Effect of contamination with provisional cement on the bond strength of self-adhesive luting cement: A systematic review and meta-analysis

Running Title: Effect of provisional cement on resin bond strength

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Abstract This systematic review and meta-analysis aimed to assess the impact of contamination with eugenol-containing or eugenol-free temporary cement on the bond strength of self-adhesive resin cement. A comprehensive electronic search was conducted across Pubmed, Scopus, and ISI databases without language or publication date restrictions, up to August 18, 2020. Eligible studies were in vitro investigations measuring the bond strength of self-adhesive cement after contamination with eugenol-free or eugenol-containing provisional cement. Articles were categorized based on the type of temporary cement (with or without eugenol), and the effect size was presented as the standardized difference in means (SDM) between the intervention and control groups. A random-effects model was employed for the meta-analysis. Out of 450 initially identified articles, four met the inclusion criteria. The results indicated a significant reduction in the bond strength of self-adhesive cement when the temporary restoration was adhered with either eugenol-containing (SDM = -1.64, $P < 0.001$, I2 = 48.48%) or eugenol-free (SDM = -1.33, $P < 0.001$, I2 = 61.68%) provisional cement, compared to the control group. Contamination with temporary cement, regardless of eugenol presence, diminishes the bond strength of self-adhesive cement. It appears that the residue of temporary cement is a more critical factor than the presence or absence of eugenol in weakening the bonding quality of permanent cement to the tooth substrate.

Keywords-- Adhesive Cement, Dental Cement, Bond Strength, Resin Cement, Dental Restoration, Systematic Review

1. Introduction

Indirect restorations in both the posterior and anterior regions of the oral cavity have gained popularity in dental practice (Peixoto et al, 2015). These restorations optimize occlusal and proximal contacts, promote gingival health, and reduce chairside time (Ribeiro et al, 2011). In clinical practice, the minimal waiting period for delivering the final indirect restoration is approximately two weeks (Zareie et al, 2020). In this period, an interim restoration is crucial to provide comfort and satisfaction while the patient awaits the final restoration (Arora et al, 2016). An interim restoration, cemented to the prepared tooth surface, helps prevent tooth hypersensitivity and displacement while enhancing soft tissue contour.

To bond interim restorations effectively, it's essential to use provisional (temporary) cements with appropriate retention. These types of cement fall into two main categories: eugenol-free, including resin-based and calcium hydroxide-based cement, and eugenol-containing materials (Sczepanski et al, 2018; Yu et al, 2014). Using provisional cements, however, may have detrimental effects on the bond strength of final restorations.

In eugenol-containing cement, mixing zinc oxide with eugenol and a small portion of water results in the formation of zinc eugenol. When this set of cement comes into contact with water, the eugenol on the surface hydrolyzes into free eugenol. This released eugenol can penetrate the dentin and interfere with the polymerization process of resin-based restoration materials. This phenomenon could decrease the sealing capability and retention of adhesive restorations and cause leakage at the bond interface, possibly leading to increased tooth sensitivity and secondary caries formation (Alrahlah et al, 2023; Arora et al., 2016; E. M. Carvalho et al, 2014; Mohtasham et al, 2023).

Another theory explaining the reduced bond strength is the presence of provisional cement residues on the surface, which prevents adequate adhesion of permanent cement to the dental substrate. Despite various mechanical and chemical protocols suggested for dentin surface cleaning, complete removal of the material is seldom achieved after temporary cementation.

Different types of cement can be used to bond permanent indirect restorations. In the 1970s, resin cement emerged as a viable alternative to acid-base reaction cement (Yu et al., 2014). Resin cements have diacrylate or acrylic resin bases and rely on resin polymerization for the setting process. They offer strong bonding with dental tissue, high compressive and tensile strength, low solubility, and excellent aesthetic properties. This makes resin cement a suitable choice in cases where adhesion is uncertain or aesthetics are of utmost importance (Ahrari et al, 2016; Ahrari et al, 2017, 2018).

Resin cements are classified into three categories: etch and rinse, self-etch, and self-adhesive types (Yu et al., 2014). Self-adhesive cement, also known as universal or multipurpose resin cement, was first developed in 2002 to simplify the cementation process and reduce its technical complexity. Unlike traditional resin cement, self-adhesive cement adheres to the smear layer in a single step without the need for prior preparation or the application of a bonding agent (Moosavi et al, 2021; Santos et al, 2011; Takimoto et al, 2012; Yu et al., 2014). It remains unclear whether the reduction in bond strength of permanent restorations is due to the release of eugenol or the remnants of temporary cement. Previous studies have yielded conflicting results regarding the impact of eugenol on bond strength. Some studies have shown a significant decrease in the bond strength of adhesive systems to dentin after the application of eugenol-containing temporary cement (Jain et al, 2018; Koch et al, 2013; Pinto et al, 2014; Ribeiro et al., 2011; Silva et al, 2011). In contrast, others have reported that the reduction in bond strength is unrelated to the presence of eugenol in the cement composition (E. M. Carvalho et al, 2014; Fiori-Júnior et al, 2010; Peixoto et al., 2015; Peutzfeldt et al, 2006; Schwartzer et al, 2007). The effect of provisional cement on bond strength becomes more critical when using self-adhesive cement for luting final restorations, because adhesion occurs without the need for separate etching, rinsing, or bonding steps (Takimoto et al, 2012). This systematic review and meta-analysis aimed to determine whether contamination with eugenol-containing or eugenol-free temporary cement can affect the bond strength of self-adhesive resin cement.

2. Materials and methods

This study adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) statement. The PICOS framework was designed as follows:

Participants: All indirect restorations that were ultimately cemented with self-adhesive resin cement.

Intervention: Exposure to temporary cement before bonding with self-adhesive cement.

Comparison: Teeth without the application of temporary cement.

Outcome: Bond strength.

Study design: In vitro studies.

2.1 Search strategy

A comprehensive electronic search was conducted across three databases: PubMed, Scopus, and ISI. The following keywords were used in the search:

(Self-adhesive OR self-adhesive OR self-bonding OR self-bonding) AND (Cement OR luting OR resin) AND (Temporary Cement OR Cleaning technique OR Provisional).

The search was completed on August 18, 2020, with no restrictions on language or date of publication.

2.2 Study selection and data extraction

Using the mentioned search terms, 72 articles were obtained from PubMed, 83 from Scopus, and

186 from ISI. Search results were imported into an EndNote library, and duplicate studies were removed.

The eligibility criteria included in vitro studies that met the following conditions:

1- The study was related to restorative prosthetic dentistry.

2- The bond strength of self-adhesive cement was measured.

3- Eugenol-free or eugenol-containing cements were used for temporary cementation.

4- A control group was present.

5- The required quantitative analysis was reported.

Two independent authors (SM and HF) screened the articles based on their titles and abstracts. Any article with a title and abstract not aligning with the inclusion criteria was excluded at this stage. In cases of disagreement, a third researcher (ASS) was consulted. Subsequently, the full texts of selected articles were thoroughly reviewed to assess their compliance with the eligibility criteria. To ensure comprehensive coverage of the literature, the reference lists of each article were manually scrutinized.

Authors of articles with missing or incomplete data were contacted via email to obtain the necessary information. If no response was received within two weeks of the initial email contact, a follow-up email was sent. If no reply or an incomplete reply was received one month after the first contact, the article was excluded.

An overview of the eligible studies is presented in Table 1. The selected articles were categorized based on the type of temporary cement (with eugenol and without eugenol). Information extracted included the brand of temporary and self-adhesive cement, the evaluated substrate, storage duration, sample size, and statistical data (mean and standard deviation of bond strength). The data were entered into a structured data extraction table.

2.3 Risk of Bias Assessment

The risk of bias was evaluated in terms of several criteria, including randomization, use of the material according to instructions, sample size calculation, selection of teeth free of caries or restoration, outcome measurements by the same operator, and blinding of the outcome assessor. Articles reporting one or two of these criteria were categorized as having a high risk of bias, those reporting three or four criteria were considered to have a medium risk, and those reporting five to six criteria were classified as having a low risk of bias.

2.4 Statistical Analysis

Statistical analyses were performed using Comprehensive Meta-Analysis 2 (CMA2) software

(Biostat, Englewood, NJ, USA) with a confidence level of 95% (α=0.05). The control group did not undergo any contamination with temporary cement. The outcomes were expressed as the standardized difference in means (SDM) between the intervention and control groups. Negative values indicated lower bond strength in the treatment group compared to the control group, and positive values indicated the opposite. Due to heterogeneity among the studies, a random-effect model was employed for the meta-analysis.

3. Results

The initial search yielded 341 results. After removing duplicates and unrelated studies, four studies that met the inclusion criteria were included in this systematic review and underwent scientific and statistical evaluation. The flowchart illustrating the inclusion of studies in this research is shown in Figure 1. In assessing the risk of bias in the included studies, two had a medium risk of bias, and two had a high risk of bias (Figure 2). The studies were categorized into two groups based on the presence or absence of eugenol in the provisional cement. The results of meta-analyses are presented in Forest plots (Figures 3 and 4).

3.1 Effect of eugenol-containing temporary cement on bond strength of self-adhesive cement

In this group, three eligible articles were included. The meta-analysis results indicated a significant decrease in the bond strength of self-adhesive cement when the temporary restoration was adhered with eugenol-containing provisional cement compared to the control group (SDM = -1.64, P < 0.001, I2=48.48%) (Figure 3).

3.2 Effect of eugenol-free temporary cement on bond strength of self-adhesive cement

In this category, three eligible articles were included. The meta-analysis results indicated a significant decrease in the bond strength of self-adhesive cement when the temporary restoration was adhered with eugenol-free provisional cement, compared to the control group (SDM = -1.33, P < 0.001, I2=61.68%) (Figure 4).

4. Discussion

This meta-analysis examined the impact of contamination with temporary cement on the bond strength of self-adhesive resin cement. The results, analyzed using a random-effects model, demonstrated that both types of temporary cement (with or without eugenol) significantly reduced the bond strength of self-adhesive resin cement.

There is some evidence that contamination with eugenol-containing provisional cement would cause a significant decline in the bond strength of permanent cement (Ribeiro et al, 2011). Eugenol is well known for its ability to inhibit resin polymerization (Alrahlah et al, 2023; C. N. Carvalho et al, 2007; Zareie et al, 2020). This inhibiting effect can occur even at low concentrations of eugenol due to its high diffusion capacity into dentin. Hume et al (Hume, 1984) found that the concentration of eugenol in the aqueous phase is relatively high just below the zinc oxide eugenol (ZOE) cement, and decreases significantly in the vicinity of the pulp tissue. The powder-to-liquid ratio of the cement may also contribute to the impact of eugenol-containing temporary cements on bond strength. Several types of ZOE cement are available in the market. Most studies have focused on type I cement for temporary cementation, which has a low powder-to-liquid ratio. It is possible that type I cement releases more free eugenol into dentin, which could be responsible for the low resin-dentin bond strength reported by some studies (C. N. Carvalho et al, 2007).

Another mechanism that could account for the diminished bond strength is the presence of residual temporary cement on the dentin surface, which may interact with the bonding performance of resin cement. Achieving the optimal moisture content on the surface is crucial for enabling adhesive cement to spread effectively over the substrate and establish durable adhesion. Takimoto et al (Takimoto et al, 2012) reported a significant decrease in both hydrogen-bonding and surface-free energy for dentin surfaces smeared with provisional cement. Considering the reduction in dentin wettability, it is plausible to assume that the residue of temporary cement plays a more critical role than the presence or absence of eugenol in compromising the bonding quality of permanent cement to the tooth substrate (Rakhshan, 2015). The findings of this systematic review support this hypothesis, as both eugenol-free and eugenol-containing cement had a detrimental effect on the bond strength of self-adhesive resins.

The etching effect in self-adhesive cement is caused by carboxylic or phosphoric acid ester groups on methacrylate monomers (Takimoto et al, 2012). A simultaneous demineralization and infiltration of resin cement occurs in the smear layer and underlying dentin, leading to the creation of micromechanical retention (Radovic et al, 2008). The adhesion of self-adhesive cement to dental tissues also involves a chemical reaction between acid monomers and calcium ions of hydroxyapatite (Radovic et al, 2008). Contamination with temporary cement may exert a more pronounced negative impact on the bond strength of self-adhesive cement compared to the three-step etch-and-rinse counterpart (C. N. Carvalho et al, 2007; Mine et al, 2021). The reason is that self-adhesive cements have hydrophilic components and adhere directly to the wet dentin surface. The quality of the dentin substrate plays a more crucial role in the adhesion of self-adhesive cement compared to other systems with a separate bonding agent application (Santos et al, 2011). Furthermore, in etch-and-rinse systems, the application of phosphoric acid reduces the eugenol content in dentin, and any remaining eugenol is further diminished by rinsing in the subsequent step (Koch et al, 2013; Pinto et al, 2014). In contrast, the smear layer remains when using self-adhesive resin cement, leading to a higher concentration of eugenol in the dental substrate.

Various strategies have been proposed to mitigate the adverse effects of temporary cement on the final bond strength of restorations. One approach involves cleaning the surface before final cementation using methods such as airborne particle abrasion, excavators, dentin conditioners, and ultrasonic scalers (Santos et al., 2011; Watanabe et al, 1999). However, previous studies on this topic have yielded somewhat conflicting results. Mosharraf et al (Mosharraf et al, 2009) demonstrated that temporary cement containing eugenol can be effectively removed from cast restoration surfaces through ultrasonic cleaning. Koch et al(Koch et al, 2013) demonstrated that conditioning with ethylenediaminetetraacetic acid (EDTA) or phosphoric acid significantly reduced the eugenol content in dentin. In contrast, several studies reported that mechanical removal of temporary cement or etching with 37% phosphoric acid may not eliminate all remnants of temporary materials (E. M. Carvalho et al., 2014; Frankenberger et al, 2007; Ribeiro et al., 2011; Watanabe et al, 2000). After observing SEM images of tooth surfaces, Takimoto et al (Takimoto et al, 2012) concluded that mechanical removal of temporary cement with an ultrasonic scaler may not eliminate all the traces of temporary cement, and compounds such as vegetable oil and glycerin that are present in some cement will reduce the surface energy of dentin.

Another strategy to counteract the negative effects of temporary cement is delaying the placement of permanent cement by one week after ZOE removal. It is believed that the inhibitory impact of eugenol on resin polymerization is dependent on its concentration (Silva et al, 2011). Schwartzer et al (Schwartzer et al, 2007) reported that the eugenol release from zinc oxide eugenol (ZOE) restorations reaches a peak of approximately 0.3 µmol/min within the first 24 hours after cementation, with the release rate gradually declining over time. Thus, the eugenol concentration in dentin is expected to have no significant impact on bond strength after a week. Silva et al (Silva et al, 2011) demonstrated that the recovery of bond strength occurs one week after the removal of eugenol-containing temporary restoration (IRM).

The immediate dentin sealing (IDS) technique is another approach to neutralizing the negative effects of provisional cements on bond strength (Frankenberger et al, 2007). IDS involves the application of a desensitizer or bonding agent to freshly cut dentin, which has been exposed during tooth preparation for indirect restorations. Gluma, a well-known desensitizer in dentistry, consists of 5% glutaraldehyde and 35% HEMA (hydroxyethyl methacrylate) in water. Several studies indicated that the application of Gluma after tooth preparation improves the bond strength of self-adhesive cement to dentin (Sailer et al, 2012). This improvement is attributed to the formation of a collagen-glutaraldehyde complex when Gluma is applied, with HEMA bonding to this complex. This enhances the wettability of the dentin surface and ultimately leads to copolymerization with the resin cement (Munksgaard et al, 1984; Santos et al, 2011).

It's important to note that this study has limitations, including the small number of included studies and the in vitro nature of the studies as they should contain bond strength measurements. Thus, the generalizability of these findings to clinical conditions may be limited. Future research should explore the impact of temporary cement contamination on the bond strength of other types of resin cement.

5. Conclusion

Contamination with temporary cement, whether they contain eugenol or not, leads to a reduction in the bond strength of self-adhesive cement.

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Table 1. The summary of studies included in this meta-analysis

Study	Type and brand of temporary cement	Brand of self-adhesive cement	Interface	Sample size	Type of bond strength test
Fiori-Júnior et al(Fiori-Júnior et al., 2010) (2010)	Eugenol-free *(Hydro C; Dentsply) and (RelyXTemp; 3M)* Eugenol-containing *(Temp Bond; Kerr)*	RelyX Unicem (3M)	Dentin-ceramic	40	SBS
Takimoto et al(Takimoto et al., 2012) (2012)	Eugenol-free (HY Bond Temporary Cement Hard; Shofu Inc.) and (IP Temp Cement; Shofu Inc.) and (Fuji TEMP; GC Corp.) and (Free eugenol Tempoaray Cement; GC Corp.)	Clearfil SA Luting (Kuraray) G-Luting (GC Corp.) G-Cem (GC Corp.)	Dentin-acrylic resin	150	SBS
Carvalho et al(E. M. Carvalho et al., 2014) (2014)	Eugenol-free (RelyX Temp; 3 M) Eugenol-containing (Provy; Dentsply)	RelyX U-100 (3M)	Dentin-composite	30	Microtensile
Jain et al(Jain et al., 2018) (2018)	Eugenol containing (Kalzinol; Dental Products of India)	RelyX U200 (3 M)	Dentin-Ni-Cr	60	Microtensile

Ni-Cr: Nickel-chrome; SBS: Shear bond strength

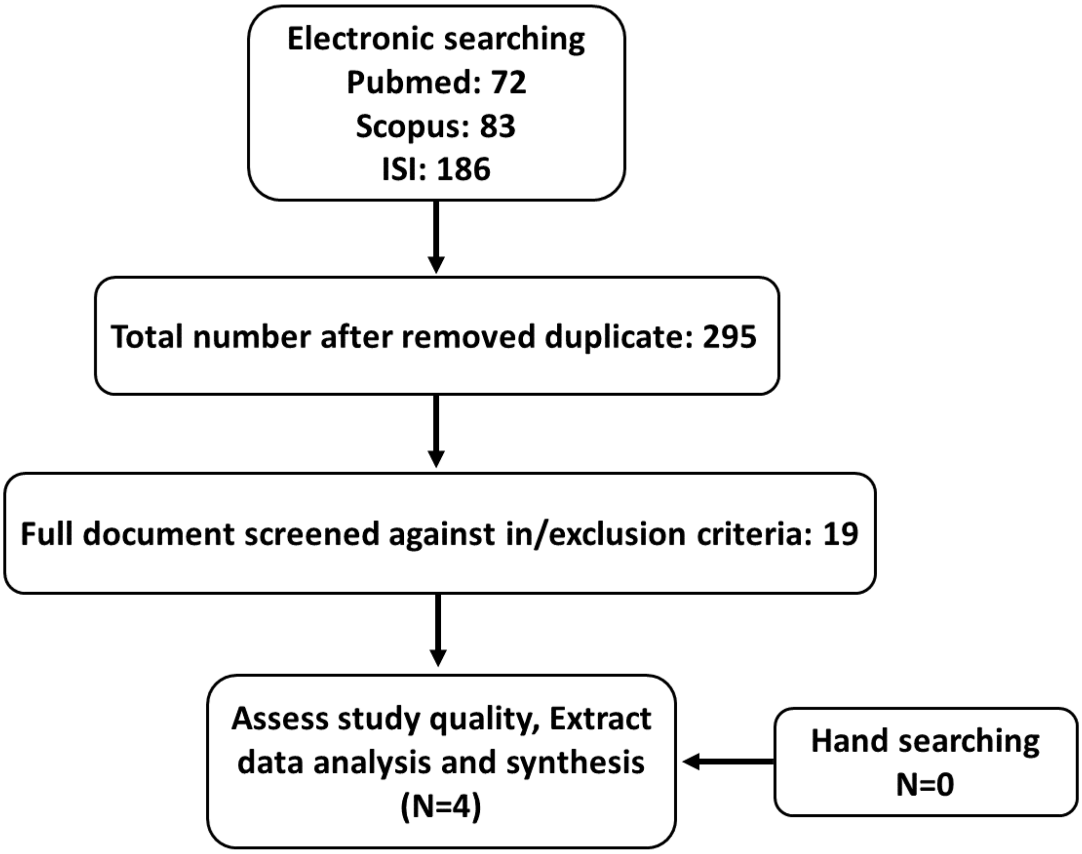

Figure 1. PRISMA flow diagram.

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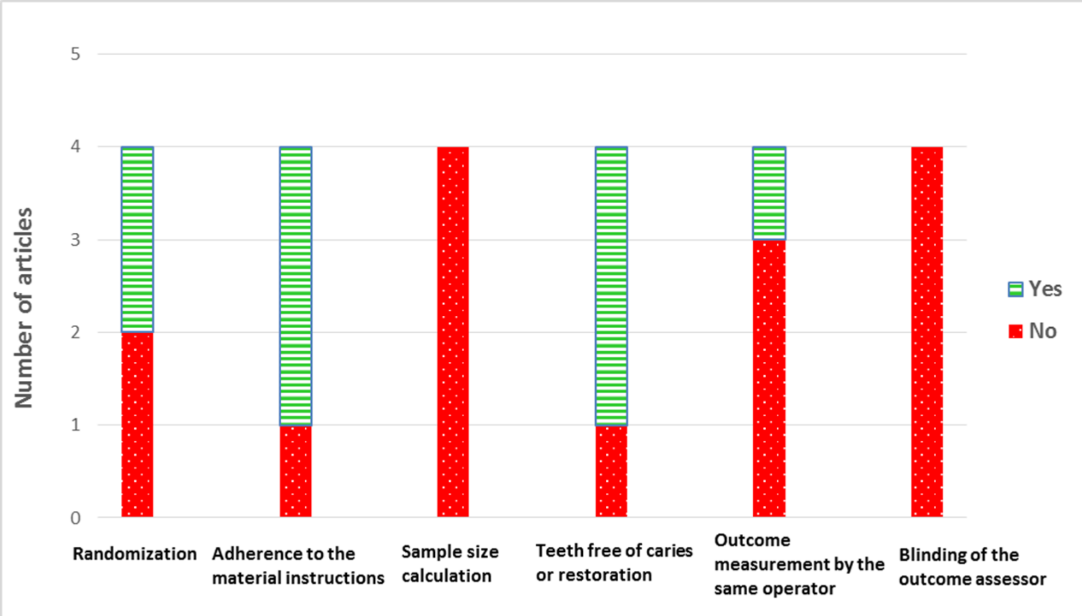

Figure 2. The result of risk of bias assessment in the included studies

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Carvalho et al	-1.248	0.691	0.478	-2.603	0.107	-1.806	0.071
Fiori et al	-1.210	0.486	0.237	-2.163	-0.256	-2.487	0.013
Jain et al 1	-2.931	0.578	0.334	-4.064	-1.798	-5.070	0.000
Jain et al 2	-1.856	0.489	0.240	-2.815	-0.896	-3.791	0.000
Jain et al 3	-1.101	0.439	0.193	-1.962	-0.240	-2.506	0.012
	-1.642	0.328	0.107	-2.284	-0.999	-5.008	0.000

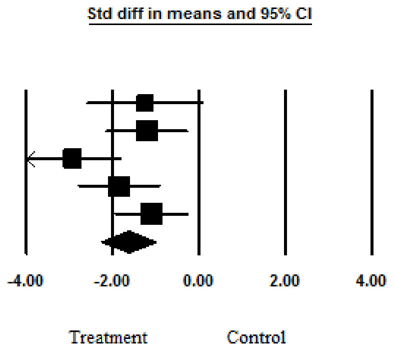

Figure 3. A forest plot comparing the bond strength of self-adhesive cement after contamination with eugenol-containing temporary cements

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
	Statistics for each study						
Carvalho et al	-0.473	0.641	0.411	-1.729	0.784	-0.737	0.461
Fiori et al 1	-0.451	0.453	0.205	-1.339	0.436	-0.996	0.319
Fiori et al 2	-0.347	0.451	0.203	-1.230	0.536	-0.769	0.442
Takimoto et al HY (SA)	-1.941	0.542	0.294	-3.005	-0.878	-3.579	0.000
Takimoto et al IP (SA)	-1.939	0.542	0.294	-3.001	-0.876	-3.575	0.000
Takimoto et al FT (SA)	-2.709	0.619	0.384	-3.923	-1.496	-4.375	0.000
Takimoto et al TC (SA)	-2.225	0.569	0.324	-3.340	-1.110	-3.910	0.000
Takimoto et al HY (GL)	-1.384	0.498	0.248	-2.359	-0.408	-2.779	0.005
Takimoto et al IP (GL)	-1.247	0.489	0.239	-2.205	-0.289	-2.552	0.011
Takimoto et al FT (GL)	-1.534	0.509	0.259	-2.532	-0.537	-3.016	0.003
Takimoto et al TC (GL)	-1.665	0.519	0.269	-2.682	-0.648	-3.208	0.001
Takimoto et al HY (GC)	-0.767	0.463	0.215	-1.675	0.141	-1.655	0.098
Takimoto et al IP (GC)	-0.648	0.459	0.211	-1.548	0.251	-1.413	0.158
Takimoto et al FT (GC)	-1.612	0.515	0.265	-2.621	-0.603	-3.132	0.002
Takimoto et al TC (GC)	-1.762	0.527	0.278	-2.794	-0.729	-3.344	0.001
	-1.335	0.179	0.032	-1.686	-0.984	-7.450	0.000

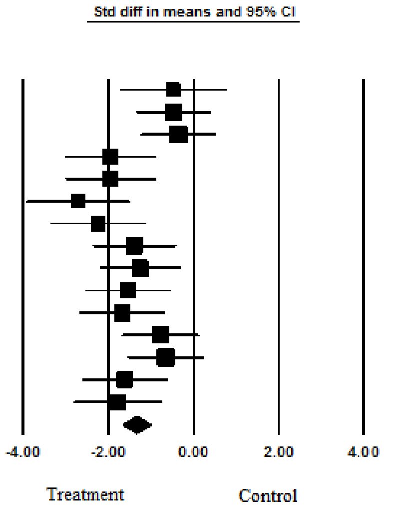

Figure 4. A forest plot comparing the bond strength of self-adhesive cement after contamination with eugenoul-free temporary cements