WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 8.084
Volume 12, Issue 9, 2262-2274. Research Article ISSN 2277– 7105

EFFECT OF DIFFERENT ADHESIVE STRATEGIES ON THE POST-OPERATIVE SENSITIVITY OF CLASS I COMPOSITE RESTORATIONS

[1*]Dr. Sana Kanwal, [2]Dr. Syed Atta Ullah Shah, [3]Dr. Hina Arif, [4]Dr. Fahad Salim Khan

[1]Resident Operative Dentistry and Endodontics at Civil Hospital Quetta.

[2]Demonstrator BUMHS, Supervisior and Consultant Operative Dentistry and Endodontics.

[3]Resident Operative Dentistry and Endodontics.

[4]MCPS Operative Dentistry and Endodontics, Demonstrator BHUM.

Article Received on
22 April 2023,

Revised on 12 May 2023,
Accepted on 01 June 2023

DOI: 10.20959/wjpr20239-27622

***Corresponding Author**
Dr. Sana Kanwal
Resident Operative Dentistry and Endodontics at Civil Hospital Quetta.

ABSTRACT

Background: Post-operative sensitivity in teeth after doing a composite restoration is caused by residual stress buildup due to polymerization shrinkage resulting in de-bonding of the restoration ensuing in an enamel crack; microleakage at the margins of the restoration and secondary caries results in postoperative sensitivity. **Materials and Methods:** Total patients 188 molar occlusal restorations were placed in 39 patients (ages between 18 and 30) using 3 different kind of adhesive systems; Optibond FL (OBF), Clearfil Protect Bond (CPB), and iBond (IB) by a post-doctorate dentist or a fifth-year dental student according to the manufacturers' instructions. Post-operative sensitivity to cold and air was evaluated using a Visual Analog Scale (VAS) after 24 hours, 30, 90, and 180 days. Data were analyzed using the Mann-Whitney U and Friedman tests ($P < 0.05$). **Results:** Post-operative sensitivity scores for OBF and CPB were higher for the dental student ($P < 0.05$), while IB scores did not differ statistical significantly according to the operator ($P > 0.05$). **Conclusion:** Operator skill and experience appears to play a role in determining the outcome of post-operative sensitivity of multi-step adhesive systems although the post-operative sensitivity was low. It is suggested that the less experienced clinicians (rather than experienced clinicians) should better use the self-etching dentin bonding systems with reduced application steps to minimize the potential risk of post-operative sensitivity of dental adhesives.

KEYWORDS: Class I composite restorations, dentin bonding systems, operator skill, post-operative sensitivity.

INTRODUCTION

Despite recent improvements in adhesive dentistry, materials and esthetic demands of the patients have contributed the frequent use of composite materials in posterior teeth, post-operative sensitivity still remains a problem.[1] This complication usually fades within the first few weeks, but may last for a longer period of time, and occasionally it results in the failure of the restoration.[2] According to Brannstrǿm, post-operative sensitivity is related to the bacteria and the microleakage between the pulp and the oral cavity.[3] Beside this theory, polymerization shrinkage of the resin-based adhesive materials result in internal stress and gap formation, especially for the multistep bonging agents, because gaps would be formed in the interface between the bonding resin and dentin, which are more prone to microleakage and post-operative sensitivity between the tooth and the material.[4]

When using recently developed dentin adhesives, one of two strategies to interact with the dentin smear layer can be used: The total-etch technique or the self-etch technique. For those using the total-etch technique, the quality of the resin-dentin adhesion can be greatly affected by the duration of the acid-etching process and the amount of surface wetness present during the adhesive application.[5] Self-etching primers use non-rinsing acidic monomers that simultaneously dissolve the smear layer and prime the dentin and enamel. The latest generation of all-in-one self-etching systems combines the etchant, primer, and adhesive in two containers or in a single component, which do not require a separate etching step result in a more uniform penetration of resin into the etched dentin maintaining a better seal, excellent clinical effectiveness with a reduced clinical application time and technique sensitivity.[6,7]

Within the clinical application technique, sensitivity discrepancies of the adhesive bonding strategies, clinical experience, and skill might also affect the performance of a restoration unless the standard instructions are strictly followed. The aim of this study was to evaluate the effect of different adhesive strategies and operator skill on the development of post-operative sensitivity in class I resin composite restorations. The null hypothesis tested was that the operator variability would not affect the prevalence and severity of post-operative sensitivity when cavities for posterior composites were tested using a three-step total-etch dentin bonding system, a two-step self-etch bonding system, and a single-step self-etch system.

METHODOLOGY

This clinical study was conducted at the Dentistry and Endodontics, Sandeman Provincial Hospital, Quetta. Patients having occlusal primary caries or needing occlusal restorations were chosen and provided informed consent to participate in the study. A total of 188 molar teeth in 39 patients (males and females, ages 18 to 30 years) required occlusal composite restorations. Each patient received minimum three restorations including one of each adhesive system, and maximum 2 of each material were applied in each quadrant by only 1st and 2nd molars. Materials shown in Table 1 were randomly assigned for each tooth.

Table 1

Compositions and application procedure according to the manufacturer's instructions of the adhesive systems used in the study.

Bonding systems	Batch no	Contents	Application procedure
Optibond FL (Kerr Dental Corporation, Orange, A, USA)	2744090	uncured methacrylate ester, triethylene glycol, monomers, dimethacrylate, ytterbium rifluoride, inert mineral fillers, photoinitiators, and stabilizers	Total-etch for 15 seconds, rinse and dry, apply Prime for 15 secs, air dry for 5 secs, and apply adhesive for 15 secs, air thin for 3 secs and light-cure for 20 seconds
Clearfilprotect bond (Kuraray Medical Inc, Okayama, Japan)	41162	2-hydroxyethyl methacrylate, sodium fluoride, bisphenol A diglycidyl methacrylate, 10-methacryloyloxydecyl dihydrogen phosphate, hydrophobic aliphatic dimethacrylate, colloidal silica dl-Camphorquinone initiators, accelerators and others	Apply primer for 20 seconds, dry with gentle air flow, apply Bond and air flow gently, light-cure for 10 seconds
iBondgluma inside (Heraeus Kulzer Gmbt, Hanau, Germany)	10088	4-methacryloxyethyltrimellitic acid anhydride, acetone, glutaral	Apply for 20 seconds, dry with gentle air flow, light-cure for 20 seconds

Inclusion criteria were the presence of molar teeth requiring composite restorations either for replacement of an existing amalgam or composite filling (secondary caries or aging) or for treatment of primary carious lesions. The selected teeth needed to have occlusal contact with natural or crowned antagonist teeth. Eligibility was confirmed through clinical and radiographical evaluation. Occlusal carious lesions and existing restorations were adjudged according to a periapical radiograph to be no more than one-half the distance from the dentino-enamel junction to the pulp. Exclusion criteria were negative reactions to the vitality test, having non-carious lesions or loss of dental hard tissues, increased hypersensitivity and a pre-operative sensitivity in the carious tooth or associated restorations, allergies to composite materials, pregnancy, systemic diseases, undesired para-functional habits (bruxism, clenching, etc.), and malocclusion.

Restorations were randomly applied by either a 12-year specialist post-doctorate dentist (PDD) or a final-year dental student (DS) who were provided with the guidelines about the

procedure and materials prior to the start of the study and were told that the guidelines to be strictly followed.

Cavities were prepared with a high-speed hand piece with water coolant and finished using a low-speed hand piece without beveling, and all restorations were done using cotton roll isolation with no lining materials under the composite restorations. Three different dentin bonding systems- Optibond FL (Kerr Hawe); *n* = 62 teeth (32 by the PDD, 30 by the DS), Clearfil Protect Bond (Kuraray, Japan); *n* = 63 teeth (32 by the PDD, 31 by the DS), and iBond (HerausKulzer, Germany); *n* = 62 teeth (32 by the PDD, 30 by the DS) were used following the manufacturer's instructions. Restorations were completed using a combination of the same manufacturer's composite resin materials (*Herculite XRV*; micro hybride composite; Kerr Dental Corporation, Orange, CA, USA; *Clearfil AP-X*; micro hybride composite; Kuraray Medical Inc., Okayama, Japan; *Charisma*, universal composite; Heraeus Kulzer Gmbt, Hanau, Germany). Color matching was disregarded, and the same color of composite material (A2) was applied incrementally for each patient. Each layer was light-cured for 40 seconds (VIP Light Curing Unit, 500-600 mW/cm^2, BISCO, Schaumburg, USA) following the manufacturer's recommendations. Articulation was checked carefully, and occlusal adjustments were performed using water spray with pear- and flame-shaped carbide, diamond finishing burs and further polishing was performed using a sequence of disks (Sof-Lex Pop-On; 3M ESPE, St. Paul, MN, USA) with decreasing coarseness.

Post-operative sensitivity was assessed at 24 hours, 1 month, 3 months, and 6 months using the VAS score. Post-operative sensitivity of each restored tooth was evaluated with a standardized cold-ice stimulus applied with ice stick and air stimulus by air blown from air syringe with a standardized distance of 5 mm (45 psi). The patients' responses were then assessed using a VAS scoring index. The VAS is a 10-cm line with the anchor words "no sensitivity" (0 cm) at one end and "intolerable sensitivity" (10 cm) at the other end. We asked each patient to place a vertical mark on the VAS line to indicate the intensity of sensitivity level after the administration of the stimuli for each tooth. A blinded co-author determined the sensitivity scores and quantified each patient's response to each restoration by measuring the distance in *cm* from the anchor word (0 cm) to the mark.

Statistical analysis

During the statistical analysis, we used teeth rather than participants as the statistical units to evaluate the intensity of post-operative sensitivity to the materials tested. Post-operative sensitivity was statistically analyzed by comparing dependent variables, such as type of adhesive system, operator skill, kind of stimuli, and time. Descriptive statistics are expressed as mean ± standard deviation (SD) based on the 10 cm VAS scores. The Kolmogorov-Smirnov test was used to check the normal distribution of data. As the mean scores of groups did not show the normal distribution, the differences between the treatment groups were analyzed using the Kruskal-Wallis one-way analysis of variance. Mann-Whitney U Test was used to conduct pairwise comparisons. In addition, Wilcoxon signed rank test was also used to determine the differences between participants' responses to each material. Commercially available software (SPSS 11.0 for Windows, SPSS, Chicago) was used to perform the statistical analysis, and the significance was set at $P = 0.05$.

RESULTS

One hundred and eighty-eight restored teeth in 39 subjects were evaluated at 24-hours, 1 month, 3 months, and 6 months [Figure 1]. Table 2 shows the mean and standard deviations for the "severity of response" to air and cold stimuli following restorations with each bonding system performed by either the PDD or a less experienced DS. The mean VAS scores and standard deviations of the groups treated with three adhesive systems by the PDD or DS are also shown graphically in Figures Figures2, 2–5. During the 6-month evaluation period, no tooth exhibited signs of pulpitis, and none of the patients complained of severe pain or strong and intolerable sensitivity. Within the treatment group comparisons, the results of the Kruskal-Wallis test showed that participants in all groups were significantly more sensitive to cold than to air stimuli at data collection points ($P < 0.05$).

Figure 1

Flowchart

Table 2

The mean visual analog scale scores for the three adhesive system applied by both post-doctorate dentist and dental student after recieving air and cold stimuli across six months.

Figure 2

The mean visual analog scale scores and standard deviations of the groups treated with three adhesive systems by the PDD in subsequent evaluations of post-operative sensitivity evaluations for air stimuli by time.

Figure 5

Groups treated with three adhesive systems by DS in subsequent evaluations of post-operative sensitivity evaluations; response to cold stimuli by time.

Figure 3

Groups treated with three adhesive systems by the DS in subsequent evaluations of post-operative sensitivity evaluations response to air stimuli by time.

Figure 4

Groups treated with three adhesive systems by the PDD in subsequent evaluations of post-operative sensitivity evaluations for cold stimuli by time.

The VAS scores decreased through the 6-month evaluation period in response to air and cold stimuli for all three materials used by both operators. In response to air stimuli, VAS scores of Optibond Fl, Clearfil Protect Bond, and iBond decreased during the time intervals without any statistical differences when applied by the DS ($P > 0.05$); Protect Bond showed a significant decrease in the intensity of post-operative sensitivity between the 24-hours and third month ($P < 0.05$).

When the restorations were performed by the PDD using Protect Bond and Optibond FL, there was no significant difference ($P > 0.05$) in VAS scores in response to air stimuli; iBond showed an insignificant lower score at 24-hours than the 6-month recall ($P > 0.05$). A regular decrease in post-operative sensitivity to cold response for each of the 3 materials applied by either the PDD or DS was demonstrated without any significant differences ($P > 0.05$). The mean VAS scores for teeth treated by the PDD with Protect Bond to cold stimuli at the first month were significantly lower than the baseline score ($P < 0.05$), whereas the scores for Optibond FL applied by the PDD showed a statistically significant decrease in response to cold stimuli between the 24-hours and 6-month measurements ($P < 0.05$).

DISCUSSION

The null hypothesis tested that there would not be a difference in the prevalence and severity of post-operative sensitivity when cavities in posterior composites were restored with a three-step total-etch dentin bonding system, a two-step bonding system, and a single-step, self-etch system was rejected. Included in the measurements was the presupposition that performance of these restorations by a post-doctorate dentist (PDD) and a less experienced dental student (DS) would make a difference. In the current study, a total of 188 restorations in 39 subjects were performed by PDD or DS who was working under the close supervision of faculty members, and the patients were assessed for 6 months for post-operative sensitivity. Only the teeth (primary carious lesions or secondary caries) requiring medium-sized composite restoration without any spontaneous pain or severe pulpal sensitivity were included. We did not group the composite restorations by the cavity depth as deep or shallow preparations and used only the lesions not to be more than half-way between the dentino-enamel junction and the pulp and excluded deep caries lesions to differentiate the outcome of post-operative sensitivity from the symptoms pulpal inflammation.

In the present study, the restorations were performed without using anesthesia to inhibit pulpal motion. In most studies, the rubber dam was preferred as a protective measure against failure and to guarantee a low incidence of post-operative sensitivity in composite restorations.[4] However, according to another clinical data, the use of anesthesia and rubber dam did not have any significant influence on post-operative sensitivity.[8] Cotton roll isolation was carefully used to obtain ideal clinical outcomes in the present study evaluating the cavities only limited by the occlusal surface.

Post-operative sensitivity might also be caused by penetrations of components of the adhesive systems into the pulp or by micro-/nanoleakage, allowing movement of the dentin liquid into those dentin areas where optimal adhesion and sealing of the dentin was accomplished.[3] Polymerization shrinkage, bulk filling technique, incomplete coating of the dentin surface with dental adhesives, and traumatic occlusion might also be responsible for post-operative sensitivity in posterior composite restorations.[9] Generally, posterior composite restorations are prone to higher post-operative sensitivity due to the etching procedure, polymerization shrinkage caused by the stress generated upon curing, and cuspal deflection related to different adhesive techniques.[10,11] The curing procedure and intensity of the light device also affect post-operative sensitivity in terms of polymerization shrinkage. To eliminate these kinds of risks in this study, composite resins were applied using the incremental filling

technique, and adequate light-curing was carefully performed. In the current study, due to their ease of preparation and lower variability in cavity boundaries, occlusal cavities were chosen to evaluate the post-operative sensitivity. However, it has been demonstrated that in occlusal cavities, the C-factor is greater than 5, thereby producing a higher concentration of stress because only one of the current 6 surfaces is free.[12] Concerning the C-factor, the highest polymerization stresses would be exhibited, which would cause higher post-operative sensitivity when occlusal cavities with 5 cavity walls are restored. However, the results of our study with its resulting low levels of post-operative sensitivity did not support this finding.

Occurrence of low post-operative pain sensation levels after different dentin bonding strategies used in the current study is in accordance with the findings of Unemori *et al*. who studied the symptoms of post-operative sensitivity after resin composite restorations for all types of cavities performed by undergraduate students and found that only 11% of all teeth showed post-operative sensitivity.[13] Similar results were found by Opdam *et al*. who reported post-operative sensitivity in 14% of class I resin composite restorations, and no sensitivity to cold was reported for self-etch adhesives.[14]

The use of a lining under the restorations to prevent the undesirable effects of restorative materials is still under discussion. It is reported that there was no significant difference in post-operative sensitivity when a liner or base had been used compared to restorations in which no lining was used.[15,16] On the contrary, acid etchants and composite materials are reported to have no adverse effects on the dental pulp and that these restorations do not require a protective liner or base because the dentin-bonding materials function as a direct pulp-capping agent.[17] In the present study, all of the restorations were performed without applying a liner or base material since the cavity depth standardized in the study did not require any pulp-capping procedure.

A subjective assessment method; a visual analogue scale (values 0 to 10) providing effective statistical test evaluation was used to evaluate the intensity of post-operative sensitivity in the present study. VAS provides more uniform instructions to participants, and the researcher avoids descriptors such as mild, moderate, and severe, which can be interpreted quite differently from one participant to another.[18]

The main problem with the three-component procedure has been unpredictability with regard to post-operative sensitivity. When three-step bonding agents are used meticulously and

adequately placed, dentin desensitization will be assured, otherwise uncomfortable tooth sensitivity is likely to be a result of the poor sealing of dentinal tubules.[19] Technically, a less complicated material could be more suitable in undergraduate teaching programs where less experienced students are involved.[13] A low frequency of post-operative sensitivity was reported for self-etching adhesives, which are less technique-sensitive than total-etch adhesives.[20] Self-etching adhesives cause less post-operative sensitivity regarding that the smear layer is not completely removed by acid etching and the de-mineralized dentin and exposed collagen-network can be completely infiltrated by resin to form a uniform hybrid layer and a reliable adhesion.[21] In the current study, Optibond FL applied by both the PDD and DS showed higher VAS levels than Protect Bond after the application of cold stimuli. This difference could be due to a number of factors. If the practitioner fails to control the moisture content of the dentin that is a major concern and difficult to standardize, post-operative sensitivity may arise due to the collapse of the collagen network.[22] Another reason is that the etching with phosphoric acid widens the dentinal tubule openings, and these may not be completely sealed by the adhesive resin. Thus, the unsealed microporous zone could then permit the shift of hydraulic dentin fluid and penetration of microorganisms into dentin tubules, possibly resulting in a slower rate of resolution of post-operative sensitivity.[23] Protect Bond is a simplified two-step antibacterial self-etching adhesive. Due to its "contact-active" antibacterial monomer MDPB, it disinfects dentin and prevents the diffusion of new bacteria via microleakage.[24] The previous version of this adhesive material without MDPB; Clearfil SE Bond, a self-etching primer, has been shown to produce a thin hybrid layer that is completely penetrated by the adhesive resin and proven to yield reliable results in terms of bonding effectiveness and durability.[25] Self-etching adhesives are not likely to result in a discrepancy between the depth of demineralization and the depth of resin infiltration because both processes occur simultaneously.[26] Primer of Protect Bond contains functional monomer 10-MDP dissolved in water and ethanol that results in a pH of approximately 2. It hybridizes the smear layer to the underlying dentin instead of removing it. Thus, smear plugs are fixed at the internal tubular walls, resulting in simultaneous demineralization and infiltration of enamel and dentin to form a continuum in the substrate incorporating the smear plug in the resin tag.[27] This leads to a uniform resin-infiltrated interface. In addition to its simplified bonding technique, Protect Bond eliminates rinsing and drying steps, which reduces the over-wetting and over-drying that can cause a negative effect on adhesion.[28] It seems possible that the phosphoric acid used with Optibond FL exerts higher osmotic pressure on the pulp dentin complex than the self-etching primer, which may explain the small difference in post-

operative sensitivity.[29] iBond is a single component self-etching adhesive containing glutaraldehyde as a desensitizer associated with its non-rinse acidic monomers. A blend of monomers (UDMA and 4-META) in a high amount of solvents (acetone and water) is present in the formulation. The bonding effectiveness of mild two-step, self-etch adhesives seems quite durable in contrast to all-in-one products such as IB adhesives that produce less durable bonds. Ibond does not contain HEMA in its formulation, and its complex blend of hydrophilic/hydrophobic ingredients, water, and a large amount of solvent makes these adhesives more prone to phase separation that leads to lower bond strength and mechanical properties.[30]

There is a common belief that the success of posterior composite restorations results from the skill of the operator as well as the material's characteristics and placement techniques.[8] To give an advanced oral health care to patients, it is important that all recent dental school graduates are skilled in a range of techniques, including the restoration of posterior teeth with resin-based composite materials.[31] Dental students may experience difficulty in the placement of posterior composite restorations and post-operative sensitivity if the procedure is not performed adequately in their under-graduate clinical practice. Experts suggest that dental students should have a clear understanding of the basics and principles of the clinical application of adhesives.[31] In this study, at all time intervals, post-operative sensitivity occurred in response to air and cold stimuli after the application of all materials applied by the PDD were lower than in restorations performed by DS. The lower VAS scores (for air stimuli) following the restorations performed by the DS were obtained for iBond at baseline and during the following 6 months in response to air stimuli. The results demonstrated that the application complexity and the variability of the dentin bonding systems affected the post-operative sensitivity, which was low for all tested materials but depended to some degree on the experience and skill of the operator. The treatments performed by the dental student were conducted under the supervision of a staff member, which might have had a positive effect on the low rate of post-operative sensitivity. Operators were told to closely follow the manufacturer's instructions and to carefully perform the restorations. The post-operative sensitivity in all treatment groups was very low following applications by both kinds of operators who worked in a faculty clinic where application procedures are strictly followed according to the principles in the adhesive literature.

CONCLUSION

The authors assume that the low post-operative sensitivity scores are due to the very careful application of the treatment procedures, the correct use of adhesive materials by following the manufacturer's instructions, and clinical techniques that might depend on materials used.

REFERENCES

1. Gordan VV, Mjör IA. Short- and long-term clinical evaluation of post-operative sensitivity of a new resin-based restorative material and self-etching primer. Oper Dent., 2002; 27: 543–8.
2. Briso AL, Mestrener SR, Delício G, Sundfeld RH, Bedran-Russo AK, de Alexandre RS, et al. Clinical assessment of postoperative sensitivity in posterior composite restorations. Oper Dent., 2007; 32: 421–6.
3. Brännström M. Communication between the oral cavity and the dental pulp associated with restorative treatment. Oper Dent., 1984; 9: 57–68.
4. Opdam NJ, Roeters FJ, Feilzer AJ, Verdonschot EH. Marginal integrity and postoperative sensitivity in Class 2 resin composite restorations *in vivo*. J Dent., 1998; 26: 555–625.
5. Swift EJ., Jr Dentin/enamel adhesives: Review of the literature. Pediatr Dent., 2002; 24: 456–61.
6. Peumans M, Munck J, Van Landuyt K, Lambrechts P, Van Meerbeek B. Three-year clinical effectiveness of a two-step self-etch adhesive in cervical lesions. Eur J Oral Sci., 2005; 113: 512–8.
7. Perdigão J. Dentin bonding as a function of dentin structure. Dent Clin North Am., 2002; 46: 277–301.
8. Auschill TM, Koch CA, Wolkewitz M, Hellwig E, Arweiler NB. Occurence and causing stimuli of postoperative sensitivity in composite restorations. Oper Dent., 2009; 34: 3–10.
9. Perdigão J, Anauate-Netto C, Carmo AR, Hodges JS, Cordeiro HJ, Lewgoy HR, et al. The effect of adhesive and flowable composite on postoperative sensitivity: 2-week results. Quintessence Int., 2004; 35: 777–84.
10. Baratieri LN, Ritter AV. Four-year clinical evaluation of posterior resin-based composite restorations placed using the total-etch technique. J Esthet Restor Dent., 2001; 13: 50–7.
11. Campos EA, Andrade MF, Porto-Neto ST, Campos LA, Saad JR, Deliberador TM, et al. Cuspal movement related to different bonding techniques using etch-and-rinse and self-etch adhesive systems. Eur J Dent., 2009; 3: 213–8.
12. Casselli DS, Martins LR. Postoperative sensitivity in Class Icomposite resin restorations *in vivo*. J Adhes Dent., 2006; 8: 53–8.

13. Unemori M, Matsuya Y, Akashi A, Goto Y, Akamine A. Composite resin restoration and postoperative sensitivity: Clinical follow-up in an undergraduate program. J Dent., 2001; 29: 7.
14. Opdam NJ, Feilzer AJ, Roeters JJ, Smale I. Class Iocclusal composite resin restorations: *In vivo* post-operative sensitivity, wall adaptation, and microleakage. Am J Dent., 1998; 11: 229–34.
15. Whitworth JM, Myers PM, Smith J, Walls AW, McCabe JF. Endodontic complications after plastic restorations in general practice. Int Endod J., 2005; 38: 409–16.
16. Burrow MF, Banomyong D, Harnirattisai C, Messer HH. Effect of glass-ionomer cement lining on postoperative sensitivity in occlusal cavities restored with resin composite-a randomized clinical trial. Oper Dent., 2009; 34: 648–55.
17. Cox CF, Hafez AA, Akimoto N, Otsuki M, Suzuki S, Tarim B. Biocompatibility of primer, adhesive and resin composite systems on non-exposed and exposed pulps of non-human primate teeth. Am J Dent., 1998; 11: S55–63.
18. Browning WD, Blalock JS, Callan RS, Brackett WW, Schull GF, Davenport MB, et al. Postoperative sensitivity: A comparison of two bonding agents. Oper Dent., 2007; 32: 112–7.
19. Pashley DH. Dentin permeability, dentin sensitivity, and treatment through tubule occlusion. J Endod, 1986; 12: 465–74.
20. Ermis RB, Kam O, Celik EU, Temel UB. Clinical evaluation of a two-step etch and rinse and a two-step self-etch adhesive system in Class II restorations: Two-year results. Oper Dent., 2009; 34: 656–63.
21. Tay FR, Sano H, Carvalho R, Pashley EL, Pashley DH. An ultrastructural study of the influence of acidity of self-etching primers and smear layer thickness on bonding to intact dentin. J Adhes Dent., 2000; 2: 83–98.
22. Cardoso MV, de Almeida Neves A, Mine A, Coutinho E, Van Landuyt K, De Munck J, et al. Current aspects on bonding effectiveness and stability in adhesive dentistry. Aust Dent J., 2011; 56(Suppl 1): 31–44.
23. Sano H, Shono T, Takatsu T, Hosoda H. Microporous dentin zone beneath resin-impregnated layer. Oper Dent., 1994; 19: 59–64.
24. Imazato S, Kinomoto Y, Tarumi H, Torii M, Russell RR, McCabe JF. Incorporation of antibacterial monomer MDPB into dentin primer. J Dent Res., 1997; 76: 768–72.

25. Peumans M, Kanumilli P, De Munck J, Van Landuyt K, Lambrechts P, Van Meerbeek B. Clinical effectiveness of contemporary adhesives: A systematic review of current clinical trials. Dent Mater, 2005; 21: 864–81.
26. Tanumiharja M, Burrow MF, Tyas MJ. Microtensile bond strengths of seven dentin adhesive systems. Dent Mater, 2000; 16: 180–7.
27. Abdalla AI, Feilzer AJ. Morphological characterization of the interface between self-etching adhesives and vital dentin. Am J Dent., 2007; 20: 305–8.
28. Can Say E, Nakajima M, Senawongse P, Soyman M, Ozer F, Ogata M, Tagami J. Microtensile bond strength of a filled vs. unfilled adhesive to dentin using self-etch and total-etch technique. J Dent., 2006; 34: 283–91.
29. Pashley DH. The effects of acid etching on the pulpodentin complex. Oper Dent., 1992; 17: 229–42.
30. Van Landuyt KL, Snauwaert J, Peumans M, De Munk J, Lambrechts P, Van Meerbeek B. The role of HEMA in one-step self-etch adhesives. Dent Mater, 2008; 24: 1412–9.
31. Lynch CD, McConnell RJ, Wilson NH. Teaching the placement of posterior resin-based composite restrations in U.S. dental schools. J Am Dent Assoc., 2006; 137: 619–25.