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LAURA TEIXEIRA MENDES

# EVIDÊNCIAS CIENTÍFICAS SOBRE RISCO DE FALHA DE RESTAURAÇÕES REPARADAS E EFEITO DO TIPO DE SILANO NO PROTOCOLO DE REPARO

Porto Alegre, RS
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Tese apresentada ao Programa de Pós-graduação em Odontologia da Universidade Federal do Rio Grande do Sul como requisito parcial para a obtenção do título de Doutora em Odontologia, Área de Concentração em Clínica Odontológica/Odontopediatria.

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Orientadora: Profa. Dra. Tathiane Larissa Lenzi

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**RESUMO**

A presente tese de doutorado é composta por dois artigos científicos. O primeiro deles, intitulado "Risk of failure of repaired versus replaced defective direct restorations in permanent teeth: a systematic review and meta-analysis" visou comparar o risco de falha de restaurações reparadas e substituídas em dentes permanentes. Para isso, uma ampla busca bibliográfica foi realizada nas bases de dados PubMed/MEDLINE, Scopus, Lilacs, BBO, Web of Science, SciELO, Cochrane Central Register of Controlled Trials (CENTRAL) e literatura cinza até Agosto de 2021 para identificar estudos clínicos longitudinais relacionados à questão de pesquisa. Dois revisores selecionaram independentemente e em duplicata os estudos, extraíram os dados, avaliaram o risco de viés e a certeza da evidência. Meta-análise com modelo de efeitos fixos comparou o efeito do tratamento (reparo e substituição) no desfecho (falha das restaurações), considerando o material restaurador (resina composta e amálgama) como subgrupos. Riscos relativos (RRs) e os intervalos de confiança de 95% (ICs) foram calculados. Dos 1224 estudos potencialmente elegíveis, treze foram selecionados para análise de texto completo e três foram incluídos na revisão sistemática e meta-análise. Não houve diferença estatisticamente significante no risco de falha de restaurações defeituosas reparadas e substituídas (RR: 1,21, IC: 95% 0,51-2,83), seja para restaurações de resina composta (p = 0,97) ou de amálgama (p = 0,51). O risco de viés foi considerado alto e a certeza da evidência muito baixa. O risco de falha de restaurações diretas parcialmente defeituosas reparadas em dentes permanentes é similar àquelas substituídas. No entanto, as evidências científicas são limitadas. O segundo artigo intitulado "Use of nonhydrolyzed silane prior to the silane-containing universal adhesive application improves the repair bond strength of resin composite" avaliou a influência do tipo de silano previamente à aplicação de sistema adesivo universal contendo silano na resistência de união de reparo de resina composta envelhecida. Para isso, 54 corpos de prova (8 mm x 8 mm x 8 mm) de resina composta (Z350 XT, cor A2B, 3M Oral Care, MN, EUA) foram previamente envelhecidos através de armazenamento em água destilada por seis meses e, então, divididos aleatoriamente em seis grupos experimentais (n = 9): adesivo universal contendo silano no modo autocondicionante (Scotchbond Universal, 3M Oral Care, MN, EUA); silano não hidrolisado (Silano, Dentsply, Brasil) + Scotchbond Universal; silano hidrolisado (RelyX Ceramic Primer, 3M Oral Care, MN, EUA) + Scotchbond Universal; sistema adesivo autocondicionante (Clearfil SE Bond, Kuraray, Noritake, Japão); silano não hidrolisado + Clearfil SE Bond; silano hidrolisado + Clearfil SE Bond. Os blocos foram reparados com a mesma resina composta (cor WE). Após 24 horas de armazenamento em água destilada, os blocos foram seccionados e os espécimes foram submetidos ao teste de microtração. Os dados obtidos foram submetidos à Análise de Variância de dois fatores (sistema adesivo e silano) e teste de Tukey considerando um nível de significância de 5%. O padrão de fratura foi avaliado descritivamente. Os maiores valores de resistência de união de reparo foram obtidos quando o silano não hidrolisado foi aplicado previamente ao adesivo universal contendo silano (p = 0,03). A aplicação prévia de silano não aumentou a resistência de união de reparo quando um sistema adesivo autocondicionante de dois passos foi utilizado. Falhas adesivas/mistas prevaleceram em todos os grupos. O uso de um silano não hidrolisado previamente à aplicação do adesivo universal contendo silano no modo autocondicionante aumenta a resistência de união de reparo entre resina composta nova e envelhecida.

**Palavras-chave:** Reparação de Restauração Dentária; Revisão Sistemática; Resistência à Tração; Silanos.

**ABSTRACT**

The present doctoral thesis is composed by two scientific articles. The first one, entitled "Risk of failure of repaired versus replaced defective direct restorations in permanent teeth: a systematic review and meta-analysis" aimed to compare the risk of failure of repaired and replaced restorations in permanent teeth. A comprehensive literature search was undertaken in PubMed/MEDLINE, Scopus, Lilacs, BBO, Web of Science, SciELO, and Cochrane Central Register of Controlled Trials (CENTRAL) databases and gray literature up to August 2021 to identify longitudinal clinical studies related to the research question. Two reviewers independently and in duplicate selected studies, extracted data, assessed the risk of bias and the certainty of evidence. Meta-analysis with fixed effects model compared the effect of treatment (repair and replacement) on the outcome (failure of restorations), considering restorative material (resin composite and amalgam) as subgroups. Relative risks (RRs) and 95% confidence intervals (CIs) were calculated. Of 1,224 potentially eligible studies, thirteen were selected for full-text analysis and three were included in the systematic review and meta-analysis. There was no significant difference in the risk of failure of repaired and replaced defective restorations (RR: 1.21, 95% CI: 0.51-2.83), either for resin composite ($p = 0.97$) or amalgam ($p = 0.51$) restorations. The risk of bias was high and certainty of evidence was very low. The risk of failure of repaired partially defective direct restorations performed in permanent teeth is similar to that of replaced restorations. However, scientific evidence is limited. The second article entitled "Use of nonhydrolyzed silane prior to the silane-containing universal adhesive application improves the repair bond strength of resin composite" evaluated the influence of the type of silane prior to the silane-containing universal adhesive application on the repair bond strength of aged resin composite. For this, 54 blocks (8 mm x 8 mm x 8 mm) of nanohybrid resin composite (Z350 XT A2B, 3M Oral Care, MN, EUA) were aged by water storage for six months, and randomly assigned into six experimental groups ($n = 9$): silane-containing universal adhesive in the self-etch mode (Scotchbond Universal, 3M Oral Care, MN, EUA); nonhydrolyzed silane (Silane Coupling Agent, Dentsply, Brazil) *plus* Scotchbond Universal; hydrolyzed silane (RelyX Ceramic Primer, 3M Oral Care, MN, EUA) *plus* Scotchbond Universal; self-etch adhesive system (Clearfil SE Bond, Kuraray Noritake Inc., Japan); nonhydrolyzed silane *plus* Clearfil SE Bond; hydrolyzed silane *plus* Clearfil SE Bond. Blocks were repaired with the same resin composite (WE shade). After 24 hours of water storage, the blocks were sectioned and bonded sticks were submitted to microtensile bond strength test. The obtained data were submitted to the two-way ANOVA (adhesive system and silane) and Tukey's test considering a significance level of 5%. The failure mode was descriptively evaluated. The highest repair bond strength values were achieved when nonhydrolyzed silane was applied prior to the silane-containing universal adhesive ($p = 0.03$). The previous silane application did not increase the repair bond strength when a two-step self-etch adhesive system was used. Mixed/adhesive failures prevailed in all groups. The use of a nonhydrolyzed silane prior to the silane-containing universal adhesive in the self-etch mode application improves the repair bond strength of new and aged resin composite.

**Keywords:** Dental Restoration Repair; Systematic Review; Tensile Strength; Silanes.

**SUMÁRIO**

# 1 INTRODUÇÃO

Apesar de todo o avanço tecnológico observado nos últimos anos, nenhum material restaurador disponível na atualidade substitui em condições de igualdade a estrutura dentária e todas as restaurações sofrem envelhecimento no ambiente bucal ao longo do tempo. A compreensão da diferença entre envelhecimento “natural” – caracterizado por alterações nas restaurações em termos de brilho, cor ou forma anatômica – e falhas importantes que justifiquem a necessidade de uma nova intervenção é fundamental para a melhor tomada de decisão terapêutica.

Fratura da restauração e presença de lesão de cárie adjacente são os principais motivos de falhas em dentes posteriores (DEMARCO et al., 2023; PEDROTTI et al., 2017), enquanto que motivos estéticos, como alteração de cor, forma anatômica e manchamento, comumente levam à reintervenção de restaurações em dentes anteriores (DEMARCO et al., 2015). As reintervenções se tornam necessárias frente à presença de falhas que comprometam o controle do biofilme cariogênico e/ou função do dente, ou ainda, suscitem alguma queixa do paciente, como dor ou insatisfação estética. Para falhas importantes nas restaurações, o clínico pode optar por realizar o reparo ou a substituição.

O reparo é uma abordagem minimamente invasiva que implica na adição de um material restaurador com ou sem preparo da restauração ou da estrutura dentária (HICKEL; BRÜSHAVER; ILIE, 2013). Além disso, tem sido evidenciado que o reparo pode aumentar a sobrevida das restaurações (CASAGRANDE et al., 2017; RUIZ et al., 2019). Nesse contexto, a escolha do reparo à substituição para o manejo de restaurações com falhas pode ser benéfica para as crianças, uma vez que parece ser uma técnica restauradora mais simples e amigável ao paciente.

É importante destacar que, em dentes decíduos, a recomendação de reparo ou substituição de restaurações defeituosas não deve ser baseada somente na avaliação da própria restauração. Outros fatores como o ciclo biológico do dente decíduo e a opinião do paciente e seu núcleo familiar devem ser levados em consideração no processo de tomada de decisão. Não intervir em restaurações defeituosas, que permitam um adequado controle do biofilme por parte do paciente, em um dente próximo à esfoliação também é uma conduta que pode ser adotada (HILGERT et al., 2016). Ademais, não há estudos clínicos prospectivos publicados que avaliem a sobrevida de restaurações reparadas e substituídas em dentes decíduos.

Tem sido evidenciado que o ensino do reparo de restaurações de resina composta em dentes decíduos (MENDES et al., 2020a) e permanentes (GIROTTO et al., 2023) está estabelecido nos cursos de graduação em Odontologia do Brasil, porém não há consenso sobre o protocolo clínico para reparar restaurações com falhas. Um levantamento realizado no Japão mostrou que a maioria das escolas (95%) aborda o reparo de restaurações defeituosas como parte do ensino nos cursos de graduação e o principal motivo para indicação de reparo está associado à maior preservação da estrutura dentária (LYNCH et al., 2013).

Embora muitos dentistas afirmem realizar reparos e essa abordagem tenha sido incluída no currículo de muitas universidades, a proporção de restaurações reparadas ainda é baixa (KANZOW et al., 2018). A taxa de falha anual das restaurações de resina composta varia entre 0,08% e 6,3% em dentes permanentes (DEMARCO et al., 2023), enquanto que a taxa de falha anual das restaurações reparadas varia entre 2,5% (KANZOW; WIEGAND, 2020) a 5,7% (OPDAM et al., 2012) para restaurações de resina composta e cerca de 9,3% para restaurações de amálgama (OPDAM et al., 2012). Em dentes decíduos, a taxa de falha anual das restaurações de resina composta varia entre 1,7 e 12,9% (CHISINI et al., 2018). Já a taxa de falha anual das restaurações reparadas de resina composta e cimento ionômero de vidro é cerca de 24,1% (RUIZ et al., 2019). Neste contexto, é importante para os clínicos que o reparo não somente aumente a sobrevida de restaurações defeituosas, mas também que uma restauração reparada apresente longevidade similar a uma restauração substituída.

Uma recente revisão sistemática (MARTINS et al., 2018) mostrou que as restaurações parcialmente defeituosas em dentes permanentes submetidas ao reparo apresentam longevidade semelhante àquelas substituídas, além de longevidade superior em comparação ao selamento marginal dos defeitos. No entanto, esta revisão sistemática apresenta limitações metodológicas e, portanto, seus resultados têm aplicabilidade limitada para a tomada de decisão clínica. Várias publicações (FERNÁNDEZ et al., 2015ab; MARTIN et al., 2013ab; MONCADA et al., 2009, 2015ab) do mesmo estudo (MONCADA et al., 2006) foram inseridas separadamente como estudos independentes. Da mesma forma, outro estudo apresentou a amostra duas vezes (GORDAN et al., 2006, 2009). O risco de viés e a avaliação da certeza da evidência foram conduzidos de forma inadequada, uma vez que todos os estudos incluídos são estudos não randomizados. Por fim, nenhuma meta-análise foi realizada.

Além disso, ainda não existe um protocolo padrão-ouro para o tratamento de superfície da resina composta envelhecida previamente ao reparo. Tem sido demonstrado que a associação de tratamentos de superfície físicos e químicos aumenta a resistência de união de reparo (VALENTE et al., 2016; MENDES et al., 2020b). A asperização da superfície da resina composta envelhecida com pontas diamantadas promove retenção micromecânica, aumentando a área de superfície para adesão entre a resina composta envelhecida e a nova (reparo) (BRENDEKE; OZCAN, 2007). Por outro lado, a aplicação de agentes de união, como o silano, formam ligações covalentes com as partículas de carga expostas na superfície da resina composta envelhecida e copolimerizam com os grupos de metacrilato do material do reparo (ÇAKIR et al., 2018). Além disso, os silanos aumentam a molhabilidade da superfície, permitindo maior difusão do sistema adesivo nas microretenções preparadas na superfície do material a ser reparado (BRENDEKE; OZCAN, 2007).

Uma recente revisão sistemática de estudos laboratoriais demonstrou que o uso de silano previamente à aplicação de sistema adesivo promove maiores valores de resistência de união de reparo (MENDES et al., 2020b). No entanto, os adesivos universais contendo silano não foram incluídos na meta-análise. O efeito do silano na resistência de união de reparo depende da quantidade de carga na superfície, da natureza e tamanho de carga, bem como da formulação química dos silanos comerciais (WENDLER et al., 2016). Os silanos podem ser hidrolisados e não hidrolisados. As soluções de silano hidrolisadas são disponibilizadas em um único frasco, já ativadas, e podem se tornar menos reativas após a abertura do frasco, perdendo o efeito desejado em longo prazo (ELIASSON; TIBBALLS; DAHL, 2014). Já as soluções não hidrolisadas são disponibilizadas em dois frascos, e consistem em silano não hidrolisado em etanol em um frasco e uma solução de ácido acético no outro. A mistura das duas soluções inicia a hidrólise do silano para uso (LUNG; MATINLINNA, 2012).

Recentemente, agentes silanos foram adicionados à composição de alguns adesivos universais para simplificar e agilizar procedimentos sensíveis à técnica, e seu uso poderia aumentar a resistência de união de reparo. Todavia, nenhum estudo laboratorial comparou o efeito dos tipos de silanos previamente à aplicação de sistemas adesivos universais contendo silano no protocolo de reparo.

Diante do exposto, no presente trabalho serão apresentados os artigos oriundos de duas investigações científicas. O primeiro deles, intitulado “Risk of failure of repaired versus replaced defective direct restorations in permanent teeth: a systematic review and meta-analysis” visou comparar o risco de falha de restaurações reparadas e substituídas em dentes permanentes, considerando resina composta e amálgama como materiais restauradores. O segundo artigo intitulado “Use of nonhydrolyzed silane prior to the silane-containing universal adhesive application improves the repair bond strength of resin composite” avaliou a influência do tipo de silano previamente à aplicação de sistema adesivo universal contendo silano na resistência de união de reparo de resina composta envelhecida.

## 2 ARTIGO 1 – Risk of failure of repaired versus replaced defective direct restorations in permanent teeth: a systematic review and meta-analysis

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# Risk of failure of repaired *versus* replaced defective direct restorations in permanent teeth: A systematic review and meta-analysis

**Laura Teixeira Mendes**[1] ORCID: 0000-0002-8003-9217

**Djessica Pedrotti**[1] ORCID: 0000-0003-1717-9097

**Luciano Casagrande**[1] ORCID: 0000-0001-9515-6048

**Tathiane Larissa Lenzi**[1] ORCID: 0000-0003-3568-5217

[1]School of Dentistry, Post-Graduate Program in Pediatric Dentistry, Federal University of Rio Grande do Sul, Rua Ramiro Barcelos, 2492, 90035-003, Porto Alegre, Rio Grande do Sul, Brazil.

✉**Corresponding Author**

Tathiane Larissa Lenzi

E-mail: tathiane.lenzi@ufrgs.br

Telephone/Fax: +55 51 3308 5027

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**Abstract**

***Objective*****:** This study aimed to systematically review the literature to compare the risk of failure of repaired and replaced defective direct resin composite and amalgam restorations performed in permanent teeth. ***Materials and Methods*****:** The PubMed/MEDLINE, Scopus, Lilacs, BBO, Web of Science, SciELO, Cochrane Central Register of Controlled Trials (CENTRAL) databases, and gray literature were searched to identify longitudinal clinical studies related to the research question. No publication year or language restriction was considered. Two authors independently selected the studies, extracted the data, and assessed the risk of bias and certainty of evidence. A meta-analysis was performed using a fixed effects model at a 5% significance level. ***Results*****:** From 1224 potentially eligible studies, thirteen were selected for full-text analysis, and three were included in the systematic review and meta-analysis. There was no difference in the risk of failure of repaired and replaced defective direct restorations (RR: 1.21, 95% CI: 0.51-2.83), either for resin composite (p=0.97) or amalgam (p=0.51) restorations. The risk of bias was high and certainty of evidence was very low. ***Conclusion*****:** Based on the very low certainty of evidence, the repair of direct restorations does not present a significant difference in the risk of failure when compared to replacements in permanent teeth.

***Clinical Relevance*****:** Restoration repair is a procedure that is included in the minimal intervention principle for improvement of tooth longevity in that the risk of failure of repaired partially defective restorations in permanent teeth seems similar to that of replacement. Further studies are required before definitive conclusions can be drawn.

**Keywords:** Dental restoration repair, Replacement, Evidence-based dentistry

## Introduction

Dental restorations are most commonly performed because of caries or fracture [1, 2] and are often considered as 'failed' when they do not meet certain criteria designed by dental researchers and clinicians [3, 4] or when the patient experiences problems with a restored tooth owing to pain or unpleasant esthetic appearance. When a restorative reintervention is needed, clinicians can decide for replacement or repair [5].

Repair is a minimally invasive treatment that involves only the preparation and restoration of the defective part of the restoration and/or tooth [5]. On the other hand, restoration replacement is often costly, technically more complex, and necessitates sacrificing of sound tooth tissues, compromising pulp vitality and potentially accelerating the restoration cycle or premature loss of the tooth [6].

Current surveys have demonstrated that the repair of partially defective restorations has gained increasing acceptance among dental practitioners and patients [7]. Large retrospective studies have shown that repair can improve the survival of failed restorations in anterior [8] and posterior teeth [9, 10]. The annual failure rate of repaired restorations has varied between 2.5% [11] and 5.7% [10] for resin composite restorations, and around 9.3% for amalgam restorations [10].

Nevertheless, for clinicians and patients facing with a partially defective restoration, it might not only be relevant if repair improves the longevity of the original restoration, but rather if the repaired restoration will last as long as replacements. A recent retrospective study [11] has shown that survival of repaired restorations is comparable to those of replacement restorations. This finding, however, should be interpreted with caution, as reasons for failure/repair are unknown.

Thus, the aim of this systematic review and meta-analysis was to assess the impact of repair on the risk of experiencing failure of direct resin composite and amalgam restorations in permanent teeth and to compare the risk of failure of repaired and replaced restorations.

## Materials and methods

This systematic review was conducted according to the Cochrane Handbook for Systematic Reviews of Interventions [12], following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement [13] and recorded in International Prospective Register of Systematic Review (PROSPERO - CRD42021224970).

The following research question was formulated to address the literature and outline the search strategy: Is there difference in the risk of failure of repaired and replaced partially defective direct resin composite or amalgam restorations in permanent teeth?

Population: Adults with partially defective direct resin composite or amalgam restorations in permanent teeth

Intervention: Restoration repair.

Comparison: Restoration replacement.

Outcome: Risk of restoration failure.

Study design: Longitudinal clinical studies.

### *Search strategy*

A comprehensive literature search was undertaken in PubMed/MEDLINE, Scopus, Lilacs, BBO, Web of Science, SciELO, and Cochrane Central Register of Controlled Trials (CENTRAL) databases to identify studies related to the research question and published up to August 2021. The gray literature was also explored using the System for Information on Grey Literature in Europe (Open Grey) and the ClinicalTrials.gov website. The search was conducted with no publication year or language restrictions.

The following search steps were performed: computer search of databases, review of reference lists of all included studies, and contact with authors by e-mail to request data not available in the articles. For the subject search, a combination of controlled vocabulary and text words was used based on the search strategy for the MEDLINE via PubMed database:

(Dental Restoration*[TW] OR Dental Filling*[TW] OR Dental Restoration, Permanent[MH]) AND (Repair*[TW]) AND (Survival[TW] OR Longevity[TW] OR Failure[TW])

The search strategy was adapted for other databases. The results of searching the various databases were cross-checked to locate and eliminate duplicates.

***Selection, inclusion, and exclusion criteria***

Firstly, titles and abstracts were reviewed independently by two authors and selected for further review if they met the inclusion criteria: longitudinal clinical studies (randomized and non-randomized) that compared the quality of repaired and replaced direct resin composite and amalgam restorations in permanent teeth.

Full-text versions of the articles selected in the previous step were retrieved and reviewed independently by the same authors, considering the exclusion criteria: follow-up less than 12 months, dropout rate ≥ 30%, absence of similar follow-up for patients in both groups evaluated in the same way, restoration failure not evaluated as outcome, and clinical criteria not used for evaluating the restorations. To avoid overlapping data, when there were multiple reports of the same study (i.e., reports with different follow-ups), only the longest follow-up study was considered. Disagreements were firstly resolved by discussion between the reviewers. If disagreements remained, a third author was consulted.

***Data extraction***

Data were extracted using a standardized sheet in Microsoft Office Excel (Microsoft; Redmond, WA, USA). For each study, the following data were systematically extracted: publication details (title, authors, country, and year), study methodology (study design, tooth type – anterior or posterior, sample size, age of participants, reasons for restoration reintervention, technique used for repair and replacement of partially defective restorations, number of operators, and clinical criteria for evaluating restorations), and outcome information (restorative failures, follow-up period, dropout rate, and pulp complications after treatments).

***Assessment of risk of bias and certainty of evidence***

Two reviewers independently assessed the risk of bias of the included studies using the Risk of Bias in Non-randomized Studies of Interventions tool (ROBINS-I) [14] based on the following criteria: judgment of confounding variables, selection of participants, classification of interventions, deviation from intended interventions, missing data, measurement of outcomes, and selection of the reported results. The domains were classified as low, moderate, serious, or critical risk of bias. For the final classification of risk of bias, disagreements between the reviewers were resolved by consensus. Furthermore, the certainty of evidence was evaluated using the Grading of Recommendations, Assessment, Development, and Evaluation approach [15].

***Statistical analysis***

A meta-analysis was performed using the fixed effects model to compare the effect of the restorative approaches (repair and replacement) on the outcome (restorative failure), considering the restorative material (resin composite or amalgam) as subgroups. Statistical differences between groups were calculated using RevMan version 5.3 (Review Manager, Cochrane Collaboration, Copenhagen, Denmark, 2014) with relative risks (RRs) and 95% confidence intervals (CIs). Differences with $p < 0.05$ were considered to be statistically significant (Z test). Statistical heterogeneity among studies was assessed via the Cochrane $Q$ test and inconsistency ($I^2$).

## Results

### *Study selection*

The search strategy identified 1224 potentially relevant studies, excluding duplicates. Four ongoing trials were identified, and after screening titles and abstracts, thirteen studies were retrieved to obtain detailed information. From the appraisal of the full-text articles, multiple publications [16–21] of the same study were found and the article with the longest follow-up [22] was included. Similarly, two studies presented the same sample twice [23–26] and thus, the studies with a shorter follow-up period were excluded [23, 25]. Finally, three studies [22, 24, 26] met the eligibility criteria and were included in the qualitative and quantitative analyses. Figure 1 summarizes the process of study selection and the reasons for exclusions.

### *Characteristics of included studies*

All clinical studies were published in English, reported from 2009 to 2018, and conducted in Chile[ 22] and USA [24, 26]. The follow-up period ranged from 7 to 12 years, with dropout rates between 3.8% and 21.4%. One study [22] reported dropout for orthodontic reasons, while two studies [24, 26] did not inform the reasons for the losses during follow-up. One study [22] included defective amalgam and resin composite restorations, one article [24] included only amalgam restorations and yet another article [26] evaluated only resin composite restorations. Anterior and posterior restorations were included in one study [26], and the other two studies [22, 24] included only posterior teeth.

All restorations were evaluated using the modified United States Public Health Service (USPHS)[3] criteria. Restorations with localized, marginal, anatomical deficiencies, adjacent caries, surface roughness, or marginal staining deviated from the ideal (Bravo or Charlie) were included. All studies considered parameters such as marginal adaptation, adjacent caries, anatomic form, and postoperative sensitivity to evaluate the repaired and replaced restorations during follow-up. In addition, occlusal or proximal contact [24, 26] were evaluated, including some esthetic parameters such as surface roughness [22, 26], luster [22, 26], color [26], and marginal staining [22, 26].

Restorative procedures varied among studies. Regarding the repair protocol of resin composite restorations, all studies performed physical surface treatment, i.e., abrasion with bur followed by chemical surface treatment that involved the application of a self-etch adhesive system [22] or of an etch-and-rinse adhesive [26]. Physical surface treatment with additional retention inside the existing restoration, followed by amalgam restoration, was the protocol used for the repair of defective amalgam restorations [22, 24].

Regarding the replacement technique, the defective restorations were totally removed and replaced by new direct resin composite or amalgam, according to the original restoration. Both treatments were carried out under rubber dam isolation [22, 26]. Only one study [24] did not clearly report the type of operative field isolation.

The main reasons for failure of the repaired restorations were marginal adaptation and adjacent caries, irrespective of the material. Adjacent caries was the reason for failure of the replaced resin composite restorations, but this information was not clear in two studies [24, 26]. None of the studies evaluated pulp injury as a secondary outcome. A more detailed summary of the included studies is shown in Table 1.

***Assessment of risk of bias and certainty of evidence of the included studies***

Findings regarding the risk of bias assessment are summarized in Table 2. The majority of the domains received low risk of bias. Considering that the outcome evaluators were not blinded, bias in the measurement of outcome was classified as moderate. Confounding bias in the domain was classified as serious risk of bias. Thus, the overall judgment was classified as serious risk of bias in all studies. A very low certainty of evidence was judged according to GRADE (Table 3).

### *Meta-analysis*

The meta-analysis was performed considering the global analysis (regardless of the restorative material) and considering two subgroups (resin composite and amalgam, separately). From the three studies included in the meta-analysis, one [22] evaluated both defective direct resin composite and amalgam restorations and, in this way, the resin composite subgroup analysis was performed with two datasets [22, 26], and the amalgam subgroup analysis with two datasets [22, 24].

The results of the meta-analysis are presented in Figure 2. In the global analysis, there was no difference in the risk of failure of repaired and replaced partially defective direct restorations (RR: 1.21, 95% CI: 0.51-2.83). The heterogeneity was high ($I^2$=65%). For the subgroup meta-analysis, there was also no difference between treatments for resin composite (RR: 0.98, 95% CI: 0.35-2.77; $I^2$=83%) and amalgam (RR: 1.66, 95% CI: 0.37 – 7.44; $I^2$=62%) restorations.

## Discussion

The concept of built-in obsolescence, i.e., periodic replacement of dental restorations, has been accepted as the *modus operandi* if not the default mode in restorative care. Conversely, repair is a more conservative approach that may be perceived as more acceptable by patients. Thus, critical, and at times difficult, balance needs to be struck between the perceived benefits and the potential harm of each of these options [27]. Although it can be expected that a repaired restoration will have a poorer prognosis than that of a replacement as the connection between the old and the new restorations is a possible weakness, the meta-analysis found no difference in the risk of failure of repaired and replaced partially defective direct restorations in permanent teeth.

However, the effect of the very low certainty of evidence on the findings must be emphasized considering that the true effect is probably markedly different from the estimated effect [15]. Few studies and few restorations were assessed. One study [26] included anterior and posterior restorations, and it was not possible to collect data separately. In the same way, restorations involving one or more surfaces were performed in the included studies and were analyzed together. It has been shown that a higher number of surfaces in cavity preparations can reduce the survival of restorations [28]. The follow-up periods of the included studies varied considerably (7 to 12 years). Despite the absence of a statistically significant difference between restorative approaches, only the study with a follow-up of 12 years [22] tended to favor replacement over repair.

While non-randomized studies are more likely to present biases [29], no randomized controlled trials were found. Defective direct resin composite and amalgam restorations were included in the studies. The subgroup analysis showed that the restorative material does not seem to have an impact on the effect of the treatment (repair or replacement). It is important to note that the restorative procedures were performed with the same material used in the original restoration.

Although there is no gold standard protocol for repair [30], it has been shown that the association of physical and chemical surface treatments improves the bonding of old and new restorative material [31]. This protocol was used in all included studies. No study, however, used air abrasion in lieu of diamond bur abrasion as physical surface treatment. *In vitro* evidence showed that air abrasion could roughen the surface of the aged resin composite by mechanical shock on alumina particles, non-selectively removing portions of the polymer matrix and filler particles. Consequently, mechanical retention occurs by interpenetration of the old and new resin composite to form a bonded interphase. In the presence of silica-coated alumina particles, air abrasion can also form a silica-reach layer on the resin composite, contributing to further chemical bonding [31]. Even though repairing amalgam restorations with amalgam was proven to be possible, the use of resin composite to repair amalgam restorations seems to be a suitable method [5]. Air abrasion also has been suggested for repairing defective amalgam restorations with resin composite [32]. Further clinical trials should evaluate the effectiveness of different repair protocols to aid in the decision-making process.

A retrospective study [10] found a better prognosis for restoration repair failure due to caries when compared to repair failure due to fracture. This information was not available in the studies included in this review. In all included studies, the modified USPHS criteria [3] were used as the most important reasons for repair or replacement and for the decision on whether procedures would be successful over time. Logically, every replacement of a restoration with several shortcomings would lead to the improvement of USPHS criteria, but an intervention (replacement or repair), when based on USPHS criteria such as Bravo or Charlie, should be performed when those criteria show less than ideal outcomes, suggesting gross overtreatment. Although the reasons for failure more frequently evaluated in the studies were marginal fit and adjacent caries, i.e., real clinical problems, some publications [22, 26] also considered small shortcomings such as color, surface roughness, and marginal staining. It can be noted that no repair failure occurred due to esthetic concerns. Therefore, these clinical conditions seemingly have a questionable predictive value on the longevity of restorations, mainly in the evaluation of posterior restorations, and are related to the demand for esthetics by patients and dentists. The criteria proposed by the World Dental Federation (FDI) classify non-acceptable restorations into two categories: whether the restoration can be repaired and whether it must be replaced completely [4]. These criteria, which are practical, relevant, and standardized [33] should be used for selecting failed restorations and assessing their outcomes in future trials, as they could therefore avoid overtreatment.

The studies included in this review were in secondary care by the same research team, which limits the external validity of the results. The quality of primary studies is of paramount importance to increase knowledge transfer to clinical practice. Therefore, there is a need for well-designed and well-reported randomized clinical trials assessing the longevity of repaired and replaced defective restorations and other relevant outcomes such as clinical time, patients' satisfaction and preference, and cost-effectiveness.

## Conclusion

Based on the very low certainty of evidence, the risk of failure of repaired partially defective direct restorations performed in permanent teeth is similar to that of replaced restorations. Further studies are required before definitive conclusions can be drawn.

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**Table 1.** Descriptive data from studies included in the systematic review.

| Author, Year, Country | Study Design | Type of teeth / Type of Class | Nº of restorations (baseline) | Nº of participants (mean age) | Repair (technique) | Operators | Follow-up (year) Dropout rate (%) | Material | Clinical Evaluation Criteria | Evaluated Clinical Parameters | Failure reasons | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Repair | Replacement |
| Gordan et al., 2009[26] USA | Non-randomized controlled study | Anterior and Posterior Class I, II, III and V | 41 | 37 (57 years) | Grinding with burs to removal of part of the restorative material adjacent to the defect + etch-and-rinse adhesive system followed by a restoration under rubber dam isolation | Third-year and fourth-year dental students | 7, 7.3 | Resin Composite (Filtek Z250, 3M Oral Care) | Modified USPHS Criteria | Marginal adaptation, adjacent caries, marginal staining, post-operative sensitivity, anatomic form, luster, color, occlusal or proximal contact, surface roughness and interfacial staining | No failure | Not clear |
| Gordan et al., 2011[24] USA | Non-randomized controlled study | Posterior Class I, II and V | 42 | 50 (56 years) | Grinding with burs to removal of part of the restorative material adjacent to the defect + mechanical retention inside the existing restoration + amalgam restoration | Third-year and fourth-year dental students | 7, 21.4 | Amalgam (Original D, Wykle Research) | Modified USPHS Criteria | Marginal adaptation, adjacent caries, post-operative sensitivity, anatomic form and occlusal or proximal contact | No failure | Not clear |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Estay et al., 2018[22] Chile | Non-randomized controlled study | Posterior Class I and II | 37 | 34 (26.4 years) | Grinding with burs to removal of part of the restorative material adjacent to the defect + self-etch adhesive system followed by a restoration under rubber dam isolation | Two clinicians | 12, 3.8 | Resin Composite (Filtek Supreme, 3M Oral Care) | Modified USPHS Criteria | Marginal adaptation, Adjacent caries, Marginal staining, Post-operative sensitivity, Anatomic form, Luster and Surface roughness | Marginal adaptation, adjacent caries | Adjacent caries |
| | | | 41 | | Grinding with burs to removal of part of the restorative material adjacent to the defect + mechanical retention inside the existing restoration + amalgam restoration under rubber dam isolation | | | Amalgam (Original D, Wykle Research) and (Tytin, Kerr Corp) | | | Marginal adaptation, adjacent caries | No failure |

**Table 2.** Methodological assessment of risk of bias according ROBINS-I.

| Study | Bias due to confounding | Bias in selection of participants into the study | Bias in classification of interventions | Bias due to departures from intended interventions | Bias due to missing data | Bias in measurement of outcomes | Bias in selection of the reported result | Overall judgment |
|---|---|---|---|---|---|---|---|---|
| Gordan et al., 2009[26] | Serious | Low | Low | Low | Low | Moderate | Low | Serious |
| Gordan et al., 2011[24] | Serious | Low | Low | Low | Low | Moderate | Low | Serious |
| Estay et al., 2018[22] | Serious | Low | Low | Low | Low | Moderate | Low | Serious |

**Table 3.** A summary of the Grading of Recommendations Assessment, Development and Evaluation approach to rating the certainty of evidence.

| Certainty assessment | | | | | | Failure/no. of restorations | | Effect | Certainty | Importance |
|---|---|---|---|---|---|---|---|---|---|---|
| No. of restorations (study design) | Risk of bias | Inconsistency | Indirectness | Imprecision | Other considerations | Repair | Replacement | Relative (95% Confidence Interval) | | |
| 146 (3 NRS) | Very serious[a] | Serious[b] | Not serious | Serious[c] | None | 7/71 (9.9 %) | 6/75 (8.0 %) | Risk Ratio 1.21 (0.51 to 2.83) | ⊕◯◯◯ Very low | Important |

[a] Failures to properly control confounding factors and problems with measurement of the outcome were detected. [b] High heterogeneity and important differences in the effects estimates of the included studies. [c] Few studies and few restorations assessed.

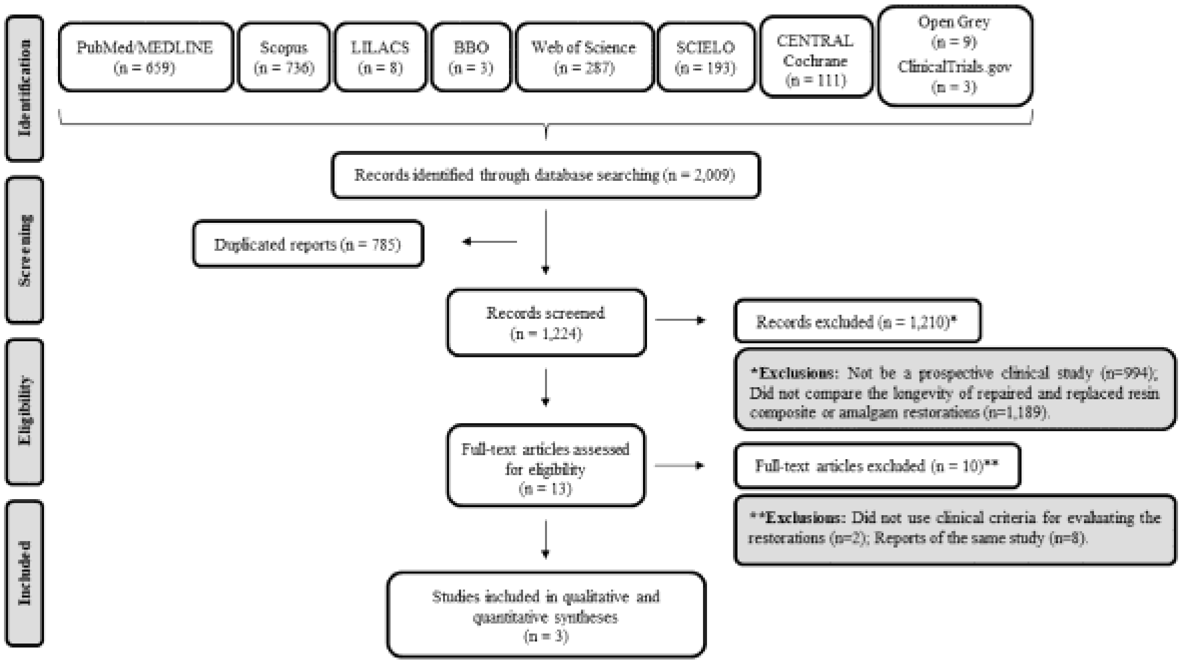


**Fig. 1** Flowchart diagram of study selection according to the PRISMA statement.

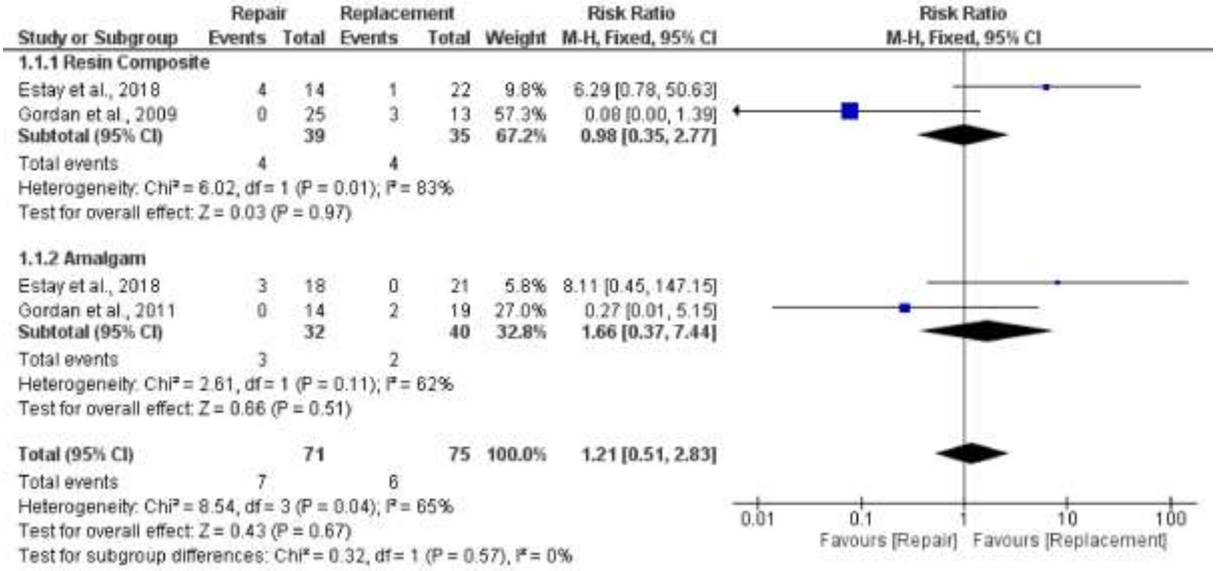


**Fig. 2** Meta-analysis of risk of failure of repaired and replaced direct resin composite and amalgam restorations.

## 3 ARTIGO 2 – Use of nonhydrolyzed silane prior to the silane-containing universal adhesive application improves the repair bond strength of resin composite

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# Use of nonhydrolyzed silane prior to the silane-containing universal adhesive application improves the repair bond strength of resin composite

**Laura Teixeira Mendes**[a]

**Djessica Pedrotti**[a]

**Vicente Castelo Branco Leitune**[b]

**Tathiane Larissa Lenzi**[a]

[a]School of Dentistry, Graduate Program in Dentistry, Federal University of Rio Grande do Sul, Rua Ramiro Barcelos, 2492, 90035-003, Porto Alegre, Rio Grande do Sul, Brazil.

[b]School of Dentistry, Dental Materials Laboratory, Federal University of Rio Grande do Sul, Rua Ramiro Barcelos, 2492, 90035-003, Porto Alegre, Rio Grande do Sul, Brazil.

✉**Corresponding Author**

Tathiane Larissa Lenzi

E-mail: tathiane.lenzi@ufrgs.br

Telephone/Fax: +55 51 3308 5027

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**Declaration of competing interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Abstract**

*Objective:* To compare the effect of hydrolyzed and nonhydrolyzed silanes prior to the silane-containing universal adhesive application on the repair bond strength between old and new resin composite. *Material and Methods:* Fifty-four blocks of nanohybrid resin composite (Z350 XT) were aged by water storage for six months. The aged specimen surfaces were wet-ground manually with 320-grit silicon carbide grinding paper and randomly assigned into six experimental groups according to surface treatment: silane-containing universal adhesive in the self-etch mode (Scotchbond Universal); nonhydrolyzed silane (Silane Coupling Agent) *plus* Scotchbond Universal; hydrolyzed silane (RelyX Ceramic Primer) *plus* Scotchbond Universal; self-etch adhesive system (Clearfil SE Bond); nonhydrolyzed silane *plus* Clearfil SE Bond; hydrolyzed silane *plus* Clearfil SE Bond. Blocks were repaired with the same composite. After 24 h of water storage, the blocks were sectioned and bonded sticks were submitted to microtensile bond strength test (μTBS). Two-way ANOVA and Tukey's tests were used to analyze the μTBS means. *Results:* The highest repair bond strength values were achieved when nonhydrolyzed silane was applied prior to the silane-containing universal adhesive system ($p=0.03$). The previous silane application did not increase the repair bond strength when a two-step self-etch adhesive was used. Mixed/adhesive failures prevailed in all groups. *Conclusion*: The use of a nonhydrolyzed silane prior to the silane-containing universal adhesive in the self-etch mode application improves the repair bond strength of old and new resin composite.

**Keywords:** Tensile strength; Dental restoration repair; Silanes

## 1. Introduction

Repair of partially defective restorations was traditionally considered as "patchwork dentistry" [1]. Nowadays, it has been shown that this approach increases restoration survival [2–4] and tooth retention time, reducing the progression of the "restoration death spiral" [5]. Although most dental schools teach repairs and dentists are theoretically accepting repairs as a treatment approach, the proportion of repaired restorations remains low [6]. One possible reason for the gap between scientific evidence and dentists' decision-making might be uncertainty regarding the protocol for repairs.

In fact, there is no standard treatment protocol of aged resin composite surface during repair procedures. Furthermore, the repair protocol may vary according to clinical conditions [7]. Roughening of the existing restoration with diamond burs, and subsequent application of silane and then an adhesive system is suggested as pretreatment for repairing resin composite restorations with chipping defects, bulk fracture, partial loss or severe wear [5]. Physical treatments have the ultimate goal to improve micromechanical interlocking between the aged and new (repair) resin composite. In contrast, chemical agents could promote the chemical bonds between resin-based materials at the adhesive interface. In this sense, silane coupling agents could promote the union of the inorganic phase of the old resin composite with the organic phase of the new resin composite [8], and facilitate the penetration of the adhesive into surface defects due to their higher surface wettability [9], improving repair bond strength.

Silane coupling agents are available in two types, either hydrolyzed or nonhydrolyzed [10]. Silane primers that contain nonhydrolyzed silane, are most often dissolved in ethanol in one bottle that needs to be activated and hydrolyzed by mixing it with an aqueous acetic acid solution or an acidic adhesive in the other bottle [10]. The hydrolyzed silanes are already activated. They are applied before the adhesive system, or alternatively, are included in some universal adhesives. Recently, silane-containing universal adhesives were introduced with the promise to simplify adhesive dentistry including resin composite repairs. However, the amount of silane in the composition of the universal adhesives (data not reported by manufacturers) may be not sufficient to promote a durable bond between the old and new (repair) resin composite.

A recent systematic review [11] showed that use of silane (preferable nonhydrolyzed) prior to the adhesive application produced higher repair bond strengths. However, the silane-containing universal adhesives were not included in the meta-analysis. In the scientific literature, the effect of nonhydrolyzed [12,13] and hydrolyzed [14–17] silane agents application prior to the silane-containing universal adhesives is still uncertain. Thus, this study aimed to compare the effect of hydrolyzed and nonhydrolyzed silanes prior to the silane-containing universal adhesive application on the repair bond strength between old and new resin composite. The null hypothesis tested was that there is no difference between hydrolyzed and nonhydrolyzed silanes as surface pretreatment prior to the silane-containing universal adhesive application on the repair bond strength of resin composite.

## 2. Material and Methods

This study followed the CRIS Guidelines for *in vitro* studies, as discussed in the 2014 concept note [18]. Two silane coupling agents: a hydrolyzed (RelyX Ceramic Primer, 3 M Oral Care, St. Paul, USA) and a nonhydrolyzed (Silane Coupling Agent, Dentsply Ind. and Com. Ltda., Petrópolis, Brazil), and two adhesive systems: a silane-containing universal adhesive system in the self-etch mode (Scotchbond Universal, 3 M Oral Care, St. Paul, USA) and a two-step self-etch adhesive (Clearfil SE Bond, Kuraray Noritake Inc., Okayama, Japan) were tested in this study. A2B and WE shades of the nanohybrid resin composite (Filtek Z350 XT, 3 M Oral Care, St. Paul, USA) were used in order to differentiate between the aged and new resin composite. More details of the materials are presented in Table 1.

*2.1. Preparation of aged composite blocks*

Fifty-four blocks of nanohybrid resin composite (A2B shade) measuring 8 x 8 mm in length and width and 4 mm in height were prepared. A metallic mold (8 x 8 x 8 mm) was placed on a glass slide, filled with two increments of resin composite and light cured for 20 s each with a light-emitting diode curing unit (Radii-cal; SDI, Victoria, AUS) with a light output of at least 1250 mW/cm$^2$. Light intensity output was monitored with a Demetron Curing Radiometer (Kerr, Orange, USA). The resin composite was carefully condensed with a clean filling instrument in order to provide complete adaptability to the mold walls and produce a smooth and even surface. After polymerization, the resin composite blocks were gently removed from the mold and the thickness of each block was confirmed with a digital caliper (Absolute Digimatic, Mitutoyo, Tokyo, Japan). The specimens were aged by distilled water storage (pH ≈ 7.0) at 37ºC for six months [19]. The storage solution was not changed and its pH was monitored monthly. The aged specimen surfaces were wet-ground manually with 320-grit silicon carbide grinding paper under running water for 5 s to obtain a flat surface with standardized roughness, corresponding to the obtained by diamond bur grinding [20]. Then, the specimens were washed and dried with air-dry spray.

*2.2. Surface treatments for repair of resin composite*

The 54 aged blocks were randomly divided (Random Allocation software, version 1.0, Iran) into six experimental groups according to surface treatments (n = 9): silane-containing universal adhesive in the self-etch mode (Scotchbond Universal); nonhydrolyzed silane (Silane Coupling Agent) *plus* Scotchbond Universal; hydrolyzed silane (RelyX Ceramic Primer) *plus* Scotchbond Universal; self-etch adhesive system (Clearfil SE Bond); nonhydrolyzed silane *plus* Clearfil SE Bond; hydrolyzed silane *plus* Clearfil SE Bond. The randomization was performed by a staff member who was not involved in any of the laboratorial phases. The allocation concealment was guaranteed by the use sequentially numbered individual containers that prevented the operator seeing the blocks before treatments.

All materials were applied according to the manufacturer's instructions (Table 1). After surface treatment, aged resin composite blocks were carefully placed over the original mold and repaired using nanohybrid resin composite (WE shade) in two incremental layers each light cured for 20 s. A transparent plastic matrix strip was placed on the top of the mold prior to curing of composite layers in order to obtain a flat surface. This process resulted in 8 mm high specimens. The repaired blocks were individually stored in distilled water at 37ºC for 24 h before testing. A single trained operator carried out all procedures.

*2.3. Preparation of specimens for the microtensile bond strength (µTBS)*

Each resin composite block was numbered according to the randomization sequence to ensure blinding of the testing machine operator. Blocks were sectioned into sticks with a cross-sectional area of approximately 0.8 $mm^2$ using a water-cooled diamond saw in a cutting machine (Isomet, Buehler, Lake Bluff, USA). Approximately 20 sticks were obtained for each block. The sample unit was the resin composite block (n = 9). The sticks were carefully examined with a stereomicroscope (HMV-2, Shimadzu Corp., Kyoto, Japan) at 40× magnification to identify voids and imperfections in the composite and the adhesive interface. Specimens with defects were discarded. The cross-sectional area of each stick was measured with a digital caliper (Absolute Digimatic, Mitutoyo, Tokyo, Japan) to calculate the bond strength values, measured in MPa. The bonded sticks were attached to a universal testing machine for microtensile testing (EZ-SX series, Shimadzu Corp., Kyoto, Japan) with cyanoacrylate and tested at a crosshead speed of 1mm/min. The µTBS, measured in MPa, was obtained by dividing the load at failure (N) by the cross-sectional area ($mm^2$) of each stick.

*2.4. Failure mode*

A trained and blinded examiner evaluated the failure mode. The fracture surfaces were examined under a stereomicroscope at 40× magnification to determine the failure mode: mixed/adhesive (failure between restorative material and bonding agent or between bonding agent and repair composite) or cohesive (failure exclusively within the aged or new resin composite). Representative specimens from each group were gold sputtered and analyzed with scanning electron microscopy (SEM) (JEOL 6060) operated in the secondary electron mode with 10 kV. Premature failure was considered to be a pre-testing failure due to the specimens' preparation.

*2.5. Statistical analysis*

The experimental unit in the current study was the resin composite block. Thus, the mean µTBS (MPa) of all sticks from the same block was averaged for statistical purposes. The µTBS mean for every testing group was expressed as the average of nine blocks used per group. The sample size was previously estimated [15] using the following parameters: 80% power, a coefficient of variation of 20%, and assuming a two-sided 5% significance level for comparisons. Specimens with cohesive failures were excluded from the data analysis. Premature failures were included in the statistical analysis with the value of 4.0 MPa [21]. This value was the lowest value obtained for one stick in this study.

The normal distribution of the data was confirmed using Shapiro-Wilk test. The µTBS means of the repaired groups were analyzed by two-way ANOVA (adhesive system *vs.* silane coupling agent) and *post-hoc* test (Tukey's test at $\alpha = 0.05$) for pairwise comparisons. Statistical significance was defined at $p < 0.05$. Statistical analyses were performed using Minitab-18 software (Minitab Inc., State College, USA).

## 3. Results

Table 2 and Table 3 shows the µTBS means and standard deviations, and distribution of the failure mode for all experimental groups, respectively. Main factors “adhesive system” ($p = 0.25$) and “silane coupling agent” ($p = 0.36$) were not statistically significant. Conversely, the cross-product interaction “adhesive system *vs*. silane coupling agent” was statistically significant ($p = 0.03$). The highest repair bond strength values were achieved when nonhydrolyzed silane was applied prior to the silane-containing universal adhesive system.

Mixed/adhesive failures prevailed in all groups. This pattern was further confirmed in SEM images (Figure 1). The majority of the cohesive fractures occurred in the old resin composite and they were more frequent in groups that presented higher repair bond strength values. Premature failures occurred irrespective of the repair protocol. However, a lower frequency of premature failures was also noted in the experimental group with highest repair bond strength values.

## 4. Discussion

This is the first study that compared the effect of hydrolyzed and nonhydrolyzed silanes prior to the silane-containing universal adhesive application in the repair protocol. It has been shown that mild universal adhesives seem to be the more stable over time, in both etch-and-rinse or self-etch strategies, in comparison with ultra-mild and intermediately strong universal adhesives [22]. Since the technique simplification is desirable in the clinical practice, a mild silane-containing universal adhesive in the self-etch mode was evaluated in this study, and a gold standard two-step MDP-containing self-etch adhesive (Clearfil SE Bond) was used as control. The use of a nonhydrolyzed silane prior to silane-containing universal adhesive improved the repair bond strength between old and new resin composite. However, previous silane application did not increase the repair bond strength when a two-step self-etch adhesive was used. Thus, the null hypothesis was rejected.

Clinically, the absorption of water by diffusion through the resin phase of composites may affect the ability of the new resin composite to adhere to the aged resin composite, because the number of available unsaturated double bonds diminishes with aging and the filler surface could be affected over the time [23]. Although there is no aging protocol that is considered the gold standard for mimicking the aging of dental resin composite that occurs in the oral environment, in our study, the resin composite was aged by water storage for six months [19]. All aged resin composites were roughened by use of 320-grit silicon carbide grinding paper, simulating the roughness obtained with a medium diamond bur [20], before any additional chemical treatments were provided. This physical surface treatment promotes the micromechanical retention, thereby increasing the surface area to improve wetting and adhesion between the aged and new (repair) resin composite. Moreover, surface roughness is also capable making of available silica at the surface of the resin composite (i.e. glass particles) to promote the chemical bonding of silane with resin composite [24].

In the repair procedures, silane coupling agents provide chemical bonding by forming siloxane bonds between silicate-containing filler particles exposed on the repair surface and the resin matrix of fresh resin layer [25]. In addition, silanes have a higher surface wettability, facilitating the penetration of the adhesive into surface defects [10], and consequently, are beneficial for improving the repair bond strength.

Repair bond strength is measured as the maximum force until the fracture. In our study, most failures were classified as mixed/adhesive for all experimental groups. A larger area of adhesive layer/nonhydrolyzed silane could be observed when the two-step self-etch adhesive system was used. We speculated that this may be attributed to a higher viscosity of the adhesive (Figure 1). A lower percentage of premature failures was observed in the experimental group with highest repair bond strength values. In the present study, the repair was evaluated immediately. The longitudinal evaluation of repaired resin composite with different surface treatments should be evaluated. The effect of aging of repaired resin composite was shown elsewhere [26]. However, the results presented indicates the importance of use of a nonhydrolyzed silane prior to the silane-containing universal adhesive system.

Most studies tested hydrolyzed silanes prior to silane-containing universal adhesive in the etch-and-rinse [14,15,17] or the self-etch [16] modes, and the results are contradictory. While some studies [14,16,17] found no difference in the repair bond strength when using the silane-containing universal adhesive with and without a silane agent, other study [15] showed that previous silane application improved the immediate repair bond strength. However, after opening the bottle, hydrolyzed silane solutions gradually become less reactive, preventing optimal adhesion in long-term [10]. The difference between studies could be associated to the technical sensitivity, since the composition changes over time after hydrolyzed silane bottle opening. Thus, it is expected the nonhydrolyzed silanes would lead to better results when repairing resins composite intra-orally.

A previous study [12] investigated the effect of a nonhydrolyzed silane (Bis-silane; BISCO) prior to use of a silane-containing universal adhesive (Scotchbond Universal) and a self-etch adhesive system (Clearfil SE Bond) on the repair bond strength between new and aged resin composite. The silane pretreatment rendered higher repair bond strength, irrespective of the adhesive system. Similar repair bond strength was achieved for both adhesives. It is important to highlight, however, that both adhesives were applied after acid etching. Etching with phosphoric acid promotes the removal of grinding debris from resin composite surfaces [27], but this step seems to have little effect in improving the bonding between old and new composite [28].

Conversely, another study [13] reported that previous application of a nonhydrolyzed silane agent (Clearfil Porcelain Bond Activator; Kuraray) did not influence the repair microshear bond strength of another silane-containing universal adhesive (Clearfil SE One; Kuraray). Differences in the composition of the materials tested may explain the controversial findings.

Silane incorporation into universal adhesives may have questionable relevance in the clinical practice. Silanes in acidic conditions may become unstable due to the self-condensation reaction of silanol groups [29], resulting in bond degradation over time [30]. Methacrylate monomers may also interfere on the ability of silane coupling agents to chemically bond to the silica fillers. The absence of methacrylate monomers during silanization seems necessary to benefit resin composite [29]. Moreover, the amount of silane in the composition of the universal adhesives (data not reported by manufacturer) may be not sufficient to promote a durable bond between the old and new (repair) resin composite.

Although the purpose of use a silane-containing universal adhesive in the self-etch mode is to reduce the number of operative steps, the need for prior a two-step silane application may increase technique sensitivity. It should be emphasized that the repair procedure for direct resin composite restorations involves the dental structure in most clinical scenarios. Although the cross-contamination of the dentin with silane before adhesive application does not seem adversely affect resin composite bond strength to dentin [31], the bonding between the silane-containing universal adhesive and dental substrate [22] could help minimize the need for silane application. It is important to note that the findings are based on immediate repair bond strength values and limited to the materials used in this study. Further studies evaluating the use of a silane-containing universal adhesive with or without pretreatment with nonhydrolyzed silane on the long-term repair durability are necessary to establish the clinical relevance.

## 5. Conclusion

The use of a nonhydrolyzed silane prior to the silane-containing universal adhesive in the self-etch mode application improves the repair bond strength of old and new resin composite.

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**Table 1.** Composition and application mode of the materials tested.

| | | |
|---|---|---|
| RelyX Ceramic Primer (3M Oral Care, St. Paul, USA)<br><br>#Batch number NA87110 | Methacryloxypropyl trimethoxysilane; water; ethyl alcohol 3-(trimetoxysilyl methacrylate) | Apply one coat of silane for 60 s<br>Gently air dry for 5 s |
| Silane Coupling Agent (Dentsply Ind. and Com. Ltda., Petrópolis, Brazil)<br><br>#Batch number 371974M | Primer: ethyl alcohol 95% and Silane A 174<br>Activator: ethyl alcohol 95% and glacial acetic acid | One drop (primer) + one drop (activator): mix for 10 s<br>Wait 5 min<br>Apply one coat for 10 s + Gently air dry for 5 s<br>Apply second coat for 10 s + Gently air dry for 5 s |
| Scotchbond Universal (3M Oral Care, St. Paul, USA)<br><br>#Batch number 2108400617 | MDP phosphate monomer, dimethacrylate resins, HEMA, methacrylate-modified polyalkenoic acid copolymer, filler, ethanol, water, initiators, silane | Apply the adhesive for 20 s with vigorous agitation<br>Gently air dry thin for 5 s<br>Light-cure for 10 s |
| Clearfil SE Bond (Kuraray, Noritake, Inc., Okayama, Japan)<br><br>#Batch number 000138 | Primer: MDP phosphate monomer, HEMA, hydrophilic aliphatic dimethacrylate, dl-Camphorquinone, N,N-Diethanol-p-toluidine, water<br><br>Bond: MDP phosphate monomer, Bis-GMA, HEMA, hydrophobic aliphatic dimethacrylate, dl-Camphorquinone, N,N-Diethanol-p-toluidine, colloidal silica | Apply the primer for 20 s + Gently air dry for 5 s<br>Apply bond for 10 s + Gently air dry for 5 s<br>Light-cure for 10 s |
| Z350 XT A2B and WE Shades (3M Oral Care, St. Paul, USA)<br><br>#Batch numbers 2032400481 and 2002800809 | Bis-GMA, UDMA, TEGDMA, Bis-EMA, non-agglomerated/ non-aggregated 20 nm silica filler, non-agglomerated/ non-aggregated 4 to 11 nm zirconia filler, and aggregated zirconia/silica cluster filler | Insert the composite in 2 mm increments<br>Light-cure for 20 s |

MDP: 10-methacryloyloxydecyl-dihydrogen-phosphate; Bis-GMA: bisphenyl-glycidyl methacrylate; HEMA: 2-hydroxyethyl methacrylate; TEGDMA: triethylene glycol dimethacrylate; Bis-EMA: ethoxylated bisphenol-A dimethacrylate; UDMA: urethane dimethacrylate

**Table 2.** The microtensile bond strength means (MPa) and standard deviations for all experimental groups.

| Adhesive system | Silane coupling agent | | |
| --- | --- | --- | --- |
| | Without silane | Nonhydrolyzed | Hydrolyzed |
| Silane-containing universal adhesive in the self-etch mode | 29.1 ± 16.0$^{B,b}$ | 47.2 ± 8.2$^{B,a}$ | 40.4 ± 15.8$^{B,b}$ |
| Two-step self-etch adhesive | 38.2 ± 13.1$^{B,b}$ | 32.9 ± 11.2$^{B,b}$ | 33.1 ± 13.1$^{B,b}$ |

Equal capital superscript letters indicate absence of significant differences between rows ($p>0.05$). Different small superscript letters indicate statistically significant differences among columns ($p < 0.05$).

**Table 3.** Distribution (%) of failure mode of evaluated groups.

| Experimental groups | Failure mode | | | |
|---|---|---|---|---|
| | Mixed/adhesive (%) | Cohesive (%) (old composite) | Cohesive (%) (new composite) | Premature failures (%) |
| Silane-containing universal adhesive in the self-etch mode | | | | |
| Without silane | 55.0 | 10.1 | 16.9 | 18.0 |
| Nonhydrolyzed | 62.9 | 24.1 | 5.2 | 7.8 |
| Hydrolyzed | 66.3 | 6.2 | 12.2 | 15.3 |
| Two-step self-etch adhesive | | | | |
| Without silane | 62.1 | 7.4 | 14.8 | 15.7 |
| Nonhydrolyzed | 57.9 | 15.0 | 13.1 | 14.0 |
| Hydrolyzed | 67.6 | 10.1 | 5.6 | 16.7 |

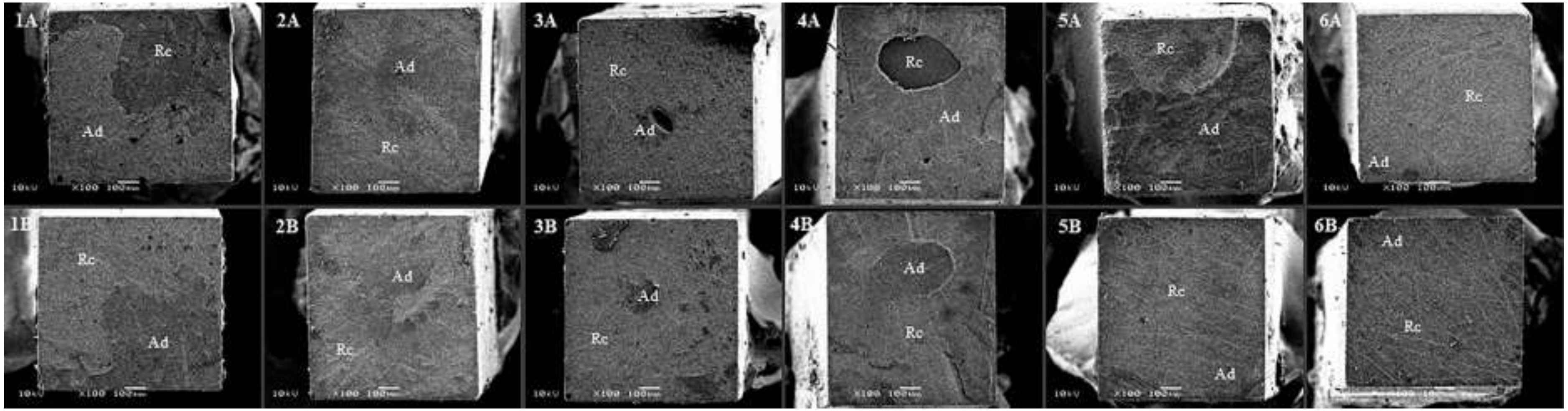


**Fig. 1.** SEM photomicrograph of fractured specimens representative of the mixed/adhesive failure pattern from 1: silane-containing universal adhesive in the self-etch mode; 2: nonhydrolyzed silane + silane-containing universal adhesive in the self-etch mode; 3: hydrolyzed silane + silane-containing universal adhesive in the self-etch mode; 4: two-step self-etch adhesive; 5: nonhydrolyzed silane + two-step self-etch adhesive; 6: hydrolyzed silane + two-step self-etch adhesive. A: new composite; B: old composite. Rc: resin composite; Ad: adhesive system.

# 4 CONCLUSÃO

Com base nos resultados dos estudos contemplados na presente tese, pode-se concluir que:

O risco de falha de restaurações de resina composta e amálgama defeituosas reparadas em dentes permanentes é similar àquelas substituídas. No entanto, a certeza da evidência é muito baixa.

O uso de um silano não hidrolisado previamente à aplicação de adesivo universal contendo silano no modo autocondicionante aumenta a resistência de união de reparo de resina composta. No entanto, estudos avaliando o uso de um adesivo universal contendo silano com ou sem pré-tratamento com silano não hidrolisado na degradação da união de reparo são necessários para estabelecer a relevância do uso desse material no protocolo de reparo.

Vale destacar que a evidência clínica disponível não pode ser extrapolada para dentes decíduos. Além disso, o uso de um adesivo universal contendo silano poderia ser suficiente para o reparo de restaurações em dentes decíduos, visto que apresentam um ciclo biológico curto. Estudos clínicos randomizados que avaliem o impacto do reparo e da substituição na sobrevida de restaurações com falhas em dentes decíduos são necessários, considerando desfechos secundários relevantes como tempo clínico, custo-eficácia e aceitação dos pacientes.

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# ANEXO A – Aprovação da Comissão de Pesquisa em Odontologia

**Sistema Pesquisa - Pesquisador: Tathiane Larissa Lenzi**

Retornar

**Dados Gerais:**

| | | | |
|---|---|---|---|
| **Projeto Nº:** | 39582 | **Título:** | EFEITO DE UM SILANO NAO HIDROLISADO PREVIAMENTE A APLICACAO DE SISTEMAS ADESIVOS UNIVERSAIS CONTENDO SILANO NA RESISTENCIA DE UNIAO DE REPARO DE RESINA COMPOSTA ENVELHECIDA |
| **Área de conhecimento:** | Odontologia | **Início:** | 01/09/2020 **Previsão de conclusão:** 01/07/2022 |
| **Situação:** | Projeto em Andamento | | |
| **Origem:** | Faculdade de Odontologia Programa de Pós-Graduação em Odontologia | **Projeto da linha de pesquisa:** | BIOMATERIAIS E TÉCNICAS TERAPÊUTICAS EM ODONTOLOGIA |
| **Local de Realização:** | não informado | | |

**Não apresenta relação com Patrimônio Genético ou Conhecimento Tradicional Associado.**

**Objetivo:**

O objetivo do estudo é avaliar a influência do uso de silanos previamente à aplicação de sistemas adesivos universais contendo silano na resistência de união de reparo de resina composta envelhecida. Para isso, 90 corpos de prova (4 mm x 4 mm x 4 mm) de resina composta (Z350 XT, 3M ESPE) serão divididos aleatoriamente em 9 grupos experimentais: silano hidrolisado (RelyX Ceramic Primer, 3M ESPE) + adesivo

**Palavras Chave:**

REPARO
RESINA COMPOSTA
RESISTÊNCIA DE UNIÃO
SILANO

**Equipe UFRGS:**

**Nome:** Tathiane Larissa Lenzi
Coordenador - Início: 01/09/2020 Previsão de término: 01/07/2022

**Nome:** Djessica Pedrotti
Ensino: doutorado - Início: 01/09/2020 Previsão de término: 01/07/2022

**Nome:** Laura Teixeira Mendes
Ensino: doutorado - Início: 01/09/2020 Previsão de término: 01/07/2022