Effect of Eugenol on Bond Strength of Adhesive Resin: A Systematic Review

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Abstract

Objective: The aim of this study is to provide an answer regarding the effect of eugenol-containing temporary restoration and cement on the bond strength of the final resinous restoration and cement based on evidence through a systematic review of the literature.

Methods: The Cochrane Oral Health Group's Trials Register, MEDLINE & EMBASE electronic databases were used for the search. All relevant randomized controlled trails; published in English, between 1995- 2013 were included. Critical reviewing was performed via tabulation. Meta-analysis was performed on six homogenous studies.

Results: Following PRISMA flow diagram, nineteen studies were included on which comparative analysis was performed. Meta-analysis of the homogenous studies showed statistically insignificant preference in bond strength toward using non-eugenol containing temporary restorations. Meta-analysis showed no statistically significant results.

Conclusions: Eugenol-containing provisional material was found to affect the bond strength to resin restoration but this effect was not statistically significant within the seven days duration assessed in this study. However, some studies claimed that this effect could be significant when shorter duration or different adhesive systems were employed. Therefore, more homogenous studies are needed for stronger evidence on the effect of eugenol containing temporary material on the bond strength under controlled variables.

Key Words: Eugenol, Phenyl propene, Polymerization, Bond strength, Resin bonding, Resin adhesion, Adhesive resin, Resin composite

Introduction

In modern dental practice, resin adhesives are becoming the materials of choice in a diversity of clinical procedures. Despite their wide utilization, they have some clinical considerations. Some pulpal or periodontal conditions require a period of provisionalization prior to final restoration. Furthermore, utilization of indirect restorations requires the use of temporary cements that can eventually be replaced by resinous final cementation. The use of eugenol-containing temporary cements might affect the quality of bonding [1]. The compatibility of provisional agents with the final resin materials was also investigated, and some constituents of provisional agents might interfere with the resin setting reaction [2]. Eugenol is a derivative of clove oil with a chemical structure of 4-allyl 2-methoxyphenol [3] and is used for its palliative effect on pulpal tissues [4]. Eugenol affects bonding of resinous material to tooth structure by inhibiting the free radicals necessary in linking monomer molecules to form resin polymers [5,6]. Eugenol is released from zinc-eugenolate mass by hydrolysis with a rate that peaks at the first twenty-four hours and declines after. This results in decreasing the polymerization rate of methyl methacrylate (MMA) [3], even with small quantities of eugenol [7]. It is of a concern whether this effect can still be present after removal of the temporary eugenol-containing agent, where residual particles of eugenol maybe remaining.

A study by Fiori-Junior M investigated the effect of temporary cement type on bond strength of the final resin cementation. Zinc oxide-based cement, zinc-oxide eugenol-based cement, and calcium hydroxide-based cement were used and compared with teeth that did not receive any provisionalization. A significantly lower shear bond strength values were reported for specimens temporarily cemented with zinc oxide eugenol based cement compared to specimens cemented by non-eugenol temporary cements [8]. On the other hand, a study conducted by Peutzfeldt A and Asmussen E in 2006 investigated the effect of eugenol-containing temporary restoration on bonding of resin composite. IRM was placed on exposed dentine, and resin composite was bonded after seven days.

There was no reported reduction in shear bond strength compared to teeth that were bonded directly with resin composite [9]. Up to date, there is a conflict in the evidence regarding the effect of eugenol-containing temporary material on bond strength of the final resin adhesive material. Evidence-based practice depends on making decisions based on integrating the best available scientific evidence, together with clinician's expertise and patient's preferences to provide optimal patient care [10] that necessitates the availability of studies with a high level of evidence [11]. Systematic review studies combine all available evidence regarding a scientific dispute and critically analyze it to answer a question [12]. There is no available systematic review addressing this specific issue. Therefore, this study aims to provide the best available evidence on the clinical significance of using eugenol- containing temporary restoration/cement on the bond strength of the final resinous restoration. The stated Null Hypothesis is that: The prior use of eugenol-containing provisional has no significant effect on the bond strength of final resinous material.

Materials and Methods

Search strategy

The Cochrane Oral Health Group's Trials Register, the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE & EMBASE were searched on December 2013. Keywords used were: eugenol, eugenol-containing temporary

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restoration, polymerization, bond strength, resin and composite. Search terms were as follows, for PubMed Central: ("zinc oxide-eugenol cement" [Mesh] AND "composite resin" [Mesh], "resin cement" [Mesh]) AND "zinc oxide-eugenol cement" [Mesh], eugenol AND resin restoration, eugenol OR resin restoration, composite AND eugenol, composite AND eugenol (Clinical Queries), composite OR eugenol, "eugenol-containing temporary restoration" [Mesh] AND "polymerization" [Mesh], eugenol-containing temporary restoration [Mesh] OR bond strength [Mesh]). For Cochrane Central Register of Controlled Trials, search terms were as follows: eugenol AND resin, eugenol AND composite, eugenol OR resin and eugenol OR composite. Filters were used in all databases to limit the search to randomized controlled trails in English language and published between the years 1995 - 2013. In addition, manual computer search of databases was conducted for relevant studies. The PICO question was: in teeth that need provisional restoration or cementation, does the use of eugenol-containing temporary have a clinically significant effect on the bond strength of the final resinous material compared to using non-eugenol provisionals or without temporization?

Selection criteria

All laboratories randomized controlled trials investigating the effect of eugenol-containing temporary restoration or cement on the bond strength of the final resin adhesive restoration or cement were included. Clinical trials studying the effect of eugenol-containing endodontic sealers on retention of intra-radicular posts were excluded. Studies investigating the effect of eugenol-containing liners or bases on the bonding or setting reaction of the overlying resinous restoration were also excluded.

Search steps

Step 1: Titles reviewed by two authors.

Step 2: Evaluation of abstracts by two authors. Abstracts fulfilling the inclusion criteria are retrieved.

Step3: The retrieved full-text studies in step 2 are to be further examined by two authors.

Assessment of bias

Publication bias was investigated using a funnel plot. Another test for bias was the Begg and Mazumdar rank correlation test. Fail-Safe N was computed to speculate about the impact of the missing studies on the observed effect of eugenol-containing temporary on the bond strength of the final resin restoration.

Meta-Analysis

Statistical analysis was performed through comparing the reported means of bond-strength in megapascals (MPa) within the studies. Meta-analysis was conducted on studies having the same temporization period (six to seven days), same mechanical testing (microshear) and published after 1999.

Results

The search returned two hundred eighty-six articles from Cochrane and MEDLINE databases. There were no relevant studies obtained from EMBASE database. After exclusion by relevance and subtraction of duplicate articles, forty-four articles were left. In step one, reviewing of titles resulted in excluding thirteen articles. After assessment of abstracts, a total of nineteen studies were included. Selection process was carried out through PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram [13] presented in *Figure 1*.

Data extraction and assessment tools

Tabulation was used for data extraction and for identification of heterogeneity and variables among and throughout the studies. The articles were categorized into either supporting or rejecting the null hypothesis for comparison and discussion. Comprehensive Meta-Analysis (CMA) software program was used for statistical analysis of the studies with more fixed variables (homogenous).

Assessment of bias

A funnel plot measures the study size (standard error) on the vertical axis as a function of effect size on the horizontal axis. The Funnel plot presented in *Figure 2* shows a relatively symmetrical distribution of studies, this indicates a low risk of publication bias present.

The Begg and Mazumdar rank correlation test, which has given a 1-tailed p-value value of 0.5. This non-significant correlation may be due to low statistical power, and cannot be taken as evidence that bias is absent. The Fail-Safe N score for these studies is nine, which means that nine null studies would need to be located and included in order for the combined 2-tailed p-value to exceed 0.05. In other words, a small number of missing studies (1.5) are needed for every observed study for the effect to be nullified indicates that the difference of the effect is nil.

Meta-analysis

The results of the meta-analysis are presented in *Table 1*, according to the six homogenous studies that were selected. Using a Random Effect Model Meta-Analysis, the pooled mean test-control difference out from six studies is -1.668 M Pascal (-3.693, 0.356) with p-value < 0.106.

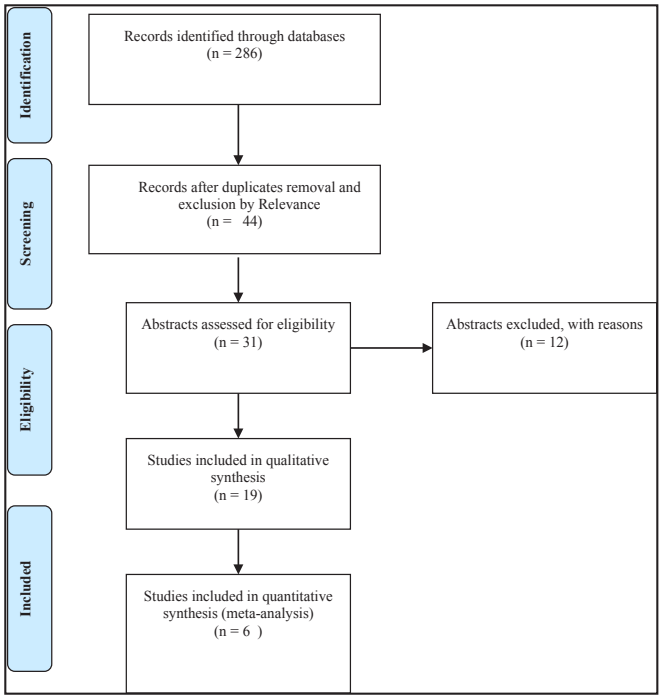

***Figure 1**. PRISMA diagram shows selection process of the randomized controlled trails. A final number of nineteen were included in the systematic review. Six of them were homogenous and were selected for meta-analysis.*

The Forest plot of the meta-analysis is presented in *Figure 3* and shows the combined effect favoring the control, but the p-value (0.106), which means that the result of the combined effect of these studies is statistically insignificant.

Discussion

Studies rejecting the null Hypothesis; Use of eugenol-containing temporary affects the bond strength of the final resin material:

"Effect of ZOE temporary restoration on resin-dentin bond strength using different adhesive strategies" by Cecinunes Carvalho et al. [14]

It concluded that eugenol-containing temporary restorations negatively influences the resin-dentin shear bond strength. This negative effect was observed more with the self-etch system compared to the two-step etch and rinse system. This may draw attention that eugenol might have different effect on the bond strength differs with various types of adhesive systems. Furthermore, the temporary restorations were replaced after twenty-four hours, which is during the peak time of eugenol release from the restoration and this could be the cause of the reduced bond strength values.

"Effect of temporary cements on the shear bond strength of luting cements" by Marco Fiori-Junior et al. [8]

This study compared the shear bond strength using two different adhesive systems after temporization with different materials. They also compared the results to the control with no prior temporization. They found that comparing between the two adhesive systems upon using the same temporary material, there was no statistical significant difference in the shear bond strength except with the ZOE temporized samples. In these samples, the shear bond strength was affected negatively in case of using RelyX unicem adhesive system and there was a positive effect (increase in bond strength) with RelyX ARC when compared to the control. This supports the finding of the study by Cecinunes Carvalho et al. [14] that eugenol might have different effects on the shear bond strength depending on the type of adhesive system used and that the type of the adhesive system is a factor that

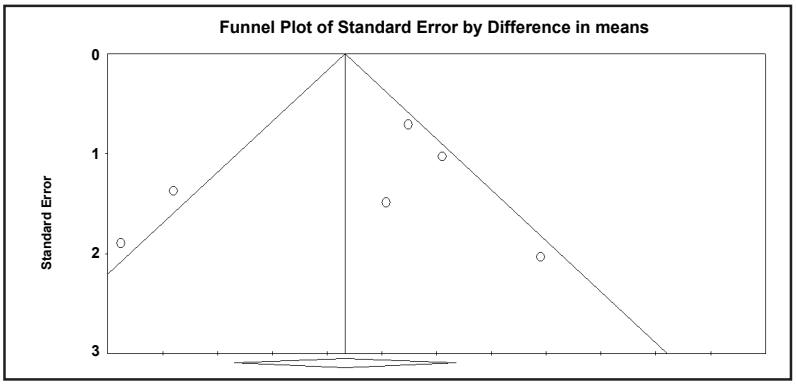

***Figure 2**. Funnel plot showing the distribution of the studies.*

***Table 1.** Using a Meta-Analysis - Random Effects Model, the pooled mean test-control difference out from 6 studies is -1.668 mpascal (-3.693, 0.356) with p-value < 0.106.*

Study Name	Test Mean	Test Std-Dev	Test Sample size	Control mean	Control Std-dev	Control Sample size	Effect direction	Difference In means	Std error
Leirskar et al, 2000	13.125	3.720	32	19.000	6.000	16	auto	-5.875	1.638
Latta et al, 2005	14.250	4.470	20	19.050	4.230	20	auto	-4.800	1.376
Fonseca et al, 2005	25.050	4.580	15	25.970	3.510	15	auto	-0.920	1.490
Peutzfeldt,2006	13.930	3.790	64	14.440	4.230	64	auto	-0.510	0.710
Erkut et al, 2007	16.990	4.170	40	16.880	5.010	40	auto	0.110	1.031
Silva et al, 2011	25.200	4.600	10	23.300	4.500	10	auto	1.900	2.035

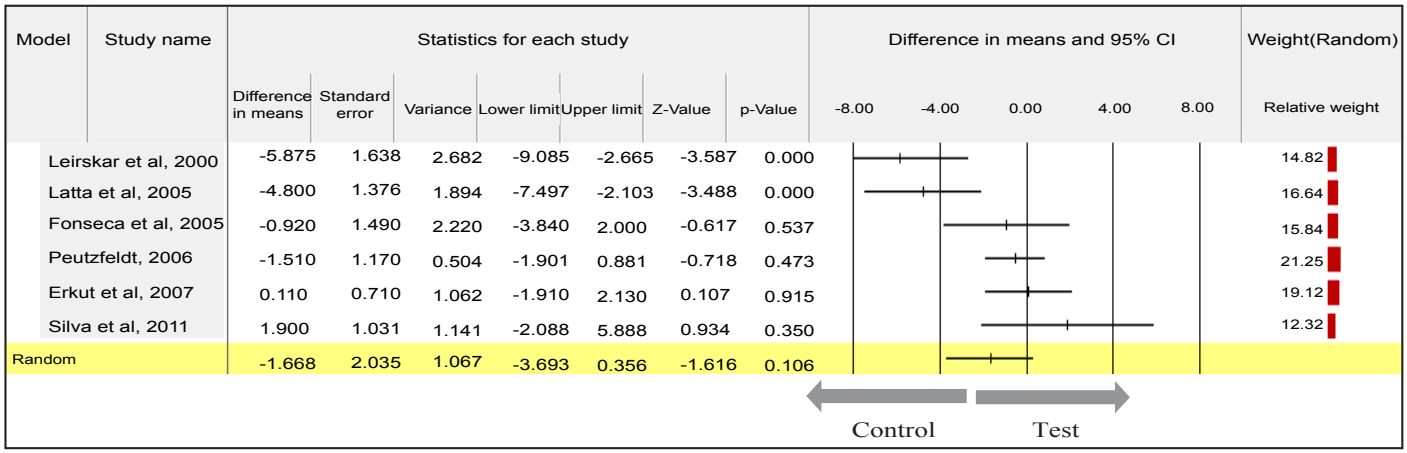

***Figure 3**. Meta-analysis and forest plot for six studies. The analysis favors the control group; non-eugenol-containing temporary restoration/ cement and no provisionalization. Relative weights are also shown.s.*

Table 2. *A brief description of all the included studies with their relative results.*

Author	Sample Source	Temporary agent	Adhesive system	Final restoration/ cement	Duration	Method of removal	Bond strength affection
Cecinunes Carvalho et al, 2007	18 human teeth	ZOE (IRM)	Two-step self-etches (Clearfill SE Bond).One-step self-etch system (iBond). Two-step etch and rinse (Single Bond).	Resin composite Z 250	24 hourst	Ultrasonic scaler & pumice water slurry	-ve affected
Martin Jung et al, 1998	56 human third molars	Temp Bond (eugenol containing) Provicol (eugnol free) ZOE Pure eugenol	Ethcing 37% phosphoric acid for 40 seconds Heliobond (Vivadent)	Composite cylinders	7 days except pure eugenol for 24 hours	Scaler	Not –ve affected * Enamel bonding. No dentin bonding.
Carolina Ganss et al, 1998	60 impacted human third molars	ZOE Temp Bond (eugenol-containing) Fermit (resin based) Provicol (eugnol Free, CaOH-containing)	Adhesive (Syntac) Bonding agent (Heliobond, Vivadent).	Dual cement (Vivadnt)	10 days	scaler	Not –ve affected
Marco Fiori-Junior et al, 2010	40 human third molars	CaOH-based cement ZO based cement ZOE based cement	Etching 35% phosphoric acid Adper Single Bond	RelyX Unicem RelyX ARC	24 hours	Hand excavator	-ve affected with RelyX Unicem
Sahar E. Abo-Hamar et al, 2005	140 human third molars	Temp Bond (eugenol contain) Temp bond NE (eugenol free)	Self etch (Panavia F 2) Total etch (Excite)	IPS Empress ceramic inserts	7 days	Excavator or & blasting	Not –ve affected
Funda Bayindir et al, 2003	60 composite cores	Temp Bond (eugenol-containing), Provilat (eugenol free)	Carboxylate cement Resin cement (Duo cement)	Co-Cr crowns over Dynamic Universal composite resin cores	10 days	Hand instrument	-ve affected *No dentine bonding was evaluated. *Tensile bond.
JPL Silva et al, 2011	16 human third molars	ZO based restorative material (IRM) ZOE	Self-etching adhesive (Adper SE plus)	Composite cylinders	24 hours 7 days 14 days	Scaler & pumice water slurry	-ve affected after 24 hours. Not -ve affected after 7-14 days.
S. J. Paul & P. Scharer, 1997	160 human third molars	Temp Bond (eugenol-containing) Kerr life (CaOH) Freegenol (eugenol free) Fermit (resin-based)	Syntac + Dual ART AllBond2 P-Bond	Composite cylinders	24 hours	Scaler, cotton pellets & non-flouridated pumice	-ve affected with ART & Syntac. Not -ve affected with P-bond
Mark A. Latta et al, 2005	140 human molars	Eugenol containing (IRM) Nogenol (eugenol free)	Prime & Bond NT SE Bond Adhesive	Panavia F Dual cure cement Calibra Esthetic cement	7 days	Dental instrument	-ve affected
Eduardo Schwartzer et al, 2007	15 bovine incisors	ZOE (TempCem) ZO & aliphatic acid replacing eugenol (TempCem NE)	Self conditioning adhesive (One-Up Bond F)	Composite restoration (Palfique estelite)	7 days	Periodontal instruments & Robinson brushes & pumice	Not -ve affected *Tensile bond.

Anne Peutzfeldt & Erik Asmussen, 1999	48 human molars	ZOE (IRM) Eugenol free Cavit	Scotchbond Multi-Purpose Plus Gluma CPS	Composite Z100	7 days	Carving instrument	Not –ve affected
Anne Peutzfeldt & Erik Asmussen, 2006	128 human molars	ZOE (IRM)	6 Self-etching adhesives: (AdheSE, Adper Prompt L-Pop, Clearfil SE Bond, iBond, OptiBond Solo Plus – Self-Etch Adhesive System, & Xeno III) Gluma Classic (-ve control) Etch-and-rinse adhesive system (OptiBond FL) (+ve control)	Resin composite (Herculite XRV)	7 days	Metal spatula	Not –ve affected
Selim Erkut et al, 2007	100 human molars	Eugenol containing (RelyX Temp E) Eugenol free (RelyX Temp NE)	RelyX ARC single bond Duo Link-One Step *Dentin bonding agent was applied prior to temporization in one group.	RelyX ARC single bond Duo Link-One Step	7 days	Scaler & prophy cup & fluoride-free pumice mixed with water	Not -ve affected
AUJ Yap et al, 2001	32 human molars	ZOE (IRM) Poly-carboxylate cement	Scotchbond Multi-Purpose plus	Composite Z100	7 days	Ultrasonic scaler & pumice-water slurry	Not –ve affected
Rodrigo Borges Fonseca et al, 2005	45 bovine incisors	CaOH (Dycal) ZOE (Provy) Eugenol free (Temp Bond NE)	RelyX ARC Single Bond	Indirect composite	7 days	Hand scaler Pumice-water slurry Al_2O_3 sandblasting	Not-ve affected *Microtensile bond.
Y Chaiyabutr & JC Kois, 2008	32 human teeth	Eugnol containing (Temp Bond)	RelyX unicem	Ceramic crowns	7 days	Excavator alone Excavator followed by prophy with a mixture of flour pumice & water Excavator followed by Al_2O_3 abrasion	-ve affected
J. Leirskar & H. Nordbø, 2000	49 human third molars	ZOE cement	Total etch (Scotchbond Multi-Purpose)	Resin composite Z100	6 days	Carving instrument Ethanol	Not -ve affected
KhalidA. A1Wazzan et al, 1997	60 human molars	Temp Bond (eugenol-containing) Temp Bond NE (eugenol free)	Self etch (Gluma)	Composite core materials: Ti-Core & Fluorocore	7 days	Hollenback carving instrument & pumice-water slurry with rubber cup	-ve affected
Jose´ C.V. Ribeiro et al, 2011	30 human third molars	Temp Bond (eugenol-containing) Freeugenol (eugenol free)	Total etch (Adper Single Bond) Self-etch (Adper Prompt)	Composite material (Filtek Z-250)	7 days	Dental instrument & cotton pellets soaked with pumice-water slurry	-ve affected

has to be tested and considered in future studies. The shear bond strength in this study was measured after twenty-four hours temporization. Further investigation on the chemical explanation of such findings has to be done.

"Effect of eugenol and non-eugenol containing temporary cement on permanent cement retention and microhardness of cured composite resin" by Funda Bayindir et al. [15]

Unlike other studies, this study evaluated the tensile instead of shear bond strength of resin cement with cast Co-Cr crowns cemented to composite cores. No dentine substrate was involved hence, the dentin- resin bond was not assessed in this study. It was concluded that pretreatment of composite cores with eugenol-containing provisional cement for ten days negatively affected the tensile bond strength of the final resin cement while it did not affect the tensile bond strength of carboxylate cements compared to the control with no prior temporization. This study cannot be compared to other studies as the method of evaluation used was measuring the tensile instead of shear bond strength and also the bonding surface was composite instead of dentine. More homogenous studies

with outlined research standards are needed for more stringent answer regarding the clinical significance of our question.

"Effect of eugenol exposure time and post-removal delay on the bond strength of a self-etching adhesive to dentin" by JPL Silva et al. [16]

This study tested the effect of eugenol exposure time on the bond strength of adhesive system to dentine. It reported that provisionalization with eugenol-containing temporary for one or two weeks has no effect on the SBS,while provisionalization for twenty-four hours reduced the SBS with compared to the control that was temporized with IRM (eugenol free). The adhesive used in this study is the self-etching adhesive. This study shares both aspects; accepting null hypothesis for the one week temporization and rejecting the null hypothesis for the twenty-four hours temporization. It supports the previously discussed studies, which found that eugenol negatively affected the SBS with twenty-four hours temporization and has no effect with one-week temporization. Also these findings support the results of the meta-analysis for insignificant effect of eugenol on SBS when used with one-week temporization period.

"Effect of provisional cements on the bond strength of various adhesive bonding systems on dentine" by S. J. Paul & P. Scharer [17].

The authors in this study replaced the eugenol-containing temporary cement; Temp Bond, after twenty-four hours and found that the bond strength was negatively affected with the adhesive systems; Syntac, ART, AllBond 2. The bond strength was acceptable when P-Bond luting system was used.

"The effect of eugenol-containing temporary cement on the bond strength of two resin composite core materials to dentin" by Khalid A.A1Wazzan et al. [18]

This study found that Eugenol-containing temporary material significantly reduces the bond strength of composite core to dentine after one week temporization when compared to specimens temporized with eugenol-free materials and to the control without prior temporization. This study contradicts the results of studies that found no negative effect of eugenol on bond strength with seven days temporization and also it contradicts the cumulative results of the meta-analysis, which found no statistical significance effect of eugenol on the bond strength of final restoration with resin adhesives. Attention must be paid when reporting the results to the clinical rather than the statistical significance of the findings, which highlights the aim of our study to translate the science into efficient practice.

The influence of temporary cements on dental adhesive systems for luting cementation by Jose´ C.V. Ribeiro et al. [19]

This study found that bond strength of both self-etch and total-etch adhesive systems to dentin were adversely affected by eugenol-containing temporary after seven days provisionalization. Groups treated with self-etch showed lower bond strength values compared to the total-etch group. Preparations of the specimens had led to the failure prior to de-bonding test, but were not calculated, which might have amplified the effect due to withdrawal bias. Also it could be explained by faults in the samples preparation and bonding techniques rather than the negative effect of eugenol on the bond strength per se.

Studies supporting the null Hypothesis; use of eugenol-containing temporary does not affect the bond strength of the final resin material:

"Effect of eugenol-containing temporary cements on bond strength of composite to enamel" by Martin Jung et al. [20]

This study investigated the effect of eugenol-containing temporary on bond strength of resin to enamel. This experiment concluded that the resin-enamel bond was not affected by eugenol-containing temporary material when etching was done with 37% phosphoric acid and bonding with Hollibond dual-curing luting resin. The results of this study cannot be compared to the other studies because this study evaluated enamel rather than dentin bonding. Enamel and dentin bonding are completely different because unlike enamel, dentine has a structural complexity that makes it a challenging surface for bonding.

"Effect of eugenol-containing temporary cements on bond strength of composite to dentin" by Carolina Ganss et al. [21]

This study concluded that ten days period of provisionalization with eugenol-containing or eugenol-free materials has no adverse effect on SBS of resin composite to dentine when Syntac was used as an adhesive. It also observed that lower values of SBS were associated with specimens with lower dentin thickness, which draws more attention to the effect of the bonded surface nature on the bond strength and the need to standardize the specimens to certain thickness and source.

"Effect of temporary cements on the bond strength of ceramic luted to dentin" by Sahar E. Abo-Hamar et al. [22]

This study showed that the bond strength of resin-dentine is affected by the type of the adhesive system used rather than eugenol content of the temporary cement. Higher bond strength values were observed with total-etch group; Exite compared to self-etch; Panavia F 2.0. It also stated that eugenol-containing and eugenol-free temporary cements have no effect on the bond strength after seven days of temporization and when ~~if~~ the temporary restoration was removed properly prior to bonding. Studies that test the effect of the method of removal of temporary materials and their effect on the bond strength of the final resinous material must be employed and tested. Also a standardized method of removal have to be used in future studies for more accurate results regarding the effect of eugenol material on the bond strength of final resinous material.

Influence of zinc oxide-eugenol temporary cement on bond strength of an all-in-one adhesive system to bovine dentin by Eduardo Schwartzer et al. [23]

Like the study by Funda Bayindir et al, [15] this experiment investigated tensile bond strength but using bovine incisors instead of composite cores with seven days temporization period instead of ten days. It concluded that the eugenol contained within temporary cement has no effect on microtensile bond strength of an all-in-one adhesive system (One-UP Bond). Again, this draws the attention that other variables like the bonded surface and period of temporization and type of adhesive used might affect the outcome of the strength of bonding rather than the eugenol effect by its own.

“Influence of eugenol- containing temporary cement on efficacy of dentin-bonding systems” by Anne Peutzfeldt and Erik Asmussen [24]

The results of this study showed no adverse effect of ZOE on dentine-resin bond with Gluma CPS or Scothchbond

Multi-Purpose Plus adhesive systems after seven days period of temporization. This result complies with the cumulative results of the meta-analysis and most of the studies after seven days period of temporization.

"Influence of eugenol-containing temporary cement on bonding of self-etching adhesives to dentin" by Anne Peutzfeldt and Erik Asmussen [9]

This other study by Anne Peutzfeldt and Erik Asmussen tested the effect of ZOE cement using six different self-adhesive systems after seven days period of temporization. There was no reduction in SBS with the self-etching adhesives, and they concluded that ZOE could be used for temporization of preparation later to be luted with self-etching adhesives. According to the two studies by Peutzfeldt and Asmussen (1999,2006) [24,9], the different type of adhesive systems used did not affect the final bond strength results after seven days temporization period.

"Influence of previous provisional cementation on the bond strength between two definitive resin-based luting and dentin bonding agents and human dentin" by S Erkut et al. [25]

This study shows reported that the temporization influences shear bond strength to dentin despite the type of final material used. Groups that received a provisional agent had lower SBS values compared to control. This result was obtained within the tested adhesive systems; (Rely X ARC-single bond and Duo Link-one step). Application of dentine bonding system prior to temporization was found to significantly increase SBS values that were declined as a result of placing a temporary material. This difference was observed in comparison to the group that received no luting procedure before temporization. The authors referred to this technique as dual bonding procedure. The application of dentine bonding system prior to provisionalization, might act as a barrier against the contact between the temporary material and the tooth structure that could contribute to the increase in the SBS interpreted in this study. No significant difference between eugenol-containing or eugenol-free samples was reported. This finding draws the attention to investigate more about the effect of temporization in general and the method of removal of temporary materials on the bond strength of final resinous materials.

"Influence of eugenol- containing temporary restorations on bond strength of composite to dentin" by AUJ Yap et al. [26]

This study shows that eugenol concentration within provisional cement determines the strength of the final resin cement. Altering powder liquid ratios affected the bond strength. Using ZOE cement as instructed by the manufacturers is crucial in order not to affect the bond strength of the final resinous cement. The results shows that eugenol effect is dose-dependent, which might explain why most of the studies showed negative effect on the bond strength of final materials when placed after 24 hours of temporization with eugenol-containing provisional restorations which is the time when the peak release of eugenol occurs by hydrolysis. Most studies having longer period of one to two weeks reported no negative effect on the bond strength.

"Influence of provisional cements on ultimate bond strength of indirect composite restorations to dentin" by Rodrigo Borges Fonseca et al. [1]

This study indicates that obtaining a clean dentin surface is crucial not to affect the tensile bond strength of the bonded resin, not the type of the temporary restoration, and that eugenol-containing provisional agent does not affect the tensile bond strength of the indirect resin restoration when replaced after seven days of temporization. Sand blasting showed the highest micro-tensile bond strength values, followed by pumice-water slurry then for manual scaling. The superficial dentin of bovine incisors was used and not human teeth.

"The effect of zinc oxide-eugenol on the shear bond strength of a commonly used bonding system" by J. Leirskar and H. Nordbo [27]

This experiment stated that thorough acid etching of the dentin surface and application of Scotchbond Multi-Purpose after removal of the temporary restoration after seven days of pacement resulted in dentin-resin bond with high SBS values. It is of a concern why the control group in this study scored low SBS values compared to the groups that had prior provisionalization.

"Effects of adhesive liner and provisional cement on the bond strength of nickel/chrome/beryllium alloy cemented to dentin" by Mark A. Latta et al. [28]

The results of this study showed low SBS with both eugenol-containing and eugenol-free provisional cements when Panavia F adhesive system was used. When an adhesive resin liner was used prior to provisionalizsation, SBS values of Panavia F was improved. No reduction was observed in SBS values with provisional cement in case of Calibra adhesive system. The study suggested that applying adhesive resin liners before temporization might reduce the negative effect of provisional cementation with Panavia F adhesive system. Also it indicates that factors other than eugenol presence in the provisional material might affect the bond strength of the final material, such as the type of adhesive and the prior use of adhesive before temporization. Provisional materials were placed for seven days before replacement.

"The effects of tooth preparation cleansing protocols on the bond strength of self-adhesive resin luting cement to contaminated dentin" by Y Chaiyabutr and JC Kois [29]

This study evaluated the effectiveness of dentine cleaning through testing four methods of temporary material removal after temporization with eugenol-containing material. The study had neither a control group nor tested an eugenol-free temporary cement. For stronger results, this test must be done compared to control groups of eugenol-free temporization and no temporization. It concluded that the highest values of SBS was for the group treated with particle abrasion, followed by the groups treated with a combination of manual excavation and pumice, and the lowest values were for manual excavation. The high SBS values with micro-abrasion may be due to the effect of abrasion that produces a rough dentine surface that promotes resin micromechanical interlocking rather than eugenol removal. Furthermore, this technique is not a clinically established method for removing temporary cements.

Overall Discussion

Heterogeneity among the studies was related to sample preparation and sources as well as methodological diversity

in types of adhesive systems, duration of temporization and methods of temporary filling removal, as presented in *Table 2*. All the included studies were level 2 of evidence according to the grading system of evidence-based dental practice journal [30]. Multiple factors affecting bond strength were assessed. However, the evidence for each factor might not be sufficient. There are four main variables that seem to play a role. First is the duration of provisionalization. All the studies in which eugenol-containing provisional agents were removed after twenty-four hours, showed significantly lower bond strength of the final resin restorations or cements [8,14,16,17]. This is consistent with a study by Hume in 1988 which reported that eugenol is released from zinc eugenolate mass by hydrolysis with a rate that peaks during the first twenty-four hours of placement and declines after [3]. Whereas, for the studies that the temporary material was placed for longer duration this effect was not necessarily absent [15,18,19,28,29]. Eleven studies in which provisionalization was for seven days reported no significant adverse effect on the bond strength [1,16,19-27]. However, when other factors were assessed, the results were not consistent regarding the effect of eugenol within duration of seven days. Second is the method of temporary restoration/ cement removal. Obtaining a clean dentine is essential for proper adhesion [1,22,29]. Aluminous oxide particle abrasion showed high values of bond strength compared to mechanical removal by scaler or pumice- water slurry [1,29]. However, the three methods yielded bond strength values within the reported acceptable range of bond strength to dentine [31]. Combination of both manual scaling and pumice results in a higher bond strength values compared to hand instrument alone [29]. Another factor that can be related to this point is the placement of adhesive prior to temporization, which was referred to by S Erkut et al. as the dual bonding procedure and can improve the bond strength of the final restoration by preventing direct contact with reminants of provisional restorations within the tooth structure [25]. Third is eugenol concentration. Altering powder liquid ratio of eugenol-containing temporary material has a negative impact on bond strength [27]. IRM has a thick consistency and some clinicians alter the proportion to improve the manipulation which increases eugenol concentration. This observation is in consistence to a study by Hume, which reported that the release of eugenol from ZOE increases as the concentration of eugenol within the mix increases and thus adversely affects the bond strength of the final resinous material [32]. The forth factor is the type of adhesive system used. It was noticed that the bond strength of the final resinous material differs with different adhesive systems used. Also it was observed that the effect of eugenol can differ from one adhesive system to another. Explanation of the causes and chemical nature of this finding has to be investigated.

Conclusion

Eugenol-containing provisional material was found to affect the bond strength to resin restoration/cement, but this effect was not statistically significant within the seven-days duration assessed in this study. However, some studies claimed that this effect could be significant when shorter duration, or different adhesive systems were employed. Therefore, more studies are needed for stronger evidence on the effect of eugenol containing temporaries on the bond strength under controlled variables.

Clinical Recommendations

1. Eugenol-containing temporary should only be used as directed by manufacturers, as high concentrations of eugenol can negatively alter bond strength.
2. Waiting at least for one week prior to replacement of eugenol-containing temporary materials with resinous final materials could be a wise decision according to the current literature.
3. Eugenol-containing provisional material needs to be removed properly from the tooth structure prior to bonding. Any remnants are capable of hindering a strong adhesive bond.
4. Finally, performing proper bonding technique for dentin pretreated with eugenol-containing provisional agent is essential. Dual bonding procedure is recommended before temporization.

Research Recommendations

1. More homogenous studies are needed to perform a meta-analysis with high power and thus more stringent results.
2. Setting research standards to answer this question will allow more homogenous studies with controlled variables to be able to relate to the effect of eugenol.
3. Attention to the statistical versus clinical significance must be given when reporting the results of the effect of eugenol on the bond strength of the final resinous material.

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