Effect of Internal, Office, and Home Bleaching on Shear Bond Strength of Enamel to Porcelain Laminate Veneers

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Submitted April 12, 2021; accepted August 2, 2022.

Purpose: To compare the effects of office, home, and internal bleaching on the shear bond strength (SBS) of enamel to porcelain laminate veneers. **Materials and Methods:** A total of 36 extracted maxillary central incisors were randomly assigned to four groups: *(1)* no bleaching (control); *(2)* office bleaching with 40% hydrogen peroxide; *(3)* home bleaching with 15% carbamide peroxide; and *(4)* intracoronal bleaching with sodium perborate using the walking bleaching technique. All teeth were separately immersed in artificial saliva for 14 days. The enamel surface was then reduced by 0.5 mm, and IPS e.max press ceramic discs were bonded using a resin cement. After 24 hours, all specimens were thermocycled (5,000 cycles, 5°C to 55°C). The SBS was measured using a universal testing machine, and the failure mode was determined using a stereomicroscope. One-way ANOVA and Tukey honest significant difference tests were used for data analysis ($P < .05$). **Results:** A significant difference was noted among the groups ($P < .001$). The highest SBS was noted in the control group (15.71 ± 5.39 MPa). The mean SBS in the office bleaching group (12.30 ± 4.64 MPa) was almost the same as the control. The lowest mean SBS belonged to the home bleaching group (5.39 ± 3.99 MPa). The mode of failure was adhesive in all four groups. **Conclusion:** If bleaching is intended to be followed by porcelain veneers, the office bleaching technique with 40% hydrogen peroxide is recommended. Delaying the bonding procedure for 2 weeks does not appear to be effective with home or intracoronal bleaching. *Int J Prosthodont 2022. doi: 10.11607/ijp.7773*

Introduction

Due to the recent advances in cosmetic dentistry and the increasing desire of patients to have a more pleasing smile, the demand for esthetic treatments has greatly increased.[1] Based on the intensity and type of tooth discoloration, the treatment option may include bleaching, direct

composite veneers, porcelain laminate veneers, or full crowns.[2] Despite a long history, composite veneers, are associated with wear, marginal fracture, and discoloration.[3] Porcelain laminate veneers are a more durable option and used to cover discolored teeth, diastema closure, and correction of lateral pegs and malposed teeth that cannot undergo orthodontic treatment.[4] Despite these benefits, the application of porcelain laminate veneers may be problematic in cases with severe discolorations such as tetracycline stains.[5] In such cases, the simultaneous use of bleaching and porcelain veneers can be considered to achieve optimal esthetic results.[6]

Tooth bleaching is a safe, effective, minimally invasive, and acceptable method for the treatment of discolored teeth. Different bleaching protocols and materials are available. Vital tooth bleaching techniques include office, dentist-supervised home, and over-the-counter bleaching.[7] Office bleaching is performed in dental clinics in one or more sessions.[8] Carbamide peroxide (CP) and hydrogen peroxide (HP) are the two components used most often. High concentrations are usually used in the office (25%-40% HP and 30%-35% CP), while tooth bleaching materials containing up to 10% HP and 20% CP can be applied at home.[9,10]

Root filling materials and medicaments remaining in the root canal system or the pulp chamber can cause coronal discoloration as a result of their penetration into the dentinal tubules.[11]The walking bleaching technique is a standard method for the treatment of such cases.[2] In this method, sodium perborate (SP) mixed with water or HP is applied in the pulp chamber for a couple of days. The procedure may be repeated until a favorable result is achieved.[11]

Obtaining a strong bond for the bonded restorations is imperative to ensure success. Any modification in the enamel surface may affect the bond strength. Although tooth bleaching shows satisfactory esthetic results, some authors have reported that it may significantly decrease the bond strength of resin-bonded materials to hard tooth structures.[12] There is a large controversy regarding

the morphological changes and variations in mineral components of enamel after bleaching. This lack of agreement in literature comes from parameters related to the substrate, such as the origin of the samples, the preparation procedures, age, tooth preservation conditions, as well as the pH and concentration of the product used, timing, and interval of the procedure.[9,13,14]

Although HP is a potent and effective whitening agent, its safety and possible adverse effects are in question. Morphological changes, variations in microhardness, the mineral component of the enamel and dentin, as well as changes in the dentin-enamel junction and structural alternations in dentin have been reported following HP applications.[9] It has been shown that HP breaks down and forms free radicals i.e. nascent oxygen and hydroxyl radicals, on the enamel surface.[15] Residual oxygen in interprismatic spaces can prevent the resin to penetrate the bleached enamel and polymerize. Morphological changes and alterations in enamel composition, such as increased porosity and loss of prismatic structure and calcium, can weaken the adhesive surface and adversely affect the bond strength.[15,16] Structural changes in the enamel have also been described with CP at low concentrations.[10,17-19] On the other hand, one study revealed that tooth bleaching for 21 days with 10% CP and 7.5% HP demonstrated no significant changes in micromorphology or microhardness of the enamel.[20]

Another critical parameter is the timing of bonding following bleaching. Cheng et al. showed that the bond strength decreases by 25-60% if the bonding procedure is carried out right after bleaching.[1] Evidence also shows that the bond strength of bonded restorations to the enamel surface improves when a period has elapsed before cementation. Accordingly, a waiting time of 24 h to 3 weeks has been suggested.[1]

The literature has already described the effects of different bleaching agents and concentrations on bond strength of adhesive materials to bleached enamel[1,16,21,22]; however,

information regarding the comparison of varying bleaching protocols on the shear bond strength (SBS) of enamel to laminate veneers is missing. Thus, the present study aimed to compare the effect of office, home, and internal bleaching on SBS of enamel to porcelain laminate veneers. The null hypothesis was they all have the same effect on SBS of porcelain veneers to enamel after 2 weeks.

Materials and Methods

36 sound human maxillary central incisors were evaluated in this experimental study. The teeth were free of caries, fractures, and cracks. The study design was approved by "XXX". Dental plaque, calculus, and residual tissues were removed, and the teeth were immersed in 0.1% thymol (Azmiran) at 4°C. The specimens were randomly assigned to 4 groups (n=9): G1: control; G2: office bleaching; G3: home bleaching, and G4: intra-coronal bleaching.

Specimen Preparation

In group 2 (office bleaching), the teeth were bleached with 40% HP gel (Opalescence ® Boost; Ultradent product Inc.) in two sessions with a week interval. According to the manufacturer's instructions, in each session, a 1-mm thick layer of the bleaching gel was applied on the labial surface of the teeth and left for 20 min. The surface was periodically checked, and the gel was re-applied on areas that needed replenishing. The gel was removed with a surgical suction and then thoroughly rinsed with an air/water spray and high-volume suction. This procedure was repeated 3 times in each session. The teeth were stored in artificial saliva during the bleaching intervals.

The teeth in group 3 (home bleaching) were bleached with 15% CP gel (Opalescence® PF, Ultradent Product Inc.) for 2 weeks. A 1-mm thick layer of the bleaching gel was applied on the

labial surface of the teeth and left for 4 h daily. The gel was removed with a surgical suction and then thoroughly rinsed with an air/water spray and high-volume suction.

In group 4, the teeth underwent standard root canal treatment (palatal access, step-back technique, master apical file 40, lateral condensation, and AH26 sealer (Dentsply)). Root filling material was removed 2 mm under the CEJ level, and the canal was sealed with a 2mm thick resin-modified glass ionomer (UltraCem, Ultradent product Inc.). SP (Merck KGaA) was mixed with distilled water to a 2:1 ratio (g/mL) and placed in the access opening according to the manufacturer's instruction. The access was sealed with non-eugenol, non-resin provisional restorative material (UltraTemp, Ultradent product Inc.) The teeth were stored in artificial saliva for 1 week. After 1 week, the bleaching agent was removed, and the access cavity was rinsed and restored with UltraTemp.[11,23]

All specimens, including group 1, which did not receive any treatment, were separately stored in artificial saliva for 2 weeks. The artificial saliva consisted of 1 gm sodium carboxymethylcellulose, 4.3 gm xylitol, 0.1 gm potassium chloride, 5 mg calcium chloride, 40 mg potassium phosphate, 1 mg potassium thiocyanate, 100 gm distilled deionized water at pH 7 and was changed twice daily.[24]

Preparation of Ceramic Discs

A total of 36 IPS e.max Press (Ivoclar Vivadent AG) ceramic discs (3 mm thickness and 4 mm width) were fabricated according to the manufacturer's instruction and stored in distilled water until the bonding procedure. The discs were waxed (SU Ceramo Carving Wax; Schuler Dental), sprued, and pressed after investment. The ceramic discs were finished with diamond burs (Shenzhen Perfect Medical Instrument Co Ltd) and glazed.The above-mentioned disc dimensions

were to ensure proper placement of the universal testing machine blade at the disc-tooth interference during the SBS test.

Bonding Procedure

The roots were separated from the crowns 2 mm below the cementoenamel junction using a tapered fissure bur (#882, Teezkavan) under water irrigation. 0.5 mm of the enamel surface was reduced from each specimen. Self-limiting depth-cutting burs of 0.5mm (#834, Teezkavan) were used to define depth cuts, and a chamfer diamond bur (#850, Teezkavan) to refine the preparation. The amount of reduction was also checked using a putty index (Asia Chemi Teb Co).

The bonding procedure of the discs to the enamel surface was performed according to the manufacturer's instruction for cementation of IPS e.max via Choice 2 light cure resin cement (BISCO, Inc.) The porcelain discs were etched for 90 s with 9.5% hydrofluoric acid (BISCO, Inc.). 1-2 coats of silane (Bis-silane, Bisco Inc.) was applied to the discs for 30 s and air-dried. The enamel surfaces were etched with 32% phosphoric acid (BISCO, Inc.) for 15 s, thoroughly rinsed for 20 s, and excess waters removed; however, the surfaces were not over-dried. Next, 2 coats of bonding agent (All-bond 3, Bisco) were applied to the enamel surfaces and gently air-dried and light-cured for 10 s. A very thin layer of porcelain bonding resin (Bisco Inc.) was applied to the bonding surfaces of the discs. Next, A1 shade of choice 2 cement was applied on the prepared surfaces of the discs. The discs were seated on the middle third of the enamel surfaces in a specially designed cementing device to apply standardized static weight (49 N m) to ensure a fixed load on each disc during cementation[24] and light polymerized with a light intensity of 470 Mv/cm2 for 5 s. Each specimen was further light-cured for 40 s on all surfaces after the removal of excess cement. The emitting tip of the curing light was held as near and vertical to the resin surface as possible.

Shear Bond Strength Test

All specimens were mounted in blocks (2.5mm×3.5mm) of auto-polymerizing acrylic resin (Acropars) while the labial surface faced upwards (Fig. 1). All specimens were thermocycled (Vafaei Industrial Co.) for 5000 cycles, equivalent to 6 months of clinical service, in water baths between 5°-55°C with a dwell time of 30 s and a transfer time of 10 s.[1] After 24 h, the teeth were placed in a universal testing machine (Zwick/Roell Z020, Zwick Gmbh) at a crosshead speed of 1 mm/min until debonding. The force was applied perpendicular to the disc-tooth interface (Fig. 2). The maximum failure load (in N) was recorded and converted into MPa by dividing the failure load by the bonding area (12.56 mm2).[25]

Mode of Failure

After SBS testing, all specimens were observed under a stereomicroscope (Nikon SMZ800) at × 10 magnification for the assessment of failure modes (Fig. 3). The mode of failure was categorized as adhesive (failure at the enamel-laminate interface), cohesive (failure in the enamel or laminate alone), or mixed (both adhesive and cohesive).

Statistical Analysis

The mean SBS of the study groups was compared using one-way ANOVA and Tukey's test via SPSS version 20 ($P<0.05$).

Results

Table 1 and Figure 4 show the measures of central dispersion of the mean SBS (MPa) of the study groups. One-way ANOVA showed a significant difference between the groups in SBS ($P<0.001$). The highest mean SBS belonged to the control group (15.7±5.3 MPa) and then to the office bleaching group (12.3±4.6MPa). No statistically significant difference was found between these two groups (P=0.3 MPa);. In contrast, the values for home bleaching (5.3±3.9 MPa) and

internal bleaching groups (8.5±3.0 MPa) were significantly lower than the values in the control group ($P<0.05$) (Table1). The lowest mean SBS belonged to group 3 (home bleaching).

Mode of failure

The predominant mode of failure in all teeth in all four groups was adhesive. Adhesive failure was divided into 3 groups: failure between the cement and enamel, failure between the cement and laminate, and both. The frequencies are presented in Figure 5.

Discussion

In the present study, delaying the bonding procedure of porcelain laminate veneers to enamel for 2 weeks and 0.5 mm reduction of the enamel surface after office bleaching resulted in average SBS values close to the controls; however, these values were significantly lower after internal and home bleaching. Therefore, the null hypothesis that the 3 bleaching techniques have the same effect on SBS of porcelain veneers to enamel after 2 weeks was rejected.

Bleaching treatments with oxidizing agents have proved to be effective for correcting and reducing intrinsic and/or external discoloration resistant to mechanical cleaning through breaking the double bonds of chromophores; however, it can lead to mineral loss, increased surface roughness, and therefore decrease the bond strength of enamel to adhesive materials.[1,12,26] The presence of free radicals that inhibit resin penetration and polymerization, loss of calcium and phosphate, and increased porosities of the enamel surface has been attributed as the causes.[27,28] Enamel is the most mineralized tissue in the human body consisting of 96% mineral and 4% organic components.[29] The structure of enamel hydroxyapatite can change as a result of bleaching.[8] Ben-Amar et al. reported an increase in enamel surface porosities and a significant decrease in enamel bond strength to composite resins after bleaching with CP.[30] Studying the effect

of various home-bleaching techniques on enamel properties, De Miranda et al found an initial loss of structural organization with 10% HP gel and 10% HP whitening strips after 4 weeks and 10% CP after 8 weeks. They stated that oxidation of proteins in enamel with sacrificial bonds capable of unfolding against tensions and recovering their arrangement with the removal of forces seems to be decisive for altering the mechanical behavior of the enamel.[31] Oliveira et al. also showed that the use of 10% CP reduces the surface microhardness of enamel.[32] Titley et al. stated that in SEM analysis of bleached samples with 35% HP to which resin composite was bonded, large areas of enamel surface were free of resins. They suggested an interaction between the resin and the remaining peroxides on the enamel surface, which can prevent the complete polymerization of the resin.[33] Increased organic ratio of enamel as a result of denaturation of proteins has also been observed.[34] As a result, the literature suggests that bonding processes should not be performed immediately after bleaching. This delay will help removal of oxygen, residual peroxide, or peroxide-related materials, and therefore remineralization of the enamel will occur in the presence of saliva.[33,35] Studies have suggested 24 h to 3 weeks elapse before cementation.[1,36,37] This study considered a 2-week interval. Although the available information is not enough regarding the number of free radicals remaining at different depths of enamel after bleaching, it is thought that changes usually occur on the surface. Therefore, the preparation of enamel may partially eliminate the effect of residual oxygen and structural changes resulting from bleaching and improve the bond strength.[1]

Office bleaching is often used when results are expected faster.[8] In the present study, 40% HP was used, and the mean values for SBS in this group were lower than the controls; however, this difference was not statistically significant. The study of Borges et al. showed that the bond strength values after bleaching with 35% HP and 35% CP were significantly different from the

controls after 1 and 2, but not 3 weeks.[38] In a study by Beltagui et al. bonding of IPS e.max press discs to bleached enamel with 40% HP caused a significant decrease in the average values of SBS immediately but not after 7 days.[16] In the two mentioned studies, the duration of bleaching was 20 minutes; however, the total bleaching time in the present study was 60 min. It can be concluded that if the bleaching time is reduced, probably less delay is required for bonding.

Home bleaching is a standard and safe method of tooth whitening.[8] Although the concentrations used for home bleaching are lower, the longer duration of treatment appears to have a significant effect on the bond strength. In the current study, 15% CP caused a significant reduction in SBS of porcelain laminate discs to the enamel. Mortazavi et al. declared that bleaching with 15% CP and bonding of composite resin 24 h later caused a significant reduction in bond strength.[39] Cavalli et al. investigated the effect of delayed bonding for 24 h, and 1, 2, and 3 weeks after bleaching with 10% to 20% CP. They declared that the bond strength first decreased compared to the controls, but not after 3 weeks.[40] Mourad et al. showed that bleaching with 20% CP and delayed bonding for 24 h using 5 different adhesive systems, the bond strength reduced in all groups compared to the controls.[41] In our study, increasing the duration of delay bonding to 2 weeks and enamel reduction did not improve the bond strength of home bleaching. This might indicate that this time was insufficient to neutralize the effect of free radicals and structural changes in the enamel. Metz et al. demonstrated that home bleaching with 15% CP and delayed bonding of composite veneers after 2 weeks did not cause a significant reduction in bond strength.[42] The results of Basting et al. also showed that bleaching with 10% to 22% CP and delayed bonding of resin composites after 15 days did not reduce the bond strength of enamel.[36] It is important to see how the bond strength will be in the long run and under various conditions such as temperature changes inside the mouth. The two latter studies, however failed to do so.

The walking bleaching technique is a standard method for discolored non-vital teeth that can be performed using SP or HP.[88] SP is easier to control and safer than HP. In the presence of an acid, warm air, or water, it breaks down to form sodium metaborate, hydrogen peroxide, and nascent oxygen.[43] Internal bleaching caused a significant reduction in SBS in the present study. Since the bleaching material is applied inside the pulp chamber, a 0.5mm reduction of the enamel surface does not improve the bond strength. In internal bleaching, the bleaching agent penetrates from the dentin to the enamel, and resin restoration of the teeth that have undergone internal bleaching requires a delay of at least 1 to 4 weeks.[44,45] Shinohara et al. indicated that intra-coronal bleaching with SP significantly decreases the bond strength of composite resins to the enamel surface after delayed bonding by 7 days.[46] Gungor et al. also stated that intra-coronal bleaching with HP, SP, and CP significantly decreases the bond strength of orthodontic brackets cemented with composite resin to enamel after delayed bonding by 4 weeks.[44]

Thermocycling is an in-vitro process routinely used to simulate the natural aging of bonded interfaces.[47,48] It causes mechanical stresses and accelerates the hydraulic degradation of adhesive hydrophilic components and hybrid layer collagen fibrils. These factors can cause depreciation at the bonding site.[49] However, it should be noted that thermocycling alone might not be sufficient to simulate the oral environment, and other methods such as dynamic loading could be accompanied by more realistic results.[47]

The mode of failure was adhesive in all specimens in the present study, which shows a weak bond between cement-laminate, and enamel-laminate. The highest frequency of failures at the cement-laminate interface was observed in the office group; while, the highest frequency of failures at the cement-enamel interface was noted in the home group, which may be due to insufficient penetration and polymerization of resin cement into the enamel, as well as higher

structural and compositional changes following bleaching with 15% CP. Failures were reported to be of adhesive[36], mixed[24,] and cohesive type[50] in other studies. The differences may be due to how the teeth were prepared, storage conditions, and the type of porcelains and cement used.

Despite the recent advances, the bonded interface is still considered the weakest point in adhesive restorations.[51] Bond strength can be assessed by laboratory methods or clinical trials. Although the relationship between laboratory test results and the reliability of clinical performance remains questionable, they can be used to gather data quickly, easily, and specifically about a parameter. Laboratory methods for evaluating the bond strength are divided into static and dynamic tests. Static tests are performed in a macro or micro design based on the bonded area.[52] Owing to the simplicity of specimen preparation, testing protocol, and lower incidence of pretest failure, SBS is commonly used for bond strength assessment; however, finite element analysis has demonstrated that conventional (Macro) shear bond strength tests might result in non-uniform and heterogenous stress patterns.[53,54] Results of shear bond strength and failure mode analysis are also influenced by loading technique and specimen dimensions; therefore, they should be extended with caution for clinical usage.[51]

Conclusion

Delaying the bonding procedure of laminate veneers for 2 weeks does not appear to affect the bond strength of these restorations to enamel surface when home or intra-coronal bleaching is planned to be performed; therefore, if the treatment plan includes bleaching followed by porcelain laminate veneers, it is recommended to perform office than home bleaching.

Acknowledgments

This study was a part of an undergraduate thesis that has been supported by the Research center, Dentistry Research Institute, Tehran University of Medical Sciences in grant no: 98-01-70-40133. The authors report no conflicts of interest.

Ethical Approval

Study design was approved by the ethics committee of Tehran University of Medical Sciences (IR.TUMS.DENTISTRY.REC.1398.034)

References

1. Cheng Y-l, Musonda J, Cheng H, Attin T, Zheng M, Yu H. Effect of surface removal following bleaching on the bond strength of enamel. BMC Oral Health. 2019; 19(1):50.

2. Setien VJ, Roshan S, Nelson PW. Clinical management of discolored teeth. Gen Dent. 2008; 56(3):294-300.

3. Cramer NB, Stansbury JW, Bowman CN. Recent advances and developments in composite dental restorative materials. J Dent Res. 2011; 90(4):402-16.

4. Muhamad A-H, Abdulgani M, Abdulgani A. Porcelain laminates: the Future of Esthetic Dentistry. IOSR-JDM. 2017; 16:68-75.

5. Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. Porcelain veneers: a review of the literature. J Dent. 2000; 28:163-77.

6. Putter H. Bleaching and/or porcelain veneers: case reports. J Esthet Dent. 1992; 4:67-70.

7. Heymann HO. Tooth whitening: facts and fallacies. Br Dent J. 2005;198:514.

8. Alqahtani MQ. Tooth-bleaching procedures and their controversial effects: A literature review. Saudi Dent J. 2014;26:33-46.

9. Llena C, Esteve I, Forner L. Effect of Hydrogen and Carbamide Peroxide in Bleaching, Enamel Morphology, and Mineral Composition: In vitro Study. J Contemp Dent Pract. 2017; 18(7):576-82.

10. Abouassi T, Wolkewitz M, Hahn P. Effect of carbamide peroxide and hydrogen peroxide on enamel surface: an in vitro study. Clin Oral Investig. 2011; 15(5):673-80.

11. Abbott P, Heah SY. Internal bleaching of teeth: an analysis of 255 teeth. Aust Dent J. 2009;54:326-33.

12. Swift EJ Jr. Restorative considerations with vital tooth bleaching. J Am Dent Assoc. 1997;128 Suppl:60S-64S.

13.Izquierdo-barba I, Torres-Rodríguez C, Matesanz E, Vallet-Regí M. New approach to determine the morphological and structural changes in the enamel as consequence of dental bleaching. Materials Letters. 2015; 141:302-6.

14. Götz H, Duschner H, White DJ, Klukowska MA. Effects of elevated hydrogen peroxide 'strip' bleaching on surface and subsurface enamel including subsurface histomorphology, micro-chemical composition and fluorescence changes. J Dent. 2007; 35(6):457-66.

15. Joiner A. The bleaching of teeth: a review of the literature. J Dent. 2006;34:412-9.

16. Beltagui S, Bakry S, Mohy El-Din M. Effect of Antioxidant Treatment and Delayed Bonding on Shear Bond Strength of Porcelain Laminate Veneers Bonded to Bleached Enamel (In Vitro Study). Int J Dent & Oral Heal. 2017;3:13-1.

17. Rodrígues JA, Basting RT, Serra MC, Rodrígues Júnior AL. Effects of 10% carbamide peroxide bleaching materials on enamel microhardness. Am J Dent. 2001; 14(2):67-71.

18. Zantner C, Beheim-Schwarzbach N, Neumann K, Kielbassa AM. Surface microhardness of enamel after different home bleaching procedures. Dent Mater. 2007; 23(2):243-50.

19. de Vasconcelos AA, Cunha AG, Borges BC, Vitoriano Jde O, Alves-Júnior C, Machado CT, et al. Enamel properties after tooth bleaching with hydrogen/carbamide peroxides in association with a CPP-ACP paste. Acta Odontol Scand. 2012; 70(4):337-43.

20.Sasaki RT, Arcanjo AJ, Flório FM, Basting RT. Micromorphology and microhardness of enamel after treatment with home-use bleaching agents containing 10% carbamide peroxide and 7.5% hydrogen peroxide. J Appl Oral Sci. 2009; 17(6):611-6.

21. Halabi S, Matsui N, Nikaido T, Abdo A, Burrow MF, Tagami J. Effect of two bleaching regimens on enamel bonding performance. Dent Mater J. 2020; 39(6):984-991.

22. Ozyilmaz O U, Aykent F, Tuncdemir A, Kara H. Influence of different bleaching systems on the bond strength of laminate veneer to enamel. IJCBR. 2018; 4:1-6.

23. Ritter A. Sturdevant's Art and Science of Operative Dentistry. St. Louis: Mosby, 2019.

24. Egala K, Hussin E, Sallam H. Effect of antioxidant application on the shear bond strength of laminate veneers bonded to bleached enamel after different time intervals from bleaching. Egypt Dent J.2014; 60:4965-80.

25. Weerasinghe DS, Nikaido T, Wettasinghe KA, Abayakoon JB, Tagami J. Micro-shear bond strength and morphological analysis of a self-etching primer adhesive system to fluorosed enamel. J Dent. 2005 May; 33(5):419-26.

26. Monterubbianesi R, Tosco V, Bellezze T, et al. A Comparative Evaluation of Nanohydroxyapatite-Enriched Hydrogen Peroxide Home Bleaching System on Color, Hardness and Microstructure of Dental Enamel. Materials (Basel). 2021;14(11): 3072-83.

27. Titley KC, Torneck CD, Smith DC, Adibfar A. Adhesion of composite resin to bleached and unbleached bovine enamel. J Dent Res. 1988;67:1523-8.

28. Rotstein I, Dankner E, Goldman A, Heling I, Stabholz A, Zalkind M. Histochemical analysis of dental hard tissues following bleaching. J Endod. 1996;22:23-5.

29. Ten Cate AR. Ten Cate's Oral Histology: Development, Structure, and Function. St. Louis: Mosby, 1994.

30. Ben-Amar A, Liberman R, Gorfil C, Bernstein Y. Effect of mouthguard bleaching on enamel surface. Am J Dent. 1995; 8(1):29-32.

31. De Miranda MSF, Eltom AE, Souza Camargo S, Rocha GM, Reis Perez CD. Effect of different home-bleaching techniques for a regular or an extended time on enamel properties. Indian J Dent Res. Nov-Dec 2020;31(6):924-929.

32. Oliveira Rd, Paes Leme AF, Giannini M. Effect of a carbamide peroxide bleaching gel containing calcium or fluoride on human enamel surface microhardness. Braz Dent J. 2005; 16(2):103-6.

33. Titley KC, Torneck CD, Smith DC, Chernecky R, Adibfar A. Scanning electron microscopy observations on the penetration and structure of resin tags in bleached and unbleached bovine enamel. J Endod. 1991; 17(2):72-5.

34. Barkhordar RA, Kempler D, Plesh O. Effect of nonvital tooth bleaching on microleakage of resin composite restorations. Quintessence Int. 1997; 28(5):341-4.

35. Dishman MV, Covey DA, Baughan LW. The effects of peroxide bleaching on composite to enamel bond strength. Dent Mater .1994; 10(1):33-6.

36. Basting RT, Rodrigues JA, Serra MC, Pimenta LA. Shear bond strength of enamel treated with seven carbamide peroxide bleaching agents. J Esthet Restor Dent. 2004; 16(4):250-9.

37.Bittencourt BF, Dominguez JA, Loguercio AD, Gomes JC, Gomes OM. Influence of two different methods of delivering fluoride on bond strength and degree of conversion of an adhesive after bleaching. J Adhes Dent. 2013; 15(6):553-9.

38. Borges AB, Rodrigues JR, Borges AL, Marsilio AL. The influence of bleaching agent on enamel bond strength of a composite resin according to the storage time. Revista de Odontologia da UNESP. 2007; 36: 77-83.

39. Mortazavi V, Fathi MH, Ataei E, Khodaeian N. The effect of 15% carbamide peroxide bleaching on the shear bond strength of composite to enamel. Shiraz Univ Dent J. 2009;9 Suppl. 1:24–30.

40. Cavalli V, Reis AF, Giannini M, Ambrosano GM. The effect of elapsed time following bleaching on enamel bond strength of resin composite. Oper Dent. 2001;26:597-602.

41. El Mourad AM. Stability of bonded resin composite restorations to enamel after bleaching with 20% carbamide peroxide. J Contemp Dent Pract. 2019; 20(2):247-257.

42. Metz MJ, Cochran MA, Matis BA, Gonzalez C, Platt JA, Pund MR. Clinical evaluation of 15% carbamide peroxide on the surface microhardness and shear bond strength of human enamel. Oper Dent. 2007;32:427-3.

43. Plotino G, Buono L, Grande NM, Pameijer CH, Somma F. Nonvital tooth bleaching: a review of the literature and clinical procedures. J Endod. 2008; 34(4):394-407.

44. Gungor AY, Ozcan E, Alkis H, Turkkahraman H. Effects of different intracoronal bleaching methods on shear bond strengths of orthodontic brackets. Angle Orthod. 2012;82:942-6.

45. Kılınç Hİ, Aslan T, Kılıç K, Er Ö, Kurt G. Effect of delayed bonding and antioxidant application on the bond strength to enamel after internal bleaching. J Prosthodont. 2016; 25(5):386-91.

46. Shinohara MS, Peris AR, Pimenta LA, Ambrosano GM. Shear bond strength evaluation of composite resin on enamel and dentin after nonvital bleaching. J Esthet Restor Dent. 2005; 17:22-9.

47. Ehlers V, Kampf G, Stender E, Willershausen B, Ernst CP. Effect of thermocycling with or without 1 year of water storage on retentive strengths of luting cements for zirconia crowns. J Prosthet Dent. 2015;113:609-15.

48. Morresi AL, D'Amario M, Capogreco M, Gatto R, Marzo G, D'Arcangelo C, Monaco A. Thermal cycling for restorative materials: does a standardized protocol exist in laboratory testing? A literature review. J Mech Behav Biomed Mater. 2014;29:295-308.

49. Xie C, Han Y, Zhao XY, Wang ZY, He HM. Microtensile bond strength of one- and two-step self-etching adhesives on sclerotic dentin: the effects of thermocycling. Oper Dent. 2010; 35(5):547-55.

50. St Germain HA Jr, St Germain T. Shear bond strength of porcelain veneers rebonded to enamel. Oper Dent. 2015; 40(3): E112-21.

51. Ismail AM, Bourauel C, ElBanna A, Salah Eldin T. Micro versus Macro Shear Bond Strength Testing of Dentin-Composite Interface Using Chisel and Wireloop Loading Techniques. Dent J (Basel). 2021;9.(12):140-51.

52. Van Meerbeek B, Peumans M, Poitevin A, et al. Relationship between bond-strength tests and clinical outcomes. Dent Mater. 2010;26(2): e100-121.

53. Odthon P, Khongkhunthian P, Sirikulrat K, Boonruanga C, Sirikulrat N. In vitro shear bond strength test and failure mechanism of zinc phosphate dental cement. Int J Adhes Adhes. 2015; 59:98-104.

54. Soares CJ, Santana FR, Castro CG, et al. Finite element analysis and bond strength of a glass post to intraradicular dentin: comparison between microtensile and push-out tests. Dent Mater. Oct 2008;24(10):1405-1411.

Tables

Table 1. Measures of central dispersion of shear bond strength (MPa) in the study groups (n=9)

Group	Minimum	Maximum	Mean	Standard Deviation	P-value
Control	9.27	26.54	15.71	5.39	
Office Bleaching	5.39	20.96	12.30	4.64	0.362
Home Bleaching	1.23	13.42	5.39	3.99	0.000
Internal Bleaching	4.01	12.45	8.59	3.08	0.008

Figures

Figure 1. Specimens mounted in blocks of auto-polymerizing acrylic resin

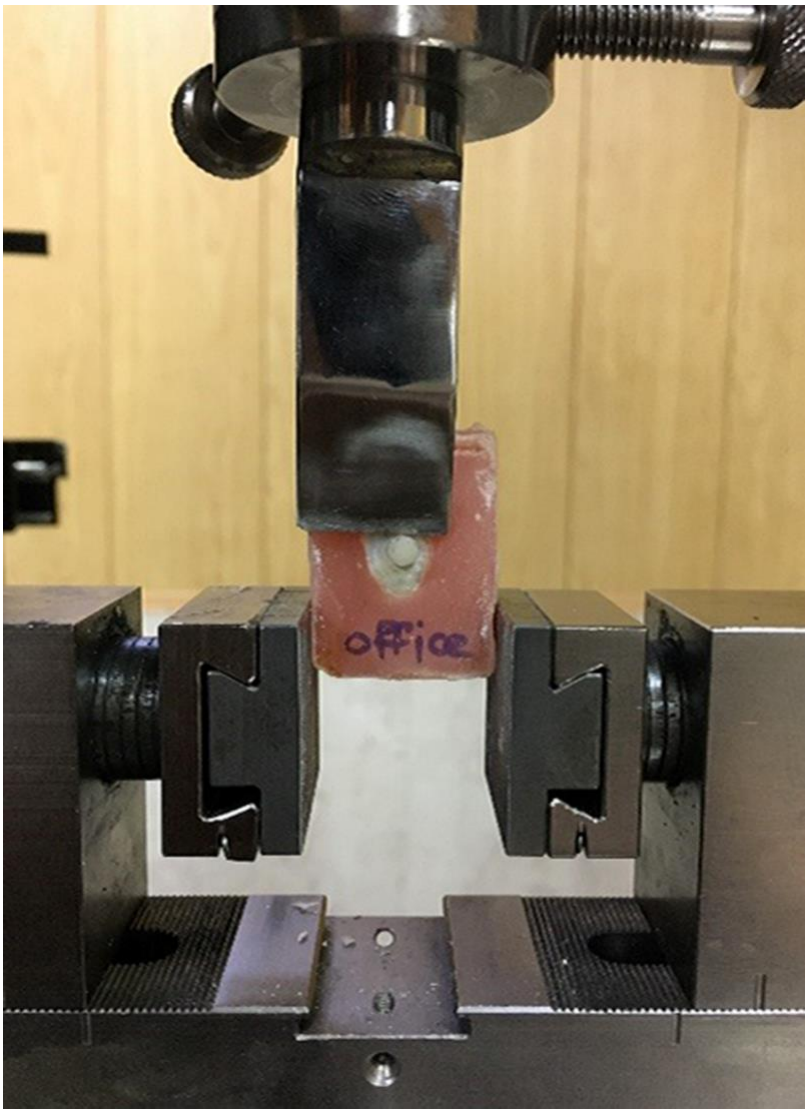

Figure 2. Examining the shear bond strength using a universal testing machine

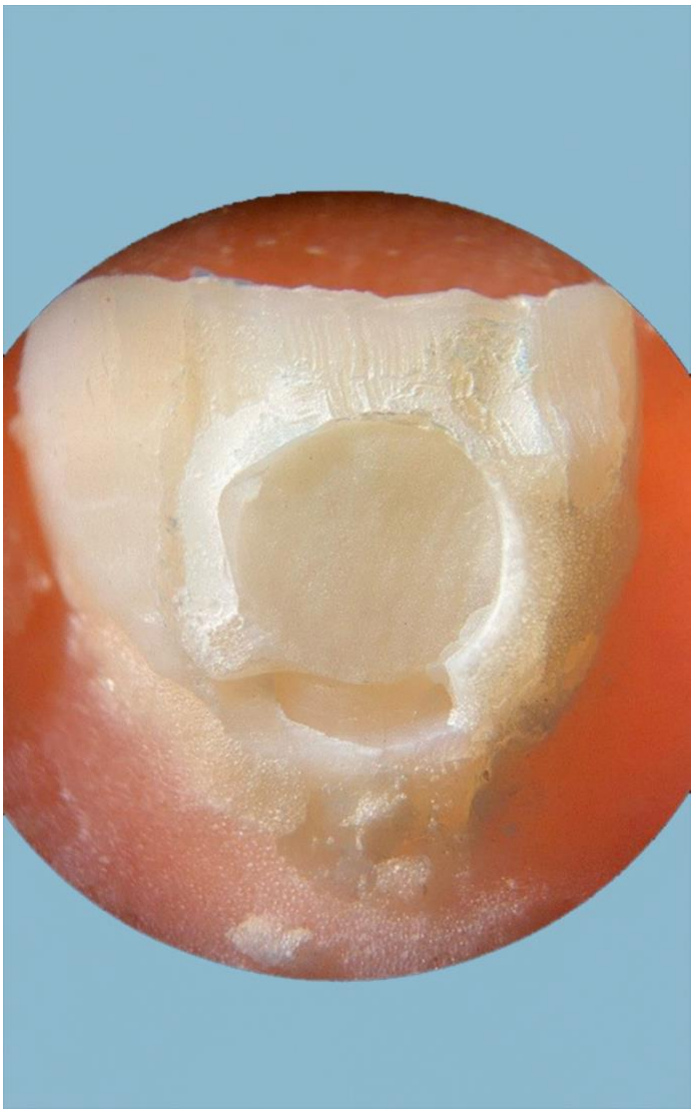

Figure 3. Adhesive failure at the cement-laminate interface observed under a stereomicroscope at ×10 magnification

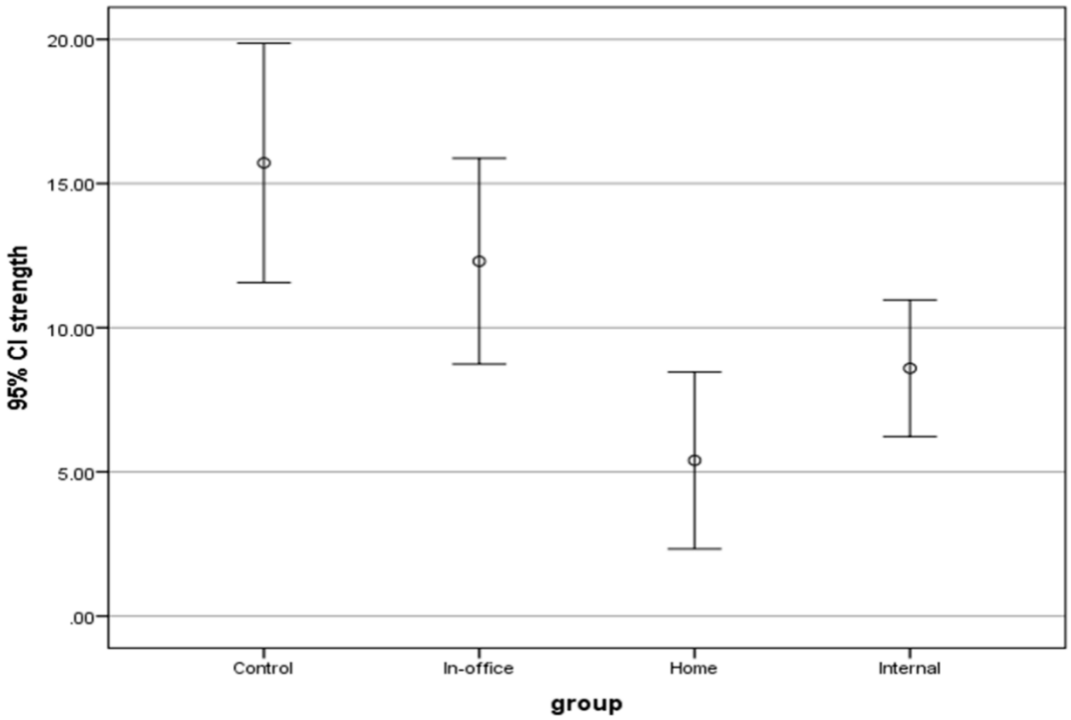

Figure 4. Error bar and 95% confidence interval of the mean shear bond strength of porcelain laminate veneers to bleached enamel

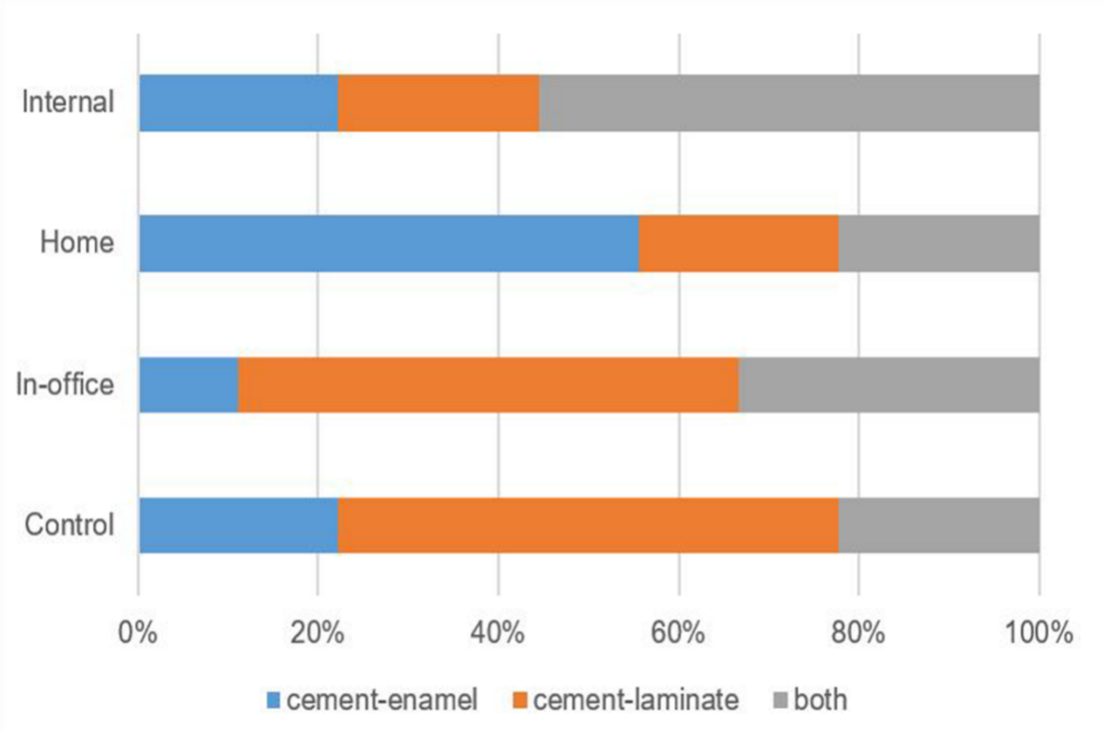

Figure 5. Frequency distribution of different adhesive failure modes in the study groups