UPDATE

Immediate dentin sealing: must it be a routine procedure in indirect bonded restorations?

Sellado Dentinario Inmediato: debe ser un procedimiento de rutina en las restauraciones adheridas indirectas?

Selamento dentinário imediato: ¿deve ser um procedimento de rotina nas restaurações adesivas indiretas?

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Abstract

Objective. To analyze the Immediate Dentin Sealing technique and their biological, bio-mechanical and clinical results. **Methodology**. A Critical Literature Review was carried out to discuss the results of systematic review and clinical and laboratory studies to answer the question of the title. **Results.** The clinical, biomechanical and biological results were varied, but in the medium and long term they did not show significant differences between Immediate Dentin Sealing and Delayed Dentin Sealing. On the other hand, the technique is more complex and takes more clinical time. **Discussion.** According to the evaluation of the results mentioned, the Immediate Dentin Sealing did not have the expected levels of efficacy and efficiency. **Conclusion.** Hitherto, Immediate Dentin Sealing would justify its application in specific situations but not as a routine procedure in performing indirect bonded restorations.

Keywords: dentin bonding agents, biocompatible materials, dental materials, permanent dental restorations, clinical trials.

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Resumen

Objetivos. Evaluar los resultados biomecánicos, biológicos, técnicos y clínicos de la técnica del Sellado Dentinario Inmediato. **Metodología.** Una Revisión Crítica de la Literatura fue llevada a cabo, para discutir los resultados de estudios clínicos, de laboratorio y revisiones sistemáticas, a fin de responder la pregunta del título. **Resultados.** Los resultados clínicos, biomecánicos y biológicos fueron variados, pero a mediano y largo plazo no mostraron diferencias significativas entre el Sellado Dentinario Inmediato y el Sellado Dentinario Diferido. Por otra parte, la técnica es más compleja e insume más tiempo clínico. **Discusión.** De acuerdo con la evaluación de los resultados mencionados, el Sellado Dentinario Inmediato no tuvo los niveles de eficacia y eficiencia esperados**. Conclusiones.** Hasta el momento, el Sellado Dentinario Inmediato justificaría su aplicación en situaciones específicas y no como procedimiento de rutina en la realización de restauraciones indirectas adheridas.

Palabras claves: agentes adhesivos a dentina, materiales biocompatibles, materiales dentales, restauraciones dentales permanentes, estudios clínicos.

Resumo

Objetivos: Avaliar os resultados biomecânicos, biológicos, técnicos e clínicos da técnica de selamento dentinário imediato.
Metodologia: Uma Revisão Crítica da Literatura foi realizada para discutir os resultados dos estudos clínicos, de laboratório e revisões sistemáticas, a fim de responder à pergunta do título.
Resultados: Os resultados clínicos, biomecânicos e biológicos foram variados, mas a médio e longo prazo não mostraram diferenças significativas entre o Selamento Dentinário Imediato e o Selamento Dentinário Tardio. Por outro lado, a técnica é mais complexa e leva mais tempo clínico.
Discussão: De acordo com a avaliação dos resultados mencionados, o Selamento Dentinário Imediato não teve os níveis de eficácia e eficiência esperados. **Conclusões:** Até o momento, o Selamento Dentinário Imediato justificaria sua aplicação em situações específicas e não como procedimento de rotina na realização de restaurações indiretas adesivas.

Palavras-chave: adesivos dentinários, materiais biocompatíveis, materiais dentários, restaurações dentárias permanentes, ensaios clínicos.

Introduction

Comprehensive Restorative Dentistry (CRD) provides all the fundamentals and techniques for performing indirect bonded restorations to restore tooth anatomy, aesthetics, and function. CRD is based on the principle of minimum invasion and maximum preservation subject to maximum restoration and tooth longevity.

Restorative procedures should be carried out *effectively* (ability to achieve the desired or expected effect) and *efficiently* (ability to achieve the desired results with the minimum possible resources and time)[1] to achieve excellent-quality and cost-effective restorations with high productivity in every stage.

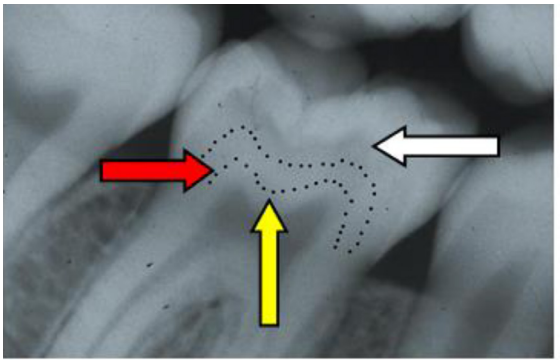
Biologically, pulp plays an essential role in dentin formation and nutrition, as well as in tooth innervation and defense. [2] The International Caries Consensus Collaboration, held in Leuven, Belgium, in 2015, established that preserving the dentin-pulp complex is a priority.[3]

Caries is the leading risk factor

The author believes that the quality of tooth preparation is the most critical factor in clinical restoration success.

Preserving the biology of the dentin-pulp complex during mechanical tooth preparation involves using sharp cutting instruments (burs, stones, hand instruments), careful and intermittent operative maneuvers, abundant irrigation, and techniques to prevent the migration of bacteria and/or chemical products.
A previous study [4] describes three carious lesion depths: superficial, medium or deep, if it covers the outer, middle or pulp third, in any or all three directions of the tooth crown (Fig. 1).

Fig. 1. Diagram of caries depth according to the dotted line: superficial (white arrow), medium (red arrow), deep (yellow arrow).



(Taken from Borgia E. et al., RODYB 2020;2:24-32).

The carious tissue can be partially or totally removed through different techniques, depending on the extent and depth of the lesion. The affected demineralized dentin in the pulp wall should be preserved. [4-10]
Dentin acquires different anatomical and histochemical characteristics depending on its depth. When tooth preparation is superficial or medium-depth, the freshly cut dentin can be sealed with a dentin adhesive. However, in lesions close to the pulp, the increased diameter and number of dentinal tubules and the reduced intertubular dentin increases pulp permeability. [11] Bacterial toxins and low-molecular-weight free monomers can migrate to the pulp and cause pulp cytotoxicity.[12,13] Remineralizing biomaterials should be used in these cases to protect the dentin-pulp complex.[14–22]
Abu-Nawareg MM et al. (23) present the following historical synthesis in a review published at the end of 2015: *The work of Bergenholtz showed that bacterial products could diffuse across freshly prepared dentin to induce pulpal inflammation. This led Pashley et al. in 1992 to propose sealing freshly prepared dentin with adhesive resins. This was endorsed by Davidson's group in 1996, Paul and Schaerer 1997, and Özturk et al. Prof. Tagami advocated 'resin coating' of freshly cut dentin to prevent pulpal irritation and to increase adhesion to dentin.*
A few years ago, Magne[24,25] reignited the subject. Applying resinous adhesives directly on freshly cut dentin in tooth preparations to receive an indirect bonded restoration is known as Immediate Dentin Sealing (IDS). The adhesive system applied when attaching a bonded indirect restoration is called Delayed Dentin Sealing (DDS).
This study aims to analyze the efficacy and efficiency of IDS according to the biological, biomechanical, and clinical results from the available literature and to discuss the opportunity and scope of its use to answer the question posed in the title.

Methodology

Immediate Dentin Sealing acquired this name about two decades ago. A critical literature review was conducted to achieve the study objectives. [26,27]
The inclusion criteria stated that the published laboratory studies, clinical studies, and systematic reviews should include any of the following items:
- Analysis of dentin bond strength (DBS) and tooth fracture resistance (TFR) and/or restoration fracture resistance (RFR) results when IDS or DDS are applied

- Results of marginal and internal adjustment in ceramic and composite restorations with IDS or DDS
- Biocompatibility of adhesive resin systems
- Comparative clinical studies of postoperative sensitivity, clinical success, and longevity of indirect bonded restorations using IDS or DDS

A search was conducted in Medline (Pubmed), Scopus, and the EBSCO database available through Timbó Portal (Uruguay) with the following search strategy:

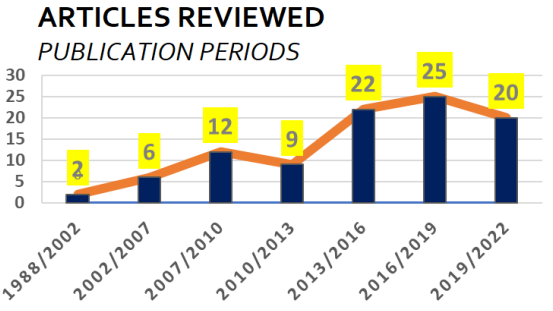
"Dental Bonding"[MeSH Terms] OR "Dentin-Bonding Agents"[MeSH Terms] AND "indirect"[All Fields] OR "indirects"[All Fields] AND "bonded"[All Fields] OR "bondings"[All Fields] OR "bonds"[All Fields] OR "object attachment"[MeSH Terms] OR "object"[All Fields] AND "attachment"[All Fields]) OR "object attachment"[All Fields] OR "bonding"[All Fields]) AND "restorability"[All Fields] OR "restorable"[All Fields] OR "restorated"[All Fields] OR "restoration"[All Fields] OR "restorations"[All Fields] OR "restorative"[All Fields] OR "restoratives"[All Fields] OR "restore"[All Fields] OR "restored"[All Fields] OR "restores"[All Fields] OR "restoring"[All Fields] OR "clinical trial"[Publication Type] OR "clinical trials as topic"[MeSH Terms] OR "clinical trials"[All Fields] AND (2002:2022[pdat])

In addition, a manual search of articles and articles by leading authors in the field was conducted.

This review was started in 2016, paused for personal reasons in 2020 and 2021, and resumed and completed in 2022.

The total number of references initially selected was 120. Twenty-four were discarded, and 96 were analyzed according to the year of publication as follows: 2 (2.1%) over 20 years old; 6 (6.25%) between 15 and 20 years old; 12 (12.5%) between 12 and 15 years old; 9 (9.4%) between 9 and 12 years old; 22 (22.9%) between 6 and 9 years old; 25 (26%) between 6 and 3 years old, and 20 (20.8%) less than 3 years old. In summary, 69.8% (67) of the papers reviewed were under 9 years old. Figure 2 charts these results.

Fig. 2. The chart shows the number of papers reviewed per publication period.



Development

IDS was assessed by analyzing its indications, the technique, and the biomechanical, biological, and clinical results found in the literature.

Indications

IDS was initially developed for pulp teeth. However, its application has been extended to endodontically treated teeth. This paper studies its use in pulped teeth.

IDS is indicated in tooth preparations for ceramic or composite resin-bonded indirect crown restorations that are partial or total, single or abutments of fixed dental prostheses (FDP). Its application can influence the biological response of the dentin-pulp complex. It can also impact the bonding strength, the structural strength of the restoration, and the restored tooth biomechanically.

In 2005, Magne[24] stated that freshly cut dentin is the ideal substrate for dentin bonding. Precuring the dentin bonding agent leads to stress-free bonding, which could increase dentin bond strength (DBS), improve restoration adaptation, and prevent postoperative sensitivity, improving patient comfort.

Immediate Dentin Sealing

Once the dental preparation is ready, the tooth must be completely isolated with a rubber dam, which is essential in the posterior area.

The resin adhesive system of the composite bonding resin is applied to seal the exposed dentinal tubules, following the manufacturer's instructions. Therefore, both materials must be manufactured by the same commercial brand.

In 2014, Magne[27] published a brief and illustrative sequence of this technique, whose reading is recommended.

A critical step is to remove the excess adhesive covering the enamel margins of the preparation. This is done at low speed, with the same bur or stone used initially to drill, preferably with magnification. This is a critical and sensitive step. In some clinical situations, the enamel may be prepared after IDS.

Temporary restorations

The main objective of temporary restorations is to protect the dentin-pulp complex.

Technological advances in developing new materials and techniques provide practitioners with a wide range of possibilities. [28]

Manufacturing techniques

Temporary restorations are classified according to the manufacturing technique as a) Direct b) Indirect and c) CAD/CAM.

Materials

Restorative materials are classified according to their composition and how they harden.

Self-curing acrylic resins

These are the conventional powder-liquid systems based on polymethyl methacrylate/methyl methacrylate. They must be handled properly due to the exothermic reaction and the degree of polymerization shrinkage. They are bonded to the tooth with eugenol-free temporary types of cement.

Composite resins

They are dispensed in paste form in the dental preparation and modeled with the corresponding instruments. The polymerization reaction can be self-curing (Duo Temp Coltêne/Whaledent; Telios CS/C&B) or light-activated (Clip F/VocoGmbH; Interval LC/Temrex Corp.). These temporary restorations are designed not to be cemented. Manufacturers claim that the polymerization expansion creates a good sealing of the preparation. However, the lack of cement facilitates bacterial microleakage and postoperative sensitivity. *IDS should be the technique of choice in these clinical situations.*

Some of these materials are available in blocks to make CAD/CAM temporary restorations.

Bis-acryl resins

They are paste-paste acryl resins dispensed from syringes. They have low polymerization shrinkage (< 3%), less exothermic reaction, and do not require polishing. Although the manufacturing technique is direct, they are programmed on (analog or CAD-CAM) wax-ups in the laboratory. Silicone molds are made and cut at the gingival margin level. They become the container where the material is dispensed from the syringe. The preparation is gently placed in the prepared teeth until adequately positioned. The excess is trimmed off, and the mold is removed after polymerization. They hold without cement, which allows for bacterial microleakage. *IDS is the technique of choice when making a bis-acryl resin temporary restoration and when the tooth preparation has exposed dentin.*

Biomechanical considerations

Dentin bond strength (DBS) and restoration fracture resistance (RFR) and/or tooth fracture resistance (TFR) were assessed.

Dentin bond strength (DBS)

DBS will include the studies analyzing RμTA, bonding, shear strength, etc.

The results found in several laboratory studies were different and/or opposite.

Leesungbok et al.[29] found that DBS decreased seven days after thermocycling and suggested cementing the restoration within seven days after IDS.

Magne et al.[30] found that DBS was not affected by IDS until 12 weeks after the restoration was made.

Three in vitro studies by Gresnigt et al., [31] Iishi et al.,[32] and Hironaka et al.,[33] found that IDS improved DBS.

A review of 40 articles showed that IDS increased DBS, decreased gap formation, bacterial leakage, and reduced postoperative sensitivity compared to DDS.[34]

Nine of ten studies evaluated in a systematic review showed that DBS and fracture strength of indirect glass-ceramic restorations were higher with IDS than with DDS. The authors conclude that it is necessary to conduct further clinical studies.[35]

A recent systematic review and meta-analysis showed that IDS improved the DBS of composite resin restorations with a three-step adhesive system.[36]

Three investigations studied DBS using the application of different adhesive systems as a secondary variable and found the following:

- The application of IDS using three adhesive systems did not statistically affect the DBS of pressed ceramic compared to the control group.[37]
- Four adhesive systems were used, and the materials were water-stored for three months. DBS did not differ between the groups with IDS and the control group without IDS.[38]
- After applying four resin adhesives, the IDS groups had a significantly lower DBS than the DDS group. Failures were adhesive in the IDS group and mixed in the DDS group.[39]

The same research topic and the consideration of simulated pulpal pressure (SPP) as a variable yielded the following results:

- DBS subjected to SPP increased with IDS in one dual-cure and one self-cure cement and decreased in two self-adhesive cements.[40]
- After three months of SPP, the combination of a conventional two-step adhesive and a conventional dual cement had the highest DBS.[41]
- Rêgo H. et al.[42] studied 40 in vivo third molars to be extracted and 80 third molars in vitro (40 with SPP and 40 without SPP) with IDS and found that:
- In vivo, DBS decreased significantly at 6 months compared to values obtained at 24 hours.
- In vitro, a significant reduction—similar to in vivo—was observed under certain conditions (water, thermal cycling, and SPP).

The studies mentioned in this section are shown in Table 1.

The results of the laboratory studies above show a clear variation in DBS, as it decreased with IDS. This would be due to the hydrolytic degradation of the hybrid layer.

Carvalho et al.[43] found that the hybrid layer clinically degrades much faster than a potential failure. Therefore, it has a secondary role in clinical survival. The success of bonded restorations would result from a combination of improved adhesive strategies and increased patient motivation for oral health care.

Additionally, physiological aging and pathological processes affect the biomechanical and biochemical properties of dentin. It is necessary to use enzymatic inhibitors such as chlorhexidine for the inhibition of dentin matrix metalloproteinases (MPPs) to reduce the hydrolytic degradation of the hybrid layer.[44]

According to Tjäderhane,[45] the overall clinical success of composite restorative procedures is multifactorial. There is limited evidence to

correlate marginal quality and bond strength in the laboratory with the clinical performance of bonded dental composites. Carious dentin is not an ideal substrate for strong and durable hybrid layer formation. Although chlorhexidine does not have sufficient evidence as an MMP inhibitor, no adverse effects have been reported.

Therefore, the goal is to find new monomers and/or polymerization mechanisms that can act and/or modify the environmental conditions in the hybrid layer.

With such goals in mind, Sabatini and Pashley [46] tested an adhesive containing 10methacryloyloxydecyl dihydrogen phosphate (MDP) with pH>3 and a blend containing ethanol/water as a solvent, with conventional benzalkonium chloride and benzalkonium methacrylate, at concentrations of 0.5%, 1%, and 2% in vitro. There was no significant difference in DBS between groups at 24 hours. At 6 and 12 months, the untreated group showed significant DBS reduction. There was no difference between the treated groups. They concluded that conventional benzalkonium chloride would provide greater stability than chlorhexidine.

Additionally, new adhesives containing quaternary ammonium methacryloxy silane would act as antimicrobial and protease inhibitors, decreasing dentin adhesion degradation.[47]

Adding a dentin MMP inhibitor (GM1489) to a commercial adhesive showed the highest significant DBS value after one year.[48]

In addition, hydrolytically stable monomers such as triethylene glycol divinylbenzyl ether (TEG-DVBE) with UDMA polymerize in clusters, producing better dentin infiltration and greater flexibility. Superior adhesive performance, increased dentin infiltration, and improved water absorption shown by the control groups in this study are promising results for the field.[49]

Temporary luting and DBS

Temporary restoration luting could impact the values of variables under study and postoperative sensitivity.

Cement removal from the walls of the dental preparation must be meticulously carried out so as not to affect the bonding. The most commonly used procedures are prophylaxis pastes, pumice-water slurry, air-abrasion, ultrasound, and dental picks.

Laboratory investigations have shown that:

- Temporary luting did not affect the results with and without IDS.[33]
- DBS was higher when IDS was applied before temporary luting.[50]
- IDS contributed to increased DBS, while the temporary restoration did not affect it.[51]
- A higher DBS was obtained with IDS than with DDS and pre-cleaning with dental picks or prophylaxis paste.[52]
- Prophylaxis pastes allowed practitioners to remove the temporary cement without altering the final adhesion.[53]
- IDS thickness is not uniform due to the topographical variation of the tooth preparation. A laboratory study analyzed the effect of polishing with prophylaxis paste and air-abrasion on dentin adhesive thickness. Wear was observed in the adhesive thickness but without a significant statistical difference.[54]
- Özcan and Lamperti[55] applied IDS and analyzed DBS and the temporary cement removal technique. They used prophylaxis paste and pumice-water slurry with nylon brushes for 15 seconds at 1,500 rpm. Other groups used air abrasion with 50 μm Al O_2 and 30 μm Si O_2 particles at 2 and 3.5 bar pressure. The various methods showed no statistically significant differences in cement removal. Bond strength failures were mixed.

The studies analyzed in this section are summarized in Table 1.

Table 1. Laboratory results of Dentin Bond Strength (DBS – main variable) comparing IDS and DDS and secondary variables (various bonding agents), luting agents applied with simulated pulpal pressure (SPP), various temporary cement removal techniques (VARIOUS TEMP. CEM. REM. TECH.).

Lit. Reference No.	DBS VARIATION with IDS or DDS	Lit. Reference No.	DBS VARIATION with various bonding agents	Lit. Reference No.	DBS VARIATION with IDS and SPP	Lit. Reference No.	DBS VARIATION with VARIOUS TEMP. CEM. REM. TECH. with IDS or DDS
29	At 7 days lower DBS	37	With IDS similar to DDS	40	Diff. Results according to bonding agent used	33	With IDS similar to DDS
30	At 12 weeks lower DBS	38	With IDS similar to DDS	41	Diff. Results according to bonding agent used	50	With IDS higher DBS
31	With IDS higher DBS	39	With IDS lower DDS	42	IDS lower than 6 months in vivo and in vitro	51	With IDS higher DBS
32	With IDS higher DBS					52	With IDS similar to DDS
33	With IDS higher DBS					54	With IDS similar to DDS
34	With IDS higher DBS						
35	With IDS higher DBS						
36	With IDS higher DBS						

Other abbreviations and symbols: Var. (various); Lit. Ref. No. (Literature reference number). The studies included in the first five rows (light green) arlab studies, and the last three rows (dark green) include literature reviews.

Restoration and tooth fracture resistance

Laboratory studies analyzed the influence that IDS may have on TFR and/or RFR.

Oliveira et al.[56] found that IDS did not influence TFR. However, another study showed that TFR in the IDS group was statistically higher (1335 ± 335 N) than in the DDS group (931 ± 274 N) ($p< 0.05$). The fracture resistance of ceramic onlays was also better.[57]

Sasse M. et al.[58] confirmed that a thickness of 0.7 mm in the fissures and 1 mm in the cusps is sufficient for full-coverage adhesively retained veneers made from lithium disilicate (LDS).

Van den Bremmer et al.[59] concluded that IDS improved the adhesion and structural strength of DSL inlays but not of multiphase composite resins.

IDS improved the adhesion and fracture strength in LDS ceramic laminates bonded to a substrate with over 50% dentin.[60]
Furthermore, two laboratory studies observed higher DBS in ceramic restorations than in hybrid materials.[61,62]

Biological aspects

The biological aspects evaluated were postoperative sensitivity prevention and biocompatibility of the adhesive systems.

Preventing postoperative sensitivity

Bacteria on the dentin surfaces may be the leading cause of postoperative sensitivity.[23] The toxins they release could diffuse through freshly cut dentin and cause pulp inflammation. In addition, the depth of the tooth preparation may be a risk factor that affects the dentinpulp complex.[11]
Indirect bonded restorations present a variable time between tooth preparation and making the restoration. Therefore, it is necessary to protect the dentinpulp complex from chemical, thermal, and bacterial agents.
This can be achieved in two ways: by applying desensitizing agents and/or sealants on freshly prepared dentin and/or by making temporary restorations that restore form, function, and aesthetics with good marginal sealing.
The literature shows varied results when applying these agents.
Researchers randomly treated 36 patients with Gluma Desensitizer and calcium hydroxide suspension before cementing the temporary restoration. They used the split-mouth technique in vital crown preparations. Sensitivity analysis at 1 week, 6 and 30 months showed no significant differences between the two products.[63]
Another publication showed that potassium nitrate was more efficient than Gluma in reducing hypersensitivity in abutment teeth, compared to the control abutment restored with ceramic crowns.[64]
A systematic review of 66 articles showed a significant reduction in hypersensitivity with potassium nitrate, arginine, glutaraldehyde with HEMA, adhesive systems, glass ionomercements, and laser.[65]
Twenty-five patients who received a three-unit fixed partial denture were randomly distributed into two groups: a) with IDS and b) without IDS. The double-masked result showed significantly reduced hypersensitivity in group a) at one week and one month. There was no difference between the two groups at 6, 12, and 24 months.[66]
In a recent paper, 60 bonded partial LDS restorations in molars were divided into two groups. Thirty patients received IDS (test); the control group received DDS at two weeks. This study did not confirm that IDS provided better results regarding tooth sensitivity and patient satisfaction.[67]
Another recent systematic review and meta-analysis comparing IDS and DDS found no statistically significant difference in postoperative sensitivity at the baseline nor at two years.[68]
Additionally, the way the primer is applied may affect the degree of dentin permeability. It is necessary to follow the manufacturer's recommendations.[69]
The results of the various types of studies presented in this section are shown in Table 2.

Biocompatibility of adhesive systems

Biocompatibility is the ability of a material not to interfere with or degrade the biological environment in which it is used.[1]
IDS should consider the depth of the tooth preparation, its relation to the dentin-pulp complex, and the composition of the materials used.
As presented above, dentin has different anatomical and histochemical characteristics as the depth increases. When tooth preparation is superficial or medium-depth, the freshly cut dentin can be sealed with a dentin adhesive.

However, in lesions close to the pulp, the increased diameter and number of dentinal tubules and the reduced intertubular dentin increase the pulp's dentin permeability.[11] Therefore, bacterial toxins and low-molecular-weight free monomers can migrate to the pulp and cause cytotoxicity.[12,13] In addition, the degree of polymerization of the monomers influences the degree of diffusion. Diffusion in the unpolymerized monomers was up to ten times higher.[12]

The exposure time and the concentration of low molecular weight monomers in the primer increase the risk of pulpal involvement. According to Ratanasethien et al.,[13] the following concentrations of low molecular weight monomers are cytotoxic: 13 µmol/l in 12 hours; 3.6 to 4 µmol/l in 24 hours; 1.02 µmol/l in 72 hours. The concentration in the primer can be 4,000 µmol/l.

The cytotoxicity of dentin adhesives at various dilutions was significantly higher in 0.5 mm than in 1.5 mm remaining dentin thickness.[2,14] It is impossible to calibrate this thickness clinically. Therefore, in these clinical situations, indirect pulp protection (IPP) with remineralizing biomaterials is indicated.[15,16]

These remineralizing agents must be biocompatible, antibacterial, and stimulate biomineralization. Its physicochemical properties should be short setting time, high mechanical strength, alkaline pH, Ca ion release, high radiopacity, low porosity and solubility.[17]

The most commonly used remineralizing materials are calcium hydroxide (CaOH2), glass ionomers (VI), and bioceramic materials based on tricalcium silicate (STr).

In deep cavities, the biological response of the dentin-pulp complex was superior with $CaOH^2$ or VI than with total etching and an adhesive system.[14]

Conventional and resin-modified glass-ionomer cement was applied in very deep cavities. Neither group showed postoperative sensitivity or persistent pulp damage, which indicates its biocompatibility.[18]

In two clinical studies, the three remineralizing materials had similar responses,[19,20] while the tricalcium silicate-based materials were superior in other studies.[21,22]

A retrospective clinical study of 160 IPP in 89 patients in a 5-18-year period, performed with glass ionomer-protected settable calcium hydroxide yielded a 98.5% functional survival rate. There were two failures. Of the 158 successful IPPs, 95 (59%) were performed on bonded restorations. The mean survival was 13 years, and the clinical success of the restorations was 94.9%.[4]

Therefore, using IDS in deep dentin preparations might be a biohazard to the dentinpulp complex.

Clinical research

The number of clinical studies evaluating the results of IDS is minimal.

IDS was used in 30 out of 60 partial molar LDS restorations (test). In the control group, DDS was applied at two weeks. This study did not confirm that IDS provided better results regarding tooth sensitivity and patient satisfaction.[67]

Another study of LDS posterior bonded partial restorations created two groups: the test group received IDS. At three years, overall survival was 98.3% and clinical success was 85%. No statistically significant difference existed between the groups with IDS and without IDS (p=0.32). Controls were performed at 1 week, 12 months and 3 years.[70]

In 104 patients, out of 384 veneers on upper anterior teeth, IDS was used in 87 teeth (22.6%) with more than 50% exposed dentin and 43 (11.2%) in endodontically treated teeth. The mean survival in teeth with 50% exposed dentin was 96.4% vs. 81.8%. The total number of failures was 19 (4.9%).[71]

The results of the clinical studies mentioned above are summarized in Table 2.

Table 2. Comparison of clinical studies regarding Dentin Bond Strength (DBS – main variable) and the use of IDS and DDS, postoperative sensitivity (POSTOP. SENSITIVITY), associated with different desensitizing agents (DESEN. AGENTS), and IDS or DDS.

Lit. Reference No.	POSTOP. SENSITIVITY with DESEN. AGENTS and IDS or DDS	Lit. Reference No.	CLINICAL RESULTS with IDS or DDS
63	With Gluma Similar effect as with CaOH2	70	LDS IN/ON with IDS or DDS without diff. at 3 years
64	With potassium nitrate lower sensitivity than Gluma	71	With IDS good clinical result without control group
66	Sensitivity similar with IDS or DDS		
67	Sensitivity similar with IDS or DDS		
65	Various materials and/or techniques lower postop. sensitivity		
68	No difference between IDS and DDS		

Other abbreviations and symbols: Lit. Ref. No. (Literature reference number). The light green cells include clinical studies, and the dark green cells, literature reviews.

The observation period of 765 bonded partial LDS restorations in 158 patients ranged from 3 to 113 months (mean survival = 53.3 months). IDS was used in all cases. Functional survival was 99.65%, and clinical success was 98.6%. The location, extent, and endodontic status did not statistically affect the cumulative success (logrank test, $p>0.05$).[72]

A review by Abu-Nawareg et al.[23] concluded that more clinical studies are needed to determine if pulp health is significantly better in teeth with IDS.

Van den Breemer et al.[73] reviewed 88 articles and found no clinical studies related to IDS.

Another review of 88 articles meeting the inclusion criteria on various aspects of IDS concluded that there are no documented reasons for its systematic use. It appears to be beneficial in some cases of indirect restorations.[74]

Borgia et al. [75] conducted a retrospective study that spanned between 5 and 18 years and included 93 bonded ceramic inlays/onlays (13 feldspathic ceramic onlays and 78 onlays and 2 IPS-Empress inlays) that met the inclusion criteria. They found that 87 (93.5%) restorations worked well during clinical evaluation. Two inlays and four onlays (6.5%) were fractured. The mean survival of the restorations in function was 10 years and 11 months, and the clinical success was 93.1%. DDS was used in these restorations.

The results of the clinical studies using IDS are similar to those of other studies of bonded restorations with DDS,[75-92] shown in Table 3.

Interferences

Resinous materials may interact with some impression materials and prevent their complete polymerization. This can be seen in the poor quality of the models.[93] Two studies found similar results with the same polyether when IDS was used.[94,95]

Discussion

In the introduction, we established that any restorative procedure should be *effective* and *efficient*.

Furthermore, freshly cut dentin is considered the ideal substrate for dentin bonding.[12,24] IDS would increase DBS values.

However, DBS showed varying biomechanical results in different studies. It was higher with IDS in three systematic reviews.[34-36] Laboratory studies showed that DBS was higher with IDS than with DDS,[29-33] similar to DDS,[37,38] lower than DDS.[39] This depended on the type of adhesive system used,[40,41] and there was a progressive DBS decrease in the short term.[42]

The DBS variation would take place due to hydrolytic degradation of the hybrid layer. This may occur much faster clinically than a potential failure, so DBS would have a secondary role in clinical survival.[43] Overall clinical success is multifactorial, and there is little evidence correlating bond strength in the clinic with laboratory results.[45]

The relevant research focuses on developing new adhesives that modify or interact appropriately with the current environmental conditions of the hybrid layer zone.[46-49]

Additionally, after removing temporary cement remnants mechanically or manually, some laboratory studies showed that DBS was higher with IDS.[50-52] In contrast, other studies did not find statistically significant differences with or without IDS.[33,53-55] The failures were mixed.[52]

Regarding the influence of IDS on dentin and/or restoration fracture resistance, some studies showed that:

- in vitro, IDS did not influence tooth fracture;[56] the fracture resistance of ceramic onlays was higher with IDS than with DDS;[57] a 0.7 mm occlusal thicknesses in the fissures and 1 mm at the cusps in bonded LDS ceramics was sufficient for fracture resistance.[58]
- in vivo, IDS improved the adhesion and structural strength of ceramic laminates in anterior teeth with 50% or more exposed dentin,[60] as well as those of LDS inlays, but not of multiphase resin composite.[59]

In the latter, one may wonder whether the inlay results of the compared materials are due to IDS or to the higher RμTA of the ceramic materials at the restoration–bonding system interface, as shown in other studies.[61,62]

Therefore, the biomechanical effectiveness of IDS is significantly affected, considering the varying DBS results and its instability over time, as well as the limited influence on TFR and RFR.

The biological aspects analyzed were postoperative sensitivity and IDS biocompatibility.

A systematic review[65] and a clinical study[63] evaluated several desensitizing agents. They showed a reduction in sensitivity without significant statistical differences in the short, medium, and long term. Another clinical study found substantial differences between two agents.[64]

A study of fixed partial dentures and IDS showed a more significant reduction in postoperative sensitivity at one week and one month. However, at 6, 12, and 24 months, there was no difference with the DDS used in the control group.[66]

A clinical comparison of two groups of 30 bonded ceramic partial restorations did not confirm that IDS was better than DDS regarding tooth sensitivity and patient satisfaction.[67]

Another recent systematic review and meta-analysis comparing IDS and DDS found no statisti-

Table 3. Results of clinical studies of bonded ceramic restorations in posterior teeth using DDS

AUTHORS	ST.	REST. (n)	MATERIALS	In function	LONG. (a)
Borgia E. et al.[75]	R	93	Vitadur 13 IPS-Emp 80	93.1%	18 (SMO 11)
Frankenberger et al.[76]	P	96	IPS-Empress	96%	12
Guess et al.[77]	P	40 40	LDS LDS-CC	100% 97%	7
Galiatsatos & Bergou[78]	R	64	IPS-Empress	94%	6
Santos et al.[79]	R	64	Duceram and IPS	87%	5
Beier et al.[80]	R	213	Feldspathic onlays	92.4%	12
		334	Feldspathic inlays	89.6%	
Collares K. et al.[81]	R	5591	Inlay/Onlay	96.2%	3 -15
Archibald et al.[82]	R	37	LDS-CC	91.5%	4
Mobilio et al.[83]	R	43	LDS-CC	94.2%	7 (4.3)
Van den Breemer et al.[84]	R	74	LDS-CC	81.9%	15 (12.8)
Schultz et al.[85]	R	107	Mirage	84%	9 (6.3)
Murgueito & Bernal[86])	P	210	IPS-Empress	97%	3
Lange & Pfeiffer[87]	R	250	Evopress	94%	9 (6)
van Dijken & Hasseirot[88]	P	228	IPS-Empress	76%	15 (12.6)
Fabianelli et al.[89]	R	33	Empress II	88%	3
Aslan et al.[90]	P	75	LDS/LAS RCII-CC	100%	1
Otto T.[91]	R	141	Cerec 1- CC	87.5%	26 to 10m
Malament et al.[92]	R	2,392 (1782 Co) (610 In/On)	Pressed e. max LDS	96.49%	16.9

(St. = studies; P = prospective; R = retrospective; Rest. (n) = restoration, number; Long. (a) = longevity, years; LDS = lithium disilicate).

cally significant difference in postoperative sensitivity at the baseline nor at two years.[68]

Based on the above results, the efficacy of IDS in reducing postoperative sensitivity is comparatively similar to that of DDS and desensitizing agents.

As for IDS biocompatibility, it depends on the depth of the carious lesion. Indeed, when the pulp wall is close to the pulp, permeability and the risk of bacterial migration increase.[11] In addition, the degree of polymerization and the amount of free unpolymerized monomers,[12] as

well as the low molecular weight of the monomers and the concentration of monomers in the primer,[13] may increase the risk of migration into the pulp and cause pulp cytotoxicity.[2] It is risky to use IDS in this clinical situation. It is advisable to apply a remineralizing agent in the area.[14-22]

Therefore, IDS biocompatibility is inadequate in lesions near the dentin-pulp complex, and its application is risky. This limitation reduces its effectiveness.

Comprehensive Restorative Dentistry also aims to develop techniques and/or materials that simplify restorative procedures without compromising or improving their results, reducing clinical times, and increasing productivity.

However, IDS is more time-consuming and complex. IDS requires isolation with a rubber dam twice: when IDS is applied and when the restoration is bonded. Conversely, DDS requires isolation only when bonding the restoration. IDS is more complex because removing excess polymerized adhesive on the enamel margins of the tooth preparation, which is inevitable, is a delicate and risky maneuver. This is the case, especially with intrasulcular gingival margins and thin enamel thicknesses, which also require more clinical time.

Layer thickness is never uniform in adhesive processes. As IDS is polymerized, the topography of the tooth preparation is not modified in either the analog or the virtual model. Conversely, when applying DDS and a light-activated polymerization adhesive system, failure to remove excess adhesive, especially in the preparation angles, might cause a discrepancy between the model and the clinical preparation after applying the sealant. This might influence the micro-adaptation of the restoration.

However, dual or chemically activated resin-based bonding systems might prevent this discrepancy. A recent laboratory study showed that ceramic inlays bonded with a dualcure resin had better internal adaptation with IDS after thermal cycling. However, there were no statistically significant differences in marginal adaptation between IDS and DDS.[96]

Additionally, IDS is a must when making temporary restorations with chemically polymerized or light-activated composite resins or Bis-acryl resins. The surface of the preparation should be covered with water-soluble glycerin gel when manufacturing the temporary restoration so that the material does not bind to the adhesive. The gel must be removed before luting the temporary restoration.

In addition, the interference of the adhesive in the polymerization of some impression materials,[93-95] although not significant, is a limitation.

Therefore, as IDS is more complex, it increases clinical times, increases cost, decreases productivity, and alters the cost-benefit ratio, reducing its efficiency.

Furthermore, any clinical procedure must have clinical evidence supported by several clinical longitudinal studies. This technique is addressed in a very small number of clinical studies,[67,70-72] which is highlighted in three reviews presented.[23,73,74] Only one study showed a long-term longevity (11 years),[72] while in the others it was 2 years,[67] 3 years,[70] and 3 to 113 months (mean survival = 53 months).[71]

The 765 restorations with IDS presented by van den Breemer et al.[69] showed excellent results, but since there was no control group, they cannot be compared with DDS. Their success is comparable to the results of Table 3 with DDS.[75-92]

The very small number of clinical studies on IDS weakens the technique's scientific evidence and therefore its efficacy.

However, we cannot discard its use, since its application depends on the clinical situation and the practitioner's scientific knowledge.

Conclusions

While laboratory studies may provide a scientific basis for clinical use, *their results are not predictors of clinical success.*
Clinical work is essential and clinical scientific evidence underpins clinical procedures and the ethical practice of dentistry.

The assessment of the biomechanical, biological, technical, and clinical results presented above show that Immediate Dentin Sealing does not have the expected levels of efficacy and efficiency.
So far, Immediate Dentin Sealing would be justified in specific situations, but not as a routine procedure when working with indirect bonded restorations.

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1. Conception and design of study
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5. Drafting of the manuscript
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