



Major outcomes of clinical and experimental studies to highlight the importance of using silane in composite resin restorations in modern dentistry: a systematic review

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Abstract

Introduction: Dental restorations are often placed due to caries or fractures, and composite resin is often the material of choice to restore teeth. Several factors may play a role related to the application of silane coupling agents, such as the type of silane (hydrolyzed or non-hydrolyzed) and the service life of the defective composite resin restoration being repaired. **Objective:** It was to analyze the main outcomes of clinical and experimental studies to highlight the importance of using silane in composite resin restorations in modern dentistry. **Methods:** The PRISMA Platform systematic review rules were followed. The search was carried out from February to April 2024 in the Scopus, PubMed, Science Direct, Scielo, and Google Scholar databases. The quality of the studies was based on the GRADE instrument and the risk of bias was analyzed according to the Cochrane instrument. **Results and Conclusion:** A total of 111 articles were found, 36 articles were evaluated in full and 30 were included and developed in the present systematic review study. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 30 studies with a high risk of bias and 22 studies that did not meet GRADE and AMSTAR-2. Most studies did not show homogeneity in their results, with $X^2=78.4\%>50\%$. It was concluded that the previous application of silane reduced the bond strength values.

The two-bottle adhesive showed better results than single-bottle or self-etching systems for composite resin repairs. Furthermore, the association of preheated hydrofluoric acid/silane applied or not with electric current promoted different values of micro shear resistance, types of fracture, and contact angles in the resin cement/ceramic connection. Silane application is essential for surfaces conditioned by hydrofluoric acid, but the use of adhesive is optional when silane is applied.

Keywords: Silane. Resin. Restoration. Resistance. Caries. Fractures.

Introduction

Dental restorations are often placed due to caries or fractures, and composite resin is often the material of choice to restore teeth. If a composite resin restoration fails, dentists may decide to replace or repair the restoration. Repair is a minimally invasive treatment that involves the removal of the defective part of the restoration, followed by restoration of the prepared defect [1,2].

Although it has been shown that repair can increase the survival time of subsequent restorations, there is no gold standard protocol for treating aged composite resin surfaces before repair. Physical surface treatments such

as grinding with drills or air abrasion have the ultimate goal of improving mechanical bonding between old and new (repair) composite resin, while chemical surface treatments such as silane or adhesives are applied to improve chemical coupling. between resin-based materials at the adhesive interface [1-3].

In this sense, it has been demonstrated that silane coupling agents appear to play a minor role in improving repair potential compared to adhesives. The use of drills, followed by acid etching and application of adhesive, appears to be used by more than 80% of dentists as a pre-treatment of the old composite to be repaired. In vitro data can help elucidate whether silane treatment of composite resin surfaces before repair is indispensable [3-5].

Furthermore, several factors may play a role related to the application of silane coupling agents, such as the type of silane (hydrolyzed or non-hydrolyzed) and the service life of the defective composite resin restoration to be repaired. A study showed that silane applied with electric current promoted different levels of adhesive strength, failure modes, and contact angles between resin cement and acid-sensitive ceramics. Furthermore, adhesive systems applied with electric current (25 and 50 μ A) improved the degree of conversion, reduced nano leakage, and increased dentin infiltration when evaluated after 1 year of storage water, while both electric current intensities promoted bonding interface with similar characteristics in stability levels [1].

Also, previous results have shown significant differences in shear strength for different bonding groups depending on the condition of the ceramic surface. For the unetched samples, significant differences in bond strength were obtained for all bonding protocols. However, for the conditioned groups there was no difference between the silane and the silane associated with dentin adhesive. Acid etching of porcelain significantly increased strength in all bonding methods and was the main contributor to the values obtained [2-4].

Thus, the present systematic review study analyzed the main outcomes of clinical and experimental studies to highlight the importance of using silane in composite resin restorations in modern dentistry.

Methods

Study Design

The present study followed the international systematic review model, following the rules of PRISMA (preferred reporting items for systematic reviews and meta-analysis). Available at: <http://www.prisma-statement.org/?AspxAutoDetectCookieSupport=1>.

Accessed on: 02/12/2024. The methodological quality standards of AMSTAR-2 (Assessing the methodological quality of systematic reviews) were also followed. Available at: <https://amstar.ca/>. Accessed on: 02/12/2024.

Data Sources and Research Strategy

The literary search process was carried out from February to April 2024 and was developed based on Medline, PubMed, Embase, and Ovid, covering scientific articles from various to the present, according to quantitative data on the types of works found in relation to silane in restoration repair with composite resin in four database (Figure 1). The descriptors (DeCS / MeSH Terms) were used: "*Silane. Resin. Restoration. Resistance. Caries. Fractures*" and using the Boolean "and" between the MeSH Terms and "or" between descriptors.

Study Quality and Risk of Bias

Quality was classified as high, moderate, low, or very low in terms of risk of bias, clarity of comparisons, precision, and consistency of analyses. The most evident emphasis was on systematic review articles or meta-analyses of randomized clinical trials, followed by randomized clinical trials. The low quality of evidence was attributed to case reports, editorials, and brief communications, according to the GRADE instrument. The risk of bias was analyzed according to the Cochrane instrument by analyzing the Funnel Plot graph (Sample size versus Effect size), using the Cohen test (d).

Results and Discussion

Summary of Findings

A total of 111 articles were found that were subjected to eligibility analysis, with 30 final studies being selected to compose the results of this systematic review. The studies listed were of medium to high quality (Figure 1), considering the level of scientific evidence of studies such as meta-analysis, consensus, randomized clinical, prospective, and observational. The biases did not compromise the scientific basis of the studies. According to the GRADE instrument, most studies showed homogeneity in their results, with $X^2=78.4\%>50\%$. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 30 studies with a high risk of bias and 22 studies that did not meet GRADE and AMSTAR-2.

Figure 1. The article selection process by the level of methodological and publication quality.

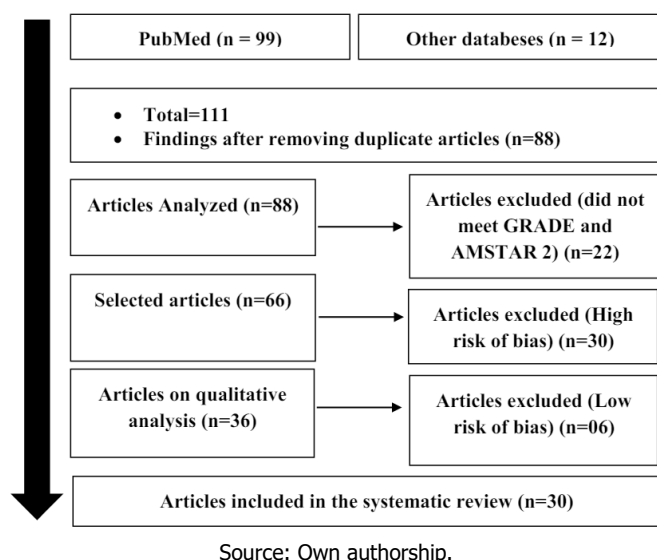
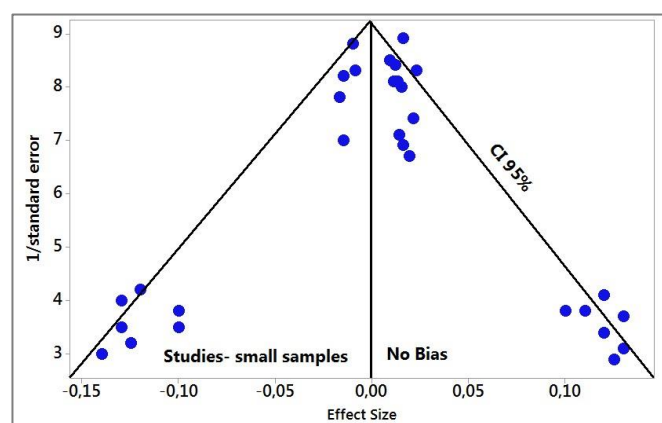


Figure 2 presents the results of the risk of bias of the studies using the Funnel Plot, showing the calculation of the Effect Size (Magnitude of the difference) using the Cohen Test (d). Precision (sample size) was determined indirectly by the inverse of the standard error (1/Standard Error). This graph had a symmetrical behavior, not suggesting a significant risk of bias, both between studies with a small sample size (lower precision) that are shown at the bottom of the graph and in studies with a large sample size that are presented at the top.

Figure 2. The symmetric funnel plot suggests no risk of bias among the small sample size studies that are shown at the bottom of the graph. High confidence and high recommendation studies are shown above the graph (n= 30 studies).



Major Outcomes

After the selection process of the main literary findings on the importance of using silane in composite resin restorations in modern dentistry, a study demonstrated the effect of applying silane (Si) and different adhesive systems on the bond strength of resin

repairs. A total of 100 cone-shaped truncated composite specimens were prepared and subjected to 5,000 thermal cycles to simulate existing restorations. Their upper surfaces were abraded with airborne particles containing aluminum oxide, etched with phosphoric acid, and divided into two groups (n = 50) with or without Si application. Each group was divided into five subgroups (n = 10) according to the adhesive system applied: Solobond Plus Primer and Adhesive (SPA)-two bottles, Solobond Plus Adhesive (SA), Admira Bond (A)-one bottle, Futurabond DC (FDC)-self-etching and Futurabond M (FM)-self-etching. New composite resin was applied to the bonded area. The application of Si reduced the bond strength of all adhesives ($p = 0.001$). The SA and SPA groups showed greater bond strength compared to the other groups ($p = 0.01$). The FDC + Si, FM, FM + Si, and A + Si groups presented lower average bond strength values than the control group ($p < 0.05$) [6].

Furthermore, a study analyzed the effect of the preheated hydrofluoric acid/silane/electric current combination on the adhesion of resin cement to ceramics. The IPS E.max Press ceramic discs embedded in rigid PVC tubes were divided into four groups combining pre-heated hydrofluoric acid and silane applied with electric current (n=10): Ha+S (heated acid + silane); Ha+S+Ec (Heated acid + silane + electric current); A+S (Acid + silane) and A+S+Ec (Acid + silane + electric current). Resin cement/ceramic samples were stored in water at 37°C for 24h. After storage, they were subjected to micro shear testing, fracture analysis, and contact angle at 24h or after thermocycling (10,000 cycles/5-55°C). At 24h, micro shear resistance presented similar values between the Ha+S, Ha+S+Ec, and A+S+Ec groups, while A+S presented the lowest value with a statistical difference. After thermocycling, Ha+S and Ha+S+Ec were similar, as were A+S and A+S+Ec. There was a significant difference in all groups comparing 24h (highest value) with after thermocycling (lowest value). Adhesive fracture was predominant in all groups and evaluation moments. The Ha+S and A+S groups presented higher contact angle values compared to the Ha+S+Ec and A+S+Ec groups with lower values [7].

A recent study carried out by authors Eggmann et al. (2024) [8] evaluated the effect of three universal adhesives and a two-component silane coupling agent on the shear strength of three [(CAD-CAM) with dispersed fillers (CCRBCs)]. A total of 864 specimens of Brilliant Crios, Lava Ultimate, and Tetric CAD were polished or sandblasted, bonded with Adhese Universal DC, One Coat 7 Universal (OC7), and Scotchbond Universal Plus (SBU) adhesive with or without silane primer. Shear strength was measured after 24 hours

and 10,000 thermocyclers. Linear regressions were performed. After thermocycling, the bond strengths were similar for the universal adhesives on the sandblasted Tetric CAD. The silane primer had minimal impact on the sandblasted Tetric CAD. Silane primer increased the bond strength of OC7 to Brilliant Crios but decreased the adhesion of SBU to Brilliant Crios and Lava Ultimate. Therefore, the bond strength of the universal adhesives varied with the type of CCRBC. The two-component silane coupling agent showed mixed effects on adhesive performance.

The authors Albashaireh et al. (2023) [9] evaluated the effects of using silane coupling agent in repair procedures for old composite restorations, with or without sandblasting their surfaces, on the clinical performance of repaired composite restorations, with 130 composite resin restorations Class I and II defects. After removing the recurrent decay, the repair process included etching with 37% phosphoric acid, application of Adper Single Bond 2 for bonding, and Filtek Z250 composite to restore all defects. Of the 130 cases, only 116 cases appeared for assessment. The main reasons for composite repair were recurrent cavities and anatomical deficiencies. No statistically significant differences were found between groups for all clinical criteria. The control group suffered one total loss and two partial losses of retention. Application of a silane coupling agent, with or without intraoral blasting, did not demonstrate an improvement in the clinical performance of repaired posterior composites after 6 months.

The authors Nogueira et al. (2023) [10] analyzed, through a meta-analysis study, the influence of different protocols on the repair of glass-ceramic surfaces with composite resins. The search identified 5,037 studies and 165 were assessed for eligibility. Finally, 123 in vitro studies were included in the systematic review and 48 in the meta-analysis. Considering different glass ceramics, bond strength tests, and aged or unaged samples, 37 meta-analyses found the effect of repair protocols: adhesive only, silane plus adhesive alone or preceded by hydrofluoric acid (HF), airborne particle abrasion (APA) with Al₂O₃ particles, silica-coated APA (SCAPA), diamond rotary instrument (DRI) and laser irradiation (LI). Therefore, for feldspathic porcelain, HF acid, APA, SCAPA, or DRI improved the micromechanical retention of the repair; silane application is essential for HF-conditioned surfaces, but the use of adhesive is optional when silane is applied. The results for leucite and lithium disilicate were inconclusive in terms of suggesting a treatment other than HF acid plus silane and adhesive applications [10].

The restorative material should join not only to tooth structure but also the resin already present in the

restoration. Stringent changes in the composite during the aging process, which may influence the success of the repair procedure, such as water absorption and chemical degradation. The repair process may be more complicated in an old composite resin restoration, because the amount of remaining carbon double bonds decreases with time, decreasing the bond strength between the different increments. The effects of pH changes, salivary enzymes, and humidity on the environmental degradation of the compounds are extensively reported in the literature [11-14].

Regarding the chemical union, silanes and uncharged resins are traditionally used as bonding agents in repairs. The separate application of a silane agent and a fluid resin (adhesive) can result in a thick interfacial layer, which can produce defects in this repair phase [15-21]. Some steps are important for the realization repair in the composite. Isolation prevents contamination with saliva making the tooth surface less favorable to adhesion, it promotes and provides the penetration of glycoproteins present in saliva. The presence of salivary proteins can prevent the penetration of monomers in the enamel pores, and the network of collagen dentine after acid etching, reducing the restoration of the bond strength [22-25].

Also, phosphoric acid exerts its function only in cases where the repair involves dental tissue. The application of bonding agents can be done in three ways, just applying the silane agent; applying the silane agent and the adhesive system (Bond); and only applying the adhesive [3] system. silane is a coupling agent between inorganic materials and organic materials. Are bifunctional molecules in which the functional radicals silico-unite the silicas of the acid-sensitive porcelain or glass fiber pins and organo-functional radicals polymerize with the organic matrix of resin cements (methacrylates). They are also called "ceramic primers" or "bonding agents" [26-30].

The adhesive is who promotes a chemical bond with the organic matrix of the composite resin, and the intermediate agent of union between the repair and the resin to be repaired. The composite resin to be used should be applied, choosing the appropriate material for each case [2,3]. Some work, analyzing the relevance of various chemical and mechanical treatments in old composite resins and repair bond strength, concluded that the improvement in the bond strength between the new and the old composite resin restoration requires increased harshness to institute micromechanical union between the surface of the old composite resin and the resin together [4,5].

Adhesive treatment performed after the mechanical preparation of the surface also has a significant effect on the bond strength of repair. The

general trend is that the adhesive to increase the bond strength due to internal flow and external leveling of mechanical micro-retentions [1]. The conditioning of the repair surfaces with silane use before application of the adhesive material, with or without the use of phosphoric acid at 37%, is recommended to improve the repair bond strength [11].

Conclusion

It was concluded that the previous application of silane reduced the bond strength values. The two-bottle adhesive showed better results than single-bottle or self-etching systems for composite resin repairs. Furthermore, the association of preheated hydrofluoric acid/silane applied or not with electric current promoted different values of micro shear resistance, types of fracture, and contact angles in the resin cement/ceramic connection. Silane application is essential for surfaces conditioned by hydrofluoric acid, but the use of adhesive is optional when silane is applied.

CRedit

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The authors declare no conflict of interest.

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