Repair of aged restorations made in direct resin composite – A Systematic Review

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Systematic Review

Keywords: Composite Resins, Dental Restoration Repair, Aging, Evidence-based practice, Systematic review

Posted Date: November 4th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2202972/v1

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Abstract

Objective: to evaluate the different bonding strategies for repairing aged resin composite restorations.

Materials and Methods: The review was reported according to PRISMA Statement and registered in the Open Science Framework (DOI:10.17605/OSF.IO/WZTGS). Two reviewers performed a literature search across Embase (758), Pubmed (1244), Scopus (4300), The Cochrane library (128), and Web of Science (2538) databases. The risk of bias was assessed according to random sequence generation, blinding of outcome assessment, incomplete outcome data, selective reporting, coefficient of variation, and other bias.

Results: Forty-four in vitro studies with different repair strategies on aged resin composite substrates were included from 1990 up to July 2022 which evaluated superficial treatment using shear, flexural, tensile, and bond strength tests. The most frequent treatments were diamond bur and air abrasion. Meta-analysis showed an overall effect significant to diamond bur (shear test; p = 0.02), air abrasion (shear; p = 0.009; flexural; p = 0.003; tensile; p = 0.004 tests), and to phosphoric acid (tensile test, p < 0.00001).

Conclusions: Within the limitations of this study, strategies for improving bond to aged composites may consider better bond using air abrasion or diamond burs, and surface etching with phosphoric followed by the application of an adhesive system. Clinical Significance: This review presents the best treatments for performing the repair on aged resin composite, as guidance for clinical studies to improve emphasis on these findings, with the aim of creating a protocol that will enable dentists to promote minimally invasive treatments.

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Introduction

Resin-based composite (RBC) gained space in dentistry, and became the first option for direct restorations [1, 2], mainly because it is a minimally invasive and esthetic material that does not require large substrate preparations [3]. The annual failure rate of resin composite restorations in permanent teeth varies from 1–3% for posterior and 1–5% for anterior teeth [4]. In cases of failure, the dental clinician can choose either to completely remove the restoration or perform a repair [5]. In this sense, when the treatment chosen is to completely remove the restoration and replace it, this procedure can result in extensive loss of dental structure that can not only weaken the substrate, but also increase the clinical time spent unnecessarily [6]. Whereas, repair is a conservative treatment with only partial removal of the restoration that allows cost reduction and improved quality and longevity of the restoration [5, 7]. Thus, composite repair has an annual failure rate of 5.7% over a 4-year period of follow-up, which demonstrates good longevity [7]. Moreover, repair causes less stress because in the majority of cases, anesthesia is not necessary [8], and it results in a reduction of chair time [9]. However, a careful clinical evaluation should be performed since in cases of extensive restorations or extensive cracks in cuspids the repair procedure is not indicated [10].

Many techniques have been described in the literature for joining an aged composite to the new type. These alternatives involve chemical or physical principles, or frequently a combination of both [11]. Among the surface treatments available, there is use of a diamond bur or silicon carbide grinding paper [5], sandblasting, air abrasion with aluminum oxide [12, 13], etching with phosphoric or hydrofluoric acid and acidulated phosphate fluoride [7]. The use of intermediate agents such as silane, adhesive, a combination of silane and adhesive, and low-viscosity flowable composites has also been suggested [14].

Despite the knowledge about minimally invasive treatments and several clinical reports of dental clinicians performing resin composite repairs, it appears that repair is still infrequently used in dental practice [7]. In general, the lack of knowledge about how to carry out surface treatments and doubts concerning the strategy for best bonding the new composite to the old RBC are among the main reasons for repair not being a common clinical practice [7, 13]. Other reviews on resin composite repair have been found in the literature, but relative to evaluation of a specific surface treatment such as silane [15], or an analysis of repair of various types of substrates without focusing on the best treatment [5]. Some reviews also focused on the reason why dentists do not perform repair of RBC [7] or focused on the number of repairs performed and the types of treatment used [12, 13].

However, there is still no gold standard protocol to guide the clinician in situations involving the need to repair aged resin composite. Moreover, no studies have focused on repairing the aged substrate, a need often encountered in the clinical routine, and knowledge about how to perform this repair would help guide dentists in their clinical decisions. Thus, the aim of this study was to evaluate the different strategies used to repair aged resin composite restorations and their outcomes by conducting a systematic review and meta-analyses.

Material And Methods

The present Systematic Review was reported following the instructions of the PRISMA statement 2020 [16]. This protocol was enrolled in Open Science Framework (OSF;DOI:10.17605/OSF.IO/WZTGS).

Eligibility criteria

The studies were considered eligible for inclusion according to the following criteria: Clinical and in vitro studies that performed repair using RBC in aged RBC substrates; studies that analyzed the technique for performing repair with RBC using aged composite; articles that had a group without the
experimental treatment (control); articles in the English language. Furthermore, studies that focused on comparing replacement of the restoration with performing a repair; studies in which the repair with RBC was performed immediately (not aged); articles published prior to 1990; aging for periods shorter than 7 days were excluded.

The inclusion and exclusion criteria were applied manually one by one to each individual study, however, they were not used in the search strategy to avoid the risk of losing some potentially important articles for review.

**Primary Outcome**

Compare the different surface treatments and intermediate agents used to repair aged RBC considering the outcomes: shear bond strength, flexural bond strength, tensile bond strength, flexural failure strength, interfacial fracture toughness.

**Data Sources**

To answer the research question: which are the best strategies for bonding new resin composites to aged resin composites? Searches were performed without language restriction in the US National Library of Medicine databases Cochrane - Central Register of Controlled Trials (CENTRAL), EMBASE, PubMed (MEDLINE), Scopus and Web of Science for articles published without restriction on date, up to July 2022, date of collection. The search strategy was based on the population-intervention-comparison-outcomes (PICOT) strategy as follows: Problem: Resin Composite. Intervention: Dental restoration repair. Control: No experimental treatment. Outcome: result of shear bond strength, flexural bond strength, tensile bond strength, flexural failure strength, interfacial fracture toughness and surface roughness analysis. Study Type: Clinical or in vitro studies.

For the search strategy in the database screening, the following words were used according to Supplementary Table 1, see online resource - keywords: Search: Composite Resins/ Resins, Composite/ filling/ composite/ Composite resin repair/ Bulk fill/ Bulk-fill/ Bulkfill/ Bulk composite/ Bulk resin/ GrandioFlow/ TetricFlow/ Tetric EvoCeram Bulk-Fill/ Venus Bulk-Fill/ Surefil SDR/ X-Tra Base/ GC EverX Posterior/ Filtek Bulk-Fill/ Filtek Bulk Fill/ SonicFill/ Beautiful Bulk/ Opus Bulk Fill/ Tetric N-Ceram Bulk Fill/ X-tra fill/ Aura bulk fill/ Sonic Fill. Block Intersection: Dental restoration Repair/ Repair, Dental Restoration/ Restoration Repairs, Dental/ Restoration Repair, Dental/ Repairs, Dental Restoration/ Dental Restoration Repairs/ Repair Bond Strength/ Repair Intraoral. The Mendeley Desktop 1.19.4 Reference Manager (England) was used to group and manage the references and they were exported to Rayyan — a web and mobile app for systematic reviews [17] for selection and reading. The references of the studies selected were searched manually for other possible relevant information from studies that could meet the inclusion criteria.

**Data extraction**

From each source of literature, two independent reviewers (MF and FI) collected and interpreted the following data: authors; year of publication; country; type of study; objective; conclusions, which were tabulated in an Excel spreadsheet (Microsoft Corporation™, Redmond, WA, USA). Data were also tabulated with respect to characterization of the samples: sample size; sample randomization; number of groups tested; treatment of each group; treatment (number of samples); and characterization of the sample material: resin composite, brand (substrate); resin composite, brand (repair). Treatments performed on the samples were analyzed considering storage before repair; type of aging; storage after repair; type of test performed; machine for performing tests; mean and standard deviation results. Furthermore, repair methods were analyzed considering different surface treatments or intermediate agent used. The bond tests used in each study were also collected together with their mean and standard deviation values. When the data were in shown graphs, the WebPlotDigitizer website was used for conversion into exact numbers.

**Risk of bias**

The risk of bias of the studies included in the present review was assessed by two reviewers (MF and FI) and was evaluated according to previous reviews of in vitro studies [18, 19], and the description given of the following parameters: random sequence generation, blinding of outcome assessment, incomplete outcome data, selective reporting, coefficient of variation and other bias. For determining the coefficient of variation (CV), the coefficient of each article was calculated and classified as low, medium, high and very high [20, 21], in which articles with low or medium CV were classified as low risk of bias, while articles with high or very high CV were classified as high risk of bias.

**Data synthesis and Statistical Analysis**

To synthesize the information, the data obtained from the articles were gathered in tables and later, a qualitative and quantitative evaluation was made. Qualitative evaluation and meta-analysis were carried out in groups according to the surface treatment or bonding agent, resulting in five divisions; agent silane, adhesive, air abrasion, diamond bur and others. In subgroups according to the test performed relative to aging of the samples, the longest time interval reported for the substrate was used. All articles included were analyzed qualitatively and quantitatively.

Meta-analysis was performed using Review Manager software version 5.4.1 (The Nordic Cochrane Center, The Cochrane Collaboration; Copenhagen, Denmark). The analyses were carried out using a random-effect model, and estimates were obtained by comparing mean difference of the different surface treatments and intermediate agents used to bond the new composite to the aged RBC substrate considering shear bond strength, tensile bond strength, surface roughness, flexural bond strength, diametral tensile strength, fracture toughness. Values that obtained a p-value < 0.05 were considered statistically significant. Statistical heterogeneity of the treatment effect among studies was assessed using the Cochran Q test and the inconsistency I² test.

**Results**
Search and selection

Two reviewers (MF and FI) independently screened the results of the search in electronic databases, which led to the identification of 8968 records. After removing the duplicates by using Mendeley Desktop 1.19.4 Reference Manager (England), 5932 records were screened. After exportation to Rayyan and analyses of the titles and abstracts, 74 studies were pre-selected for the full-text analysis by two reviewers (MF and FI). The kappa index ($\kappa = 0.99$) in the selection by title and abstract and in the selection by full reading was calculated by using Excel professional Plus 2016. Subsequently, the reviewers selected 44 studies ($\kappa = 0.96$) for qualitative analysis, and all were included in the meta-analysis. The reasons for exclusion of the studies are described in Fig. 1. Although the research sought articles based on clinical and in vitro studies, only in vitro studies met the inclusion criteria.

Characteristics of the included studies

The characteristics of the 44 studies are summarized in Supplementary Table 2, see online resource. The type of aging varied considerably, the majority of samples were stored in water at 37°C [22, 23, 32–41, 24, 42–45, 25–31], the second most common type of aging found was performed by thermal cycling [30, 38, 52–60, 41, 43, 46–51]. Other types also found were boiling and storage in water [50, 61, 62], storage in artificial saliva [31, 63], immersion in citric acid [50], artificial accelerated aging with exposure to ultraviolet rays (UV-B) [31, 64], and storage in 0.9% saline solution at 37°C [65].

There were 19 different types of procedures performed in the in vitro studies. These were categorized into the use of surface treatments or intermediate agents, according to Table 1. Surface treatments: air abrasion with aluminum oxide / silica-coated [26, 27, 40–42, 45, 46, 48, 50, 51, 54, 56, 28, 57–60, 64–66, 29, 31–33, 37–39], diamond bur [22, 30, 51, 54–60, 63, 64, 32, 35, 39, 42, 44, 46, 47, 49] silicon carbide paper [33, 66], phosphoric acid [22, 23, 42, 43, 47, 49, 50, 53, 56–58, 60, 30, 61, 63, 64, 31, 32, 34–37, 41] hydrofluoric acid [46, 58, 61] maleic acid [27], polyacrylic acid [27], acetone gel [28], liquid acetone [28], toluene [36], liquid alcohol [28], alcohol gel [28], plasma argon [29, 40], atmospheric plasma jet [56] Er:YAG laser [30, 63], Er,Cr:YSGG laser [47, 53]. Intermediate agent: silane [22, 24, 40, 42, 43, 45–47, 54–57, 25, 58, 62, 64, 65, 26, 28, 29, 33–35, 39], low-viscosity composite [32, 51, 63], adhesive. Among the adhesives, the following types were found: 2-steps conventional adhesive, 3-steps conventional adhesive, universal adhesive, self-etching adhesive. Adhesive systems were tested in 100% of the articles selected, but not tested in all groups. Most groups tested surface treatment concomitantly with intermediate agents.
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Air abrasion was carried with the CoJet system in the majority of cases. This system consists of CoJet Prep, the intraoral microblasting unit; CoJet Sand, the coating medium for cold silicatisation of the restoration surface; ESPE Sil, the silane coupling agent (for silicated surfaces); Sinfony™ Opaquer for masking exposed metal surfaces; Visio™ Bond, the bonding agent for use with the restorative or veneering composite of the dentist's choice. However, the studies did not use the complete system because the item Sinfony was not mentioned in any article, while the others were used in different combinations.

**Meta-analyses**

The analyses consisted of using a specific treatment (test group) or not (control group). When evaluating the use of air abrasion as a physical surface treatment, the general effect test for shear strength resulted in significant adhesion ($p = 0.009$. Figure 3a); this was the case for flexural strength ($p = 0.003$. Figure 3b), and for tensile strength ($p = 0.004$. Figure 4). With reference to the subgroup analyses, for the shear strength test, the surface treatment using the CoJet system with air abrasion, silane agent and adhesive ($p = 0.0009$. Figure 3a) resulted in statistical union, when compared with the total etching adhesive; using air abrasion before universal adhesive ($p = 0.008$. Figure 3a); air abrasion before a universal primer ($p = 0.02$. Figure 3a); in addition the use of air abrasion alone resulted in significant bonding ($p < 0.00001$. Figure 3a) when compared with the universal primer alone; in the same way, using air abrasion alone resulted in significant adhesion ($p = 0.0006$. Figure 3a) when compared with using argon plasma alone. Considering the flexural bond strength, air abrasion performed before the conventional 2-step adhesive bond was significant ($p = 0.02$. Figure 3b). Whereas in the tensile test it resulted in a static bond: air abrasion and CoJet system adhesive ($p < 0.00001$. Figure 4) compared with the conventional 2-step adhesive; the CoJet system with air abrasion, silane agent and adhesive ($p = 0.002$. Figure 4) compared with silane and universal adhesive; use of air abrasion after abrasive paper followed by universal adhesive ($p = 0.008$. Figure 4); and air abrasion of the CoJet system before phosphoric acid and unfilled resin resulted in statistical union ($p = 0.03$. Fig. 4). In the interfacial fracture toughness test, it resulted in statistical adhesion to air abrasion with CoJet system, diamond bur, silane and adhesive system ($p < 0.0001$) when compared with air abrasion, diamond bur and universal adhesive.

The diamond bur, another physical surface treatment used, resulted in a statistical union in the general effect obtained for the shear strength test ($p = 0.02$. Figure 5). Among its subgroups, the use of diamond bur (coarse grained) was significant ($p = 0.007$. Figure 5); also significant was the use of only the diamond bur and universal adhesive ($p = 0.004$. Figure 5) when compared with using only laser. Relative to the tensile strength test, the diamond bur (extrafine grained) ($p = 0.008$) resulted in statistical adhesion, followed by phosphoric acid, silane agent and universal adhesive; and so did the fine diamond bur ($p = 0.005$) when compared with super fine grained when it was followed by phosphoric acid and universal adhesive. Whereas, differently from these results, the diamond bur was negative when compared with air abrasion, which showed statistical adhesion ($p = 0.001$) when associated with phosphoric acid and universal adhesive; this was similar to air abrasion only ($p < 0.0001$) when compared with using only the diamond bur.

With reference to chemical surface treatments, the silane agent showed no improvement in adhesion, in which no overall effect of the tests was significant. Only some subgroups showed significant bonding, such as: for the flexural bond strength test, using silane agent before the universal adhesive ($p = 0.004$). In the tensile strength test, silane ($p = 0.0001$) associated with diamond bur, phosphoric acid and conventional 2-step adhesive. However, in the shear strength test, the control group resulted in significant adhesion, such as: the use of the total conditioning adhesive ($p = 0.006$) compared to the addition of silane; this also occurred with air abrasion and conventional 3-step adhesive ($p = 0.00001$) when compared with the test group that included the silanization step.

Another chemical treatment was the use of adhesive, in which no differences were found in the general effect, but some evaluations of subgroups showed statistical union, such as: in tensile strength, the conventional 3-step adhesive ($p < 0.00001$) when compared with that of 2 steps; this also occurred with the conventional 3-step adhesive ($p = 0.002$) when compared with the self-etching adhesive, after using a diamond bur; and the conventional 3-step adhesive ($p = 0.04$) compared with the universal adhesive, used after sandblasting with aluminum oxide and silane agent. In the flexural bond strength test, the use of universal adhesive ($p < 0.00001$) in comparison with the conventional 3-step adhesive, both previously etched with phosphoric acid.

In addition to these bonding treatments, chemical surface treatment with acids was also shown to aid adhesion. In the tensile strength test, phosphoric acid had no general effect ($p < 0.00001$. Figure 5b), and in its subgroups phosphoric acid 35% showed significant union ($p < 0.00001$. Figure 5b) associated with diamond bur and universal adhesive; this also occurred with phosphoric acid ($p < 0.0003$. Figure 5b) associated with a diamond bur,
silane and universal adhesive. In the shear strength test, 10% hydrofluoric acid before the conventional adhesive resulted in statistical adhesion ($\rho = 0.002$) compared with the use of phosphoric acid. The figures relative to the other analysis are shown in the supplementary material, see online resource.

**Risk of bias of the studies included**

According to the parameters considered in the risk of bias analysis, the studies included in this review showed a high risk, most frequently for the blinding criteria relative to the evaluation of results, in which only two studies reported blinding. For the other criteria, generation of random sequence, incomplete data for results, selective report, variation coefficient and other biases, over 50% of the articles presented a low risk of bias, as shown in Fig. 2.

**Discussion**

The fact that there is no widely accepted protocol is the main reason why many dentists do not perform resin composite repair in their clinical practice, in spite of several benefits provided by this procedure [13]. Other reviews of the literature [8, 12] have corroborated the need for compiling the outcomes found after performing resin composite repairs because so far nothing conclusive has been found. Moreover, the lack of clinical trials may be due to the lack of a guide concerning the best in vitro treatment options. The present systematic review, as well as those previously mentioned, also identified a large number of possibilities for surface treatments and bonding agents tested in vitro to promote the bond of the new composite resin to the aged resin composite substrate. Among them, there were some simple techniques with use of materials such as phosphoric acid and conventional adhesive [67] and others not as common, such as laser and air abrasion with the CoJet system that was developed for intraoral repair of defective porcelain.

The lack of standardization in the studies began with aging of the specimens, as there is no protocol relative to time interval required for aging samples in **in vitro** tests with resin composite [11, 68]. The purpose of aging is, however, to simulate the degradation that would occur in a restoration within the oral cavity [11, 69]. Among the studies evaluated in the present review, the majority used storage in water at 37°C, which, maintained for a long time simulates a hydrolytic degradation [70], followed by thermal cycling, in which the number of cycles ranged from 1,000 to 50,000. This artifice reduces the time needed for simulating the aging process, but requires special devices for performing the process, considering that 10,000 cycles are required to correspond to 1 year of aging in vivo [68]. In both ways of aging the composite, it will absorb water, resulting in the breakdown of structures (hydroxy, carboxyl), impairing the durability of the bonding agent, causing hydrolysis at the RBC interface, simulating the process that occurs in the oral cavity [52].

As mentioned, the resin composite layers are mainly joined by chemical bonds, these occur between the groups of unreacted free monomers of the newly light-cured composite and monomers of the new increment [71], however the failures in RBC tend to occur later when the composite has aged [70] and there are no longer any free radicals and monomers to help the bond, thus physical and chemical treatments are required to promote this process [11].

Therefore, in the articles evaluated in the present review, physical surface treatments that promoted roughness were used, which are indicated for promoting the bond of overlapping surfaces of composites [72]. The meta-analysis showed that the majority of comparisons of tests with the use of air abrasion resulted in a statistically higher bond strength. These results suggested that mechanical roughness of the aged composite may be necessary before application of the adhesive to obtain improved adhesion to the substrate [73]. This surface treatment removes the surface layer that has been altered by saliva and wear and tear, and simultaneously promotes a larger surface area and microretention [11]. Furthermore, when CoJet is used, it worked as a tribochemical system, since this material is coated with silica, which in addition to the roughness produced by air abrasion with aluminum oxide, resulted in high surface energy, thereby improving the chemical bond with the silane used later [74].

Roughness was also tested using a diamond bur, since this is a simple and common treatment used in clinical practice [75]. Our findings suggested that this abrasion was capable of aiding the adhesion of repairs, as it resulted in removing the surface layer of the composite on aged substrate making it rougher, thereby improving micromechanical retention [15, 76] and consequently, promoting adhesion [75].

Furthermore, in addition to using surface treatment to promote bonding between the old restoration and a new composite, the procedure also depends on the addition of some intermediate material [77]. One of the materials found was the silane agent, described in the literature as a chemical bonding agent [11], indicated for improving the adhesion between resin composites [15]. However, these results were not found in the literature reviewed here, in which the use of silane associated with different products was evaluated, and resulted in bond strength values similar to those of the control group. This may have occurred because silane can impair the interaction between the monomers of the resin composite and those of the adhesive, as it forms a thick and multiphase interfacial layer [76]. The outcome of using silane was positive in two situations, when applied after the surface roughness with a diamond bur, followed by phosphoric acid and conventional adhesive, and when applied previously to the total conditioning adhesive, which could be explained by the interaction between silane and silica. In order to expose the silica component of the RBC, it is necessary to remove the surface layer of the aged composite [15], as was done in both situations.

Another chemical intermediate agent used in resin composite repairs was adhesive [15]. Studies have reported that the best adhesive to use is the type with a composition similar to that of the substrate, however, in the case of repairs, this data is usually non-existent [70]. Moreover, among the different comparisons, some specific types of adhesives, such as the conventional 3-step adhesive provided better adhesion than the 2-step adhesive. Although the latter type is more costly in terms of time spent for application, the literature presents this type as the gold standard for restorations [68].

Nevertheless, due to its composition, it can also be indicated for repairs, as the primer contains a copolymer, poly (alkenoic) acid, which moistens the composite surface, promoting adhesion, however. this association requires further investigation [31]. Furthermore, after etching with phosphoric acid, the
universal adhesive was also better than the conventional 2-step adhesive, and this was probably due to its potential for adhesion to different materials [78] since its composition of methacryloxidecyl monomer and silane phosphate is combined to provide this bond. Therefore, not only has the Universal adhesive been indicated for repairing aged composites [37] because of its greater adhesive range, but it was also aided by the microretentions on the surface of the composite created by the phosphoric acid etching, thus resulting in greater penetration of the adhesive into the aged composite [79].

Another factor to be taken into account is that performance of the adhesive is also dependent on the technique performed, as indicated by the manufacturer [70].

Other chemical surface treatments were scarcely evaluated or by only one study, such as phosphoric acid etching that showed the best bond (values?) when applied after diamond bur abrasion and followed by silane and universal adhesive, or universal adhesive only. According to the literature, the main function of this acid conditioning is to clean the surface that was abraded, by superficial removal of the RBC and remnants of the material, thereby increasing the adhesive interaction with the substrate [68]. In addition to being indicated for repairs, etching is mainly performed for cleaning possible contamination of the restoration surface by saliva or blood [80]. However, this benefit in bonding was found in only one article, when followed up in the long term, when it no longer resulted in a difference in comparison with its control [42]. In addition, etching with hydrofluoric acid showed better adhesion compared with phosphoric acid. This may have been associated with its greater corrosive power that resulted in dissolution of part of the glass phase, thus creating microretentions in the RBC [81], but further studies are needed to prove this result.

Thus, the findings shown in the present review were similar to those found by dentists in restoration repair treatments performed in clinical practice, basically consisting of producing surface roughness that can be done with a diamond bur, acid etching of the surface and application of an adhesive [82]. The studies included were extremely heterogeneous relative to the treatments tested, in addition to showing no standardization in the use of materials or in the performance of the tests, which makes it difficult to establish a standard clinical protocol. Another limitation was the lack of randomized clinical trials capable of guiding the practice of repair, thus our suggestion is that restoration repairs should be performed based on the significant results of our meta-analysis.

Conclusions

Within the limits of this study, the following conclusions could be drawn:

- Standardize composite aging time in multiples of 6 months, either in water storage or thermal cycling so that a proper comparison can be made;
- Perform micro-retentions on the aged composite substrate, using air abrasion or diamond burs;
- Condition the roughened surface with phosphoric or hydrofluoric acid;
- Use the conventional 3-step adhesive or universal adhesive;

Further studies comparing these bonding strategies, including clinical trials, are needed to produce better evidence of the best repair protocol for dentists.

Declarations

Ethical approval

Not applicable

Competing interests

The authors report no conflicts of interest.

Authors’ contributions

M.D.F. Investigation, Methodology, Resources, Software, Writing-original draft;
F.I. Methodology, Resources, Writing-original draft, Investigation;
W.L.O.da-R. Formal analysis, Writing-review & editing, Formal analysis;
E.P. Data curation, Formal analysis;
A.F.S. Conceptualization, Supervision; Formal analysis, Writing-review, Project administration;

All authors reviewed the manuscript.

Funding

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001 and in part by the Research Support Foundation of the State of Rio Grande do Sul (FAPERGS), Grant 21/2551-0000691-9.

Availability of data and materials
References


Figures

Figure 1

Identification of studies via databases and registers

Records identified from:
- Embase: (n = 756)
- Pubmed/Medline: (n = 1244)
- Scopus: (n = 4300)
- The Cochrane library: (n = 128)
- Web of Science: (n = 2538)

Records (n = 8068)

Records removed before screening:
- Duplicate records removed (n = 3016)
- Records marked as ineligible by automation tools (n = 3016)
- Records removed for other reasons (n = 0)

Records (n = 5052)

Records excluded:
- (n = 0)

Records included in review:
- (n = 44)
- Reports of included studies (n = 0)

Figures
Selection of studies for systematic review according to Prisma 2020 (PAGE et al., 2021)

Figure 2

Risk of bias analysis: judgments for each item assessed in all the studies included, showing the proportion of studies with low, medium or high risk of bias for each item.
Results of analysis of use of air abrasion were divided into using or not using (control) the surface treatment. Fig. (a) shows the results for the shear bond strength test in which the adhesion was significant (p<0.05) for the use of air abrasion. In fig. (b) the results of the flexural bond strength test showed that it also resulted in significant adhesion (p<0.05) with the use of air abrasion.
### Air Abrasion: Tensile Bond Strength

<table>
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<th>Total</th>
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**Figure 4**

Results of the analysis of use of air abrasion for tensile bond strength test showed that this treatment resulted in significant adhesion (p<0.05)
Figure 5

Results of the analysis of use of diamond burs as physical surface treatments resulting in significant adhesion (p<0.05)

Phosphoric Acid: Tensile Bond Strength

Figure 6

Analysis of use of phosphoric acid resulted in statistical adherence (p < 0.05)
Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryFig1Resultsofanalysisoftheuseofsilaneagent.docx
- SupplementaryFig2Resultsofanalysisoftheuseofsilaneagentanddiamondbur.docx
- SupplementaryFig3Resultsofanalysisoftheuseofadhesives.docx
- SupplementaryFig4Resultsofanalysissilaneandairabrasion.docx
- SupplementaryFig5Resultsofanalysisoftheuseofthefififentreatments.docx
- SupplementaryTable1keywords.docx
- SupplementaryTable2Descriptionsurfacetreatmentsandintermediateagents.docx