

Factors that Affect the Shear Bond Strength of Pit and Fissure Sealants to Tooth Structure: A Systematic Review

Keywords

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ABSTRACT

Introduction: Pit and fissure sealants are effective in preventing caries disease, however, they may present flaws that damage the physical barrier leading to treatment failure. *Objective:* To answer the question “Do pit and fissure sealants present good adhering to the dental structure when analyzed by their resistance to shear/microshear?”. *Methods:* This systematic review followed the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) and was recorded in Open Science Framework. Embase, PubMed, SCOPUS, and Web of Science databases were used for the search strategy. The articles were selected according to the eligibility criteria. The risk of bias was performed with the adaptation of the quasi-experimental studies tool by Joanna Briggs Institute (JBI). *Results:* 1245 studies were found in the databases when applying the search strategy, after removal of duplicates 881 were evaluated and 44 were selected. After applying the JBI tool, 30 studies presented low risk and 15 moderate risk of bias. *Meta-analysis* was not possible to performed due to the heterogeneity of the studies. *Conclusion:* The adhesion is dependent on the application protocol, and among the protocols evaluated, conditioning with 37% phosphoric acid for 60 seconds and contamination of the substrate, as these can affect sealant adhesion.

INTRODUCTION

The pit and fissure sealants are effective in preventing caries disease as they act as a physical barrier to the invasion of bacteria and plaque accumulation, however it is still a constant challenge to adhere to the dental structure due to physiological conditions, alteration of pH, temperature, masticatory forces, constantly submitted to the oral cavity.^{1,2} For this reason, researchers aim to improve their physical-chemical and mechanical properties in order to increase their resistance to adherence and thus provide greater longevity and consecutive clinical success of preventive treatment.¹⁻³

To provide adhesion to the sealants, conditioning with phosphoric acid is the most used method because it provides the formation of micropores on the enamel surface allowing the penetration of the material.^{3,4} There are also alternative preparation methods such as the application of lasers, air abrasion and invasive preparations with drills that increase retention through macroscopic changes in the substrate.^{5,6} In recent years, the application of self-etching adhesives has become popular, as it allows for a reduction in clinical time and simplification of the technique.^{7,8}

The micromechanical retention of sealants can be affected by the adverse conditions present in the oral cavity, the main one being salivary contamination, so adequate saliva control and isolation of the operative field are paramount during the operative technique, especially in care of young children, patients with special needs and newly erupted teeth.^{4,9} The presence of saliva affects the adhesion of sealants and their reduction compromises their marginal integrity by favoring the occurrence of microleakage and consequent secondary caries, postoperative sensitivity, adverse pulp response and loss of restoration, with reduced clinical performance and preventive potential.^{3,4,10}

The challenge of adhesion of sealants to the substrate is assessed by researchers by the shear strength and microcutting tests as they are useful tools for determining the retention capacity of dental materials on enamel and predicting their clinical effectiveness *in vitro*. It is noteworthy that a low resistance to these tests is associated with inadequate connections and wider gaps between the sealant and the substrate, while a high with greater predictability of clinical success.^{5,10,11}

Despite the proven clinical efficacy of sealants and the relative ease of application, retention and longevity remain a challenge, so this systematic review aims to critically assess the existing literature and answer the question "Do pit and fissure sealants present good adhering to the dental structure when analyzed by their resistance to shear/microshear?".

MATERIAL AND METHODS

PROTOCOL

This systematic review was prepared in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analyses Protocols (PRISMA 2020) to answer the question "Do pit and fissure sealants present good adhering to the dental structure when analyzed by their resistance to shear/microshear?", and its protocol was registered in the Open Science Framework (<https://osf.io/dwk2f>).

ELIGIBILITY CRITERIA

In vitro experimental studies that evaluated the adhesion of pit and fissure sealants (glass ionomer sealants, auto-polymerized sealants, light-polymerized sealants, resin based sealants) in human teeth (permanent or deciduous) and bovine by the methods of shear resistance and micro-shear, without restriction of time and language, were included. And excluded if: a) they did not carry out the shear tests (SBS) or micro shear (μ SBS); b) sealants for orthodontic and endodontic purposes; c) article not available in full; d) articles published in journals without Journal Citation Reports (JCR); f) clinical articles, reviews, chapters, conference, short communications.

SEARCH STRATEGY

The databases Embase, PubMed, SCOPUS, and Web of Science were used for the personalized search strategy: ("dental sealants" OR "pit and fissure sealants" OR "tooth sealants" OR "Fissure sealants") AND ("shear strength" OR "adhesion test") on March 31st, 2023. The EndNote X8 software was used to remove duplicates and the Rayyan web application was used to select articles by title and abstract.

SELECTION PROCESS

The reviewers I.F and J.D.C.T evaluated the articles found independently in two phases according to the eligibility criteria. In the first phase, they selected according to the title and abstract, and in the second, through the full reading of the articles. Doubts and discrepancies were resolved at the consensus meeting with the coordinator A.C.R.

DATA TABULATION

I.F and J.D.C.T tabulated the data in an excel spreadsheet (Microsoft Corporation, Redmond, USA) independently according to author, year, objective, groups evaluated, types of teeth, trial, result expressed in Table 1.

ANALYSIS OF THE RISK OF BIAS

The quasi-experimental studies (non-randomized experimental studies) from the Joanna Briggs Institute (JBI) has been adapted to assess the risk of bias.^{12,13} For the classification of the methodological quality of the studies, each question was scored with "yes", "no" and "uncertain", so when all questions were answered with "yes" the study was considered to be of high quality (low risk of bias), studies that had 6 to 7 "yes" moderate quality (medium risk of bias) and when 5 or less "yes" low quality (high risk of bias). The analysis was performed using the RevMan 5.3 software.

RESULTS

SELECTION PROCESS

When applying the search strategy, 1245 studies were found in the databases, after removing the duplicates, 881 were evaluated by title and summary, which resulted in 86 to be read in full when applying the eligibility criteria 44 were selected. The selection process is illustrated in the flowchart in Figure 1.

RISK OF BIAS

The risk of bias was increased in some studies because 42 studies^{2-11,14-35,38-47} evaluated the connection interface only once (after applying the cause), 15 of them^{3,6,8,18,20,22,23,29,30,37,39,41,45-47} do not have a control group, and 1 with data measurement using a different methodology²¹ (Figures 2 and 3). Thus, 30 studies had a low risk of bias and 15 a moderate risk of bias.

Table 1. Data tabulation according to the author, year, objective, groups evaluated, type of teeth, assay, and result.

Author, year	Aim	Groups	Type of teeth	Assay	Result
Dewji et al 1998 ³⁶	To Compare the adhesion of resin sealants, Delton Opaque®, and ionomeric sealants, Fuji III Self Cure®, Fuji III L.C.®, and Fuji III L.C.®.	G1: Delton Opaque®- 10% phosphoric acid; G2: Fuji III Self Cure® - no conditioning; G3: Fuji III L.C.® - 20% Polyacrylic acid plus 3% Aluminium Chloride; G4- Fuji III L.C.® - 10% phosphoric acid.	Bovine teeth	SBS	Fuji III L.C.® resin-modified ionomer sealant showed higher SBS compared to Delton Opaque® and Fuji III Self Cure®.
Ellis et al 1999 ³⁷	To investigate short-term, 72 hours, and long-term, 120 days, resistance to thermal shear of Pit and Crack Sealants, Delton®, following various methods of surface pretreatment for enamel, air abrasion, acid etching, pumice stone, and 3% hydrogen peroxide.	G1: no surface pretreatment or control conditioning; G2: air abrasion. No conditioning; G3: phosphoric acid 35%; G4: cleaned with a pumice stone without fluorine + phosphoric acid 35%; G5: submitted to air abrasion + phosphoric acid 35%; G6: washing with 3% hydrogen peroxide for one minute. + phosphoric acid 35%.	Permanent human teeth	SBS	Showed average values of stored SBS 72h after conventional conditioning, while the air abrasion + acid etching showed greater adhesion and stability in 120 days stored followed by 800 cycles of thermal cycling.
Tulunoglu et al 1999 ²⁶	To evaluate the shear strength between saliva-contaminated and washed enamel before application of a fluoride-releasing sealant, and bonded with three agents, Scotchbond Multi-Purpose Plus®, Optibond® and Syntac®.	G1: No adhesion and uncontaminated, control group; G2: No adhesion contaminated, control group; G3: Scotchbond® uncontaminated; G4: Scotchbond® contaminated; G5: Syntac® uncontaminated; G6: Syntac® contaminated; G7: Optibond® uncontaminated; G8: Optibond® contaminated.	Deciduous teeth	SBS	The presence of salivary contamination decreased the SBS regardless of the type of adhesive agent used.
Drummond et al 2000 ¹⁸	To evaluate the shear strength of bovine enamel between teeth with acid and teeth with a laser. With and without an experimental primer.	G1: acid + sealant condition; G2: acid + primer + sealant condition; G3: laser + sealant condition; G4: laser + primer + sealant condition.	Bovine teeth	SBS	Larger SBS for conventional compared to the CO2 laser, and the developed primer promotes greater adhesion.
Yamamoto et al 2003 ³⁴	To evaluate the effects of tooth conditioning agents on the bond strength of resin-modified glass ionomer sealant, Fuji III LC®, to bovine enamel.	G1: conditioning with 10% polyacrylic acid; G2: conditioning with 20% polyacrylic acid; G3: conditioning with 12% citric acid; G4: conditioning with 35% phosphoric acid; G5: no surface pretreatment, control.	Bovine teeth	SBS	The 10% polyacrylic acid had the lowest SBS values than 20% polyacrylic acid, 12% citric acid, and 35% phosphoric acid, however, the conditioning promotes an increase in SBS regardless of the conditioning agent.
Castro et al 2004 ⁶	To evaluate the effect of three invasive methods of crack preparation, drill, air abrasion, and Er, Cr: YSGG laser, on the retention of the sealant, Embrace®, on the permanent molar surfaces.	G1: drill + acid etching; G2: drill + acid etching + Excite® adhesive; G3: air abrasion + acid etching; G4: air abrasion + acid etching + Excite® adhesive; G5: laser Er,Cr:YSGG + acid etching; G6: laser Er,Cr:YSGG + acid etching + Excite® adhesive.	Permanent human teeth	SBS	Reported higher SBS for drill, air abrasion, and laser Er preparations: Cr YSGG when conditioned by the conventional method with Excite®.
Peutzfeldt et al 2004 ⁸	To evaluate the short and long-term shear strength of a sealant, Clear®, for primary and permanent enamel, which has been conditioned with phosphoric acid or a self-adhesive adhesive, Prompt L-Pop®.	G1: deciduous; G2: permanent; Subgroups: 1- the enamel was engraved for 30 seconds with 38% phosphorus acid gel; 2- the enamel was treated with Prompt L-Pop®.	Permanent and Deciduous teeth	SBS	Reduced SBS for deciduous with sealant Clear® after conditioning with Prompt L-pop® and conventional when compared to permanent. No differences between conventional and self-etching.

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Knobloch et al 2005¹⁰	To compare the effect of air abrasion, acid attack, 37% phosphoric acid, and the combination of both procedures on the SBS of a light-curing sealant, Delton®, to the enamel of human primary molar teeth.	G1: control group; G2: acid etching; G3: air abrasion; G4: air abrasion + acid etching.	Deciduous teeth	SBS	Reported higher SBS in the combination of air abrasion and conventional acid etching methods.
Lepri et al 2008⁴	To evaluate the shear strength of a sealant Er: YAG laser irradiated with enamel after salivary contamination.	G1: surface treatment with 37% phosphoric acid; G2: surface treatment with Er: YAG laser, 80 mJ/ 2 Hz + phosphoric acid; Subgroups: 1- no salivary contamination; 2 with salivary contamination.	Permanent human teeth	SBS	Higher SBS for conventional preparation when compared to laser Er: YAG and salivary contamination affects the SBS of sealants regardless of preparation.
Wadenya et al 2009²⁷	To compare the SBS of a self-conditioning resin sealant, Enamel Loc®, to a sealant using the acid conditioning technique, Clinpro®.	G1: control - Clinpro® with traditional acid conditioning; G2: Enamel Loc® self-conditioning.	Permanent human teeth	SBS	Clinpro® SBS was statistically higher than Enamel Loc®.
Moslemi et al 2010⁵	To evaluate whether the sealant bond strength to the enamel increased when the cracks were prepared with air abrasion or with Er, Cr: YSGG laser followed by acid etching.	G1: Acid etching, control group; G2: Abrasion to air/acid etching; G3: Laser irradiation/acid storage.	Permanent human teeth	SBS	Higher SBS in the combination of air abrasion + acid etching methods.
Rirattanapong et al 2011⁹	To evaluate the effect of saliva contamination and compare the shear strength of three different sealants Concise®, Clinpro®, and Fuji VII®.	G1: saliva contamination; G2: non-saliva contamination. 3 sub-groups: 1- Concise®; 2- Clinpro®; 3- Fuji VII®.	Permanent human teeth	SBS	The presence of contamination reduces SBS mainly in the Fuji VII® ionomer sealant when compared to the resin Concise® and Clinpro®.
Marchesi et al 2012¹⁹	To evaluate the influence of ozone gas on the immediate bond strength of two fissure sealants, Concise®, and Ultraseal XT®.	G1: Concise® - ozone + sealant; G2: Concise® - sealant only; G3: Ultraseal XT® - ozone + sealant; G4: Ultraseal XT® - sealant only.	Bovine teeth	SBS	Ozone-treated specimens did not differ statistically from controls for both tested sealant systems.
Margvelashvili et al 2013³	To test Vertise Flow® on its bond strength to intact enamel. For comparative purposes, sealants marketed for use in combination with phosphoric acid or a self-adhesive adhesive, Prompt L-Pop®, were also evaluated.	G1: Etchant Gel + Vertise Flow®; G2: Etchant Gel + Guardian Seal®; G3: Adper Prompt L-Pop® + Clinpro Sealant®.	Permanent human teeth	SBS	Higher SBS for the association of methods self-etching vs acid etching, and Vertise Flow® has registered higher SBS than Guardian Seal®.
Stellini et al 2013³⁰	Compare the joint strength between two different types of crack sealant, Clinpro® and Quick Seal®, and the tooth enamel surface.	G1: Clinpro®; G2: Quick Seal®.	Permanent human teeth	SBS	The self-etching sealants had lower SBS values than the conventional method.
Biria et al 2014²⁸	To determine the SBS of a micro enamel sealant material, Enamel Loc®, to enamel and compare it to the bond strength of a conventional sealant, Concise®, with a full etching technique or a self-adhesive adhesive, Prompt L-pop®.	G1: Concise® - attack with phosphoric acid; G2: Concise® - used the L-pop adhesive; G3: Enamel Loc® - no pre-conditioning.	Permanent human teeth	µSBS	The conventional acid etching showed respectively higher µSBS than with Prompt L-pop®.

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Derelioglu et al 2014²⁰	To compare the SBS of an ionomeric sealant, Fuji Triage Capsule®, a self-adhesive, Vertise Flow®, and a conventional resin sealant, Grandio seal®, with or without phosphoric acid pre-conditioning.	G1: phosphoric acid + Grandio seal®; G2: phosphoric acid + Fuji Triage Capsule®; G3: Fuji Triage Capsule®; G4: phosphoric acid +Vertise Flow®; G5: Vertise Flow®.	Permanent human teeth	SBS	The SBS of Grandio seal® + acid etching and Vertise Flow® + acid etching were higher than Fuji Triage Capsule® + acid etching and Fuji Triage Capsule® sealants without etching.
Tavassoli-Hojjati et al 2014²³	To investigate the effect of variable concentrations, 1, 2, 3, 4, and 5 wt.% of b-TCP nanoparticles, on micro shear mechanical properties.	G1: b-TCP-NPs 1wt.%; G2: b-TCP-NPs 2wt.%; G3: b-TCP-NPs 3wt.%; G4: b-TCP-NPs 4wt.%; G5: b-TCP-NPs 5wt.%; G6: control groups containing additive-free crack sealants; G7: commercial control Concise®.	Permanent human teeth	µSBS	Did not show significant differences in the mean values of the micro shear between the various experimental groups and between the control groups.
Schuldt et al 2015³⁵	To investigate the shear strength and sealing techniques in comparison with conventional pit and fissure sealing.	G1: self-etching/self-adhesive sealant Constic®, without acid etching; G2: self-etching/self-adhesive sealant Constic®, with prior acid etching; G3: conventional fissure sealing, control group- Helioseal F®.	Permanent human teeth	SBS	The Constic® with acid etching and the Helioseal F® control group performed equally well, while the Constic® obtained a significantly lower SBS after thermocycling compared to the control group. The Constic® without acid recording obtained a lower SBS for all aging protocols.
Teixeira et al 2015³³	To define the effect of APP on the mechanical properties of enamel and its ability to promote the bonding of sealant, UltraSeal XT®.	G1: conditioned enamel; G2: non-conditioned enamel. Subgroups: 1- received APP treatment for 15 seconds; 2- NaOH treatment for 60 seconds; 3- the recorded and unrecorded control groups received 15 seconds of compressed air application.	Permanent human teeth	SBS	Reported higher µSBS for APP preparation compared to NAOH when conditioned by a conventional method.
Chiang et al 2016¹⁷	To determine the influence of tooth site selection, prismatic compared to. aprismatic enamel, conditioning time, aging, and shear procedure on SBS;	G1: prismatic enamel; G2: aprismatic enamel; Subdivide in 1- acid etching 30s or 60s; 2- aging: 1 day or 3 months or 5000 thermocyclers; 3- shearing: bevel edge method or knife edge method.	Permanent human teeth	SBS	Larger SBS with conventional conditioning for 60 seconds aprismatic and 30s for prismatic.
Kucukyilmaz et al 2016²⁵	To determine the bond strength of three different glass ionomer-based fissure sealants, Fuji Triage®, Fuji VII EP®, and GCP Glass Seal®.	G1: Fuji Triage ®; G2: Fuji VII EP®; G3: GCP Glass Seal®	Permanent human teeth	SBS	The Fuji VII EP® exhibited the highest shear strength score, which was significantly different from Triage Fuji® and Glass Seal GCP®.
Schuldt et al 2016¹¹	To assess the SBS of a self-conditioning adhesive, Adper Prompt L-Pop®, compared to acid pre-conditioning sealing, Clinpro®, and Helioseal F®.	G1: experimental group: Adper Prompt L-Pop®; G2: prior acid conditioning. Subgroups: 1- 1 day storage in distilled water at 37°C in a thermal oven; 2- 3 months of storage in distilled water at 37°C in a thermal oven; 3- 1 day storage in distilled water at 37°C followed by 5,000 cycles in a thermal cyclor bath.	Permanent human teeth	SBS	Conventional conditioning showed respectively higher µSBS and SBS than with Prompt L-pop®.
Birlbauer et al 2017²¹	To determine the SBS according to different aging procedures of a new EFP.	G1: EFP; G2: EFP-1; G3: EFP-2; G4: EFP-3; Subgroups: 1- stored 1 day in water; 2- stored 3 months in water; 3- thermocycling.	Permanent human teeth	SBS	The EFP-3 group showed the highest SBS values under in vitro conditions compared to the groups that were tested previously and all groups showed SBS decrease after thermocycling.

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Fiorati-Aguiar et al 2018¹⁶	To evaluate the properties of a new bisphenol-A free sealant, Embrace Wetbond®, compared to a conventional sealant Fluoroshield®.	G1: Embrace Wetbond®; G2: Fluoroshield®. Subgroups- 1: water contaminated; 2: not water contaminated.	Permanent human teeth	SBS	Saliva and water contamination reduced Embrace Wetbond® and Fluoroshield® SBS respectively.
Odabasi et al 2018²²	To evaluate the bond strength of two different resin-based crack sealants, Clinpro® or Fissurit Fx®, packed with Er: YAG laser and/or in vitro phosphoric acid.	G1: Clinpro®; G2: Fissurit Fx®. Subgroups: 1- Laser; 2- acid etching; 3- acid etching + laser.	Permanent human teeth	SBS	Observed a higher SBS for conventional preparation when compared with laser Er: YAG.
Pitchika et al 2018⁷	To evaluate the SBS of a new sealant compared to a conventional acid etching sealant.	G1: BeautiSealant Paste®; G2: Helioseal F®, control group.	Permanent human teeth	SBS	SBS decreased slightly in both groups after 3 months of water storage and significantly after 5,000 cycles of thermal cycling.
Memarpour et al 2019²	To investigate the efficacy of nano-HA in Clinpro® sealant to remineralize artificial caries lesions, comparing the SBS after nano-HA treatment.	G1: control group, acid etching; G2: nano-HA 0,15%; G3: nano-HA 0,03%; G4: nano-HA 0,15% + SHMP 0,05%; G5: nano-HA 0,03% + SHMP 0,01%.	Permanent human teeth	SBS	The higher concentration of nano-HA, 0.15%, led to the increased shear strength of the sealant compared to conventional application.
Zhang et al 2019¹⁴	To evaluate the influence of sub-pressure in the bonding of sealants before and after thermocycling.	G1: Concise® without sub pressure; G2: Concise® with sub pressure; G3: Helioseal F® without sub pressure; G4: Helioseal F® with sub pressure.	Permanent human teeth	SBS	Sub Pressure groups had a significantly higher SBS than specimens in groups without sub-pressure. Thermocycling decreased the SBS compared to non-aging specimens.
Çelik et al 2020³⁸	To compare the effects of laser and ozone pretreatment on the enamel surface for decontamination on SBS of three types of pit and fissure sealants.	G1: Nd:YAG laser; G2: ozone; G3: Control group. Subdivided into 3 groups according to the type of sealant: giomer, glass ionomer, and resin-based.	Permanent human teeth	SBS	The pretreatment reduced the SBS of glass ionomer and resin-based sealants compared to the control. There was no statistical difference between the types of pretreatment, and the resin-based sealants had the highest SBS value and glass ionomer sealants the lowest.
Cocco et al 2020³²	To evaluate pits and fissure sealants containing ZnM or SnM have been developed to achieve easy handling/ application and powerful anti-biofilm activity.	G1: Control; G2: ZnM 2.5%; G3: ZnM 5%; G4: SnM 2.5%; G5: SnM 5%.	Did not inform the type of teeth	µSBS	No statistical differences were observed in the µSBS of the experimental sealant when modified by ZnM and SnM.
Fei et al 2020²⁴	To develop the first pits and fissures sealant containing nCaF2 and DMAHDM, and investigate mechanical properties.	1) Helioseal F® (Commercial control); 2) 50% BT + 0% DMAHDM + 0% nCaF2+ 50% glass (Experimental control); 3) 45% BT + 5% DMAHDM + 0% nCaF2+ 50% glass; 4) 45% BT + 5% DMAHDM + 10% nCaF2+ 40% glass; 5) 45% BT + 5% DMAHDM + 15% nCaF2+ 35% glass; 6) 45% BT + 5% DMAHDM + 20% nCaF2+ 30% glass; 7) 45% BT + 5% DMAHDM + 25% nCaF2+ 25% glass.	Permanent human teeth	SBS	The 5% DMAHDM+20% nCaF2 group produced a bond strength similar to commercial control.
Garcia et al 2020¹⁵	To add METAC to the formulation of the sealants and check its influence on the properties.	G1: Control group, without METAC; G2: 2,5% of METAC; G3: 5% of METAC	Bovine teeth	µSBS	Adherence showed no statistical difference between groups with METAC.

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Table 1 continued:

<p>Ibrahim et al 2020³¹</p>	<p>To evaluate DMAHDM and NACPs compound pits and fissures sealants for their properties.</p>	<p>G1: Control, commercial sealant - Virtuoso®; G2: 0% DMAHDM and 0% NACPs- experimental control; G3: 5% DMAHDM and 0% NACPs; G4: 0% DMAHDM and 20% NACPs; G5: 5% DMAHDM and 20% NACPs.</p>	<p>Permanent human teeth</p>	<p>SBS</p>	<p>The sealant developed with the incorporation of 5% DMAHDM and 20% NaCPs did not alter the SBS when compared to the experimental control alone or associated.</p>
<p>Lo et al 2020²⁹</p>	<p>To evaluate the shear strength, SBS) of a sealing material, Helioclear F®, under the inclusion of different commonly recommended acid attack times, 15, 30, 45, and 60 s in a permanent tooth.</p>	<p>G1: etching for 15s; G2: etching for 30s; G3: etching for 45s; G4: etching for 60s. Subgroups: 1- prismatic enamel; 2- aprismatic enamel.</p>	<p>Permanent human teeth</p>	<p>SBS</p>	<p>No statistically significant differences between acid etching times for prismatic and aprismatic enamel.</p>
<p>Attar et al 2021³⁹</p>	<p>To evaluate the effects of Co-curing or Staged-curing adhesives compared to No-bonding on the adhesion of different pit and fissure sealants.</p>	<p>G1: Seal-it™; G2: Helioclear-F™; G3: Climpro™. Subdivided into: No-bonding; Staged-curing e Co-curing.</p>	<p>Permanent human teeth</p>	<p>SBS</p>	<p>The sealants that were applied with Staged-curing showed the best SBS results for Seal-it™ and Climpro™. Only Helioclear-F™ showed no difference with No-bonding. Co-cure had the lowest SBS values for all groups.</p>
<p>Bao et al 2021⁴⁰</p>	<p>To evaluate the SBS of contaminated and uncontaminated resin sealants with the variables of rinsing, reapplication of acid etching, and use of a universal adhesive.</p>	<p>G1: no contamination and stored for 24h; G2: no contamination and thermocycled; G3: contaminated and stored for 24h; G4: contaminated and thermocycled; G5: contaminated, rinsed and stored for 24; G6: contaminated, rinsed and thermocycled; G7: contaminated, Re-etching and stored for 24h; G8: contaminated, Re-etching and thermocycled; G9: contaminated, adhesive, stored for 24h; G10: contaminated, adhesive, thermocycled.</p>	<p>Permanent human teeth</p>	<p>SBS</p>	<p>Saliva contamination significantly reduced the SBS values. The storage for 24 hours showed better SBS for the G9 group, while the groups that were thermocycled, all showed a reduction in SBS, but the G8 group obtained better values compared to the G2 group.</p>
<p>Memarpour et al 2021⁴¹</p>	<p>To evaluate the SBS of saliva-contaminated and non-contaminated pit and fissure sealants.</p>	<p>G1: dry with Resin-based sealant; G2: dry with ACP-containing sealant; G3: dry with Glass ionomer-based sealant; G4: Saliva contamination removed by cotton pellet with Resin-based sealant; G5: Saliva contamination removed by cotton pellet with ACP-containing sealant; G6: Saliva contamination removed by cotton pellet with Glass ionomer-based sealant; G7: Saliva contamination removed by air-drying with Resin-based sealant; G8: Saliva contamination removed by air-drying with ACP-containing sealant; G9: Saliva contamination removed by air-drying with Glass ionomer-based sealant.</p>	<p>Permanent human teeth</p>	<p>SBS</p>	<p>The salivary contamination showed a reduction in the SBS of the three types of sealants evaluated. There was no statistical difference between drying the contamination with cotton pellets or air-drying.</p>

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Table 1 continued:

Beltrami et al 2022 ⁴²	To compare the adhesion of pit and fissure sealants on untreated and eroded enamel with self-adhesive systems.	G1: control; G2: etch-and-rinse technique; G3: immersed for 24 h in acid drink, acid etching, and self-adhesive technique; G4: immersed for 24 h in acid drink, acid etching, and adhesive, an etch-and-rinse technique.	Bovine teeth	SBS	There was a statistical difference between the groups, with higher SBS values in MPa for group G2 and similar results between groups G1, G3, and G4. Enamel with simulated erosion showed no significant effect on the SBS of sealants.
Ersan et al 2022 ⁴³	To evaluate the SBS of pit and fissure sealants in enamel prepared with Er, Cr:YSGG, CPP-ACP containing paste and sodium hypochlorite application.	G1: Er, Cr: YSGG laser + CPP-ACP + fissure sealant G2: Er, Cr: YSGG laser + fissure sealant G3: NaOCl + fissure sealant G4: NaOCl + CPP-ACP + fissure sealant G5: CPPACP + fissure sealant G6: fissure sealant (control group).	Deciduous teeth	SBS	The application of laser Er, Cr: YSGG did not affect the adhesive properties of sealants with results higher than the control and CPP-ACP showed no statistical difference with the control, maintaining the SBS. The NaOCl group showed a significant reduction in the SBS of the sealants.
Mézquita-Rodrigo et al 2022 ⁴⁴	To evaluate the SBS of pit and fissure sealants after enamel conditioning with different new-generation self-etching agents.	G1: Conventional etching Climpro™ G2: Conventional etching Teethmate F1™; G3: Self-etching BeautiSealant™; G4: Selfetching Climpro™; G5: Selfetching Teethmate F1™; G6: Self-etching BeautiSealant™ with BeautiBond™.	Permanent human teeth	SBS	The SBS was lower for groups G1 and G3, while although there was no statistical difference between them, groups G2, G4, G5, and G6 had the highest SBS values. Self-adhesive agents can be indicated for clinical use.
Sayeh et al 2022 ⁴⁵	To investigate the μ SBS of pit and fissure sealants applied with different techniques.	G1: acid etch + bonding + fissure sealant Clinpro™; G2: acid etch + Vertise Flow™; G3: Vertise Flow™.	Permanent human teeth	μ SBS	The group that did not have acid etching showed a reduction in SBS when compared to the groups that had the acid etching step.
Souza-Penha et al 2022 ⁴⁶	To evaluate the SBS of pit and fissure sealants with a self-conditioning system with pre-reacted glass.	G1: Fluroshield™; G2: BeautiSelant™.	Bovine teeth	SBS	The group with conventional acid etching G1 with phosphoric acid showed higher SBS than the self-etching group at both 24hrs and 30 days. After 30 days of storage, both sealants showed a reduction in SBS.
Kharouba et al 2023 ⁴⁷	To evaluate whether μ SBS of pit and fissure sealants in deciduous teeth is altered with decreasing enamel acid etching times.	G1: 8s; G2: 15s; G3: 30s	Deciduous teeth	μ SBS	Acid conditioning time had no statistically significant change in μ SBS of pit and fissure sealant.

APP, plasma treatment under atmospheric pressure; b-TCP, β tricalcium phosphate; DMAHDM, dimethylamino dodecyl methacrylate; EFP, experimental crack primer; METAC, [2-(methacryloyloxy)ethyl] trimethylammonium chloride; NACPs, amorphous calcium phosphate nanoparticles; nano-HA, nano-hydroxyapatite; nCaF₂, calcium fluoride nanoparticles; SBS, shear bond strength; SHMP, sodium hexametaphosphate; SnM, di-nbutyldimethacrylate-tin; ZnM, zinc methacrylate; Nd: YAG, Neodymium-doped yttrium aluminum garnet; ACP, amorphous calcium phosphate; CPP, Casein phosphopeptide; ACP, amorphous calcium phosphate; Er, Cr: YSGG, Erbium, chromium: yttrium-scandium-gallium-garnet; NaOCl, Hitherto sodium hypochlorite;

STUDY CHARACTERISTICS

Morphological Conditions

Chiang *et al.* and Lo *et al.* compared the influence of conditioning time in prismatic and aprismatic enamels in terms of adhesion by shear strength (SBS). Chiang *et al.* found higher SBS values

after conditioning with 37% phosphoric acid (conventional) for 60 seconds for the aprismatic enamel and for 30 seconds for the prismatic enamel. Lo *et al.*, on the other hand, found no statistically significant differences.^{17,29}

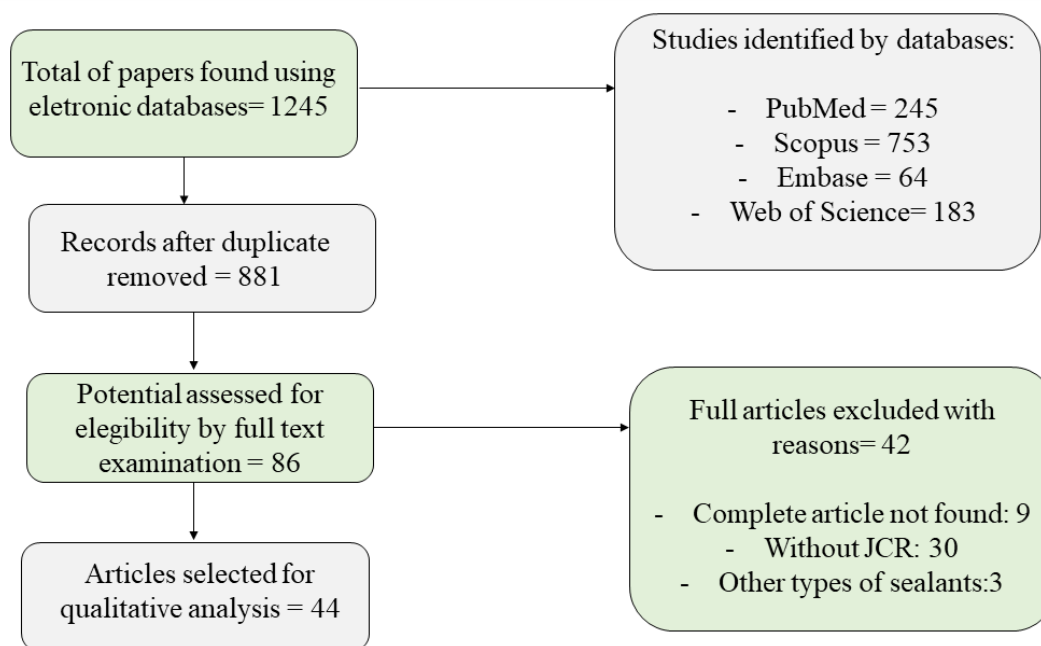


Figure 1: Flow diagram of literature search and selection criteria.

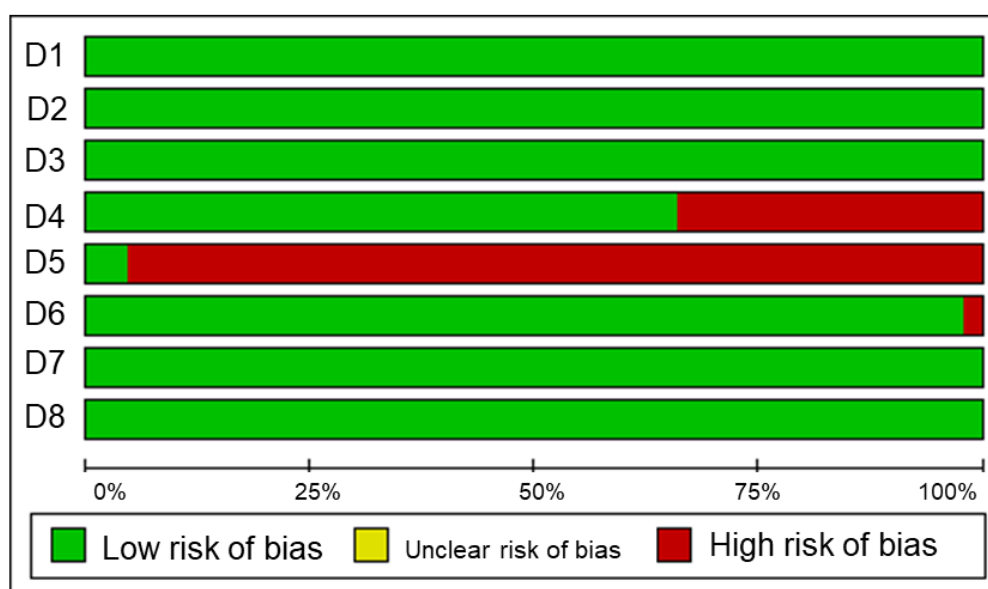


Figure 2: Qualitative analysis with adapted the quasi-experimental studies appraisal tool by the Joanna Briggs Institute. D1-Is it clear in the study what is the ‘cause’ and what is the ‘effect’; D2- Were the specimens included in any comparisons similar?; D3- Were the specimens included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?; D4- Was there a control group?; D5- Were there multiple measurements of the outcome both pre and post the intervention (surface treatment)?; D6- Were the outcomes of specimens included in any comparisons measured in the same way?; D7- Were outcomes measured in a reliable way?; D6- Was appropriate statistical analysis used?

Peutzfeldt *et al.* observed lower SBS values for deciduous teeth with Clear® sealant after conditioning with Prompt L-pop® and conventional when compared to the permanent ones.⁸

Beltrami *et al.* compared sealant adhesion on enamel, eroded or not, conditioned by an adhesive system, etch-and-rinse or self-adhesive. They observed that sealant adhesion was not significantly affected by erosion, with the best result attributed to the etch-and-rinse adhesive system on eroded enamel.⁴²

Substrate Preparation

Lepri *et al.* and Odabasi *et al.* observed a higher SBS for the conventional preparation when compared to the Er: YAG laser.^{4,22} Knobloch *et al.* and Moslemi *et al.* observed a higher SBS in the combination of air + conventional abrasion methods.^{5,10} Drummond *et al.* obtained a higher SBS for the conventional compared to the CO₂ laser, in addition to the developed primer promoting greater adhesion.¹⁸ In addition to Moslemi *et al.*, they observed no statistical difference for SBS between conventional Er: Cr YSGG lasers.⁵

Author et al. Year	D1	D2	D3	D4	D5	D6	D7	D8
Attar et al 2021	●	●	●	●	●	●	●	●
Bao et al 2022	●	●	●	●	●	●	●	●
Beltrami et al 2022	●	●	●	●	●	●	●	●
Biria et al 2014	●	●	●	●	●	●	●	●
Biribauer et al 2017	●	●	●	●	●	●	●	●
Castro et al 2004	●	●	●	●	●	●	●	●
Çelik et al 2020	●	●	●	●	●	●	●	●
Chiang et al 2016	●	●	●	●	●	●	●	●
Cocco et al 2020	●	●	●	●	●	●	●	●
Dereçlioglu et al 2014	●	●	●	●	●	●	●	●
Dewji et al 1998	●	●	●	●	●	●	●	●
Drummond et al 2000	●	●	●	●	●	●	●	●
Ellis et al 1999	●	●	●	●	●	●	●	●
Ersan et al 2022	●	●	●	●	●	●	●	●
Fei et al 2020	●	●	●	●	●	●	●	●
Fiorati-Aguiar et al 2018	●	●	●	●	●	●	●	●
Garcia et al 2020	●	●	●	●	●	●	●	●
Ibrahim et al 2020	●	●	●	●	●	●	●	●
Kharouba et al 2023	●	●	●	●	●	●	●	●
Knobloch et al 2005	●	●	●	●	●	●	●	●
Kucuklymaz et al 2016	●	●	●	●	●	●	●	●
Leprini et al 2008	●	●	●	●	●	●	●	●
Lo et al 2020	●	●	●	●	●	●	●	●
Marchesi et al 2012	●	●	●	●	●	●	●	●
Margvelashvili et al 2013	●	●	●	●	●	●	●	●
Memarpour et al 2019	●	●	●	●	●	●	●	●
Memarpour et al 2021	●	●	●	●	●	●	●	●
Mézquita-Rodrigo et al 2022	●	●	●	●	●	●	●	●
Moslami et al 2010	●	●	●	●	●	●	●	●
Ocabasi et al 2018	●	●	●	●	●	●	●	●
Peutzfeldt et al 2004	●	●	●	●	●	●	●	●
Pitchika et al 2018	●	●	●	●	●	●	●	●
Rirattanapong et al 2011	●	●	●	●	●	●	●	●
Sayeh et al 2022	●	●	●	●	●	●	●	●
Schuldt et al 2015	●	●	●	●	●	●	●	●
Schuldt et al 2016	●	●	●	●	●	●	●	●
Souza-Penha et al 2022	●	●	●	●	●	●	●	●
Stellini et al 2013	●	●	●	●	●	●	●	●
Tavassoli-Hojjati et al 2014	●	●	●	●	●	●	●	●
Teixeira et al 2015	●	●	●	●	●	●	●	●
Tulunoglu et al 1999	●	●	●	●	●	●	●	●
Wadenya et al 2009	●	●	●	●	●	●	●	●
Yamamoto et al 2003	●	●	●	●	●	●	●	●
Zhang et al 2019	●	●	●	●	●	●	●	●

Figure 3: Quantitative analysis with adapted the quasi-experimental studies appraisal tool by the Joanna Briggs Institute per studies. D1-Is it clear in the study what is the ‘cause’ and what is the ‘effect’; D2- Were the specimens included in any comparisons similar?; D3- Were the specimens included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?; D4-Was there a control group?; D5- Were there multiple measurements of the outcome both pre and post the intervention (surface treatment)?; D6- Were the outcomes of specimens included in any comparisons measured in the same way?; D7- Were outcomes measured in a reliable way?; D8- Was appropriate statistical analysis used?

Memarpour *et al.*, observed greater SBS when they prepared with 0.15% nano-HA (hydroxyapatite) compared to the conventional method.² Teixeira *et al.* observed greater resistance to microcutting (μ SBS) for the preparation with plasma under atmospheric pressure (APP) in relation to NaOH when conditioned by the conventional method.³³ Marchesi *et al.* observed that Ultraseal XT® and Concise® sealants when treated with or without ozone did not obtain SBS statistically different.¹⁹ Castro *et al.* observed greater SBS for preparations with drills, air abrasion and with Er: Cr YSGG laser when conditioned by the conventional method with Excite®.⁶

Çelik *et al.* reported a reduction of SBS of resin and ionomeric sealant on substrates prepared with Neodymium-doped yttrium aluminum garnet (Nd: YAG) laser and ozone compared to control.³⁸ Ersan *et al.* compared the effect of substrate preparation with Erbium laser, chromium: yttrium-scandium-gallium-garnet (Er, Cr: YSGG), Casein phosphopeptide - amorphous calcium phosphate (CPP-ACP) and Hitherto sodium hypochlorite (NaOCl) in different associations. They observed that Er, Cr: YSGG, and CPP-ACP did not affect adhesion, while the use of NaOCl reduced SBS.⁴³

Acid Conditioning and Adhesive System

Lo *et al.* observed through a linear regression analysis that the time of 60 seconds is greater than the times of 15, 30 and 45 seconds for promoting greater SBS.²⁹ Kharouba *et al.* observed that reducing the acid etching time to 8 seconds on deciduous teeth did not affect SBS.⁴⁷ Yamamoto *et al.* found that 10% polyacrylic acid had the lowest SBS values than 20% polyacrylic acid, 12% citric acid and 35% phosphoric acid, however conditioning results in an increase in SBS regardless of the conditioning agent.³⁴

Biria *et al.* and Schuldt *et al.* observed that conventional conditioning had higher μ SBS and SBS, respectively, than with Prompt L-pop®^{11,28} and Souza-Penha *et al.* observed that conventional acid etching shows better SBS compared to self-etchant at 24 h and 30 days after application.⁴⁶ While Peutzfeldt *et al.* found no statistical differences.⁸ Pitchika *et al.*, Stellini *et al.*, and Wadenya *et al.* observed that the self-etching sealants had lower SBS values than the conventional method.^{7,27,30} Mézquita Rodrigo *et al.* observed that SBS is directly proportional to the percentage of phosphoric acid used (32% or 40%) and that new-generation adhesive agents can be used without compromising adhesion on dental enamel.⁴⁴

Schuldt *et al.* observed that the association of self-etching sealant with pretreatment obtained a similar performance to the group with conventional pretreatment.³⁵ While Margvelashvili *et al.* obtained a higher SBS for the association of the methods.³ Attar *et al.* reported better SBS for sealants that performed the application of the adhesive system in stages compared to the self-adhesive and co-cure groups.³⁹

Contamination

Rirattanapong *et al.* observed that the presence of contamination reduces SBS mainly in the ionomeric sealant Fuji VII® when compared with the resinous Concise™ and Clinpro™.⁹ Fiorati-Aguiar *et al.* observed that contamination by saliva and water reduced the SBS of Embrace Wetbond® and Fluorshield® respectively.¹⁶

Leprini *et al.* found that salivary contamination affects the SBS of sealants regardless of conventional preparation and Er: YAG laser, which showed the lowest values.⁴ Tulunoglu *et al.* observed that the presence of salivary contamination decreases SBS regardless of the type of adhesive used.²⁶

Memarpour *et al.* reported that salivary contamination reduced SBS, even when using the cotton pallet drying and air-drying protocols.⁴¹ Bao *et al.* reported reduced SBS with salivary contamination and pointed out that under contaminated conditions, re-etching may increase SBS when compared to re-application of the adhesive or rinsing.⁴⁰

Aging

Pitchika *et al.*, Chiang *et al.*, Birlbauer *et al.*, and Zhang *et al.* found that after 5000 cycles of thermocycling the SBS was lower for Heliobond F®.^{7,14,17,21} And Schuldt *et al.* found that Constic® has the lowest SBS regardless of time and Heliobond F® with conventional conditioning had the lowest in 1 day and 3 months.³⁵

The Delton® sealant analyzed by Ellis *et al.* demonstrated average values of SBS stored 72h after conventional conditioning, while the association of the conventional with air abrasion showed greater adhesion and stability in 120 days stored followed by 800 cycles of thermocycling.³⁷

Comparison Between Sealants

Dewji *et al.* observed that the ionomeric sealant modified by Fuji III LC® resin showed higher SBS compared to Delton Opaque® and Fuji III Self Cure® when associated with 10% polyacrylic acid, while Derelioglu *et al.* found greater adhesion to Grandio seal® in compared to Fuji Triage Capsule® and Vertise Flow® when associated with the conventional method.^{20,36} Kucukyilmaz *et al.* observed that the Fuji VII EP® sealant had a higher SBS compared to Fuji Triage® and GCP Glass Seal®.²⁵ Sayeh *et al.* reported that there is no statistical difference in SBS between Climpro® and Vertise flow®.⁴⁵

Innovation

Garcia *et al.* observed that there were no statistically significant differences for μ SBS of the developed sealant (control) and with incorporation of 2.5% and 5% of 2- (methacrylononyloxy) ethyl] trimethylammonium chloride (METAC).¹⁵

Tavassoli-Hojjati *et al.* observed the absence of statistical differences in the μ SBS between the control group (experimental), Concise® and in the experimental group with incorporation of β -tricalcium phosphate nanoparticles (β -TCP-NPs).²³ Cocco *et al.*, on the other hand, did not observe statistical differences in the μ SBS of the experimental sealant when modified by zinc methacrylate (ZnM) and tin di-n-butyl methacrylate (SnM).³²

Ibrahim *et al.* observed that the sealant developed with the incorporation of 5% of dimethylaminohexadecyl methacrylate (DMAHDM) and 20% of amorphous calcium phosphate nanoparticles (NaCPs) did not alter the SBS when compared to the experimental control alone or in association.³¹

Fei *et al.* observed that the combination of 5% DMAHDM + 20% nCaF₂ to the experimental sealant presented SBS similar to the commercial control group Heliobond F®.²⁴

DISCUSSION

In order to solve the gaps still present in the literature regarding the adhesion of sealants to the dental substrate, the following question “Do pit and fissure sealants present good adhesion to the dental structure when analyzed for their shear / microshear resistance?” Directed the systematic review due to the success of the preventive treatment with pit and fissure sealants being directly associated with its resistance to adhesion. Thus, it aimed to critically analyze the included *in vitro* studies^{2-11,14-47} most well designed with low risk of bias for some of the questions adapted from evaluation tool for quasi-experimental studies from JBI (quasi-experimental studies (non-randomized experimental studies) from the Joanna Briggs Institute), however, the results were interpreted with caution for those studies with a high risk of bias, in addition to the impossibility of accomplishing a goal-analysis due to the heterogeneity of the included studies.

Regarding the morphological condition of the substrate, biases are found between the clinical condition of application of the sealants, aprismatic enamel, in relation to the laboratory ones, prismatic enamel, a fact justified by the need for the standardization of the surface *in vitro*, making it flat, through superficial treatments that remove the aprismatic layer providing them with less resistance to acid conditioning as reported by Chiang *et al.*¹⁷ and Lo *et al.*,²⁹ so special attention must be given by clinicians to the conditioning time.^{17,29,48} Kharouba *et al.* reported that for deciduous teeth acid etching for 8 seconds promoted acceptable SBS and suggested the indication of this protocol for uncooperative children with the advantage of being a fast procedure and lower risk of salivary contamination.⁴⁷ With regard to deciduous teeth in the study by Peutzfeldt *et al.*, even after the standardization of the samples, an aprismatic layer remained, which affected the SBS, a fact justified by the selected region being the cervical one,⁸ attributed to dental enamel presenting anisotropy and the direction and morphology of the prisms and dentinal tubules influence the adhesion of sealants with the dental structure according to the review by Mourad *et al.*⁴⁹

Beltrami *et al.* observed that there is no significant difference in the SBS of sealants in eroded and healthy enamel, justified by the surface erosion associated with the adhesive system acting synergistically on sealant adhesion.⁴² It was observed in this systematic review the use of different types of teeth such as bovine,^{15,18,19,34,36,42,46} permanent human^{2-7,9,11,14,16,17,20-25,27-31,33,35,37-41,44,45} and deciduous,^{8,10,26,43,47} a factor that may contribute to the divergence of results since bovine teeth diverge from human ones by presenting larger dentin tubules that favor sealant adhesion. Regarding human teeth, third molars were the most investigated,^{2,4,7,9,11,16,17,21,22,24,28-30,35,38,40,41,44} it is noteworthy that their morphology may affect the clinical representation of the results since they are more permeable than erupted and restored teeth that present sclerotic dentin and therefore are more resistant to acid etching.⁴⁹

One way to increase adherence is the preparation on the dental surface, conditioning with phosphoric acid is the conventional method used as a standard to compare techniques. This promotes the removal of the smear layer and creates a uniform micro-retentive pattern, due to the selective dissolution and removal of the hydroxyapatite crystals, which favors the penetration of the material in the micropores.⁴

The conventional method provides a greater SBS than preparations with Er: YAG laser, since the second causes the vaporization of water and dental organic components with consequent micro-explosive destruction of inorganic substances, in which the intra and interprismatic spaces are blocked, restricting the diffusion of the material.^{4,22,50} The lower SBS obtained with the use of the CO₂ laser, reported by Drummond *et al.*, can be explained by the lower surface energy after the laser application, in addition to the decrease in the amount of water present, which makes it difficult for the sealant to penetrate.¹⁸ Çelik *et al.* inferred that preparation with Nd: YAG laser promoted chemical and morphological changes in the tooth structure, which increased the distribution of oxygen, calcium, and phosphorus, which makes the substrate more resistant to acid etching.³⁸ On the other hand, Ersan *et al.* when applying the Er, Cr: YSSG laser found no reduction in sealant adhesion, for unjustified reasons.⁴³

The systematic review conducted by Lopes *et al.* reports that there is no definite consensus on the influence of lasers in substrate preparation on the SBS of sealants, even if potency, exposure, and wavelength parameters are well defined. The authors also point out that the acid etching step should not be ignored since the association of methods tends to present better SBS.⁵¹

The association of air abrasion + acid conditioning promoted greater SBS in the studies by Knobloch *et al.* and Moslemi *et al.* due to air abrasion increasing macroscopic roughness, eliminate organic material from the fissures and make the enamel surface more reactive to the acid etching it promotes the formation of micropores justified by the increase in surface area and strength of adhesion.^{5,10,52} Preparations with innovative techniques, such as nano-HA and APP also showed improvement in the SBS of the sealants, because the hydroxyapatite promotes the creation of a reactive layer between the sealant and the nano-HA, while the APP increases the surface energy of the substrate allowing an interaction more intimate with the material.^{2,33}

The preparation of the substrate with ozone can impair the polymerization of the sealants and consequently their adhesion, as it is an oxidizing material and reacts with the monomer radicals as observed in the study by Çelik *et al.*³⁸ However, Merchesi *et al.*, when using a drying agent, PrimaDry®, obtained better penetration of the sealants and no change in adhesion.¹⁹

The use of self-etching adhesives and sealants has increased in recent years as they allow for a reduction in clinical time and practical application. However, we can infer through this

systematic review, that the self-etchers provide less adhesion than the conventional method, due to the simultaneous application of the conditioner and primer to decrease the depth of surface demineralization with consequent less penetration of the sealants.^{11,27,28,44,46} Souza-Penha *et al.* reported that the SBS of substrates conditioned conventional adhesive system was higher than the self-etching ones after 24hrs and 30 days, justified by the low pH (2.3) of the phosphoric acid of the conventional adhesive system inducing higher microporosity.^{46,53}

The adhesion of sealants can be affected by contaminants present in the oral cavity, so the proper control of saliva, through the isolation of the operative field is essential. Lepri *et al.*, Tulunoglu *et al.*, Rirattanapong *et al.*, Memarpour *et al.* and Bao *et al.*, reported reduced adhesion of sealants due to salivary contamination justified by the formation of an organic film on conditioned surfaces, which promotes the obliteration of formed micropores, impairing the bonding of sealants.^{8,9, 26,40,41} Memarpour *et al.* evaluated different methods to minimize the effects of contamination, cotton pallet drying, and air drying. They observed that the cotton pallet technique was the best, because it eliminated from the microporosities, besides the humidity, salivary proteins that are not removed by air drying.⁴¹

The success of a treatment with sealants is clinically evaluated for its durability and effectiveness, already *in vitro* by the thermocycling test, which simulates changes in the temperature of the oral cavity. Chiang *et al.* emphasize that the thermocycling of 5000 cycles should be standardized as an ideal test to evaluate the aging of sealants, as it represents more faithfully the changes present in the oral cavity. It should be noted that storage in water causes instability and hydrolysis of the monomers while thermocycling shows the thermal performance of the sealants.^{14,17,35,37}

Conditioning with 10% polyacrylic acid for the application of the Fuji III LC® resin-modified ionomeric sealant promotes a surface with more micropores compared to 20% polyacrylic acid + 3% aluminum chloride, so the increase in SBS resulted from the association of mechanical, micropore, and chemical characteristics, polar / ionic bonding, promoted by the particles of the glass ionomer cement present in the formulation.³⁶ The comparison of ionomeric sealants modified by Fuji VII EP® resin, Fuji Triage® and GCP Glass Seal® performed by Kucukyilmaz *et al.* demonstrated that the Fuji VII EP® sealant presented a higher SBS due to the incorporation of casein phosphopeptide – amorphous calcium phosphate (CPP -ACP) (1-5%).²⁵ The self-etching sealant, Vertise Flow®, contains a higher pH compared to 37% phosphoric acid, which promotes a surface with fewer micropores with consequent reduced SBS, due to less penetration of the material.²⁰

In this systematic review we analyze the innovations applied to the sealants and their consequent influences on the mechanical property of shear strength and micro shear. The evaluated studies aimed to incorporate the antimicrobial agents METAC,²¹ β-TCP-NPs,²³ ZnM and SnM,²⁴ BMAHDM^{24,31} to the sealants and showed no change in adhesion and suggested

that these materials developed can be used as a potential material in the prevention of caries disease due to its antimicrobial properties.^{15,23,24,31,32}

The qualitative analysis of the included studies allowed to infer that: 1) The standardization of the samples *in vitro* studies interferes with the resistance to the adhesion creating biases between the clinical and laboratory conditions, so special attention must be given by the clinicians to the conditioning time; The association of air abrasion + acid conditioning methods showed better SBS results; 2) The conventional method of conditioning with phosphoric acid 37% is the most used and presents the best adhesion results; 3) Salivary contamination reduces SBS by promoting the formation of an organic film on conditioned surfaces, which obliterates the formed micropores, impairing the bonding of sealants; 4) Thermocycling with 5000 cycles is the ideal test to assess the aging of sealants, as it faithfully represents the changes present in the oral cavity; 5) The innovative sealants showed no change in adhesion and improved preventive capacity by the addition of antimicrobial agents.

This systematic review had limitations due to the fact that it evaluated *in vitro* studies that showed wide heterogeneity, thus, it suggests to researchers that they develop randomized clinical studies so that it can be evaluated the adhesion of pit and fissure sealants in a faithful way.

CONCLUSION

The question “Do pit and fissure sealants present good adhering to the dental structure when analyzed by their resistance to shear/microshear?” can be answered through the critical analysis of the studies included in this systematic review, and it can be inferred that the adhesion of pits and fissures are dependent on the application protocol, substrate morphological condition and changes in composition, which directly interfere with its longevity.

REFERENCES

- Borges, B.C.D., Souza-Júnior, E.J., Catelan, A., Lovadino, J.R., Dos Santos, P.H., Paulillo, L.A.M.S., et al. Influence of extended light exposure time on the degree of conversion and plasticization of materials used as pit and fissure sealants. *J Investig Clin Dent*. 2010; **1**:151–155.
- Memarpour, M., Shafiei, F., Rafiee, A., Soltani, M. and Dashti, M.H. Effect of hydroxyapatite nanoparticles on enamel remineralization and estimation of fissure sealant bond strength to remineralized tooth surfaces: An *in vitro* study. *BMC Oral Health*. 2019; **19**:1–13.
- Margvelashvili, M., Vichi, A., Carrabba, M., Goracci, C. and Ferrari, M. Bond strength to unground enamel and sealing ability in pits and fissures of a new self-adhering flowable resin composite. *J Clin Pediatr Dent*. 2013; **37**:397–402.
- Lepri, T.P., Souza-Gabriel, A.E., Atoui, J.A., Palma-Dibb, R.G., PÉcora, J.D., and Milori Corona, S.A. Shear bond strength of a sealant to contaminated-enamel surface: Influence of erbium : Yrnet laser pretreatment. *J Esthet Restor Dent*. 2008; **20**:386–392.
- Moslemi, M., Erfanparast, L., Fekrazad, R., Tadayon, N., Dadjo, H., Shadkar, M.M., et al. The effect of Er,Cr:YSGG laser and air abrasion on shear bond strength of a fissure sealant to enamel. *J Am Dent Assoc*. 2010; **141**:157–161.
- Camacho, L., Ana, C. and Galvão, C. Improvement of Sealant Retention 2004; **28**:1–4.
- Pitchika, V., Birlbauer, S., Chiang, M.L., Schuldt, C., Crispin, A., Hickel, R., et al. Shear bond strength and microleakage of a new self-etch adhesive pit and fissure sealant. *Dent Mater J*. 2018; **37**:266–271.
- Peutzfeldt, A. and Nielsen, L.A. Bond strength of a sealant to primary and permanent enamel: Phosphoric acid versus self-etching adhesive. *Pediatr Dent*. 2004; **26**:240–244.
- Rirattanapong, P., Vongsavan, K. and Surarit, R. Shear bond strength of some sealants under saliva contamination. *Southeast Asian J Trop Med Public Health*. 2011; **42**:463–467.
- Knobloch, L.A., Meyer, T., Kerby, R.E. and Johnston, W. Microleakage and bond strength of sealant to primary enamel comparing air abrasion and acid etch techniques. *Pediatr Dent*. 2005; **27**:463–469.
- Schuldt, C., Birlbauer, S., Pitchika, V., Crispin, A., Hickel, R. and Kühnisch, J. Shear bond strength and microleakage of a self-etching adhesive for fissure sealing after different types of aging. *Dent Mater J*. 2016; **35**:490–497.
- Tufanaru, C., Munn, Z., Aromataris, E. and Campbell, J.H.L. Chapter 3: systematic reviews of effectiveness. In: Aromataris, E., Munn, Z., editors. *Joanna Briggs Institute reviewer’s manual*. The Joanna Briggs Institute; 2017.
- Gama, L.T., Duque, T.M., Özcan, M., Philippi, A.G., Mezzomo, L.A.M. and Gonçalves, T.M.S.V. Adhesion to high-performance polymers applied in dentistry: A systematic review. *Dent Mater*. 2020; **36**:e93–108.
- Zhang, C., Li, Y., Zhang, Z., Tian, Y., Ding, N. and Ma, Y. Improvement of Pit-and-Fissure Sealant Bonding to Enamel with Subpressure Treatment. *Biomed es Int*. 2019; **2019**:5070383.
- Garcia, I.M., Rodrigues, S.B., de Souza Balbinot, G., Visioli, F., Leitune, V.C.B. and Collares, F.M. Quaternary ammonium compound as antimicrobial agent in resin-based sealants. *Clin Oral Investig*. 2020; **24**:777–784.
- Fiorati-Aguiar, S.M., Lucisano, M.P., Silva, L.A.B.D., Silva, R.A.B.D., Spadaro, A.C.C., Borsatto, M.C. and Nelson-Filho, P. Mechanical, chemical and antimicrobial properties of a bisphenol A-free pit-and-fissure sealant. *Am J Dent*. 2018; **31**:279–284.
- Chiang, M.L., Birlbauer, S., Lo, Y.F., Pitchika, V., Crispin, A., Ilie, N., et al. Which factors influence the shear bond strength of sealant materials? *J Adhes Dent*. 2016; **18**:397–404.
- Drummond, J.L., Wigdor, H.A., Walsh, J.T., Fadavi, S. and Punwani, I. Sealant bond strengths of CO₂ laser-etched versus acid-etched bovine enamel. *Lasers Surg Med*. 2000; **27**:111–118.
- Marchesi, G., Petris, L.C., Navarra, C.O., Locatelli, R., Di Lenarda, R., Breschi, L., et al. Effect of ozone application on the immediate shear bond strength and microleakage of dental sealants. *Pediatr Dent*. 2012; **34**:284–288.
- Simsek Derehlioglu, S., Yilmaz, Y., Celik, P., Carikcioglu, B. and Keles, S. Bond strength and microleakage of self-adhesive and conventional fissure sealants. *Dent Mater J*. 2014; **33**:530–538.
- Birlbauer, S., Chiang, M.L., Schuldt, C., Pitchika, V., Hickel, R., Ilie, N., et al. Shear bond strength and microleakage results for three experimental self-etching primer compositions for pit and fissure sealing. *Clin Oral Investig*. 2017; **21**:1465–1473.

22. Odabasi, D., Oruc, E. and Duruk, G. The effectiveness of erbium: Yttrium-aluminum-garnet laser on enamel conditioning: An *in vitro* study. *Niger J Clin Pract.* 2018; **21**:1317–1322.
23. Tavassoli-Hojjati, S., Atai, M., Haghgoo, R., Rahimian-Imam, S., Kameli, S., Ahmaian-Babaki, F., et al. Comparison of various concentrations of tricalcium phosphate nanoparticles on mechanical properties and remineralization of fissure sealants. *J Dent (Tehran).* 2014; **11**:379–388.
24. Fei, X., Li, Y., Weir, M.D., Baras, B.H., Wang, H., Wang, S., et al. Novel pit and fissure sealant containing nano-CaF₂ and dimethylaminohexadecyl methacrylate with double benefits of fluoride release and antibacterial function. *Dent Mater.* 2020; **36**:1241–1253.
25. Kucukyilmaz, E. and Savas, S. Evaluation of shear bond strength, penetration ability, microleakage and remineralisation capacity of glass ionomer-based fissure sealants. *Eur J Paediatr Dent.* 2016; **17**:17–23.
26. Tulunoğlu, Ö., Bodur, H., Üçtaşlı, M. and Alaçam, A. The effect of bonding agents on the microleakage and bond strength of sealant in primary teeth. *J Oral Rehabil.* 1999; **26**:436–441.
27. Wadenya, R.O., Yego, C., Blatz, M.B. and Mante, F. Bond strength and microleakage of a new self-etch sealant. *Quintessence Int.* 2009; **40**:559–563.
28. Biria, M., Ghasemi, A., Torabzadeh, H., Shisheian, A. and Baghban, A.A. Assessment of Microshear Bond Strength: Self-Etching Sealant versus Conventional Sealant. *J Dent (Tehran).* 2014; **11**:137–142.
29. Lo, Y.F., Pitchika, V., Ilie, N., Hickel, R. and Kühnisch, J. Does etching time affect the *in vitro* performance of a sealant material? *Dent Mater J.* 2020; **39**:862–868.
30. Stellini, E., De Francesco, M., Arenti, M., Gracco, A., Berengo, M., Simonato, F., et al. *In vitro* comparison of the bond strength to the enamel of conventional and self-etching dental fissure sealants. *Eur J Paediatr Dent.* 2014; **14**:319–322.
31. Ibrahim, M.S., Balhaddad, A.A., Garcia, I.M., Hefni, E., Collares, F.M., Martinho, F.C., et al. Tooth sealing formulation with bacteria-killing surface and on-demand ion release/recharge inhibits early childhood caries key pathogens. *J Biomed Mater Res - Part B Appl Biomater.* 2020; **108**:3217–3227.
32. Cocco, A.R., Cuevas-Suárez, C.E., Liu, Y., Lund, R.G., Piva, E. and Hwang, G. Anti-biofilm activity of a novel pit and fissure self-adhesive sealant modified with metallic monomers. *Biofouling.* 2020; **36**:245–255.
33. Teixeira, H.S., Coelho, P.G., Duarte, S., Janal, M.N., Silva, N. and Thompson, V.P. Influence of atmospheric pressure plasma treatment on mechanical properties of enamel and sealant bond strength. *J Biomed Mater Res - Part B Appl Biomater.* 2015; **103**:1082–1091.
34. Yamamoto, K., Kojima, H., Tsutsumi, T. and Oguchi, H. Effects of tooth-conditioning agents on bond strength of a resin-modified glass-ionomer sealant to enamel. *J Dent.* 2003; **31**:13–18.
35. Schuldt, C., Birlbauer, S., Pitchika, V., Crispin, A., Hickel, R. and Ilie, N.K.J. Shear Bond Strength and Microleakage of a New Self-etching/Self-adhesive Pit and Fissure Sealant. *J Adhes Dent.* 2015; **17**:491–497.
36. Dewji, H.R., Drummond, J.L., Fadavi, S. and Punwani, I. Bond strength of Bis-GMA and glass ionomer pit and fissure sealants using cyclic fatigue. *Eur J Oral Sci.* 1998; **106**:594–599.
37. Ellis, R.W., Latta, M.A. and Westerman, G.H. Effect of air abrasion and acid etching on sealant retention: an *in vitro* study. *Pediatr Dent.* 1999; **21**:316–319.
38. Çelik, N., Yapar, M.I., Karalar, B. and Kılıç, M. Influence of Laser and Ozone Pretreatment on the Shear Bond Strength of Fissure Sealants: An *In Vitro* Comparative Study. *J Advan O Res.* 2020; **11**:189-195.
39. Attar MH, Abdallah MA, Alharthy HA, El Meligy OA. Effect of Bonding Agent on Retention of Different Sealants: An *in Vitro* Study. *J Clin Pediatr Dent.* 2021 Jul 1; **45**(3):177-185. doi: 10.17796/1053-4625-45.3.6
40. Bao, Z., Sun, H., Fan, D., Wang, X. and Wang, Q. Shear Bond Strength and Microleakage of Pit and Fissure Sealants Placed after Saliva-Contaminated Etched Enamel. *Coatings.* 2022; **12**:441.
41. Memarpour, M., Rafiee, A., Shafiei, F., Doruzizadeh, T. and Kamran, S. Adhesion of three types of fissure sealant in saliva-contaminated and noncontaminated conditions: an *in vitro* study. *Eur Arch Paediatr Dent.* 2021; **22**:813-821.
42. Beltrami, R., Colombo, M., Cavada, A., Panizzi, S., Poggio, C. and Scribante, A. Influence of Enamel Exposure to Acidic Drink on Shear Bond Strength of Different Fissure Sealants. *Bioengineering (Basel).* 2022; **9**:20.
43. Ersan, Z., Yazicioglu, I., Serin, A.B. and Dogan, M.C. The effects of disinfection with Er, Cr:YSGG laser, application of CPP-ACP and sodium hypochlorite on shear bond strength. *Niger J Clin Pract.* 2022; **25**:1949-1954.
44. Mézquita-Rodrigo, I., Scougall-Vilchis, R.J., Moyaho-Bernal, M.A., Rodríguez-Vilchis, L.E., Rubio-Rosas, E. and Contreras-Bulnes, R. Using self-etch adhesive agents with pit and fissure sealants. *In vitro* analysis of shear bond strength, adhesive remnant index and enamel etching patterns. *Eur Arch Paediatr Dent.* 2022; **23**:233-241.
45. Sayeh, R., Sara, R.E. and Saide, N. Evaluating micro shear bond strength of two different materials in permanent teeth. *Medi Scien.* 2022; **26**:ms138e1893.
46. Souza Penha, K.J., Oliveira Roma, F.R.V., Jansen Dos Santos, M., Soares do Couto, G.A. and Firoozmand, L.M. *In vitro* and *in vivo* performance of self-conditioning sealants with pre-reacted glass for caries prevention. *J Mech Behav Biomed Mater.* 2022; **133**:105304.
47. Kharouba, J., Gonoratsky, A.A., Brosh, T., Masri, M., Iraqi, R. and Blumer, S. Effect of Different Etching Times on Pit-and-Fissure Sealant Micro-Shear Bond Strength to the Enamel of Primary Teeth. *Children.* 2023; **10**:461.
48. Reis, A.F., Aguiar, F.H. and Pereira, P.N. and Giannini, M. Effects of surface texture and etching time on roughness and bond strength to ground enamel. *J Contemp Dent Pr.* 2009; **10**:17–25.
49. El Mourad, A.M. Assessment of Bonding Effectiveness of Adhesive Materials to Tooth Structure using Bond Strength Test Methods: A Review of Literature. *Open Dent J.* 2018; **12**:664-678.
50. Shahabi, S., Bagheri, H.G. and Ramazani, K. Tensile bond strength of sealants following Er:YAG laser etching compared to acid etching in permanent teeth. *Lasers Med Sci* 2012; **27**:371–375.
51. Lopes, R.M., Trevelin, L.T., da Cunha, S.R., de Oliveira, R.F., de Andrade Salgado, D.M., de Freitas, P.M., de Paula Eduardo, C. and Aranha, A.C. Dental Adhesion to Erbium-Lased Tooth Structure: A Review of the Literature. *Photomed Laser Surg.* 2015; **33**:393-403.
52. Bagherian, A. and Sarraf Shirazi, A. Preparation before acid etching in fissure sealant therapy: yes or no?: A systematic review and meta-analysis. *J Am Dent Assoc.* 2016; **147**:943-951.
53. David, C., Cardoso de Cardoso, G., Isolan, C.P., Piva, E., Moraes, R.R. and Cuevas-Suarez, C.E. Bond strength of self-adhesive flowable composite resins to dental tissues: A systematic review and meta-analysis of *in vitro* studies. *J Prosthet Dent.* 2022; **128**:876-885.