Original Article

The effect of dentin surface treatment with disinfectant on the shear bonding strength of luting cements

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Abstract *Background/purpose:* Few studies have comprehensively assessed the shear bonding strength of the luting cements between abutments and fixed partial dentures after dentin surface treatment with disinfectants. The purpose of the study was to evaluate the effect of three commonly used disinfectants (2.5% sodium hypochlorite, 0.2% chlorhexidine, and 0.2% benzalkonium chloride) on the shear bonding strength of four luting cements.
Materials and methods: Teeth were mounted on Teflon cylinders and prepared for dentin exposure. Three different disinfectants were used to treat the dentin surface. Nickel-chromium posts were cemented with resin cement, glass ionomer cement, polycarboxylate cement, or zinc phosphate cement. The shear bonding strength of the cement was examined using an Instron testing machine. Two-way analysis of variance (ANOVA) was used to examine the differences in shear bonding strength between the cements. If a statistically significant difference was found through ANOVA, a post hoc test with Tukey's honest significant difference was conducted.
Results: Disinfectants significantly decreased the shear bonding strength of resin cement, with 2.5% sodium hypochlorite causing the most substantial decrease. The zinc phosphate cement group displayed minimal shear bonding strength regardless of the disinfectant used.
Conclusion: The presence of 2.5% sodium hypochlorite significantly reduced the shear bonding strength of resin cements. During permanent cementation of indirect restorations, the choice

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of luting cement paired with the proper disinfectant is of utmost importance to maintain the shear bonding strength.

Introduction

The shear bonding strength between abutments and fixed partial dentures is an important factor in the long-term success of indirect restorations.[1] Luting cements provide retention and seal the space between abutments and indirect restorations.[2] However, before permanent cementation of indirect restorations, abutments are often contaminated with saliva,[3] and if microleakage occurs through inadequate bonding strength, bacterial invasion will occur in the restorations,[1,4] leading to recurrent caries, pulp disease, and postoperative sensitivity.[5] To prevent these problems, many clinicians use disinfectants on abutments prior to final cementation of indirect restorations; however, the effect of disinfectants on the shear bonding strength of luting cements has not been elucidated.

During the preparation of abutment teeth, 1 to 2 million dentinal tubules are exposed, resulting in increased pulp permeability and allowing greater ease of bacterial penetration through the dentinal tubules, thus leading to pulpal disease.[6—8] In a study by Crone et al., half of the histologically prepared teeth investigated still contained microorganisms.[9] Furthermore, it has been reported that bacteria remaining in cavity preparations can survive beyond a year.[10] Ingress of bacteria and toxins may not yield immediate symptoms, but the consequences of pulpal infection may be clinically detectable even after several years.[8,11] According to Brännström, 5—24% of crowns and fixed partial dentures may cause pulpal diseases with time.[12] If incomplete disinfection is coupled with microleakage, the growth of residual bacteria will increase the likelihood of caries, tooth sensitivity, and pulp complications.[13,14] The use of luting cements with disinfectants can prevent bacterial contamination and decrease hypersensitivity via the sealing of dentinal tubules, thus reducing pulp-associated complications.[15—17]

In dental application, the four most used luting cements are resin cement (RC), glass ionomer cement (GIC), polycarboxylate cement (PCC), and zinc phosphate cement (ZPC). ZPC is the oldest luting cement used in dental restorations; however, because of the low pH value after placement, it is not recommended for deep preparations or when pulpal irritation is a concern.[17] However, when cavity varnish is applied to the prepared teeth before cementation with ZPC, it displays pulpal protection and attenuation of postoperative sensitivity.[18] PCC has a higher tensile bonding strength than ZPC and causes less pulpal irritation.[19] GIC possesses good biocompatibility, can release fluoride ions, and is the most used cement by dentists.[20] RC has high compressive and tensile strength, lower solubility compared to other cements, and has seen increased use with rising demands for all-ceramic restorations.[21]

The commonly used disinfectants in dental treatment include sodium hypochlorite (NaOCl), chlorhexidine (CHX), and benzalkonium chloride (BZK). The effect of disinfectants on the shear bonding strength between the luting cement and dentin has not been fully investigated. This study aimed to evaluate the shear bonding strength of different cements in prepared tooth specimens with and without disinfectant treatment.

Materials and methods

Experimental design

Since the retention of the fixed partial denture is related to the fixed partial denture material, tooth preparation and surface treatment of the abutment, and the bonding mechanism of the luting cements, the study is designed extraorally to simulate the junction conditions among the fixed partial denture, luting cement and abutment tooth, and to explore shear bonding strength of luting agents between abutments and fixed partial dentures after dentin surface treatment with disinfectants.

Collection of teeth

The compositions, lot numbers, and manufacturers of the luting cements used are listed (Table 1). A total of 160 recently extracted, sound human molars from collection box of waste teeth were selected for this study. The teeth were obtained from patients who visited the Department of Dentistry, Tri-Service General Hospital, Taipei, Taiwan. The teeth that were decayed or underwent restoration or root canal therapy were excluded from this study. After the teeth were collected, any adhering soft tissues and blood were removed by scraping under running water and were stored in frozen form until use. The teeth were embedded in self-curing acrylic resin (Ortho-Jet™, Lang Dental Manufacturing, Wheeling, IL, USA) using a Teflon mold.

Preparation of cross-sectional occlusal surfaces

A water-cooled stone trimmer (Y-230, Yoshida, Tokyo, Japan) was used to section the teeth parallel to the occlusal plane to expose the dentin, and the dentin was polished using 240-grit, followed by 600-grit, electrode-coated silicon carbide waterproof abrasive sandpapers (Dongguan Golden Sun Abrasives Co., Ltd., Dongguan, China). The dentin surface was checked for the absence of enamel using a stereomicroscope (SZ-PT, Olympus, Tokyo, Japan) at 25 × magnification (Fig. 1).

Table 1 Luting cements used in this study.

Brand	Composition	Lot No.	Manufacturer
Variolink N	Dual-polymerizing resin cement	Etchant: W87271 Primer: W34446 Adhesive: W35790 Bonding agent: W39719 Base: W40848 Catalyst: W89356	Ivoclar Vivadent, Schaan, Liechtenstein
Fuji I	Glass Ionomer Cement	Power: 1606071 Liquid: 1606061	GC Corporation, Tokyo, Japan
HY-Bond	Polycarboxylate cement	Power: 031716 Liquid: 031715	Shofu, Kyoto, Japan
Super cement	Zinc Phosphate Cement	Power: 031752 Liquid: 011719	Shofu, Kyoto, Japan

Figure 1 Cross-sectional surface of the teeth was ground flat with water-cooled stone trimmer followed by polishing with 240-grit and 600-grit abrasive sandpapers.

After preparation, the exposed dentin of each sample was cleaned for 10 min in an ultrasonic bath and air-dried.[22] All specimens were prepared by a single investigator and randomly divided into four groups (40 teeth per group). In the control group, the specimens were irrigated with normal saline for 30 s. In the experimental groups, the specimens were separately irrigated with the disinfectants for 30 s, followed by irrigation with distilled water for 10 s and air drying by air jet treatment for 5 s. The disinfectant groups were as follows: (a) 2.5% NaOCl (Diluted Gau Lih Shyhu bleaching agent, LCY Chemical Crop, Taiwan); (b) 0.2% CHX (Parmason, Shining Biomedical Co., Ltd., Taiwan), and (c) 0.2% BZK (Veterans Pharmaceutical Co., Ltd., Taiwan).

Specimens from these four groups were further divided into four subgroups (10 teeth per group) as follows: (1) cemented with RC (Variolink N, Ivoclar Vivadent, Schaan, Liechtenstein); (2) cemented with GIC (GC Fuji I ®, GC, Tokyo, Japan); (3) cemented with PCC (Hy-Bond, Shofu, Kyoto, Japan), and (4) cemented with ZPC (Super Cement, Shofu, Kyoto, Japan). All cements were mixed according to the manufacturer's instructions, and a nickel-chromium casting post (3 mm diameter, 6 mm length) was cemented

with a force of 5 kg for 1 min, determined by Jorgensen.[23,24] A nickel-chromium metal alloy (Argeloy NP, Argen, CA, USA), with a composition of 76% nickel, 14% chromium, 6% molybdenum, 2% aluminum, and 1.8% beryllium, was fabricated using the conventional lost-wax technique.

Shear bonding strength testing

After 1 h of cementation, the specimens were immersed in a water bath with 1000 times thermal circulation (5–50 °C/ 10 s). After 24 h had elapsed since the start of the mixing process, the shear bonding strength was determined by mounting a sample on a universal testing machine (Lutron Electronic Enterprise Co., Ltd., Taiwan) with the casting post parallel to the direction of force at a crosshead speed of 0.5 mm/min until the post was dislodged. A perpendicular load was applied at a distance of 0.5 mm from the cement-post interface, to avoid contact with the cement (Fig. 2). The maximum load (shear bonding strength) was recorded in Newton (N) and converted to megapascals (MPa).

Statistical analysis

Multiple group comparisons were first analyzed by two-way analysis of variance (ANOVA) followed by examining the shear bonding strength of the four cement groups after treatment with three different disinfectants. If statistical significance was detected, a post hoc test with Tukey's honest significant difference test was conducted.

The results are presented as mean ± standard deviation. Statistical significance was set at $P < 0.05$. Statistical analysis was performed using SPSS 9 (SPSS Inc.).

Results

According to the two-way ANOVA (Table 2), the P value as $P < 0.01$ in cements and disinfectant solutions demonstrated disinfectant effect and cement effect on shear bonding strength and a significant interaction between different luting cements and disinfectant solutions on shear bonding strength was also noted ($P < 0.01$). Therefore, we evaluated the main effect of the disinfectants on each luting cement, and a significant difference in Table 3 was
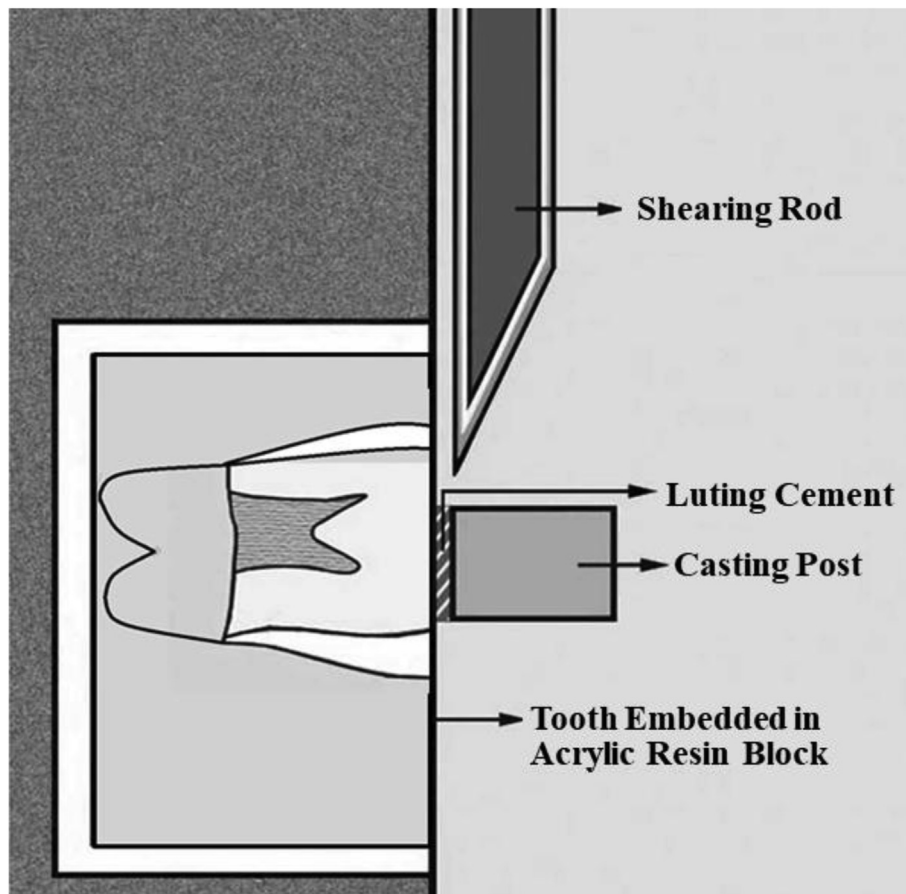
Figure 2 Schematic illustration of the assembly for shear bonding strength testing.

Table 2 Examine the cement or disinfectant effect on shear bonding strength and interaction between different cements and disinfectants by two-way ANOVA test.

Variable	df	F	P
Cement	3	104.520	<0.01**
Disinfectant	3	10.586	<0.01**
Interaction	9	6.494	<0.01**

*: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$.

Table 3 Comparison of shear bonding strength values (MPa) of the cements determined after treatment with different disinfectant preparations.

Cements	Disinfectants	N	Mean	SD	P
RC	Control	10	26.67	± 4.09	<0.01**
	NaOCl	10	6.70	± 1.18	
	Chlorhexidine	10	19.37	± 5.51	
	Benzalkonium chloride	10	19.59	± 5.32	
GIC	Control	10	18.64	± 7.02	0.15
	NaOCl	10	15.16	± 4.37	
	Chlorhexidine	10	18.20	± 6.87	
	Benzalkonium chloride	10	21.45	± 4.80	
PCC	Control	10	16.87	± 4.30	0.95
	NaOCl	10	15.27	± 3.35	
	Chlorhexidine	10	16.36	± 9.66	
	Benzalkonium chloride	10	15.47	± 8.09	
ZPC	Control	10	0.99	± 0.50	0.09
	NaOCl	10	1.91	± 0.80	
	Chlorhexidine	10	1.07	± 0.85	
	Benzalkonium chloride	10	1.28	± 0.71	

Data analysis was performed using by one way ANOVA test. RC: resin cement; GIC: glass ionomer cement; ZPC: zinc phosphate cement; PC: polycarboxylate cement.

found only in the RC group ($P < 0.01$). We conducted a Tukey honest significant post-hoc test (Table 4). For RC, on comparing with the control group (26.67 ± 4.09 MPa), a significant decrease in shear bonding strength was found in the NaOCl (6.70 ± 1.18 MPa), CHX- (19.37 ± 5.51 MPa), and BZK (19.59 ± 5.32 MPa)-treated groups, with NaOCl exhibiting the greatest decrease in shear bonding strength ($P < 0.001$). Furthermore, NaOCl also significantly decreased the shear bonding strength than CHX ($P < 0.001$) and BZK ($P < 0.001$), but no difference was found between CHX and BZK ($P = 1$). In addition, in the ZPC group, the shear bonding strength was small in the control group and in the groups treated with any disinfectant solution.

Table 4 Variance analysis for shear bonding strength of resin cement as a luting agent corresponding with different disinfectant treatments by Tukey's honest significant post-hoc test.

				P
Resin cement	Control	VS.	NaOCl	<0.001***
	Control	VS.	CHX	0.004**
	Control	VS.	BZK	0.005**
	NaOCl	VS.	CHX	<0.001***
	NaOCl	VS.	BZK	<0.001***
	CHX	VS.	BZK	1

NaOCl: sodium hypochlorite; CHX: chlorhexidine; BZK: benzalkonium chloride.

Discussion

Our study revealed that RC possessed the greatest shear bonding strength within the control groups, followed by GIC, PCC, and ZPC (Fig. 3). If disinfection of dentin is not a concern for the clinician, RC is the cement of choice because of its excellent bonding strength. In the CHX and BZK groups, there were no significant differences between RC, GIC, and PCC.

All disinfectants used in the RC group showed a significant decrease in shear bonding strength, with the most substantial decrease being with NaOCl. In the other three luting cement groups, no significant difference was noted between the control and experimental groups (Fig. 4).

Our results suggest thorough removal of all disinfectants prior to final cementation with RC in order to prevent failure of indirect restorations. As NaOCl is frequently used in root canal irrigation, endodontists should either avoid cementation of indirect restorations with RC or completely remove NaOCl prior to RC application.

The mechanism by which NaOCl decreases the shear bonding strength of RC remains undetermined.

Theoretically, the removal of organic components, primarily collagen, by NaOCl should allow monomers to penetrate the demineralized dentin structure with greater ease. However, NaOCl decomposes into sodium chloride and oxygen, with the latter capable of greatly inhibiting the interfacial polymerization of resin bonding materials.[25,26] Additionally, oxygen bubbles at the resin-dentin interface interfere with resin infiltration of the tubules and intertubular dentin. Morris et al. reported that 15—20 min of NaOCl treatment reduced the bonding strength of RC to dentin by 67%,[27] which is consistent with our findings.

Surface treatment of dentin by disinfectants does not always cause a decrease in the shear bonding strength of luting cements. In our study, GIC treated with BZK (Fig. 4) exhibited an increase in shear bonding strength, although the difference was not significant. However, this finding is concurrent with several other studies that investigated the effects of BZK on the shear bonding strengths of cements.[28,29]

Interestingly, the shear bonding strength of ZPC was much lower than that of the other cements. After application of the breaking force, ZPC primarily stuck to the dentin, not metal. This is possibly because ZPC is a non-adhesive cement that is incapable of chemical bonding, thus relying on mechanical bonding.[30] ZPC maintains restorations by filling small, irregular surfaces on the surfaces of teeth and restorations. In our study, the metal post was smooth; thus, mechanical bonding was difficult to achieve. The use of ZPC in cementing smooth metal surfaces should be exercised with caution.

This study was limited by its inability to provide a realistic intraoral environment for testing. Clinical factors, such as abutment coverage by full restorations, retention, and resistance form of the preparation, were not considered. The primary focus of this in vitro study was to assess the shear bonding strength of four different cements treated with three different disinfectants. However, in this experimental design, only one surface of contact, as opposed to five in most intraoral situations, was available.
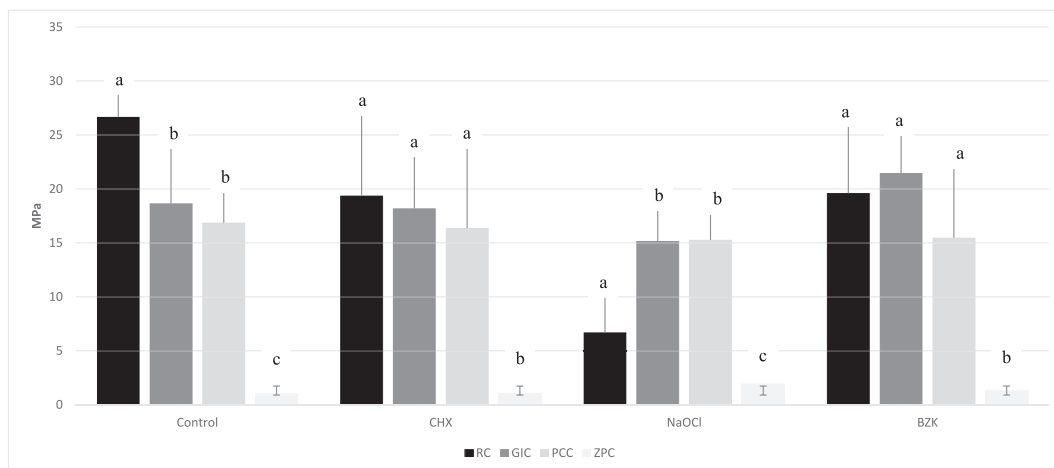
Figure 3 Shear bonding strength of different luting cements with disinfectant treatment. In each disinfectant group, different letters (a, b, c) are used to subdivide two or three subgroups according to shear bonding strength and indicate significant differences between subgroups (P < 0.05). RC: resin cement; GIC: glass ionomer cement; PCC: polycarboxylate cement; ZPC: zinc phosphate cement; CHX: chlorhexidine; NaOCl: sodium hypochlorite; BZK: benzalkonium chloride.
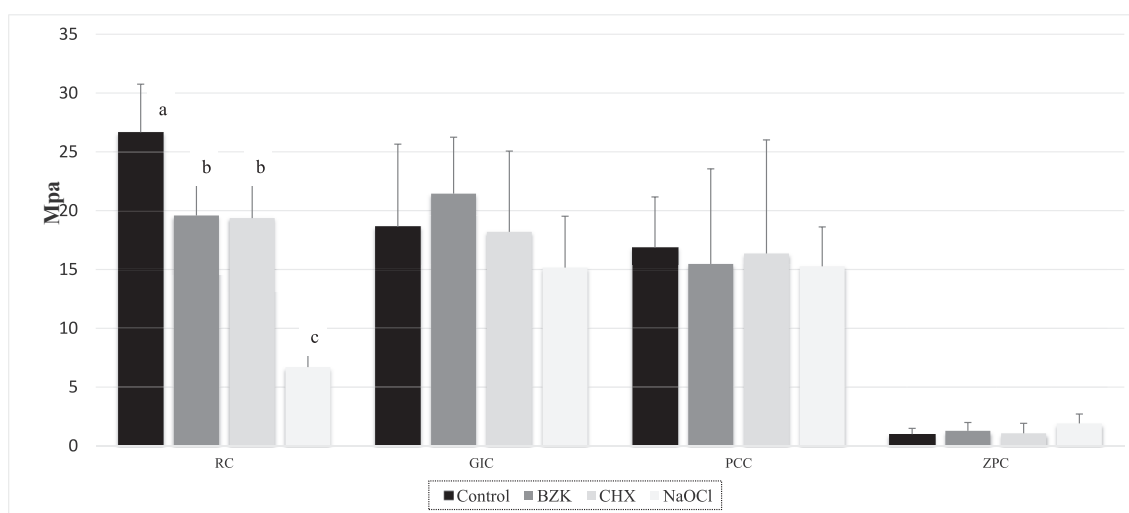
Figure 4 Shear bonding strength of different luting cements with and without treatment with different disinfectants. In RC group, different letters (a, b, c) are used to subdivide three subgroups according to shear bonding strength and indicate significant differences between subgroups ($P < 0.05$). In GIC, PCC, and ZPC group, no significant difference was noted between the control and experimental groups. RC: resin cement; GIC: glass ionomer cement; PCC: polycarboxylate cement; ZPC: zinc phosphate cement; BZK: benzalkonium chloride; CHX: chlorhexidine; NaOCl: sodium hypochlorite.

Thus, the results of ZPC, considering its non-adhesive property coupled with the lack of five surfaces from a full-coverage crown, do not adequately reflect the potential of ZPC in clinical application.

The results of this study indicate that disinfectants used prior to RC will significantly decrease the shear bonding strength of RC, and the use of 2.5%NaOCl with RC is especially cautioned. Dentin surface treatment with 2.5%NaOCl should be cleaned completely before permanent cementation of indirect restorations with resin cement. The disinfectant and cement for permanent cementation of fixed partial dentures should be selected appropriately to reduce the risk of pulp irritation and maintain the shear bonding strength of the cement.

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Declaration of competing interest

The authors have no conflict of interest relevant to this article

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References

1. Bauer JG, Henson JL. Microleakage: a measure of the performance of direct filling materials. *Operat Dent* 1984;9:2–9.
2. Aguiar TR, André CB, Correr-Sobrinho L, Arrais CA, Ambrosano GM, Giannini M. Effect of storage times and mechanical load cycling on dentin bond strength of conventional and self-adhesive resin luting cements. *J Prosthet Dent* 2014; 111:404–10.
3. Hori R, Kohno S, Hoshino E. Bactericidal eradication from carious lesions of prepared abutments by an antibacterial temporary cement. *J Prosthet Dent* 1997;77:348–52.
4. Dahl BL. Dentine/pulp reactions to full crown preparation procedures. *J Oral Rehabil* 1977;4:247–54.
5. Brännström M, Vojinović O. Response of the dental pulp to invasion of bacteria around three filling materials. *Am Soc Dent Child J Dent Child* 1976;43:83–9.
6. Richardson D, Tao L, Pashley DH. Dentin permeability: effects of crown preparation. *Int J Prosthodont (IJP)* 1991;4:219–25.
7. Bergenholtz G. Inflammatory response of the dental pulp to bacterial irritation. *J Endod* 1981;7:100–4.
8. Bergenholtz G, Cox CF, Loesche WJ, Syed SA. Bacterial leakage around dental restorations: its effect on the dental pulp. *J Oral Pathol* 1982;11:439–50.
9. Crone FL. Deep dentinal caries from a microbiological point of view. *Int Dent J* 1968;8:481–8.
10. Besic FC. The fate of bacteria sealed in dental cavities. *J Dent Res* 1943;22:349–54.
11. Goldman M, Laosonthorn P, White RR. Microleakage-full crowns and the dental pulp. *J Endod* 1992;18:473–5.
12. Brännström M. Reducing the risk of sensitivity and pulpal complications after the placement of crowns and fixed partial dentures. *Quintessence Int* 1996;27:673–8.
13. Chan MF, Jones JC. A comparison of four in vitro marginal leakage tests applied to root surface restorations. *J Dent* 1992; 20:287–93.
14. Brännström M. The cause of postrestorative sensitivity and its prevention. *J Endod* 1986;12:475–81.
15. Meiers JC, Kresin JC. Cavity disinfectants and dentin bonding. *Operat Dent* 1996;21:153–9.
16. Meiers JC, Shook LW. Effect of disinfectants on the bond strength of composite to dentin. *Am J Dent* 1996;9:11–4.
17. Johnson GH, Powell LV, DeRouen TA. Evaluation and control of post-cementation pulpal sensitivity: zinc phosphate and glass ionomer luting cements. *J Am Dent Assoc* 1993;124:38–46.
18. Felton DA, Kanoy BE, White JT. Effect of cavity varnish on retention of cemented cast crowns. *J Prosthet Dent* 1987;57: 411–6.

19. Going RE, Mitchem JC. Cements for permanent luting: a summarizing review. *J Am Dent Assoc* 1975;91:107—17.

20. De Caluwé T, Vercruysse CW, Ladik I, et al. Addition of bioactive glass to glass ionomer cements: effect on the physico-chemical properties and biocompatibility. *Dent Mater* 2017;33:e186—203.

21. Saygili G, Sahmali S. Effect of ceramic surface treatment on the shear bond strengths of two resin luting agents to all-ceramic materials. *J Oral Rehabil* 2003;30:758—64.

22. Ozcan M, Vallittu PK. Effect of surface conditioning methods on the bond strength of luting cement to ceramics. *Dent Mater* 2003;19:725—31.

23. Jorgensen K. Factors affecting the film thickness of zinc phosphate cements. *Acta Odontol Scand* 1960;18:479—90.

24. Pilo R, Cardash HS, Baharav H, Helft M. Incomplete seating of cemented crowns: a literature review. *J Prosthet Dent* 1988; 59:429—33.

25. Nikaido T, Takano Y, Sasafuchi Y, Burrow MF, Tagami J. Bond strengths to endodontically-treated teeth. *Am J Dent* 1999;12: 177—80.

26. Rueggeberg FA, Margeson DH. The effect of oxygen inhibition on an unfilled/filled composite system. *J Dent Res* 1990;69:1652—8.

27. Morris MD, Lee KW, Agee KA, Bouillaguet S, Pashley DH. Effects of sodium hypochlorite and RC-prep on bond strengths of resin cement to endodontic surfaces. *J Endod* 2001;27:753—7.

28. Say EC, Koray F, Tarim B, Soyman M, Gülmez T. In vitro effect of cavity disinfectants on the bond strength of dentin bonding systems. *Quintessence Int* 2004;35:56—60.

29. Türkün M, Türkün LS, Kalender A. Effect of cavity disinfectants on the sealing ability of nonrinsing dentin-bonding resins. *Quintessence Int* 2004;35:469—76.

30. Diaz-Arnold AM, Vargas MA, Haselton DR. Current status of luting agents for fixed prosthodontics. *J Prosthet Dent* 1999;81: 135—41.