS

Sample selection and distribution:

72 sound premolars were used in the study. The teeth were collected from the outpatient clinic of Faculty of Dentistry, Mansoura University. The collected teeth were extracted for orthodontic reasons. The collection/storage of teeth was subjected to infection control standards approved by the Faculty of Dentistry-Mansoura University Ethical committee (M13011122).

The collected teeth were examined macroscopically to exclude the teeth with fractures, caries and restorations. The teeth were cleaned, residual tissue removed and disinfected in 1% chloramine T solution, stored in distilled water at 4°C [16,17] and used within three months after extraction.[18,19]

On each tooth's buccal surface, a standardized box-form Class V cavity was prepared using a high-speed carbide bur # 271 (SS white) with air-water coolant. The occlusal margin of the cavity was placed 1mm above the cementoenamel junction (CEJ), while the gingival margin was placed 1mm below the cementoenamel junction (CEJ). Cavity dimension was measured 2 mm height, 3 mm width, and 2 mm depth. A stopper was used to control the depth of the cavity during preparation and confirmed regularly using a periodontal probe. [20] A new bur was used for preparing five cavities then discarded. [21]

Sample size calculation was based on mean difference between using two types of dentin disinfectants on dentinal margin sealing of resinous and non-resinous self-adhesive restorative materials retrieved from the literature [22]. Using G*power version 3.0.10 to calculate sample size based on effect size =1.40, 2-tailed test, α error =0.05 and power = 90.0% then total sample size was 12 samples in each group.

The samples were alienated into three groups (n=24) according to dentin pretreatment method (figure 1):

Group I: No dentin pretreatment.

Group II: Dentin pretreated using DOX: 2% doxycycline solution was applied with a micro-brush for 60 seconds on the dentin surface. Gentle air stream waw used to dry the dentinal surfaces.

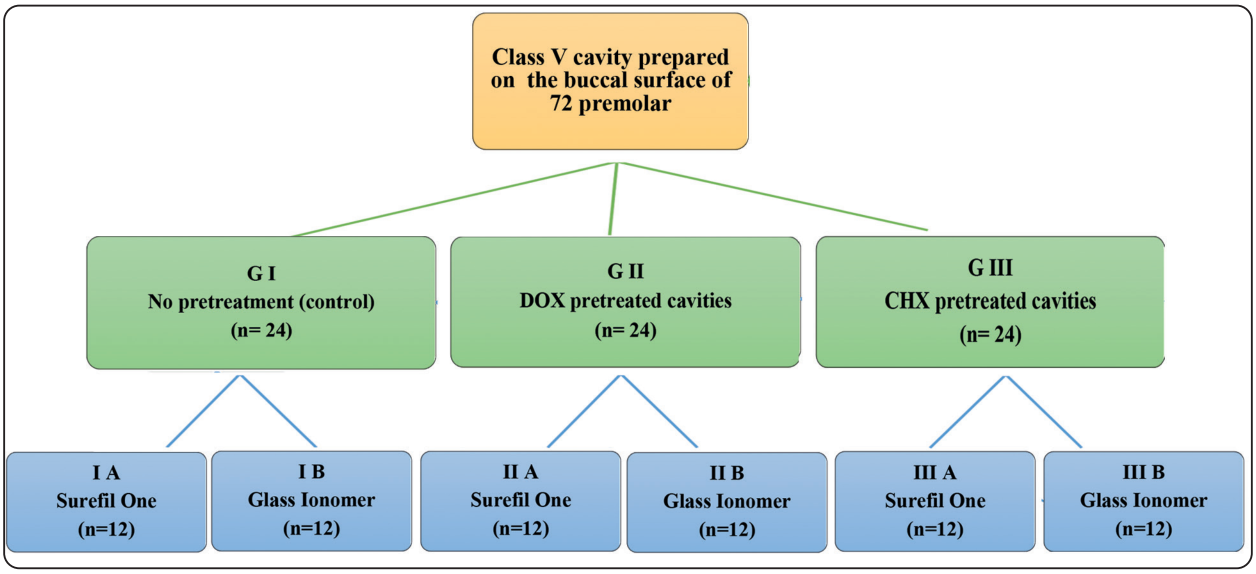

Fig. (1) Flow chart for the study groups.

Group III: Dentin pretreated using CHX: 2% chlorhexidine gluconate solution was applied with a micro-brush for 60 seconds on the dentin surface. Gentle air stream was used to dry the dentinal surfaces.

Each group was then subdivided into two subgroups (n= 12) according to restorative material used (table 1)

- Subgroup A: Restored with Surefil One, Self-adhesive bulk-fill resinous restorative material.
- Subgroup B: Restored with non- resinous EQUIA Fil Conventional glass ionomer restorative material.

Restorative Procedure

Subgroup A: Surefil one restorative material:

Following the manufacturer's instructions, the activated capsules were mixed for 10 seconds in a capsule mixer, the material was dispensed directly into the cavity using the capsule extruder. The cavity was filled in bulk and the surface was contoured using a hand instrument. According to manufacturer instructions, light curing for 20 seconds was performed.

Subgroup B: EQUIA Fil restorative material,

According to the manufacturer's recommendations, each capsule was mechanically mixed for 10 s before being injected into the cavity starting from the deepest portion till complete filling. Contouring of the surface was done using a hand instrument. The protective coating material (EQUIA Forte Coat, GC Corp.) was applied with a micro brush to the top surface of the restoration after 10 min at room temperature, rubbed for 20 s, and then light-cured for 60 s. [23]

Finishing and polishing for both subgroups was done with politip-p (NSK panaAir FX, Japan) after keeping the specimens for 24 hours at 37°C in distilled water.

Artificial aging:

The restored teeth were subjected to artificial aging by thermocycling after 24 hours of storage in distilled water at 37°C. For 500 cycles, all specimens were immersed in water baths at 5°C and 55°C, with a dwell time of 30 seconds in each bath and a transfer time of 15 seconds. [24]

The specimens' apices were sealed with paraffin, and all of the tooth surfaces received two coats of nail varnish, leaving the restoration and one millimeter from the peripheral margins exposed. Following a

TABLE (1) Materials used in the study.

Restorative material	Composition	Manufacturer	Description
Surefil One	Powder: silanated aluminum-phosphor-strontiumsodium-fluoro-silicate glass, dispersed silicon dioxide, ytterbium fluoride, pigments. Liquid: acrylic acid, polycarboxylic acid, bifunctional acrylate, self-cure initiator, camphorquinone, stabilizer	Dentsply-Sirona, Konstanz, Germany	Self-adhesive bulk-fill resinous restorative material
EQUIA Fil	Powder: 95% strontium fluoro-alumino silicate (FAS) glass Liquid: 40% aqueous poly acrylic acid liquid	GC Corporation, Tokyo, Japan	Conventional glass ionomer
G-Coat Plus	50% methyl methacrylate, 0.09% camphorquinone	GC Corporation, Tokyo, Japan	Low-viscosity resin coat

24-hour period of soaking in methylene blue dye at room temperature, the teeth were washed with water and longitudinally sectioned in the buccolingual direction using a diamond disk at low speed under water cooling. Using the stereomicroscope (Olympus SZX16; Olympus, Tokyo, Japan) at X40 magnification, the dye leakage was measured.

Microleakage scores was assessed using the subsequent criteria: [25]

1. Negative dye penetration.
2. Dye penetration not surpassing the middle of the cavity depth.
3. Dye penetration exceed the middle of the cavity depth.
4. Dye penetration extends over the axial wall.

Statistical analysis and data interpretation:

Data analysis was accomplished by SPSS software, version 18 (SPSS Inc., PASW statistics for windows version 18. Chicago: SPSS Inc.). Qualitative data were illustrated using number and percent. Quantitative data were defined using median (minimum and maximum) for non-normally distributed data and mean± Standard deviation for normally distributed data after testing normality using Shapiro Wilk test. Significance of the attained results was predetermined at ($P\leq0.05$) level.

- Monte Carlo test was used to compare qualitative data among studied groups.
- Kruskal Wallis was used to compare between 2 calculated groups for non-normally distributed data.

RESULTS

Table 2 shows the distribution of dye leakage scores in the samples of each of the three groups tested.

TABLE (2) Distribution of microleakage scores among group samples.

Study Group		Score 1	Score 2	Score 3	Score 4
Group I	Subgroup A	1	3	8	0
	Subgroup B	1	6	2	3
Group II	Subgroup A	2	2	7	1
	Subgroup B	2	5	3	2
Group III	Subgroup A	0	2	6	4
	Subgroup B	3	7	2	0

Group Comparison:

Comparison of the leakage score median for the three tested groups using Kruskal-Wallis showed no significant difference between non treated and pretreated specimens using DOX or CHX disinfectants either with resinous or non-resinous restoration (table 3)

Comparison between the subgroups in each tested group using Monte Carlo tests revealed no significant difference between resinous and non-resinous restorative materials for both non-pretreated (table 4), (figure 2) and DOX pretreated groups (table 5), (figure 3). However, a significant difference ($P=0.001^{*}$) was noticed between the two tested restorative materials in CHX pretreated group with non-resinous Glass Ionomer material showed less microleakage median (table 6), (figure 4).

TABLE (3) Comparison of microleakage scores median between studied groups for both restorative materials using Kruskal Wallis test.

Subgroup	Score median (min-max)			p value#
	Group I Non-pretreated Specimens	Group II DOX pretreated specimens	Group III CHX pretreated specimens	
A (Surefil One)	3(1-3)	3(1-4)	3(2-4)	p=0.124
B (Glass Ionomer)	2(1-4)	2(1-4)	2(1-3)	p=0.220

TABLE (4) Comparison of microleakage scores between tested restorative materials in group I using Monte Carlo test.

Microleakage Scores	Group I Non-pretreated Specimens		p value#
	I A (Surefil One) n(%)	I B (Glass Ionomer) n(%)	
Score 1	1(8.3%)	1(8.3%)	0.799
Score 2	3(25.0%)	6(50%)	
Score 3	8(66.7%)	2(16.7%)	
Score 4	=0	3(25%)	

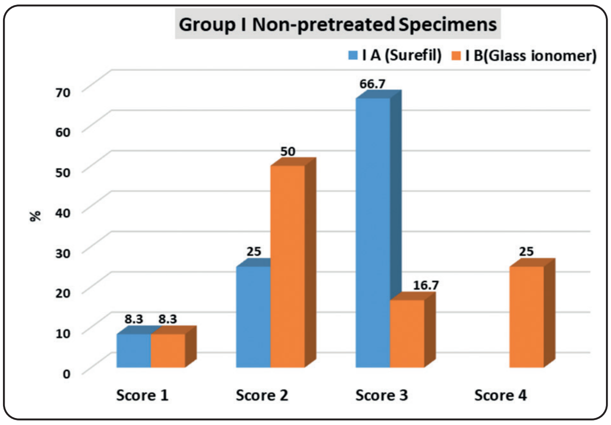

Fig. (2): Comparison of microleakage scores between tested restorative materials in Group I.

TABLE (5) Comparison of microleakage scores between tested restorative materials in group II using Monte Carlo test.

Microleakage Scores	Group II DOX		p value#
	II A (Surefil One) n(%)	II B (Glass Ionomer) n(%)	
Score 1	2(16.7%)	2(16.7%)	0.590
Score 2	2(16.7%)	5(41.7%)	
Score 3	7(58.3%)	3(25%)	
Score 4	1(8.3%)	2(16.7%)	

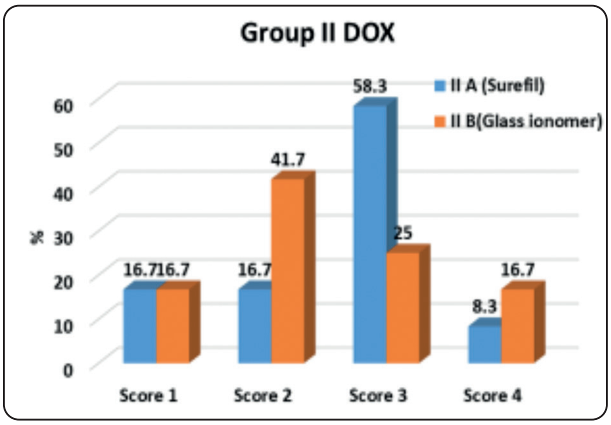

Fig. (3): Comparison of microleakage scores between tested restorative materials in Group II.

TABLE (6) Comparison of microleakage scores between tested restorative materials in group III using Monte Carlo test.

Microleakage Scores	Group III CHX		p value#
	III A (Surefil One) n(%)	III B (Glass Ionomer) n(%)	
Score 1	0	3(25%)	0.001*
Score 2	2(16.7%)	7(58.3%)	
Score 3	6(50%)	2(16.7%)	
Score 4	4(33.3%)	0	

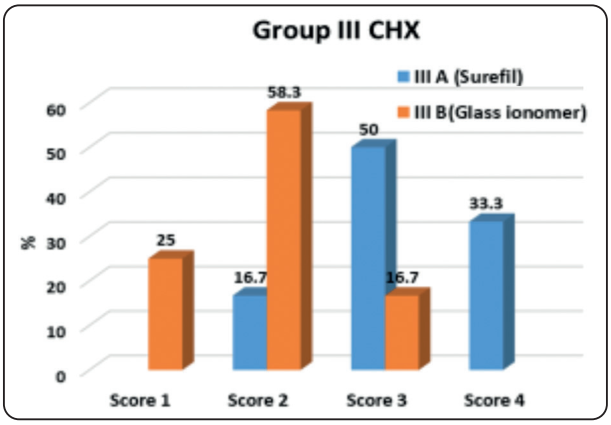

Fig. (4): Comparison of microleakage score between tested restorative materials in group III..

DISCUSSION

Obtaining a good seal at the tooth surface-restoration interface is crucial for a clinically durable restoration. [26] Microleakage which is defined as the flow of bacteria, fluids, and ions along the tooth-restoration interface is considered as a significant cause of recurrent caries and regarded as the most typical reason for restoration failure. [27-29] Finding a restorative material that has improved bond properties in a trial to reduce microleakage is professionally needed. Chemical bonding on tooth structure is crucial for maintaining marginal integrity, stability, and the durability of adhesive bonds. [30]

Glass ionomer cement (GIC) is the only restorative material that able to develop a chemical as well as a micromechanical bond with the tooth substance.[31,32] Ionic bonds between GIC and tooth structure are created as a result of the chemical reaction that occurs at the surfaces of teeth between carboxylic groups of polyalkenoic acid and calcium ions of hydroxyapatite. [33] In spite of the development of different types of GIC, several investigations showed that none of those materials produce ideal marginal seal, which is thought to be a primary cause of microleakage. [34,35]

Recently self-adhesive composites have combined properties of restorative composites and self-adhesive monomers, thereby neglecting the adhesive application step and in turn, simplifying direct restorative procedures. [36] To establish sufficient adhesion, acidic groups were added to the structural monomers. [37] Surefil One self-adhesive resin-based bulk-fill restorative material has recently been created to combine the self-adhesive properties of classic polyacids of glass ionomer cements with the crosslinking capacity of structural monomers of resin composites by incorporation of the modified polyacid system of high molecular weight (MOPOS). [38]

Unavoidable degree of resin composite shrinkage continually occurs during its polymerization resulting in uncontrolled stresses on the dentin/ restoration margins causing marginal leakage, post-operative sensitivity and secondary caries.[39] Therefore, it is advisable to use powerful disinfectants preceding cavity restoration that should be anti-bacterially active and at the same time not interfering with the bonding of the applied restorations.[40]

Chlorhexidine (CHX), one of the cavity disinfectants, has been widely used. It is suited for use as a primer because it has been an antibacterial agent in dentistry. [41] CHX was chosen in the present study due to its clinical applicability, wide availability in dental offices, and its brief clinical application time.[42] CHX retains a great affinity for dental tissue by adhering to the negative carboxyl groups of the collagen matrix and the phosphate groups of calcified dentin crystallites.[43] CHX water-based solutions, which also operate as rehydrating agents, maintain the humidity necessary to keep the collagen network of dry dentin in an extended condition. [44] Doxycycline belongs to the tetracycline antibiotics with a broad-spectrum activity against both gram-positive and gram-negative microorganisms that could be used as a potent cavity disinfectant. [45]

Microleakage as a critical factor in determining the success of any restorative material used in tooth restorations particularly in the cervical margin, [46] in the current study, the microleakage of one type of conventional glass ionomer restoration and one type of self-adhesive bulk fill resin composite was examined using dye penetration test after pretreatment with two types of cavity disinfectants; CHX and DOX. Using of dye penetration method with methylene blue was chosen in this study due to its cost-effectiveness, widespread use and popularity among researchers. [47-49] The importance of the common dye penetration method following thermocycling for assessment of microleakage lies in the fact that it is comparable to what restorations face during their actual clinical service. [50]

Thermocycling is a critical technique for determining the sealing capability of restorative materials. [51] The discrepancy in the coefficient of thermal expansion between the tooth and the restorative material causes thermally induced stresses, that can result in gap formation and microleakage. [52] Comparing the microleakage degree of the two types of restoration used in the current study, we found that conventional glass ionomer showed lesser degree of dye leakage than self-adhesive resin composite particularly in CHX pretreated specimens. This could be explained by the fact that the coefficient of thermal expansion of traditional GICs is near to the thermal expansion coefficient of hard dental tissues, which has been identified as a key factor for good marginal adaptability in comparison to resinous restorative materials. [53,54] In addition to the inherent ability of CHX to maintain dentin humidity that improve the interaction of GICs with non-collapsed collagen networks. [44]

A recent study has reported that CHX disinfectant causing improvement in the cervical marginal seal of bulk-fill composite restoration. [22] However, according to Campos et al. [55], the use of 2% CHX was detrimental to bond strength and should be avoided before using self-etch adhesives. Additionally, Stanislawczuk et al.[56] observed that 2% doxycycline threaten the bond strength and quality of hybrid layer of different adhesives. In the present study we evaluated the effect of CHX and DOX cavity disinfectants on dentinal marginal seal and no statistically significant difference was observed in the mean microleakage value between the non-pretreated and CHX & DOX pretreated specimens for both types of restorations. This is in accordance with Bin-Shuwaish et al. who stated that microleakage at dentin margins was not affected by CHX-pretreatment in teeth restored with bulk fill composite using the self-etch mode of adhesion. [57] The same finding confirmed by Loguercio et al. who found that using 2% minocycline and 2% CHX did not jeopardize the integrity of the resin-dentin interface. [58] Additionally, Sung et al. found that Chlorhexidine has no negative effect on marginal seal ability of resin composite in Class V cavities. [59] Thus, the findings of the current study are consistent with the null hypothesis tested.

CONCLUSION

The current study's findings indicate that using of cavity disinfectants has no effect on gingival margin sealing of both resinous and non-resinous restorative materials. Long-term clinical trials are recommended to support these findings.

REFERENCES

1. Minguez N, Ellacuria J, Soler JI, Triana R, Ibaseta G. Advances in the history of composite resins. J Hist Dent. 2003; 51:103-5.
2. De Brito, O., de Oliveira, I. & Monteiro, G. Hydrolytic and biological degradation of bulk-fill and self-adhering resin composites. Oper. Dent. 2019; 44: E223-E233.
3. Nakano EL, de Souza A, Boaro L, Catalani LH, Braga RR, Gonçalves F. Polyermization stress and gap formation of self-adhesive, bulk-fill and flowable composite resins. Oper. Dent. 2020; 45: E308-E316.
4. Dionysopoulos P, Kotsanos N, Papadogiannis Y, Konstantinidis A. Artificial secondary caries around two new F-containing restoratives. Oper Dent. 1998;23:81-6.
5. Mickenautsch S, Yengopal V. Demineralization of hard tooth tissue adjacent to resin-modified glass-ionomers and composite resins: A quantitative systematic review. J Oral Sci 2010; 52:347-57.
6. Iazzetti JC, Burgess D. Selected Mechanical properties of fluoride-releasing restorative materials. Oper Dent. 2001; 26:21-6.
7. Fleming G. Advances in Dental Materials. Prim. Dent. J. 2014, 3, 54-61.
8. Peterson J., Rizk M., Hoch M., Wiegand A. Bonding performance of self-adhesive flowable composites to enamel, dentin and a nano-hybrid composite. Odontology 2018; 106: 171-180.
9. Ayuk S. M., Abrahamse H. & Houreld N. N. The Role of Matrix Metalloproteinases in Diabetic Wound Healing in relation to Photobiomodulation. J Diab Res.2016; 28: 95-98.
10. Mohammed Hassan A, Ali Goda A, Baroudi K. The effect of different disinfecting agents on bond strength of resin composites. Int J Dent. 2014;2014:231-235.
11. Chuang SF, Jin YT, Liu JK, Chang CH, ShiehDB. Influence of flowable composite liningthickness on Class II composite restorations. Oper Dent 2004;29:301-8.

12. Dionysopoulos D. Effect of digluconate chlorhexidine on bond strength between dental adhesive systems and dentin: A systematic review. Conserv Dent. 2016; Jan-Feb:19(1): 1-6.

13. Hameed H, Babu B, Sagir VM , Chiriyath K, Mathias J, Shaji A P. Microleakage in Resin Composite Restoration following Antimicrobial Pre-treatments with 2% Chlorhexidine and Clearfil Protect Bond Journal of International Oral Health 2015; 7(7):71-76.

14. Manhart J, Chen H Y, Mehl A, Weber K, Hickel R. Marginal quality and microleakage of adhesive class V restorations. J Dent. 2001;29(02):123–130.

15. Türkün M, Türkün L S, Kalender A. Effect of cavity disinfectants on the sealing ability of nonrinsing dentin-bonding resins. Quintessence Int. 2004;35(06):469–476.

16. Zheng P, Zaruba M, Attin T, Wiegand A. Effect of different matrix metalloproteinase inhibitors on microtensile bond strength of an etch-and-rinse and a self-etching adhesive to dentin. Oper Dent. 2015 Jan-Feb;40(1):80-6.

17. Zheng P., & Chen H. Evaluate the effect of different MMPS inhibitors on adhesive physical properties of dental adhesives, bond strength and MMP substrate activity. Scientific Reports, 2017: 7(1), 4975.

18. Ebrahimi-Chaharom ME, Abed-Kahnamoui M, Bahari M, Hamishehkar H, Gharouni M. Effect of different concentrations of specific inhibitor of matrix metalloproteinases on the shear bond strength of self-adhesive resin cements to dentin. J Clin Exp Dent. 2017 Mar 1;9(3):e431-e436.

19. Miranda M., Silva E.M.D., Oliveira M.F., Simmer F.S., Santos G.B.D., Amaral C.M. Resin-dentin bond stability of etch-and-rinse adhesive systems with different concentrations of MMP inhibitor GM1489. J Appl Oral Sci. 2020;28.

20. De Caluwé T, Vercruysse CW, Ladik I, et al. Addition of bioactive glass to glass ionomer cements: effect on the physicochemical properties and biocompatibility. Dent Mater 2017;33(4):e186-e203.

21. Jyothi K, Annapurna S, Kumar AS, Venugopal P, Jayashankara C. Clinical evaluation of giomer- and resin-modified glass ionomer cement in class V noncarious cervical lesions: an in vivo study. J Conserv Dent 2011;14(4):409-413.

22. Bin-Shuwaish M, AlHussaini A, AlHudaithy L, AlDukhiel S, AlJamhan A, Alrahlah A. Effects of different antibacterial disinfectants on microleakage of bulk-fill composite bonded to different tooth structures. BMC Oral Health. 2021 Jul 16;21(1):348.

23. Ebaya MM, Ali AI, Mahmoud SH. Evaluation of Marginal Adaptation and Microleakage of Three Glass Ionomer-Based Class V Restorations: In Vitro Study. Eur J Dent. 2019 Oct;13(4):599-606.

24. García Marí L, Climent Gil A, LLena Puy C. In vitro evaluation of microleakage in Class II composite restorations: High-viscosity bulk-fill vs conventional composites. Dent Mater J. 2019 Oct 2;38(5):721-727.

25. Abd Al Hbdan A. Review of microleakage evaluation tools. J Int Oral Health 2017;9(4):141–145

26. Majety KK, Pujar M.In vitro evaluation of microleakage of class II packable composite resin restorations using flowable composite and resin modified glass ionomers as intermediate layers. J Conserv Dent 2011;14:414-7.

27. Bergenholtz G, Cox CF, Loeshe WJ, Syed SA. Bacterial leakage around dental restorations: its effect on the dental pulp. J Oral Pathol. 1982; 1:439-450.

28. Eriksen HM, Pears G. In vitro Caries related to marginal leakage around composite resin restorations. J Oral Rehab. 1978; 5:15-20.

29. Brannstrom M. Communication between the oral environment and the dental pulp associated with restorative treatment. Oper Dent. 1984; 9:57-68.

30. Mitra SB, Lee CY, Bui HT, Tantbirojn D, Rusin RP. Long-term adhesion and mechanism of bonding of a paste-liquid resin-modified glass-ionomer. Dent Mater. 2009; 25: 459-466.

31. De Munck J, Van Landuyt K, Peumans M, Poitevin A, Lambrechts P, Braem M, et al. A critical review of the durability of adhesion to tooth tissue: Methods and results. J Dent Res 2005;84:118-32.

32. Tyas MJ, Burrow MF. Adhesive restorative materials: A review. Aust Dent J. 2004;49:112-21.

33. Wilson AD, Prosser HJ, Powis DM. Mechanism of adhesion of polyelectrolyte cements to hydroxyapatite. J Dent Res. 1983; 62: 590-592.

34. Diwanji A, Dhar V, Arora R, Madhusudan A, Rathore AS. Comparative evaluation of microleakage of three restorative glass ionomer cements: An in vitro study. J Nat Sci Biol Med. 2014; 5: 373-377.

35. Rekha CV, Varma B, Jayanthi Comparative evaluation of tensile bond strength and microleakage of conventional glass ionomercement, resin modified glass ionomer cement and compomer: An in vitro study. Contemp Clin Dent. 2012; 3: 282-287.

36. Kamatchi M, Ajay R, Gawthaman M, Maheshmathian V, Preethi K, Gayatrikumary T. Tensile Bond Strength and Marginal Integrity of a Self-adhering and a Self-etch Adhesive Flowable Composite after Artificial Thermomechanical Aging. Int J Clin Pediatr Dent 2022;15(2):204-209.
37. Sidhu S. K. & Nicholson J. W. A review of glass-ionomer cements for clinical dentistry. J. Funct. Biomater. 2016. 7: 16.
38. Klee J. E., Renn C. & Elsner O. Development of novel polymer technology for a new class of restorative dental materials. J. Adhes. Dent. 2020; 22(1), 35-45.
39. Ferracane JL. Resin composite--state of the art. Dent Mater 2011;27(1):29-38.
40. Breschi L, Mazzoni A, Ruggeri A, Cadenaro M, Di Lenarda R, De Stefano Dorigo E. Dental adhesion review: Aging and stability of the bonded interface. Dent Mater 2008;24:90-101.
41. Gendron R, Grenier D, Sorsa T, Mayrand D. Inhibition of the activities of matrix metalloproteinases 2, 8, and 9 by chlorhexidine. Clin Diagn Lab Immunol. 1999;6:437-9.
42. Kim J., Uchiyama T., Carrilho M., Agee K.A., Mazzoni A., Breschi L., Carvalho R.M., Tjäderhane L., Looney S., Wimmer C., Tezvergil-Mutluay A., Tay F.R., Pashley D.H. Chlorhexidine binding to mineralized versus demineralized dentin powder. Dent. Mater. 2010;26(8):771-778.
43. Matos AB, Trevelin LT, Silva BT, Francisconi-Dos-Rios LF, Siriani LK, Cardoso MV. Bonding efficiency and durability: Current possibilities. Braz Oral Res 2017;31:e57
44. Soares CJ, Pereira CA, Pereira JC, Santana FR, do Prado CJ. Effect of chlorhexidine application on microtensile bond strength to dentin. Oper Dent 2008;33:183-8.
45. Windley W, Teixeira F, Levin L, Sigurdsson A, Trope M. Disinfection of immature teeth with a triple antibiotic paste. J Endod. 2005 Jun;31(6):439-43.
46. Mali P, Deshpande S, Singh A. Microleakage of restorative materials: an in vitro study. *J Indian Soc Pedod Prev Dent*. 2006; 24: 15-18.
47. Singla T, Pandit IK, Srivastava N, Gugnani N, Gupta M. An evaluation of microleakage of various glass ionomer based restorative materials in deciduous and permanent teeth: An in vitro study. Saudi Dent J 2012;24:35-42.
48. Yavuz I. New direction for measurement of microleakage in cariology research. J Int Dent Med Res 2010;3:19-24.
49. Sharafeddin F, Feizi N. Evaluation of the effect of adding micro-hydroxyapatite and nano-hydroxyapatite on the microleakage of conventional and resin-modified glass-ionomer Cl V restorations. J Clin Exp Dent 2017;9:e242-8.
50. Abdelaziz KM, Abogazalah NN, El-Malky W. Microleakage in contemporary esthetic restorations following cyclic wet-dry storage. Saudi J Dent Res 2016;7:81-90.
51. Wahab FK, Shaini FJ, Morgano SM. The effect of thermocycling on microleakage of several commercially available composite Class V restorations in vitro. J Prosthet Dent 2003;90:168-74.
52. Versluis A, Douglas WH, Sakaguchi RL. Thermal expansion coefficient of dental composites measured with strain gauges. Dent Mater 1996;12:290-4.
53. Burgess J, Norling B, Summitt J. Resin ionomer restorative materi-als: the new generation. J Esthet Dent. 1994; 6:207-15.
54. Morabito A, Defabianis P. The marginal seal of various restorative materials in primary molars. J Clin Pediatr Dent. 1997; 22:51-4.
55. Campos EA, Correr GM, Leonardi DP, Pizzato E, Morais EC. Influence of chlorhexidine concentration on microtensile bond strength of contemporary adhesive systems. Braz Oral Res 2009;23:340-5.
56. Stanislawczuk R, Costa JA, Polli LG, Reis A, Loguercio AD. Eff ect of tetracycline on the bond performance of etch-and-rinse adhesives to dentin. Braz Oral Res 2011;25:459-65.
57. Bin-Shuwaish MS, AlHussaini AA, AlHudaithy LH, Al-Dukhiel SA, Al-Jamhan AS. An in vitro evaluation of microleakage of resin based composites bonded to chlorhexidine-pretreated dentin by different protocols of a universal adhesive system. Saudi Dent J. 2021 Nov;33(7):503-510.
58. A D Loguercio, R Stanislawczuk, P Malaquias, M F Gutierrez, J Bauer, A Reis. Effect of Minocycline on the Durability of Dentin Bonding Produced with Etch-and-Rinse Adhesives. Oper Dent. 2016; Sep-Oct;41(5):511-519.
59. Sung EC, Chan SM, Tai ET, et al. Effects of various irrigation solutions on microleakage of Class V composite restorations. J Prosthet Dent 2004;91(3):265- 7.