REVIEW ARTICLE

Reinforced Immediate Dentin Sealing vs Conventional Immediate Dentin Sealing on Adhesive Behavior of Indirect Restorations: A Systematic Review

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Abstract

Aim: The aim of this systematic review is to compare the bonding performance of indirect restoration with the reinforced immediate dentin sealing (IDS) method as opposed to the conventional IDS method.

Materials and methods: A literature search was conducted in PubMed, Cochrane, and EBSCOHost up to January 31st 2022, accompanied by a hand search in Google Scholar. Inclusion criteria involved studies comparing conventional IDS and reinforced IDS protocol and evaluating various parameters influencing the bonding performance, such as type of indirect restoration, etching protocol, cavity design, tooth surface preparation, method of oral cavity simulation, and processing after luting. The quality of six included studies was appraised using CRIS guidelines.

Results: A total of 29 publications was identified, and 6 of them fulfilled the inclusion criteria. All of the included studies were *in vitro* studies. The predetermined data were independently extracted and evaluated by four reviewers. It was observed that most of the studies showed an improvement in bond strength with reinforced IDS when compared with conventional IDS. Also, etch-and-rinse and 2-step self-etch adhesive protocols have shown better bonding performance than universal adhesive systems.

Conclusion: Reinforced IDS has similar or better bond strength to that of conventional IDS strategies. The need for prospective studies is highlighted. The future clinical studies for immediate dentin sealing ought to be reported in a uniform and methodological way.

Clinical significance: Application of an additional layer of low-viscosity resin composite provides a thicker adhesive layer, prevents re-exposure of dentin during the final restoration, and allows a smoother preparation in lesser clinical chair time and eliminates any possible undercuts. Thus, reinforced IDS has shown to result in better preservation of the dentinal seal than IDS technique.

Keywords: Bond strength, Indirect restorations, Reinforced immediate dentin sealing, Resin coating technique.

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Introduction

The success of partial ceramic restorations primarily relies on the good adhesion to enamel and dentin. Indirect restoration attributes of postoperative sensitivity, thereby resulting in bacterial infiltration during cavity preparations, as significant removal of dentin leads to increased dentinal tubule exposure during cavity preparation.[1] The overall potency of an indirect restoration–tooth complex depends on the quality and quantity of the remaining tooth enamel and the quality of the adhesive procedure.

The tooth prepared for indirect restoration in the meanwhile is restored with a short-term filling material to protect the intact and recently cut dentin until the ultimate prosthesis is fabricated and luted with a dental adhesive. However, the poor seal ability of the temporary filling material has been shown to increase microleakage and postoperative sensitivity.[2] In case of such delayed dentin sealing (DDS), the presence of temporary filling can impede the final bonding of the indirect restoration with the dentin adhesive. So, IDS was introduced as an achievable adhesive mechanism for indirect prosthesis to enhance their adhesion to dentin. The huge disparity between these two techniques lies as a matter of fact that the traditional IDS strategy involves application of a dentin bonding agent on freshly cut dentin. In contrast, in the DDS, the tooth preparation is coated with an adhesive resin layer just before luting the restoration. Immediate dentin sealing procedure minimizes the postoperative sensitivity and gap formation post cementation, thereby reducing bacterial invasion[3] and reinforcing the tooth structure, improving their clinical performance and survival rates.[4–6]

An adequate resin-to-resin bond between the new luting composite resin and the adhesive resin coating is assured in case of IDS, which might be attributed to the fact that freshly prepared dentin is more permeable for the penetration of the bonding agent deeper, resulting in better bonding.[7] However, IDS had a few drawbacks, such as the pooling of adhesive into tooth preparation margins, and inadequate polymerization of those pooled resins could interfere with the polymerization of impression materials. Moreover, cleaning the preparation prior to the final delivery of

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the crown might induce the possibility of removal of the existing thin adhesive layer and re-revealing the dentin.[4]

The reinforced immediate dentin sealing approach (reinforced IDS or R-IDS) was introduced to overcome the disadvantages of the conventional IDS technique. Reinforced IDS involves the application of low-viscosity composite resin (LVCR) in addition to the adhesive layer above, which is said to reduce the gap formation between the resin/cement and dentin interface, improving the bond strength. With this technique, the increase in bond strength of the luting material can also help in increasing the fracture strength of the restorative material.[8] Moreover, this acts as a flexible layer between the prosthesis and dentin, consuming the tension created by the resin cement during polymerization shrinkage and masticatory forces.[9] Furthermore, applying an additional layer of LVCR provides a thicker adhesive layer that not only prevents re-exposing of the dentin during the final restoration but also allows for a smooth preparation in shorter chair time and eliminates any possible undercuts. With the reinforced IDS approach, the hybridized dentin gets strengthened showing a possible increase in the dentin bond strength.[4] However, there is very limited evidence on comparing the conventional IDS approach and reinforced IDS approach that urged the need for conducting this systematic review.

Thus, the present systematic review intends to compare the bonding performance of indirect restoration with the reinforced IDS method as opposed to the conventional IDS method.

Materials and Methods

Review Question

According to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines,[10] the focused review question constructed was "Does the Reinforced IDS approach improve the bond strength of indirect restorations when compared to the conventional IDS approach"?

The PICOS question for the systematic review was:

- Population (P) – teeth requiring indirect restorations
- Intervention (I) – reinforced immediate dentin sealing
- Comparison (C) – conventional immediate dentin sealing
- Outcome (O) – bond strength assessment
- Study design (S) – *In vitro* studies

Eligibility Criteria

Articles were chosen to be included in this systematic review after passing the inclusion and exclusion criteria. The inclusion criteria for evaluating the eligibility included: (a) studies in English, (b) studies evaluating bonding performance in indirect restorations, and (c) studies comparing conventional IDS and reinforced IDS. The exclusion criteria included: (a) studies comparing only conventional IDS and DDS, (b) studies involving direct restorations, (c) studies conducted on primary dentition, (d) review articles, case reports, conference abstracts, clinical trials, and animal studies, and (e) languages other than English.

Search Methods for Identification of Studies

Electronic Searches

An exhaustive literature exploration was performed using succeeding databases such as PubMed, Cochrane Library, EBSCOhost databases, and also hand search in addition with Google Scholar from January 1st 2003 to January 31st 2022.

Search Terms

"Immediate dentin sealing" OR "IDS" OR "Dentin prebonding" OR "Dentin treated with adhesive".

"Reinforced immediate dentin sealing" OR "Reinforced-IDS" OR "Resin coating technique" OR "Reinforcement of dentin adhesive with flowable composite" OR "Immediate dentin sealing followed by flowable composite resin" OR "Immediate dentin sealing with low viscosity composite" OR "Dentin treated with an adhesive and low-viscosity composite."

"Bond strength" OR "Bonding performance" OR "Improvement in bond strength" OR "Tensile bond strength" OR "Micro-tensile bond strength" OR "Micro-TBS" OR "Shear bond strength" OR "SBS".

"Indirect restorations" OR "Inlay" OR "Onlay" OR "Veneer" OR "Crown" OR "Aesthetic indirect restorations" OR "Ceramic restorations" OR "partial-ceramic restorations" "Indirect composite restorations".

Study Selection and Data Extraction

Three reviewers (PV, YM, and MR) independently screened the title and abstract of all the articles obtained through the initial search. The full text of potentially relevant studies was assessed to find out whether they met the inclusion criteria. A flowchart of the study selection following PRISMA guidelines has been depicted in Flowchart 1. Data extraction was done from the final articles that were involved in the systematic review. The data extraction included name of the author, article-published year, type of dentition, size of the sample to be collected, cavity design, type of indirect restoration, type of etching, groups compared, method of bond strength assessment, oral cavity simulation methods, method of surface preparation, processing after luting/thermocycling, results, and conclusion of the study. The authors of the included studies were contacted for any missing information. Any difference of opinion on the selection of studies was resolved in agreement with a fourth reviewer (LB).

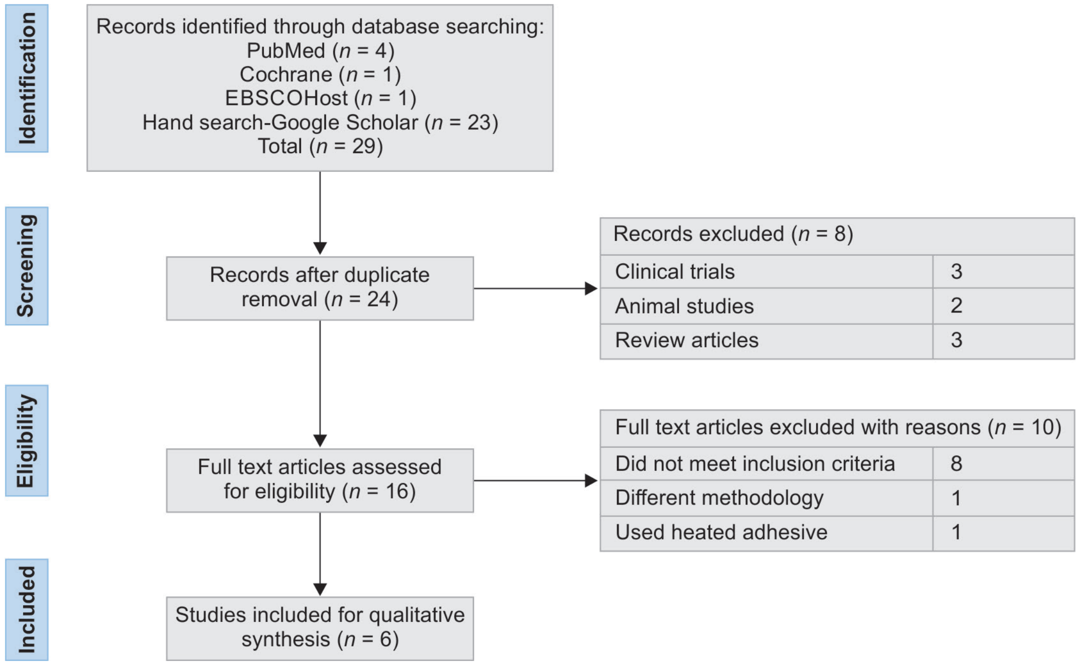
Quality Assessment

The quality assessment for the included articles was performed following the guidelines previously reported for *in vitro* studies, and the criteria for evaluation were adopted from the CRIS guidelines for the assessment of the quality of *in vitro* studies. The following domains were used to assess the risk of bias, which includes sample size calculation, presence of control groups, sample preparation method, whether tooth randomization, thermocycling, and statistical analysis was performed, and mentioning of surface preparation, cavity design, and oral simulation method.

Results

A total of 29 articles were identified from the initial search. After the removal of duplicates, screening of title and abstract was done for 24 studies, following which 8 articles were excluded because they did not meet the inclusion criteria. The full text of the remaining 16 articles was assessed for eligibility, from which 10 articles were excluded after full-text screening: one study having evaluated cuspal deflection and fracture resistance,[11] one being a study that used the heated adhesive method,[12] four being studies that

Flowchart 1: PRISMA flowchart



compared delayed dentin sealing and reinforced dentin sealing,[13–16] one being a study that did not evaluate bond strength,[8] and three studies were excluded because those studies did not meet the inclusion criteria.[7,17,18] A total of 6 articles[2,4,9,19–21] were included for qualitative assessment (based on CRIS guidelines).[22] The clinical characteristics of the studies included in this review have been described in Tables 1 and 2.

The included studies in the present systematic review were published in between 2003 and 2020. The effect of reinforced IDS and conventional IDS on bond strengths was evaluated in the present review, along with various etching protocols. The universal adhesive was the most commonly used adhesive during the reinforced IDS procedure.[2,4,9,19,20] Along with the universal adhesive, four studies compared and assessed the samples with self-etch adhesives,[2,4,12,21] and two studies assessed reinforced IDS with the total-etch method.[4,21]

Evaluation of the bond strength in indirect composite restorations was done by three studies.[4,9,19] Further, one study assessed the bond strength in CAD/CAM resin inlays,[2] one study evaluated the bond strength in glass–ceramic restorations,[21] and one study assessed the bond strength in indirect hybrid–ceramic restorations.[20]

All the involved studies evaluated adhesive strength of indirect restorations, out of which four studies evaluated the bond strength by microtensile bond strength (μ-TBS) testing methodology,[2,4,9,19] and the other two studies evaluated the bond strength by shear bond strength testing methods (SBS).[20,21]

Almost all the included studies procured molar tooth samples for evaluation except the study by Jayasooriya et al.,[19] where premolars were used. The sample size ranged from 18 in the study by Kesimli et al.[20] to the highest sample size in the study by Breemer et al.,[21] consisting of 140 samples. The studies by Jayasooriya et al.[19] and Andrade et al.[9] had a sample size of 33 and 35, respectively, while the studies by Rozan et al.[2] and Carvalho et al.[4] had a sample size of 72 and 75, respectively.

The cavity design was similar in four of the included studies,[9,19–21] where the teeth were trimmed/ground occlusally to create a flat dentin surface. However, Andrade et al.[9] along with flattening the occlusal surface, standardized Class I preparations with margins entirely positioned in the dentin (4 ± 1 mm diameter and 2.5 ± 0.5 mm deeper). In their study, Rozan et al.[2] prepared Class II MOD cavities with a width of 4 mm and a depth of 3 mm from the deepest point of the fissure, while Carvalho et al.[4] prepared cavities using dentin discs.

The medium for oral cavity simulation prior to cementation of the final restoration showed that three studies had incubated/stored the samples in distilled water,[2,9,20] and two studies stored the samples in water.[19,21] Carvalho et al.,[4] in their study, used artificial saliva as the storage medium. In most of the included studies, the temperature at which the samples were incubated was 37°C. The study by Breemer et al.[21] stated that the samples were incubated at room temperature, and the study by Andrade et al.[9] incubated their samples at 4°C. The duration of storage of samples before luting of the restorations showed variations. Two studies[4,21] incubated the samples for 2 weeks. Kesimli et al.,[20] in their study, incubated the samples for 1 week, while the studies by Jayasooriya et al.[19] and Rozan et al.[2] mentioned that the samples were incubated for 24 hours and 1 hour, respectively. Andrade et al.,[9] in their study, did not mention the duration of sample incubation before cementation.

The surface preparation of dentin prior to luting varied considerably in almost all the included studies. In the present review, two studies[20,21] showed similar dentin surface conditioning methods using pumice slurry, while the study by Breemer et al.[21] followed two methods, one method of surface conditioning with a pumice–water paste, while the other method using a pumice–silica coating. Kesimli et al.[20] prepared the surface of samples using pumice slurry, followed by air-abrasion, and the restoration surface was sandblasted with aluminum oxide (50 μm) particles exclusively for the IDS samples and not for the control group. Jayasooriya et al.[19] used a cotton pellet immersed in

Table 1: Characteristics of included studies

Author name/ Year	*Type of tooth and Sample size*	*Type of indirect restoration*	*Type of etching*	*Groups compared*	*Method of bond strength assessment*	*Results*	*Conclusion*
Rozan et al. 2020[2]	72 third molars	CAD/CAM resin inlays	(1) Universal adhesive (G-Premio Bond, GC) (2) Self-etch adhesive (Clearfil SE Bond 2, Kuraray)	Groups (n = 24) *GI*. Uncoated group 1.1 – RXU 1.2 – LinkForce 1.3 – PV5 *GII (IDS)* Universal adhesive layer 2.1 – RXU 2.2 – LinkForce 2.3 – PV5 *GIII (R-IDS)* Self-etch adhesive + flowable resin 3.1 – RXU 3.2 – LinkForce 3.3 – PV5	Micro-tensile bond strength	For RXU, on µTBS, significant differences were seen among the uncoated, 1-step, and 2-step + Flow groups ($p > 0.05$). For LinkForce, significant differences among the groups were evident (between the uncoated group, 1-step groups and the uncoated group, 2-step + Flow groups) ($p < 0.05$). However, 1-step and 2-step + Flow groups were not statistically different ($p > 0.05$). For PV5, significant differences were seen among the uncoated, 1-step and 2-step + Flow groups ($p < 0.05$)	Combined use of a two-step self-etch adhesive and a flowable resin composite may show improved bond strength in comparison to resin coating with a one-bottle adhesive.
Carvalho et al. 2021[4]	75 third molars	Indirect composite restorations	(1) Total-etch adhesive (Optibond FL, Kerr; Scotchbond Multipurpose, 3M ESPE; Single Bond Plus, 3M ESPE) (2) Self-etch adhesive (Clearfil SE Bond, Kuraray) (3) Scotchbond Universal adhesive (3M ESPE)	*Groups (n = 25)* *GI – DDS* a. Optibond FL b. Scotchbond MP c. Single bond plus d. Clearfil SE e. Scotchbond Universal *GII – IDS* a. Optibond FL b. Scotchbond MP c. Single bond plus d. Clearfil SE e. Scotchbond Universal *GIII – R-IDS* a. Optibond FL b. Scotchbond MP c. Single bond plus d. Clearfil SE e. Scotchbond Universal	Micro-tensile bond strength	The reinforced IDS (IDS + RC) improved the bond strength of DBA (both unfilled/lightly filled) (SBMP, SBP, CFSE and SBU) in comparison to either DDS or IDS strategy	Dentin bonding agents (filled/partially filled) have to be reinforced with a flowable resin coating in order to improve the µTBS to dentin for IDS

(Contd...)

Table 1: *(Contd...)*

Author name/ Year	*Type of tooth and Sample size*	*Type of indirect restoration*	*Type of etching*	*Groups compared*	*Method of bond strength assessment*	*Results*	*Conclusion*
Andrade et al. 2007[9]	33 Molars	Indirect composite restorations	Universal adhesive (Single Bond, 3M)	*Groups (n = 11)* Buccal wall *G1B – DDS* (one adhesive layer) *G2B – IDS* [two adhesive layer (IDS + 1 layer before luting)] *G3B – R-IDS* (adhesive layer + flowable resin layer) Pulpal wall *G1P – DDS* (One adhesive layer) *G2P – IDS* [two adhesive layer (IDS + 1 layer before luting)] *G3P – R-IDS* (adhesive layer + flowable resin layer)	Micro-tensile bond strength	For buccal wall, G2B shows high bond strength values when compared to G1B and G3B. A statistically significant difference was seen in R-IDS [3B] than DDS [1B] For pulpal wall, G1P showed higher and statistically significant bond strength values when compared to G2P and G3P, when SB was applied just before luting the restoration. There was no significant difference between the IDS group [i.e., G2P, G3P].	Application of dentin adhesive immediately after tooth preparation and an additional coat just before the luting the restoration was shown to be an effective alternative technique with regards to marginal adaptation of indirect composite resin restorations and bond strength at the interface.
Jayasooriya et al. 2003[19]	35 Premolars	Indirect composite restoration	Universal adhesive (Single Bond, 3M) and Self-etch adhesive (Clearfil SE Bond, Kuraray)	*Groups* *(n = 7)* G1 – control G2 (IDS) – 1 coat of SE G3 (R-IDS) – 1 coat SE + 1 coat PLF G4 (IDS) – 1 coat of SB G5 (R-IDS) – 1 coat of SB + 1 coat of PLF	Micro-tensile bond strength	The combination of a dentin bonding system with a flowable resin showed significantly higher bond strengths when compared to application of Dentin Bonding agent alone ($p < 0.05$)	For indirect restorations, a resin coating consisting of a DBS followed by a layer of flowable resin composite.
Kesimli et al. 2020[20]	18 Molars	Indirect Hybrid ceramic restorations	Universal adhesive (G-Premio Bond, GC)	*Groups* *(n = 6)* G1 – DDS G2 – IDS (Universal adhesive G3 – R-IDS (Universal adhesive + flowable resin)	Shear bond strength (SBS)	No statistically significant difference was evident irrespective of the dentin sealing methods ($p > 0.05$)	The application of the DBA followed by a flowable composite showed no statistical significant improvement to dentin with respect to their SBS values ($p > 0.05$).
Breemer et al. 2019[21]	140 Molars	Glass-ceramic restorations	Total-etch adhesive (Optibond FL, Kerr), Self-etch adhesive (Clearfil SE, Kuraray)	*Groups (n = 70)* G1 – AC (Self-etch) 1. IDS-1L 2. IDS-2L 3. R-IDS 4. DDS G2 – AO (Total etch) 1. IDS-L 2. IDS-2L 3. R-IDS 4. DDS	Shear bond strength (SBS)	The DDS group showed significantly lower SBS values than the IDS groups. There was no statistically significant difference within the various IDS groups [i.e., 1L, 2L, F] ($p = 0.43$)	IDS layer increases the shear bond strength (SBS) of exposed dentin when compared with the DDS strategy. Applying [Optibond FL] a Total etch adhesive showed higher SBS values than Self-etch Adhesive [Clearfil SE].

Table 2: Methodology of Included studies

Author name/Year	*Cavity design*	*Method of surface preparation*	*Method of oral cavity simulation*	*Processing after luting/Thermocycling*
Rozan et al. 2020[2]	Class II MOD preparation (4 mm wide and 3 mm deep from the deepest point of fissure)	Inlay surfaces: air-abraded with alumina powder (10 s) Dentin surfaces: etched with phosphoric acid	Distilled water at 37°C for 1 hr	Distilled water at 37°C for 24 hrs, followed by thermocycling at 5–55°C for 5000 cycles, dwell time 30 s
Carvalho et al. 2021[4]	Dentin disks	Dentin surfaced: cleaned with 50 µm aluminum oxide airborne particle for 5 s, followed by phosphoric acid etching for 15 s.	Artificial saliva at 37°C for 2 weeks	Immersed in distilled water at room temperature for 24 hrs
Andrade et al. 2007[9]	Flat-dentin occlusal surface followed by standardized class I cavities with margins completely located in the dentin (4 ± 1 mm diameter and 2.5 ± 0.5 mm deep)	Dentin surface etched with 35% phosphoric acid	Distilled water 4°C	Distilled water at 37°C for 24 hrs + thermocycling at 5–55°C for 1200 cycles, dwell time 30 s
Jayasooriya et al. 2003[19]	Flat superficial dentin occlusal surface	Cotton pellet soaked in ethanol wiped over dentin surface for 10 s	Water storage at 37°C for 24 hrs	Water storage at 37°C for 24 hrs
Kesimli et al. 2020[20]	Flat dentin surfaces, deep, non-retentive	All dentin samples: cleaned with pumice slurry followed by air-abrasion in IDS. Restorations: sandblasted with 50-µm aluminum oxide particles (15 s)	Distilled water at 37°C for 1 week	Thermocycled at 5–55°C for 5500 cycles, dwell time 30 s
Breemer et al. 2019[21]	Flat occlusal dentin surface	Samples prepared with either pumice-water paste or pumice and silica coating	Stored in water at room temperature for 2 weeks	Thermocycled at 5–55°C for 10,000 cycles, dwell time 30 s

Table 3: Risk of bias assessment

Author	Sample size calculation	Tooth randomization	Control group	Cavity design	Surface preparation	Sample preparation	Oral simulation method	Thermocycling	Statistical analysis	Total score
Rozan et al. 2020[2]	?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Carvalho et al. 2021[4]	?	Yes	Yes	No	Yes	No	Yes	No	Yes	5
Andrade et al. 2007[9]	?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Jayasooriya et al. 2003[19]	?	Yes	Yes	No	Yes	?	Yes	No	Yes	5
Kesimli et al. 2020[20]	?	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	7
Breemer et al. 2019[21]	?	Yes	Yes	No	Yes	?	Yes	Yes	Yes	6

ethanol to wipe over the dentin surface for 10 seconds for surface preparation, while the study by Andrade et al.[9] prepared the dentin surface by etching with 35% phosphoric acid. Rozan et al.,[2] in their study, also prepared the dentin surface by etching. Along with that, the bondable surfaces of the inlays underwent air-abrasion procedure using alumina powder for 10 seconds. Carvalho et al.,[4] in their study, prepared the dentin by air abrasion with 50 μm aluminum oxide particle for 5 seconds, followed by phosphoric acid etching for 15 seconds.

Most of the studies used thermocycling for aging of the samples after luting the final restoration[2,9,20,21] in a temperature range of 5–55°C with a dwell time of 30 seconds. However, the number of cycles varied between the studies, with the least being 1200 cycles in the study by Andrade et al.,[9] 5000 cycles in Rozan et al.[2] research article, 5500 cycles in Kesimli et al.[20] study, and 10,000 cycles in Breemer et al.[21] research article. In two studies,[4,19] the final samples were stored in water for 24 hours at 37°C room temperature. However, Andrade et al.[9] and Rozan et al.,[2] in their studies, stored the samples in distilled water at 37°C for 24 hours, followed by thermocycling.

In most of the studies,[2,4,9,19] resin coating technique or reinforced IDS seemed to improve the bond strength of resin cement to dentin than conventional IDS. Furthermore, the total etch adhesive system was shown to have improved the bond strength than the self-etch or universal adhesive systems, according to Breemer et al.[21]

Risk of Bias Assessment

Among the six studies included for qualitative analysis, three[2,9,20] showed a low risk of bias and the remaining three studies[4,19,21] showed a moderate risk of bias (Table 3). None of the authors had stated as to how they derived the sample size required for the study. All the included articles had details regarding the presence of the control group, tooth randomization, oral cavity simulation methods, dentin surface preparation before luting, and performance of the statistical analysis. The cavity design was not standardized in four studies.[4,19–21] In addition, three studies had not specified the method of sample preparation,[2,4,19] and two studies[4,19] did not conduct thermocycling during the experiment.

Discussion

The life span of a restoration primarily relies on the adhesive behavior with the tooth structure. The bonding of indirect restorations is predominantly influenced by numerous factors such as cavity design, type of dental adhesive used, the thickness of luting cement, dentin surface preparation procedures prior to luting of final restoration, and forces acting on tooth-restorative interfaces. To an extent, the interim restorations affect the bond strength of indirect restorations by interfering with the adhesive monomer penetration into the tooth substrate.[23]

The IDS technique was developed in order to overcome the above-mentioned problems. Although IDS with any type of DBA exhibited positive results in enhancing the adhesive strength in comparison to delayed dentin sealing, applying an additional film of flowable resin composite provides a thicker adhesive layer that not only prevents re-exposing of the dentin during the final restoration but also allows for a smooth preparation in lesser chair time and eliminates any possible undercuts.

Bond strength tests are usually carried out under tension or shear modes. Microtensile bond strength (MTBS) testing is currently one among the most standard and versatile bond strength tests with a greater discriminative capability than the traditional macroshear bond test.[24] Almost all the studies involved in the systematic review have assessed the microtensile bond strength for their samples, except for two studies by Kesimli et al.[20] and Breemer et al.,[21] which assessed the shear bond strength (SBS).

In the present systematic review, six *in vitro* studies assessed the bonding performance of indirect restorations following the application of conventional IDS or reinforced IDS technique,[2,4,9,19,20,21] while few included articles compared the delayed dentin sealing (DDS) with the R-IDS strategies.[4,9,20,21]

Reinforced IDS vs IDS

The studies by Jayasooriya et al.,[19] Rozan et al.,[2] and Carvalho et al.[4] showed that when the application of dentin adhesive was blended with a LVRC on a prepared dentin, it remarkably enhanced the μTBS of the resin cement.[2,4,19] The above observation was ascribed to the elastic modulus of the PLF (flowable resin), which is larger than the resin bonding and resin cement, thereby performing as a stress breaker. However, the studies by Kesimli et al.[20] and Breemer et al.[21] stated that there were no significant differences in the bond strengths between the conventional and reinforced IDS strategies. The reason could be that an all-in-one bond adhesive coating might lead to degradation of the hybrid layer in the preliminary phase.

Effect of Cavity Design on Bond Strength

The longevity of a minimally invasive restoration is affected primarily by the design of the cavity, and studies are usually performed on flat dentin surfaces, not considering factors like cavity configuration (C-factor) and masticatory forces, which can influence the bond strength, and subsequently, the long-term durability of the restorations.[23,25,26] Almost all the studies[4,9,19–21] were conducted with flat surfaces of dentin, whereas a class II preparation was followed by Rozan et al.[2] resulting in a greater configuration factor. The authors attributed this phenomenon to having caused substantial polymerization contraction stresses, which were produced by shrinkage stresses of resin cement post polymerization and propagated along the interface between the restoration and the cavity walls, possibly influencing the bond performance and inner adaptation. According to a study by Gresnigt et al.,[26] in the case of limited dentin involvement (less than one-fourth of the surface), IDS shows no impact on the bonding behavior over DDS.

Effect of Etching Protocol

According to Magne et al.,[27] the three-step total-etch approach is considered the most reliable choice for IDS strategy, and the three-step etch-and-rinse procedure and dual-step self-etch procedure generates remarkable results in comparison with a single-step protocol in terms of longevity, aging, and bonding behavior.[28] Breemer et al.[21] revealed that the total-etch adhesive system showed higher SBS values (15.59 MPa) when compared with self-etch adhesive system (13.95 MPa).

The study by Rozan et al.[2] stated that bonding performance was influenced by the application of a resin coating, either using one-bottle adhesive alone or a combination of a two-step self-etch adhesive and a flowable resin composite. The relatively hydrophilic adhesive covered by a hydrophobic flowable composite behaved like a physical barrier to the diffusion of water through the adhesive layer. Thus, resin coating with a combination of etch and rinse/two-step self-etch adhesive and a flowable resin composite could be more efficacious than universal adhesive coating.[29]

Effect of Surface Preparation

A substrate that is contaminant-free is ideal for optimum bonding. Hence, selecting an appropriate conditioning method is essential. However, Breemer et al.[21] observed that cleaning with pumice alone or in addition to tribo-chemical silica coating had no effect on bond strength. Methods such as air abrasion should be performed for a limited duration as it may enhance the diffusion of resin cement.[30] After cleaning, the dentinal surface subsequently has to be reactivated by the adhesive resin. In the study by Carvalho et al.,[4] the sealed surfaces were scrubbed with a soft brush and pumice, then air-abraded with aluminum oxide of 50 μm size followed by acid etching using phosphoric acid for degreasing. It was emphasized that wetting the preparation with a bonding agent (without polymerization) was recommended when using heavily filled luting materials (such as preheated restoratives), while flowable luting cement could be applied directly to the preparation. Kesimli et al.[20] insisted the importance of tooth surface cleaning of the teeth prior to luting of the final prosthesis irrespective of the type of cement used.

Effect of Thermocycling

Thermocycling in water, being economical, is considered to be the method recommended for artificial aging to simulate the clinical scenario.[31] Thermal cycling induces stress both within a material and between the bonded interfaces due to the different thermal expansion coefficients, water sorption, and thermal conductivity properties of materials, thereby simulating the oral environment. About four of the included studies[2,9,20,21] employed thermocycling from 5°C to 55°C in a duration ranging from 1200 to 10,000 cycles. A thermocycling period of 5000 cycles corresponds to one-and-a-half years of oral mastication.[2]

Effect of Storage Medium Prior to Luting of Final Restoration

Magne[32] recommends that in the case of using the IDS approach, the placement of restoration can be delayed up to 12 weeks. To achieve this, the existing adhesive layer has to be conditioned. However, the results of Leesungbok et al.[7] stated that the dentin bond strength of a lithium-disilicate ceramic when influenced by IDS under various thermocycling periods (1, 2, 7, and 14 days) showed that a reduced bond strength was evident after 1 week and a greater one (recognized by a larger area of detached cement and exposed dentin) 2 weeks later. Thus, the completion of terminal bonding should be carried out within 7 days after IDS application as strongly recommended by authors.

Effect of Thickness of Hybridized Layer/Cement

After conditioning, there is a risk of re-exposure to dentin, which is influenced by both the conditioning method performed and the thickness of the IDS film. Zheng et al.[33] in their study obtained higher bond strength values when adhesive layer thickness ranged between 25 μm and 50 μm. A layer of a LVCR in addition to the DBA is recommended, especially during the use of unfilled DBAs[4] in order to improve the polymerization of the adhesive systems. The study by Andrade et al.[9] stated that when an additive layer of dentin adhesive or LVCR layer was applied (group II – conventional IDS and group III – reinforced IDS), the flow phenomenon happened toward the pulpal wall. The addition of successive layers resulted in a higher thickness on the pulpal wall surface, which probably compromised the bond strength in this region. Conversely, for the buccal wall, the second layer of adhesive (group II) provided adequate thickness and hence produced a higher bond strength in that region, even though statistically insignificant. The above observation can be explained by the almost parallel tubule orientation, which could have eased the adhesive infiltration in peritubular dentin, creating a huge bonding area that resulted in greater bond strength in that portion. The study by Jayasooriya et al.[19] mentioned that the resin cement thickness was restricted to 100 μm since the resin cement was considered to be the weak link of tooth-colored inlays, and its thickness might influence the bond strengths. Furthermore, it was advocated that for the resin coating, a suitable microfilled dentin bonding agent should be selected for better bonding performance.

About three of the studies included had a low risk of bias. All the other included studies had moderate risk of bias. The details regarding the sample-size calculation were unclear in all of the included studies. So, the overall risks of bias of the included studies ranged from moderate to low.

On the collective analysis of the data and evidence from the included articles, it can be concluded that reinforced IDS technique results in similar or better long-term bond strength than the conventional IDS technique in indirect restorations, especially when a two-step self-etch adhesive protocol or use of a three-step etch-and-rinse adhesive system is employed.

The limitations of this systematic review involve the inclusion of only *in vitro* studies for qualitative assessment, and hence cannot be extrapolated to the clinical scenario. Furthermore, heterogeneity in the methodologies of sample preparation and adhesive systems limits the study for conducting a quantitative assessment or meta-analysis.

Conclusion

Within the constraints of the current review, it can be concluded that reinforced IDS has similar or better bond strength when compared with the conventional IDS strategies. The bonding performance of reinforced IDS may be further enhanced with the use of an etch-and-rinse or a 2-step self-etch adhesive system and the use of a filled LVCR. Future clinical trials assessing the bond strength of various dentin adhesives with low viscosity composite at regular time intervals, the potential for microleakage and bacterial contamination, and pulpal pressure should be conducted to arrive at further conclusive evidence for reinforced IDS strategy.

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