Original Article

Effect of Zinc Oxide-Eugenol Temporary Restorations on Bond Strength of Composite Resin

Parnian Zareie [1], Ching Wen Tan [1], Joycelyn Jia Ying Ho[1], Paul V Abbott [1]

[1] UWA Dental School, the University of Western Australia, Perth, Australia

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Abstract

Introduction: Effect of zinc oxide-eugenol (ZO-E) on bond strength of composite is equivocal. The aim of the present study was to determine if ZO-E affects shear bond strength. **Methods**: For the purposes of the study, extracted human molar teeth were ground so thatcomposite rods could be bonded to dentine. In group 1, dentine was not exposed to ZO-E. In group 2, ZO-E was applied to dentine for 10 days prior to acid etching and bonding the composite. A universal testing machine was used to determine the composite's shear bond strength. Data were analyzed using t-test**. Results**: Mean score of shear bond strengths were 137.15 (± 46.82) and 140.08 (± 40.39) N for groups 1 and 2, respectively, with no statistically significant difference. Majority of samples in Group 1 (74% vs. 65%) had "clean breaks" where the composite fractured without any dentine attached, while the rest of the samples had some dentine attached.

Conclusions: ZO-E can be used for temporary fillings without affecting bond strength of subsequent composite restorations**.**

Keywords: Composite Resin, Shear Bond Strength, Zinc Oxide-Eugenol

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Introduction

Zinc oxide-eugenol (ZO-E) is a widely used temporary restorative material in both restorative dentistry and endodontics. ZO-E is well known for its sedative, analgesic and antibacterial properties (1, 2), which make it an ideal material to use in the treatment of pulp symptoms such as reversible pulpitis. ZO-E is also routinely used to fill endodontic access cavities during the course of root canal treatment due to its ability to impede bacterial ingress, its wear resistance and its strength against occlusal forces (2). In the modern era of dentistry, composite resins are increasingly chosen over amalgam due to their aesthetic tooth-colored nature, as well as their adhesive ability which allows for conservative cavity preparations and support of tooth structure. However, the effect of ZO-E on the bonding of composite has been equivocal in the related literature. According to previous research, ZO-E decreases the bond strength of composite resin materials to tooth surfaces (3) and increases microleakage (4). On the other hand, there are other studies which have shown that the interaction between free radicals and eugenol is associated with the suppression of composite polymerization (5, 6). The reversible chemical reaction of ZO-E starts with a chelation reaction, which produces solid zinc-eugenolate when zinc oxide is mixed with eugenol in the presence of water (7,8). When the zinc-eugenolate encounters liquid from the dentinal tubules or the oral cavity, eugenol is released. Eugenol, a phenolic compound, reacts with free radicals and inhibits polymerization of resin monomers. A study by Hansen and Asmussen in 1987 (6) concluded that microscopic remnants of ZO-E and eugenol in the dentinal tubules inhibited the polymerization reaction of composite resin materials, and this may decrease the bond strength of permanent composite restorations (6). This was further reinforced in more recent studies conducted by Carvalho *et al.* (9, 10), who maintained that any form of residue from previous temporary restorative materials and/or cements is detrimental to the bond strength of dentine adhesives and self-etch adhesive systems. Such reduction could potentially affect the bond of the permanent composite resin restoration. A study conducted by Carvalho *et al.* (10) indicated that it is more likely that the presence of residue causes this decrease rather than the presence of eugenol *per se*. On the other hand, other studies have demonstrated that with a strong enough etchant such as orthophosphoric acid, which is used with most (if not all) modern composites, any microscopic remnants of ZO-E are removed before resin bonding takes place, and therefore the effect of ZO-E on resin bonding is negligible (11, 12). Furthermore, other studies have reported that the effects of ZO-E on microleakage (13), adhesive bond strength (14) and composite bond strength (15) depend on the powder to liquid ratio used for temporary restoration. As a result of the variations in experimental methods and observations, there are varying conclusions and theories surrounding the effects of ZO-E when used as a temporary restorative material before the use of definitive composite resin. Previous research has investigated the effects of ZO-E on composite materials, adhesives and luting cements (4, 11, 16-18), however, there are only a few studies (15, 18) conducted on composite resins that are currently used. Hence, the present study aimed to investigate the effect of ZO-E on the shear bond strength of a newer generation of composite resin material.

Materials and Methods

One hundred extracted human molar teeth were used for this study. The inclusion criteria consisted of sufficient horizontal cross-sectional surface area to which composite could be bonded, absence of visible caries or cracks, and sufficient root length to ensure adequate retention during mounting for the test procedure. The teeth were obtained from the collection of extracted teeth held by the University of Western Australia Dental School. Prior to use, all teeth had been disinfected with formalin and sodium hypochlorite and they were then stored in a saline and 0.2% thymol solution. The samples were also stored in the same solution throughout the experiment except when being prepared or tested. A flat surface of dentine was prepared perpendicular to the long axis of each tooth using a high-speed handpiece and diamond flat fissure or wheel burs. A minimum surface area of 30mm^2 ensured adequate space to which a composite rod of 7mm diameter and 10mm length could be bonded to the tooth. The teeth were divided into two groups. Group 1 was the control group in which the prepared surfaces of the teeth were not exposed to any substances before bonding the composite rod to the dentine. Group 2 was the treatment group which had ZO-E applied to the prepared dentine surface prior to bonding the composite rods. The ZO-E was mixed at a powder to liquid ratio of 10g:1g, according to the manufacturer's instructions. The ZO-E was left on the teeth for ten days and the specimens were stored in the saline/thymol solution during this period. The ZO-E was then removed with hand instruments and saline irrigation. Complete removal was verified microscopically. Details of all materials used in this experiment are shown in Table I. The composite resin used was 3M ESPE Z100 (3M ESPE Dental Products, St. Paul, Minn. USA) which was bonded to the dentine of all the teeth according to the manufacturer's instructions. First, 37.5% orthophosphoric acid etch (Scotchbond Multipurpose Etchant - 3M ESPE Dental Products, St. Paul, Minn. USA) was placed on the dentine for 20 sec. This was followed by a 10-sec rinse and then Scotchbond Universal Bond (3M ESPE Dental Products, St. Paul, Minn. USA) was placed on the surface and agitated with a microbrush for 20 sec and then light-cured for 20 sec. A 7 mm diameter and 10 mm long clear matrix (Odus Universal Strips, Odus Dental, Vevey, Switzerland) was used to place the composite rods. The composite resin rod was placed in five 2 mm increments and light-cured for 20 sec each with a Bluephase Style light-curing unit (Ivoclar Vivadent, Schaan, Liechtenstein) which has a light intensity of 1200 mW/cm^2. Once the composite rods were placed, the specimens were left for 24 h inside a specimen jar with a saline-saturated piece of gauze to provide an environment with 100% humidity in order to ensure complete polymerization of the material. All of the teeth were then mounted in acrylic blocks within stainless steel tubes. A universal testing machine (Instron, Norwood, MA, USA) was used for shear testing of the composite rod bond strengths. The stainless steel tubes containing the teeth in acrylic were secured in the vice of the machine and a perpendicular force was applied at a crosshead speed of 1mm/min to the composite resin rod with a blunt, rounded tip. A small countersunk depression was made at the midpoint of each composite rod to prevent slipping of the Instron attachment tip. The tip of the universal test machine was applied to this countersunk depression. The force required to shear the composite from the tooth was recorded at the point where complete fracture occurred. In addition, the location of the fracture was assessed by examining the specimens under a stereomicroscope at 2.5× magnification and the fractures were recorded as either a fracture between the composite-tooth interface (adhesive failure), a fracture of the tooth or a fracture within the composite (cohesive failure). The nature of the fracture was also assessed as either a 'clean break' when there was no dentine attached to the broken composite rod, or a 'half-clean break' when a small area of dentine remained on the composite rod after fracture.

Data were analyzed statistically through Stata Software (StatCorp, Texas, USA) using an unpaired two-sample t-test with unequal variance and compared with a significance level of 0.05

Table I. The materials used and their compositions

Material	Composition
Z100 Restorative Paste	• Silane treated ceramic • 2,2'-ethylenedioxydiethyl dimethacrylate • (1-methylethylidene)bis[4,1-phenyleneoxy(2-hydroxy-3,1-propanediyl)] • Bismethacrylate • 2-(2H-Benzotriazol-2-yl)-p-cresol
Scotchbond Multi-Purpose Etchant	• Water • Orthophosphoric acid • Poly (vinyl alcohol)
Scotchbond Universal	• 2-Hydroxyethyl methacrylate • (1-methylethylidene)bis[4,1-phenyleneoxy(2-hydroxy-3,1-propanediyl)] bismethacrylate • Decamethylene dimethacrylate • Ethanol • 2-Propenoic acid,2-methyl-,3-(trimetoxysilyl)propyl ester, hydrolysis products with silica • Water • 1,10-Decanediol methacrylated phosphates • Copolymer of acrylic and itaconic acid • Camphorquinone • Ethyl 4-dimethylaminobenzoate
IRM powder	• Zinc oxide
IRM Liquid	• Eugenol • Acetic acid

Results

Data were gathered from 31 control samples and 40 ZO-E samples for the analysis. The other 29 teeth had to be excluded from the final analysis since they dislodged from the stainless steel tubes in which they were mounted, or the fractures were not caused by composite-dentine bond failure. Results of the shear bond strength tests are shown in Table II. The mean forces required to break the bond between composite and dentine were 137.15±46.82 N and 140.08 ± 40.39 N for the control and treatment groups, respectively. The raw data shows the average force required to break the bond between tooth and composite was very similar for the two groups. Since the P-value of 0.783 was greater than 0.05, there was no statistically significant difference between the forces required for both groups. Therefore, application of ZO-E prior to placing composite rods did not influence the bond strength of the composite resin to dentine when 37% phosphoric acid and Scotchbond Universal Adhesive were used to prepare the dentine surface before placing the composite. The type of fractures in proportion to the number of teeth are shown in Figure 1. None of the composite rods were completely covered in dentine after fracturing off the tooth. The majority of the samples in Group 1 had a "clean break" compared to those of the Group 2. The teeth with "clean breaks" all underwent adhesive failures of the bond between the teeth and composite resin. There were no cases of cohesive failure of the composite resin specimens with half-clean breaks had a mixture of adhesive failure of the bond plus fracture of the dentine, with the latter being a cohesive failure of the dentine.

Table II. Mean (Newtons), median and standard deviations for the two groups

Group	Mean (Newtons)	Median	Standard Deviation
Group 1: Control (n = 31)	137.15	136.65	46.82
Group 2: *Treatment (With ZO-E)* (n = 40)	140.08	134.50	40.39

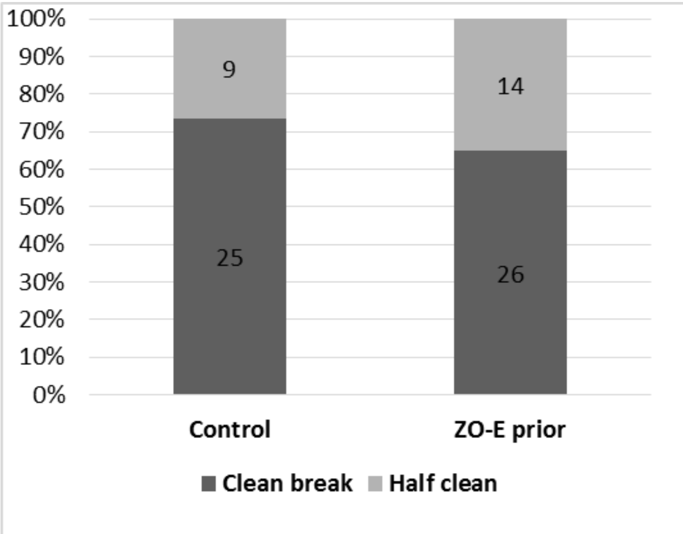

Figure 1. The number of "clean breaks" and "half -clean breaks" in each group. A "clean break" designates that no dentine was attached to the broken composite rod, while a 'half -clean break' designates that there was a small area of dentine remaining attached to the composite rod after fracture

Discussion

Previous studies exploring the bond strength of composite resins after exposure to zinc oxide-eugenol have had varying results (3-6, 9-18). Several studies have demonstrated that prior exposure of the dentine to zinc oxide-eugenol did not affect the mean force required to break the bond (i.e. bond strength) between composite and dentine. Furthermore, one study even reported that the required force was greater when the dentine had been previously exposed to ZO-E (12, 18). In the current study, the mean force required to break the bond between composite and dentine in the control group was 137.15 (±46.82) N. Regarding the treatment group, following the application of ZO-E for 7 days, the mean shear bond strength was 140.08 N (±40.39) which had no significant difference with the control group. Therefore, the null hypothesis was accepted. The values of shear bond strength in this study were quite different from the results of previous studies (19, 20). However, due to variations in laboratory conditions, testing methods and materials in other *in vitro* investigations, a direct comparison cannot be made and only the trend should be taken into account. The nature of the fracture was mixed in both groups. Adhesive failure occurred in 75% of the control group, where the composite rod broke off completely from the dentine surface, leaving a 'clean break'. The remaining 25% of the teeth in this group experienced cohesive failure of dentine, where part of the tooth fractured off together with the composite rod as a half-clean break. In the test group, the values for clean and half-clean breaks were 65% and 35%, respectively. None of the teeth in both groups exhibited cohesive failure of the composite rod itself. It is difficult to draw a conclusion from this information and further research need to be conducted to determine the reasons for clean breaks and half -clean breaks. In the present study, the effect of ZO-E temporary filling on the bond strength of subsequent composite resin (Z100) was negligible. There were no negative effects when any microscopic remnants of ZO-E were removed and the bonding protocol for composite restoration followed the manufacturer's instructions. This involved the use of 37% orthophosphoric acid etching for 20 sec and the application of a bonding agent (Scotchbond Universal) before placing the composite resin. The use of acid etching has been suggested to be responsible for the elimination of the alleged negative effect of eugenol on resin bond strength, which is consistent with the results of a study conducted by Peutzfeldt (12). The use of etch-and-rinse bonding protocols with a strong acid results in a demineralization depth of 10-15µm (21), compared to self-etching adhesive systems where the depth of demineralization ranges from 0.4-5µm (22). The latter is similar to earlier adhesive systems with mild conditioning agents such as maleic acid, oxalic acid, and EDTA (23). It has thus been suggested that perhaps an aggressive adhesive system may be more effective in removing eugenol remnants and thus eliminating its effect on resin polymerization (6, 11, 24). However, two studies performed by Peutzfeldt and Asmussen (11, 12) found that self-etching adhesive systems were as effective in removing eugenol remnants as etch-and-rinse systems using strong etchants. This is due to the release of calcium ions from hydroxyapatite on the dentine surface after the use of an acidic primer. Any absorbed eugenol from ZO-E temporary restoration may react immediately with the calcium ions to form calcium eugenolate, which means its radical scavenging effect diminishes (11, 12). The results of this study are in contrast with previous studies, such as a study performed by Koch *et al.* (16) who investigated the effect of ZO-E on bond strength of resin composite using uTBS. They found a significant reduction in the bond strength and efficacy of the adhesive systems after exposure to ZO-E. Others have reported that microshear and microtensile tests have less discriminative power than the uTBS test (25), which may explain the fewer adverse effects of ZO-E (16). The slight 'positive' effect of ZO-E on the bond strength that was observed in this study was also found in the study conducted by Leirskar and Nordbø (18), where the mean shear bond strength was 28.1 MPa in their test group. This was significantly higher than the 19.0 MPa found in their control group. Similarly, Peutzfeld and Asmussen (12) reported the bond strength in the control group to be 25.9 MPa and the test group was 27.9 MPa, but with no significant difference. The authors of that study postulated that there were two possible explanations for this. The first theory was that the calcium eugenolate which is formed when ZO-E contacts dentine may not have the same radical scavenging effect as free eugenol. The second, and the more likely explanation, is that the bond strength is affected by remnants of materials that remain on the dentine, rather than by eugenol itself, since they found the same effects on bond strengths when non-eugenol temporary cements were tested. Even though there was no significant difference between the two groups in the current study, more studies are needed to further investigate this aspect. The teeth were stored in a saline/thymol solution following disinfection and throughout all phases of the experiment except when they were being prepared and tested. It has been shown that the storage of human teeth in this solution does not affect their bond to dental materials *in vitro* (19).

Conclusion

There was no statistically significant difference in the shear bond strength of composite resin to dentine when ZO-E was applied to the dentine compared to when there was no exposure to ZO-E. Hence, zinc oxide-eugenol can be used as a temporary filling material without affecting the bonding of subsequent composite resin restorations.

Conflict of Interest

The authors declare that they have on conflict of interest with respect to this study.

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Corresponding Author
Paul V Abbott
UWA Dental School, the University of Western Australia, Perth, Australia Tell: +61 86457 7665
Email: paul.v.abbott@uwa.edu.au