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Review Article

Substantial in-vitro and emerging clinical evidence supporting immediate dentin sealing

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ABSTRACT

The application of resin adhesive to freshly cut dentin after teeth preparation, the so-called immediate dentin sealing (IDS) has been suggested as an alternative to the delayed dentin sealing (DDS), a technique in which resin adhesive is applied just before final bonding of indirect restorations.

The aim of this review is to demonstrate the evidence of the claimed advantages made by the proponents of IDS technique.

The results of this review revealed substantial in-vitro evidence supporting the IDS benefits including improved bond strength, reduced dentin permeability, improved restorations' adaptation, and increased fracture strength of the restorations. Clinical studies have shown that IDS improves survival of ceramic laminate veneers bonded to prepared teeth with increased exposure of dentin. Moreover, it has been shown that IDS reduces post-cementation hypersensitivity in full coverage restorations, which is characterized by exposure of a large number of dentinal tubules. The selection of filled resin adhesive that is capable of producing thick adhesive layer appears to contribute to the success of the technique. Furthermore, careful management of the oxygen inhibition layer before conventional impression making and proper cleaning of the residual temporary cement used with provisional restorations appears to affect the outcome of the restorations.

1. Introduction

Emphasis on conservation of tooth structure and increased demand for esthetic restorations coupled with advances in materials and techniques have resulted in increased use of bonded indirect restorations. Such restorations include ceramic laminate veneers (CLV), inlays, onlays, and full ceramic crowns. As the profession discovered the benefits of bonding ceramic to etched enamel [1,2] there was an increased use of CLV as an esthetic restoration for anterior teeth. Furthermore, while direct restorations is the preferred treatment as it allows maximum preservation of tooth structure [3], restoration of extensively damaged posterior teeth using indirect restorations including inlays and onlays have the advantages of improved anatomic tooth form, contour, refined occlusal contacts, as well as better mechanical properties [3–5]. Recently, indirect ceramic and composite resin restorations have eclipsed the traditional cast gold inlays and onlays as result of improved materials' mechanical properties, development of reliable adhesion techniques, advancement of new fabrication technology, increased demand of aesthetic restorations as well as increased price of gold [3,6,7]. Recent surveys also demonstrated an increased use of all ceramic crowns, particularly on anterior teeth, by dentists in different parts of the world [8,9].

The fabrication of indirect bonded restorations involves several procedural steps including tooth preparations, impression making, provisionalization, laboratory fabrication and adhesive cementation of the indirect restorations.

An increased emphasis has been placed on conservation of sound tooth structure as the concept of minimal intervention has become widely accepted [10]. The extent of tooth preparation, however, depends on the severity and size of the lesion affecting the tooth structure. Inlays, onlays, and full crowns are usually used for restoration of grossly damaged teeth with associated exposure of large amount of dentin [11,12]. Furthermore, while CLV are regarded as intra-enamel restorations, clinical stud-

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ies demonstrated that preparations of teeth affected by caries, existing restorations, tooth wear, fractures, discoloration, as well as hypocalcification and amelogenesis imperfecta can result in substantial exposure of dentin under CLV restorations [13–17].

Adhesive cementation of indirect restorations with substantial exposure of dentin structure is regarded among the most challenging tasks of bonded indirect restorations [18]. Traditionally, application of dentin resin adhesive to exposed dentin was performed just prior to cementation, so-called delayed dentin sealing (DDS), where curing of the dentin bonding resin was performed together with the luting agent to allow proper adaptation of the restoration to preparation margins [19].

Concerns were raised regarding increased dentin permeability following crown preparations with increased chance of development of post-operative sensitivity as well as possibility of vital pulp irritation [20]. In a subsequent study by the same group, Pashley et al. [21] demonstrated that the application of resin adhesive immediately following crown preparations can reduce dentin permeability. Later studies found that dentin surface contamination through remnants of luting cements used during the provisional phase can negatively affect the bond strength between tooth structure and adhesively luted indirect restorations [22,23], thus may jeopardizes the clinical longevity of bonded indirect restoration [18].

The first evidence of a technique to address issues related pulp irritation, postoperative sensitivity, and improved marginal adaptation of indirect restorations appeared in the Japanese literature in the early 1990s where eminent Japanese clinicians described the so-called resin coating technique [24,25]. In this technique, resin adhesive agent is applied to both enamel and dentin surfaces that were exposed after tooth preparation [25]. Subsequently, a similar idea, the so-called dual bonding technique, was reported by Bertschinger et al. [26] where resin adhesive agent was immediately applied to exposed dentin after tooth preparation followed by a second application at the time of final cementation. Further studies suggested that the dual bonding technique improve bond strength of indirect restorations as a result of stronger hybrid layer formed on freshly cut dentin as compared to that in DDS technique, where contamination and collapse of the hybrid layer might have occurred following the provisional phase [19,22,23,26].

Based on the concept of dual bonding technique, Magne and coworkers coined the term immediate dentin sealing (IDS) and extended its use for other indirect bonded restorations with particular emphasis on bonding of CLV [27,28]. Since then the clinical application of the IDS technique was advocated for adhesive luting procedures of indirect restorations made of ceramic or composite resin materials [18,29,30].

Resin coating technique has been thoroughly reviewed in several publications [5,25,31]. On the other hand, despite extensive in vitro evidence, several reviews [32,33] were not able to identify clinical evidence for the benefits of IDS technique. Thus, the aim of this review was to evaluate recent literature and emerging clinical evidence for the effect of the IDS technique on clinical longevity of indirect restorations.

2. Invito studies

2.1. Bond strength of indirect restorations using IDS

Based on the assumption that the stronger the bond, the better it will resist stresses during clinical service, assessment of the adhesive potential of a material relies on bond strength testing. Studies consistently demonstrated that the use of IDS technique produced significantly higher mean bond strength as compared to DDS. Based on methods and materials tested, bond strength values for IDS were reported to range from 11 to 66 MPa, where as that for DDS to range from 2 to 41 MPa [28,34–38].

Table 1
Classification of resin adhesive systems.[a]

Resin adhesive systems		
Adhesive system	Classification	Subclassification
Etch and rinse (Total-etch)	Three-steps (1) Etch, (2) Prime, (3) Bond Two-steps (1) Etch, (2) Prime & Bond	
Self-etch	Two-steps (1) Etch & Prime, (2) Bond One-step (all in one) (1) Etch, Prime & Bond	
Universal (Multi-mode)	Self-etch Etch and rinse	Total-etch (1) Etch [enamel & dentin] (2) prime & bond Selective enamel etching (1) Etch enamel (2) self-etch dentin, prime & bond

[a] Based on classifications by Sofan et al. [39], Van Meerbeek et al. [40], and Alex [41].

2.1.1. Factors affecting bonding properties of IDS

As IDS technique involves application of first dentin adhesive layer on freshly cut dentin before impression making, and a second application after removal of provisional restorations, several factors such as type of resin adhesive, choice of impression materials, as well as the provisional restorations may affect the bond strength.

2.1.1.1. Type of resin adhesive system. Many resin adhesive systems were developed over the last decades. From a clinical point of view these can be classified into etch and rinse, self-etch, and universal adhesives (Table 1). For in depth discussions of the types and mechanisms of resin adhesive systems, the reader is referred to the excellent reviews on the subject [39–42].

The type of adhesive resin system used can positively or negatively affect adhesion to dentin [43]. Based on proven reliability and improved adaptation to dentin among the bonding agents available at the time [28,44,45] suggested the use of Optibond FL (Kerr, Orange, Calif, USA), which is a 3-step etch and rinse adhesive resin. With advances in adhesive technology and the introduction of new resin adhesives, other types of resin adhesives were tested. In a subsequent study, Magne et al. [34], found that the use of Clearfil SE Bond (Kuraray, Tokyo, Japan), a 2-step self-etching adhesive resin, produced significantly higher bond strength when used with IDS as compared to DDS technique. In the same study, although the bond strength produced by the Clearfil SE Bond (51.96 and 45.76 MPa at 7 and 12 weeks respectively) was found to be lower than that produced by Optibond FL (66.59 and 59.11 MPa at 7 and 12 weeks respectively) when used with the IDS technique, they concluded that the difference was not significant and that both Optibond FL and Clearfil SE Bond can be used for IDS technique [34].

Several other studies investigated the bond strength produce by the 2-step etch and rinse as compared to 2-step self-etch resin adhesives. Duarte et al. [35], found that Adper Single Bond (3M ESPE, St. Paul, Minn, USA), a 2-step etch and rinse adhesive, produced a higher bond strength than Adper Prompt L-Pop (3M ESPE, St. Paul, Minn, USA), a 2-step self-etch adhesive, when used for IDS technique. Furthermore, Clearfil SE Bond produced higher bond strength than Adper Single Bond 2 (3M ESPE, Seefeld, Germany), a 2-step etch and rinse adhesive resin [37,46].

On the other hand, Ferreira-Filho et al. [47], compared the tensile bond strength of four resin adhesives after 30 days of water storage. They found that there was no significant differences in tensile bond strength between the tested adhesives, although Optibond FL (28.3 ± 9.2 MPa) and Clearfil SE Bond (25.4 ± 3.9 MPa) demonstrated higher values as compared to one-step self-etch Xeno V (Dentsply De Trey) and the 2-step etch and rinse XP Bond (Dentsply De Trey) (18.6 ± 9.8 and 21.9 ± 2.5 MPa respectively). In this study, however, the small sample size (n = 5) and the known premature failure of samples that can occur with micro-tensile bond strength testing could have accounted for lack of statistical significance differences between the groups.

In addition to the type of the adhesive resin, thickness of the adhesive resin layer may also play an important role in bond strength. As immediate application of the resin adhesive after tooth preparation allows improved penetration of resin monomers to form a hybrid layer [48,49], improved bonding strength was seen when using a micro-filled resin adhesive as compared to unfilled resin adhesive [46]. This is believed to be due to the thicker polymerized uniform layer provided by the low viscosity, filler-containing resin adhesive that enables the hybrid layer to act as an elastic buffer to absorb the internal or the external stress as a result of polymerization contraction of the overlying luting agent or when subjected to functional stresses [50,51]. An additional advantage of the thick layer of resin adhesive is that cleaning following removal of provisional restorations will less likely expose dentin [46,52]. The consistent results obtained with the filled resin adhesive Optibond FL was attributed to its increased uniform thickness (of about 80 μm) as compared to unfilled adhesive resins [53,54]. In addition to presence of fillers, the thickness of the resin adhesive has been shown to be affected by surface morphology of teeth and application of air. Depending on the surface of the prepared tooth, it has been shown that the thickness of polymerized resin adhesive on average to vary between 60 to 80 μm on smooth convex surfaces and up to 200–300 μm on concave structures such as chamfer finish lines [21,54]. To avoid obliteration of shallow preparation features such as finish lines, gentle air thinning (0.5 kg/m^2) of adhesive resin has been shown not to affect bond strength as compared to aggressive air application [36]. In this respect, it should be remembered that adhesive resins have an oxygen inhibition layer (OIL) of around 40 μm [55]. Excessive thinning of, or the use of, unfilled adhesive resin make the dentin adhesive layer too thin that it may weaken the bond strength between adhesive resin and tooth structure [55].

The application of flowable resin composite over immediately applied resin adhesive has been shown to increase the bond strength [46]. In 2014 Magne [56] recommended the use of 3-step etch and rinse or 2-step self-etching filled adhesive resin. He further recommends that if unfilled resin adhesive is used for IDS, it should be protected with a layer of flowable composite resin [56]. This latter recommendation is endorsed with earlier findings that the addition of a layer of flowable resin protects the hybrid layer and improves the peripheral seal of the restoration thus reduces post-operative pain, enhances the resin cement-dentin bonding resulting in improved performance of restorations [25,46,57,58]. The added advantage of flowable resin layer is that undercuts can be blocked in extensive inlay and onlay preparations, therefore avoiding removal of sound tooth structure to improve path of insertion and removal for such indirect restorations resulting in conservation of sound tooth structure [25]. However, while the application of flowable resin composite may be feasible clinically in deep preparations such as those of inlays and onlays, the lack of space in other preparations such as CLV and full crowns may make its application clinically unfeasible.

2.1.1.2. Impressions procedures. It has long been known that an OIL, of about 40 μm thick, is formed on the surface of the resin adhesive following polymerization [55,59–61]. In the IDS technique, as resin adhesive is applied before impression making, concerns have been raised about possible interactions between the unpolymerized resin in the OIL and impression materials resulting in inaccurate impressions [62–65]. Interactions between the OIL and impression materials result in inhibition of polymerization of polyvinyl siloxane (PVS) [53,65]. It has also been shown to cause adherence and inhibition of polymerization of polyether impression materials [53,65,66]. As a result, different techniques to eliminate the OIL (Table 2) have been proposed and investigated (Table 3).

Using optical microscope, evaluation of residual impression materials on teeth surfaces sealed with Optibond FL or Clearfil SE Bond resin adhesives revealed that the combination of air blocking followed by pumicing of resin adhesive surface resulted in accurate impressions made with PVS materials [65]. However, these techniques resulted in unpredictable impressions made with polyether impression material [65]. Other studies using stereomicroscope [67] or photographs [66,68] to detect residual impression materials on teeth surfaces confirmed that unpredictable polyether impressions were produced following air blocking and/or pumicing.

While Magne and Nielsen [65] emphasized the need for combination of techniques and that one technique (air blocking or pumicing) is not sufficient to remove the OIL and ensure accurate PVS impressions, other studies [66] showed that one technique (air blocking, pumicing, alcohol, detergent, or cleaning with an Opticlean bur at 500 rpm) is sufficient to produce accurate PVS impressions. The contradictory results of these studies might be due to lack of sensitivity of the assessment methods used to evaluate t remnant impression materials on teeth surfaces. On the other hand, when residual impression materials on teeth surfaces were quantitively evaluated using scanning electron microscope, Sinjari et al. [69] found that the combination of air blocking followed by cleaning with prophy paste and a surfactant agent (Marseille soap) on teeth surfaces sealed with Optibond FL produced accurate impressions made of either PVS or polyether impression materials [69]. This latter study [69] concurs with the findings of Magne and Nielsen [65] emphasizing the need to use a combination of OIL elimination techniques to produce accurate impressions.

In addition to type of impression material and OIL elimination technique, the type of resin adhesive used seems also to affect the accuracy of impressions. Most studies agree that accurate impressions can be obtained when either Optibond FL or Clearfil SE Bond was used to seal the exposed dentin [65–69]. Several other resin adhesive agents tested (including Scotchbond Universal, Optibond XTR and Filtek LS, and Adper single bond 2) have shown unpredictable PVS and polyether impressions as compared to Optibond FL or Clearfil SE Bond despite the use of OIL elimination techniques [66,67]. The exact reason for this is not known, however, investigators suggested that this could be due to the low pH of adhesive resins tested [66].

Placement of composite resin liner over the resin adhesive has been shown to consistently improve the quality of PVS and polyether impressions [66,68]. The advent of digital impression techniques may resolve all possible issues related to interactions of impression materials with sealed dentin surfaces, however, no study compared the accuracy of impressions using conventional and digital impressions.

2.1.1.3. Provisional restorations. In principle, the success of the IDS depends on the bond strength of the first precured resin adhesive applied immediately after tooth preparation and a second resin adhesive layer applied just before final cementation. As indirect bonded restorations fabricated with conventional technique requires placement of provisional restorations until the final restoration is inserted, therefore, contamination of the first pre-

Table 2
Techniques used to eliminate oxygen inhibition layer of resin adhesive in IDS.

Technique	Description	Reference
Air blocking	Applying a thick layer of glycerine jelly followed by additional polymerization of resin adhesive for 10–20 s, then rinsed by water and dried with air.	Magne & Nielsen [65]; Bruzi et al., [66], Ghiggi, et al. [68]; Sinjari, et al. [69],
Pumicing	Gentle application of a mix of pumice-water with a soft rubber prophy cup in a slow speed handpiece running at 500 rpm.	Magne & Nielsen [65]
Cleaning with prophy paste	Gentle cleaning with prophy paste using coping brush in low speed handpiece running at 500 rpm under water spray.	Sinjari et al. [69]
Cleaning with alcohol	Surface wiped by a cotton pellet soaked in 70% alcohol for 10–15 s followed by rinsing with water and air drying.	Bruzi et al., [66], Ghiggi, et al. [68],
Cleaning with a detergent	A detergent (Liquid soap, Lucky SuperSoft) rubbed on the surface using cotton pellet for 15 s followed by rinsing with water and air drying.	Bruzi et al. [66]
Cleaning with a surfactant agent	Surface cleaned with a surfactant (Marseille soap).	Sinjari et al. [69]
Mechanical removal	Gentle cleaning of polymerized surface of resin adhesive using an Opticlean bur (Kerr, USA) in low speed handpiece running at 500 rpm.	Bruzi et al. [66]
Application of microfilm	Microfilm (Kerr, USA) sprayed onto air blocked resin adhesive followed by air dryness before making impression.	Bruzi et al. [66]
Application of liner coating	Filled composite liner (flowable composite) applied and cured over the first resin adhesive layer of the IDS.	Bruzi et al. [45]; Ghiggi et al. [47]
Combination	Several studies used a combination of techniques described above.	Magne & Nielsen [65]; Bruzi et al., [66], Khakiani et al. [67] Ghiggi, et al. [68]; Sinjari, et al. [69]

cured resin adhesive surface during the provisional phase may affect the final bond strength.

Several studies have shown that the contamination of resin adhesive with provisional cements reduces bond strength of resin cement for the final cementation [64,70–76]. The selection of provisional cement has been shown to exert a significant effect on the bond strength of the final restorations. The use of calcium hydroxide and zinc oxide eugenol-free cement has been shown to have little or no effect on bond strength of final restorations as compared to zinc oxide-eugenol and resin-based provisional cements [76–78].

As provisional cement potentially contaminates the surface of the first layer of the resin adhesive resulting in compromised bond strength, a thorough cleaning of provisional luting cements before final cementation is essential [79–82]. Different provisional cement cleaning methods have been suggested which can be categorized as mechanical [76–80,82–86] chemical [78,80,87] and laser [80] (Table 4). It is important that the cleaning method being used removes all remnants of provisional cement from the surface of the first resin adhesive layer to allow optimal bonding with the second resin adhesive layer that is applied during the final cementation. Contradictory results have been found between studies investigating the various methods of provisional cement cleaning on bond strength (Table 5). The search for an optimal method of provisional cement cleaning seems to continue. In addition, concerns have been raised regarding the possibility of removing the first resin adhesive layer during provisional cement cleaning [18,29]. It is interesting to note that at least one study [83] has shown that higher bond strength can be achieved even when eugenol-containing provisional cement was used suggesting that the cleaning method may be more important than the type of cement used.

To simplify the provisional restoration and overcome issues related to provisional cement contamination, proponents of the IDS recommend placement of provisional restorations without provisional cements [18,27,29,88]. As provisional restorations are made of methacrylate- or composite resin-based materials, they may adhere to the underlying resin adhesive layer causing difficulty during subsequent removal [27]. To overcome this, it has been recommended to apply a separating media such as petroleum jelly prior to provisional restoration placement [27]. Nowadays, special materials (pro-V coat by BISCO, IL, USA; Glycerin Insulating gel, Heraeus-Kulzer, Germany) are available to help prevent this undesirable adhesion between the resin adhesive layer and provisional restoration [88]. Additional provisional materials placed into the embrasures and/or splinting adjacent restorations can enhance the retention of the provisional restoration [27,88].

Early studies suggested that the final bond strength is not affected when provisional restorations were kept up to 12 weeks [34]. Nevertheless, as a result of the possible effects of oral fluids and water sorption mechanisms [89] on the resin adhesive layer, it is recommended that provisional restorations should be kept to a maximum of 2 weeks [27]. However, recent study showed that the bond strength was reduced after thermocycling particularly when stored more than 7 days [90]. These results were associated with the observations that the exposed dentin and collapsed hybrid layer were seen in groups that were subjected to thermocycling for more than 7 days [90]. The authors concluded that ceramic restorations should be bonded using resin cement within one week after IDS procedure [90]. The increased popularity of the same-day fabrication of CAD/CAM restorations, where teeth are prepared and restored on the same day without the need for provisional restorations is expected to resolve all concerns regarding the provisional phase.

2.1.1.4. Marginal integrity and internal adaptation. Several studies evaluated the effect of IDS on marginal integrity and internal adaptation of bonded indirect restorations [91–93]. Schenke et al. [91], found that IDS improved marginal sealing in partial ceramic crowns with margins placed in dentin after thermocycling and mechanical loading as compared to those bonded without IDS. Similarly, Kitayama et al. [92], found that the IDS technique reduced microleakage at margins of CAD/CAM inlays with margins placed in dentin. More recently, Ashy et al. [93], found that IDS improved marginal adaptation and provided superior internal adaptation of ceramic inlays following IDS.

2.1.1.5. Fracture strength. Adhesive cementation of ceramic restorations has been shown to increase the fracture strength of restored teeth [94–96] and bonded ceramic restorations [97–99]. Spohr et al. [100], have provided evidence that IDS procedure increases the fracture load of full ceramic crowns [100]. More recently, Gresnigt et al. [101] demonstrated that IDS improved

Table 3
Studies investigating the interaction of impression materials and oxygen inhibition layer of adhesive resin.

Reference	Study design	Conclusions
Magne and Nielsen [65]	Evaluated possible interactions of: IM: Extrude (PVS) and Impregum Soft – PE (PE). RA: Optibond FL and Clearfil SE Bond. OIL ET: Air blocking (Glycerine Jelly) and air blocking followed by pumicing. Assessment: Qualitative evaluation of presence of absence of residual IM on tooth surface using optical microscopy.	• Air blocking followed by pumicing prevents interaction of PVS with both RA. • PE is not recommended in IDS.
Bruzi et al. [66]	Evaluated possible interactions of: IM: Express STD (PVS) and Impregum F (PE) RA: Optibond FL, Scotchbond Universal, Optibond XTR and Filtek LS Composite liner: Filtek Supreme Ultra or Miris 2 applied over the RA. OIL ET: Air blocking, alcohol, detergent (Liquid Soap), Microfilm sprayed onto the sealed/air-blocked preparation, and cleaning with an Opticlean bur at 500 rpm. Assessment: Qualitative evaluation of presence or absence of residual IM detected on photographs of teeth surfaces after impressions.	• Placement of composite liners over RA prevented interactions of all IM tested. • Combinations of Optibond FL followed with any OIL ET produced 100% perfect PVS impressions. However, all other RA followed with any OIL ET produced unpredictable PVS impressions. • The use of any RA tested followed by any OIL ET produced unpredictable PE impressions.
Khakiani et al. [67]	Evaluated possible interactions of: IM: Aquasil (PVS) and Impregum Soft (PE). RA: Adper single bond 2 and Clearfil SE Bond. OIL ET: Air blocking and air blocking followed by pumicing. Assessment: Qualitative evaluation of presence or absence of unpolymerized IM on teeth surfaces seen under stereomicroscope.	• The application of air blocking (layer of glycerine jelly) followed by pumicing results in accurate PVS impressions. • Air blocking or pumicing alone is not sufficient to prevent the effect of OIL and produce accurate PVS impressions.
Ghiggi et al. [68]	Evaluated possible interactions of: IM: Express XT (PVS) and Impregum (PE). RA: Clearfil SE Bond Composite liner: Protect Liner F. OIL ET: Air blocking with glycerine Jelly, 70% alcohol. Assessment: Qualitative evaluation of presence or absence of unpolymerized or residual IM detected on photographs of teeth surfaces after impression.	• The application of air blocking or alcohol prevent interactions between Clearfil SE Bond and PVS as well as between Protect Liner F and PE. • Air blocking or alcohol were not effective in preventing interactions between Clearfil SE Bond and PE or between Protect Liner F and PVS.
Sinjari et al. [69]	Evaluated possible interactions of: IM: Extrude medium (PVS) and Impregum Penta (PE). RA: Optibond FL OIL ET: Air blocking and cleaning with prophy paste, air blocking followed by cleaning with prophy paste then cleaning with surfactant agent (Marseille soap). Assessment: Quantitative evaluation of residual IM detected under SEM.	• The combination of air blocking followed by cleaning with prophy paste and then cleaning with Marseille soap produced accurate impressions for both PVS and PE impressions.

IM = impression material(s); RA = resin adhesive(s); OIL = oxygen inhibition layer; ET = elimination technique(s).

adhesion and thereby the fracture strength of lithium disilicate laminate veneers bonded to dentin surfaces as compared to those bonded with DDS technique [101]. The improved fracture strength of posterior inlay/onlay lithium disilicate ceramic restorations, following the use of IDS technique, has also been shown in in vitro study by van den Breemer et al. [102].

It has been suggested that polymerization shrinkage of luting resin may create stress concentration at the adhesive interface which may initiate crack formation at the ceramic subsurface [103]. It is believed that with the IDS technique, the delayed final bonding and functional loading of the restoration, allows the development of dentin bond to develop without stress and, therefore, subjects the restoration to less crack development [104,105]. This, in addition to the findings that bonding ceramic restorations to tooth structure strengthen ceramic restorations [97–99], would contribute to improved fracture strength of bonded restorations observed following the IDS technique.

2.2. Clinical studies

2.2.1. Survival rate

The effect of dentin exposure on debonding and retention of indirect bonded restoration is apparent when restorations with compromised conventional retention and resistance forms were evaluated. In this respect, several studies have shown that the survival rate of ceramic laminate veneers (CLV) with deeper preparations exposing dentin was significantly lower than CLV with intra-enamel preparations [106–108]). Gurel et al. [106] found that CLVs bonded to dentin and teeth with preparation margins in dentin were about 10 times more likely to fail than CLVs bonded to enamel. In that study, the failure rate of CLVs with preparation margins in dentin were 89.3% whereas that of preparation margins in enamel was 3.1% over a 12 year follow up. Furthermore, dentin exposure on axial surfaces occurred as a result of preparation depth resulted in failure rate of 31.9% whereas that

Table 4
Techniques of cleaning provisional cements.

Technique	Description	Reference
Mechanical methods		
Air-abrasion using aluminium oxide particles	Sandblasting with 50-μm aluminium oxide particles for 5 s at a pressure of 4 bars and a source-to-sample distance of 2 cm	Augusti et al. [78]; Fonseca et al. [83]
Air-abrasion using silica	Air-borne particle abrasion with 30 μm Si O_2 particles at 2 bar.	Ozcan and Lamperti [79].
Air-abrasion using glycine	Air-borne particle abrasion using 25 μm glycine powder.	Augusti et al. [78]
Non-fluoridated prophylaxis paste	Paste applied using rotary nylon brush in low speed at 1500 rpm for 15 s.	Sailer et al. [76]; Ozcan and Lamperti [79]
Pumicing	Gentle cleaning of surface using pumice-water slurry and rubber cup or brush in low speed handpiece for 10 s.	Erkut et al. [82]; Fonseca et al. [83]; Brigaga˜o et al. [84]; Ribeiro da Saliva et al. [85]
Cleaning with hand scaler	Gentle cleaning of the provisional cement using hand scaler for 10 s.	Augusti et al. [78]; Erkut et al. [82]; Fonseca et al. [83]; Ribeiro da Saliva et al. [85]
Cleaning with explorer	Mechanically cleaning with a dental explorer until the surface was macroscopically clean.	Altintas et al. [77]; Altintas et al. [80]; Brigaga˜o et al. [84]
Bur	Treating with a yellow tape diamond bur (Komet Dental Gebr. Brasseler GmbH and Co. KG, Lemgo, Germany) at 10,000 rpm for 3 s placed tangential to the surface under water cooling	Altintas et al. [80]
Polishing brush	Cleaning with polishing brush under water	Hayashi et al. [86]
Chemical methods		
Liquid chemical solvent (i.e. D-limonene)	Application of liquid chemical solvent (Bio Orange Solvent, Ogna S.p.a., Italy) containing D-limonene (also known as monocyclic monoterpene).	Augusti et al. [78]
Etching with orthophosphoric acid	Etching the surface with 37% orthophosphoric acid for 15 s	Altintas et al. [80]; Dillenburg et al. [87]
Laser		
Applying Er, Cr:YSGG laser (Waterlase MD, Biolase, Irvine, CA, USA)	Irradiation of surface with 2780 nm wavelength, 20 mHz frequency, 3 W power, 15 mJ energy and 119.42 J/cm^2 energy density with 50% water and 60% air in contact mode. The distance from the surface is kept minimal, and the hand piece was moved with a sweeping motion. The quartz mz tip with 800 μm diameter (Waterlase MD, Biolase, Irvine, CA, USA) was used.	Altintas et al. [80]

of intra-enamel restorations had 1.3% failure rate [106]. Recently, Gresnigt et al. [109] demonstrated the positive effect of IDS on survival of CLVs. They reported an overall failure rate of 5% (19 out of 348 PLVs placed), with 16 of the failed CLVs seen when the IDS technique was not used (84.6% survival rate) as compared to only 3 failed CLVs (99.1% survival rate) when the IDS technique was used [109]. Interestingly, in teeth with more than 50% dentin exposure, they observed that IDS resulted in significant increase in survival rate (96.4%) whereas the survival rate of those bonded with a DDS technique was about 81.1% [109]. On the other hand, van den Breemer et al. [110], reported no difference in survival rate of posterior inlays and onlays ceramic restorations bonded by IDS and DDS after 3 years of function [110]. In a subsequent study by the same group [33] reported on the survival of 765 posterior inlay and onlay restorations bonded using the IDS technique after a mean observation period of 53 months (range 3–113 months). They found that the estimated cumulative survival rate was 99.6% after 5 years and 96% after 7 years of function [33]. During this follow up period 9 teeth (out of 765) required endodontic treatment that was performed without loss of original restorations, secondary caries occurred in one tooth and debonding in another tooth.

Differences in the effect of IDS on survival of different restorations supports the presumption that improving bond strength of CLVs as a result of IDS technique may be more critical, as they rely mainly on bonding to tooth structure rather than conventional retention and resistance tooth preparation features. In addition, it has been suggested that CLV restorations on anterior teeth are subjected to both shear and tensile forces during function which further stresses the bonding surfaces, while posterior inlay/onlay restorations are subjected mainly to axial loading which can also explains the difference of the effect of IDS on survival rates of CLVs and posterior inlay/onlay restorations [102].

2.2.2. *Post-cementation hypersensitivity*

In vital teeth, post-cementation hypersensitivity occurs due to thermal and/or chemical stimuli during the provisional phase and/or following cementation of indirect restorations [111]. In most cases the post-cementation hypersensitivity is self-limited and resolved in about 24 months after cementation of indirect restoration [112].

A clinical study utilizing a double-blind and split-mouth design, the incidence of post-cementation hypersensitivity in vital teeth with full coverage restorations was investigated [113]. It was found that the use of IDS significantly reduced post-cementation hypersensitivity as compared to those with DDS technique up to 1-month post-cementation [113]. However, there was no difference in post-cementation hypersensitivity at 6- and 24-months follow up [113]. Similar findings were also observed in another study investigating post-cementation hypersensitivity following full coverage restorations made on vital teeth [114]. These results are consistent with in vitro evidence demonstrating that the application of adhesive resin immediately after tooth preparation reduced dentin permeability [20,115]. Contrary to these findings, in a prospective randomized clinical trial of posterior inlay and onlay restorations, no difference in post-cementation hypersensitivity was found between restorations bonded with IDS as compared to those bonded with DDS at 1 week, 3 months, and 12 months follow up [110]. It is well known that tooth preparations for full coverage restorations expose substantially a greater number of dentinal tubules [115]. The different types of restorations inves-

Table 5
Studies investigating effect of method of provisional cement cleaning on the bond strength of final restoration.

Reference	Materials and methods	Conclusions
Fonseca et al. [83]	Cleaning methods evaluated: Air-abrasion using 50-µm aluminium oxide particles compared to pumicing, and hand scaler. Provisional cements used: Calcium hydroxide cement (Dycal, Dentsply/Caulk, Milford, DE, USA), zinc oxide-eugenol cement (Provy, Herpo/Dentsply, Sa˜o Paulo, Brazil), zinc oxide eugenol-free cement (TempBond NE, Kerr, Orange, CA, USA)	• Higher bond strength values were achieved when aluminium oxide sandblasting was used as the cleaning dentin method regardless of type of cement.
Erkut et al. [82]	Cleaning methods used: Hand scaler followed by pumicing using rubber cup. Provisional cements used: Eugenol-free (Rely X Temp NE, 3M ESPE, St Paul, MN, USA); Eugenol based (Rely X Temp N, 3M ESPE, St Paul, MN, USA) provisional cements.	• In IDS technique, the application of cement did not reduce the shear bond strength (of two different resin luting systems) after cleaning with hand scaler followed by pumicing.
Dillenburg et al. [87]	Cleaning methods used: Airborne abrasion (50-µm alumina particles); Phosphoric acid 37% for 15 s followed by washed with air/water spray for 15 s; Combined air abrasion followed by application of 37% phosphoric acid Provisional cements used: Eugenol-free temporary cement (Rely X Temp NE, 3 M ESPE, USA).	• Combined use of air abrasion followed by application of 37% phosphoric acid removed cement remnants and provided high bond strength as compared to air abrasion or phosphoric acid alone.
Altintas et al. [77]	Cleaning methods used: Provisional cement mechanically removed with a dental explorer until the dentin surface was macroscopically clean, then dentin surface was rinsed with an air–water spray. Cement removed with a rotary instrument (W&H Trend WD-58, W&H Dentalwerk Bürmoos GmbH, Austria) and cleaning bur (Opticlean, Kerr, Dan-bury, CT, USA) for 1 min. Provisional cements used: eugenol-free provisional cement (Cavex, Holland BV, Haarlem, Holland), calcium hydroxide (Dycal, Kerr, Dan-bury, CT, USA), and light-cured provisional cement (Tempond Clear, GC, Alsip, IL, USA).	• Selection of type of cement is important as calcium hydroxide and eugenol-free cements produced higher bond strength irrespective of cleaning method. • Light-cured provisional cement produced lower bond strength irrespective of cleaning method. • Cleaning with explorer or bur is sufficient when calcium hydroxide or eugenol-free cement is used.
Sailer et al. [76]	Cleaning methods used: abrasive fluoride-free polishing paste (Cleanic; Kerr Hawe SA, Bioggio, Switzerland) in combination with a hand-piece-driven rubber cup. Provisional cements used: Freegenol (GC Intl, Tokyo, Japan).	• The bond strength was not affected after removal of provisional cement with polishing paste using rubber cup in low speed hand piece.
Ozcan and Lamperti [79]	Cleaning methods used: Air-borne particle abrasion with 50 µm Al_2O_3 particles at 2 bar; air-borne particle abrasion with 30 µm Si O_2 particles at 2 bar; Prophylaxis paste; pumice-water slurry using rotary nylon brush in low speed at 1500 rpm for 15 s. Provisional cements used: Eugenol-free provisional cement (Freegenol, GC International, Tokyo, Japan)	• All cleaning methods produced similar shear bond strength of resin luting cement to dentin. • All cleaning methods produced lower bond strength as compared to non-contaminated control group (freshly ground dentin).
Ribeiro da Saliva et al. [85]	Cleaning methods used: Remnants of provisional cement was mechanically removed with curette followed by non-fluoridated pumice flour for 10 s; Provisional cements used: Dycal (Dentsply, York, USA); Temp bond NE (Kerr, orange, USA) as compared to direct placement of methacrylate-based temporary restorative material (Clip F, Voco, Cuxhaven, GER).	• Cleaning of Dycal or Temp bond NE with curette followed by pumice for 10 s produced bond strength similar to control (no provisional cement). • Direct placement of methacrylate-based temporary restorative material (Clip F, Voco, Cuxhaven, GER) following IDS reduced bond strength.
Augusti et al. [78]	Cleaning methods used: Hand-scaler; air borne particle abrasion using 50 µm aluminium oxide particles (Al_2O_3); airborne particle abrasion using 25 µm glycine powder; liquid chemical solvent (Bio Orange Solvent, Ogna S.p.a., Italy) containing D-limonene (also known as monocyclic monoterpene). Provisional cements used: eugenol-free temporary cement (Temp Bond NE®, Kerr, Orange, CA); resin-based light-cured temporary luting agent (Temp Bond Clear®, Kerr, Orange, CA; CL Group).	• All cleaning methods are effective with eugenol-free temporary cement. • Only glycine air-abrasion was effective for the removal of the resin-based, light- cure temporary cement. • Bond strength was higher for groups cemented with eugenol-free cement as compared to groups cemented with resin-based temporary cement.
Brigaga˜o et al. [84]	Cleaning methods used: Dental excavator followed by pumicing using a rotary brush attached to a low-speed handpiece. Provisional cements used: Eugenol-free interim resin cement (Rely X Temp; 3M, ESPE).	• Use of temporary cement following IDS reduces bond strength of final restorations
Altintas et al. [80]	Cleaning methods evaluated: Er, Cr:YSGG laser (Waterlase MD, Biolase, Irvine, CA, USA) compared to etching with 37% orthophosphoric acid; treating with a yellow tape diamond bur (Komet Dental Gebr. Brasseler GmbH and Co. KG, Lemgo, Germany); or mechanically cleaning with a dental explorer. Provisional cements used: Calcium hydroxide temporary cement (Dycal, Dentsply Caulk, DE, USA)	• Laser irradiation or diamond bur cleaning methods produced higher shear bond strength than other cleaning methods.
Hayashi et al. [86]	Cleaning methods used: Cleaned with a polishing brush (Merssage brush CA No.1, Shofu) Provisional cements used: Non-eugenol zinc-oxide cement (TempBond NE; Kerr, USA)	• Bond strength was not affected by provisional cement that was cleaned with polishing brush.

tigated, therefore, may account for the differences in the findings of clinical studies on post-cementation hypersensitivity.

3. Conclusions

In vitro and clinical evidence support the use of IDS when bonding indirect restorations on prepared teeth with exposed dentin. The premise that IDS enhances bond strength and subsequently improves the survival of restorations is supported by ample in vitro evidence. This is further supported by clinical studies on survival of bonded restorations with compromised conventional retention and resistance forms such as CLVs. In these restorations, which rely primarily on bonding to tooth structure, dentin exposure may compromise retention of the restoration as dentin bonding of resin cements is known to be less reliable than that to enamel. In addition, anterior CLVs restorations are believed to be subjected to complex share and tensile forces which further stresses the bonded surfaces rendering improved bond strength using the IDS technique crucial for bond strength of such restorations. Furthermore, IDS which has been shown to reduce permeability of dentin may reduce early incidence of postoperative hypersensitivity following insertion of restorations. Clinically this effect can be seen in extensive restorations such as full crown restorations on vital teeth where an increased number of dentinal tubules are exposed following tooth preparation.

Other advantages of IDS such as improved adaptation of restorations and increased fracture strength is supported by in vitro evidence, however, there is lack of clinical evidence to support these claims.

The selection of filled resin adhesive that is capable of producing thick adhesive layer appears to contribute to the success of the IDS technique. In addition, careful management of the OIL before conventional impression making and proper cleaning of the residual temporary cement used with provisional restorations appears to affect the success of the technique. These later concerns can be overcome with the use of digital techniques; however, this presumption needs to be ascertained with experimental evidence.

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Conflicts of interest

The authors declare no conflict of interest.

References

[1] Calamia JR. Etched porcelain facial veneers: anew treatment modality based on scientific and clinical evidence. N Y J Dent 1983;53:255–9.
[2] Horn H. A new lamination, porcelain bonded to enamel. N Y State Dent J 1983;49:401–3.
[3] Angeletaki F, Gkogkos A, Papazoglou E, Kloukos D. Direct versus indirect inlay/onlay composite restorations in posterior teeth. A systematic review and meta-analysis. J Dent 2016;53:12–21.
[4] Wassell RW, Walls AW, McCabe JF. Direct composite inlays versus conventional composite restorations: three-year results. Br Dent J 1995;179:343–9.
[5] Nikaido T, Inoue G, Takagaki T, Takahashi R, Sadr A. Resin coating technique for protection of pulp and increasing bonding in indirect restorations. Curr Oral Health Rep 2015;2:81–6.
[6] Irusa K, Al-rawi B, Donovan T, Abd Alraheam I. Survival of cast gold and ceramic onlays placed in a school of dentistry: a retrospective study. J Prosthodont 2020;29:693–8.
[7] Kenneth J, Anusavice KJ, Shen C, Rawls HR. Dental casting alloys and metal joining. In: Phillips' science of dental materials. 12th ed. Elsevier Saunders; 2013. ISBN: 978-1-4377-2418-9.
[8] Makhija SK, Lawson NC, Gilbert GH, Litaker MS, McClelland JA, Louis DR, et al. Dentist material selection for single-unit crowns: findings from the national dental practice-based research network. J Dent 2016;55:40–7.
[9] Rauch A, Annett Schrock A, Schierz O, Hahnel S. Material selection for tooth-supported single crowns: a survey among dentists in Germany. Clin Oral Investig 2021;25:283–93.
[10] Mount GJ, Ngo H. Minimal intervention: a new concept for operative dentistry. Quintessence Int 2000;31:527–33.
[11] Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designs for anterior teeth. J Prosthet Dent 2002;87:503–9.
[12] Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designs for posterior teeth. Int J Periodontics Restorative Dent 2002;22:241–9.
[13] Dumfahrt H, Schaffer H. Porcelain laminate veneers: a retrospective evaluation after 1 to 10 years of service: part II: clinical results. Int J Prosthodont 2000;13:9–18.
[14] Peumans M, De Munck J, Fieuws S, et al. A prospective ten-year clinical trial of porcelain veneers. J Adhes Dent 2004;6:65–76.
[15] Fradeani M, Redemagni M, Corrado M. Porcelain laminate veneers: 6- to 12-year clinical evaluation—a retrospective study. Int J Periodontics Restorative Dent 2005;25:9–17.
[16] Guess PC, Stappert CF. Midterm results of a 5-year prospective clinical investigation of extended ceramic veneers. Dent Mater 2008;24:804–13.
[17] Burke FJT. Survival rates for porcelain laminate veneers with special reference to the effect of preparation in dentin: a literature review. J Esthet Restor Dent 2012;24:257–65.
[18] Dietschi D, Spreafico R. Evidence-based concepts and procedures for bonded inlays and onlays. Part I. Historical perspectives and clinical rationale for a biosubstitutive approach. Int J Esthet Dent 2015;10:210–27.
[19] Dietschi D, Spreafico R. Current clinical concepts for adhesive cementation of tooth-colored posterior restorations. Pract Periodontics Aesthet Dent 1998;10:47–54.
[20] Richardson D, Tao L, Pashley DH. Dentin permeability: effects of crown preparation. Int J Prosthodont 1991;4:219–25.
[21] Pashley EL, Comer RW, Simpson MD, Horner JA, Pashley DH, Caughman WF. Dentin permeability: sealing the dentin in crown preparations. Oper Dent 1992;17:13–20.
[22] Paul SJ, Schärer P. Effect of provisional cements on the bond strength of various adhesive bonding systems on dentine. J Oral Rehabil 1997;24:8–14.
[23] Paul SJ, Schärer P. The dual bonding technique: a modified method to improve adhesive luting procedures. Int J Periodontics Restorative Dent 1997;17:536–45.
[24] Nikaido T, Yoda A, Foxton RM, Tagami J. A resin coating technique to achieve minimal intervention in indirect resin composites: a clinical report. Int Chin J Dent 2003;3:62–8.
[25] Nikaido T, Tagami J, Yatani H, Ohkubo C, Nihei T, Koizumi H, et al. Concept and clinical application of the resin-coating technique for indirect restorations. Dent Mater J 2018;37:192–6.
[26] Bertschinger C, Paul SJ, Lüthy H, Schärer P. Dual application of dentin bonding agents: its effect on the bond strength. Am J Dent 1996;9:115–9.
[27] Magne P. Immediate dentin sealing: a fundamental procedure for indirect bonded restorations. J Esthet Restor Dent 2005;17:144–55.
[28] Magne P, Kim TH, Cascione D, Donovan TE. Immediate dentin sealing improves bond strength of indirect restorations. J Prosthet Dent 2005;94:511–9.
[29] Rocca GT, Rizcalla N, Krejci I, Dietschi D. Evidence-based concepts and procedures for bonded inlays and onlays. Part II. Guidelines for cavity preparation and restoration fabrication. Int J Esthet Dent 2015;10:392–413.
[30] Rigos AE, Dandoulaki C, Kontonasaki E, Kokoti M, Papadopoulou L, Koidis P. Effect of immediate dentin sealing on the bond strength of monolithic zirconia to human dentin. Oper Dent 2019;44:E167–79.
[31] Nikaido T, Takahashi R, Ariyoshi M, Sadr A, Tagami J. Protection and reinforcement of tooth structures by dental coating materials. Coatings 2012;2:210–20.
[32] Qanungo A, Aras MA, Chitre V, Mysore A, Amin B, Daswani SR. Immediate dentin sealing for indirect bonded restorations. J Prosthodont Res 2016;60:240–9.
[33] van den Breemer CR, Gresnigt MMM, Marco S, Cune MS. Cementation of glass-ceramic posterior restorations: a systematic review. Biomed Res Int 2015;2015:148954, http://dx.doi.org/10.1155/2015/148954.
[34] Magne P, So W-S, Cascione D. Immediate dentin sealing supports delayed restoration placement. J Prosthet Dent 2007;98:166–74.
[35] Duarte Jr S, de Freitas CR, Saad JR, Sadan A. The effect of immediate dentin sealing on the marginal adaptation and bond strengths of total-etch and self-etch adhesives. J Prosthet Dent 2009;102:1–9.
[36] Lee JI, Park SH. The effect of three variables on shear bond strength when luting a resin inlay to dentin. Oper Dent 2009;34:288–92.
[37] Choi YS, Cho IH. An effect of immediate dentin sealing on the shear bond strength of resin cement to porcelain restoration. J Adv Prosthodont 2010;2:39–45.
[38] Ozturk N, Aykent F. Dentin bond strengths of two ceramic inlay systems after cementation with three different techniques and one bonding system. J Prosthet Dent 2003;89:275–81.
[39] Sofan E, Sofan A, Palaia G, Tenore G, Romeo U, Migliau G. Classification review of dental adhesive systems: from the IV generation to the universal type. Ann Stomatol (Roma) 2017;8:1–17.

[40] Van Meerbeek B, Yoshihara K, Yoshida Y, Mine A, De Munck J, Van Landuyt KL. State of the art of self-etch adhesives. Dent Mater 2011;27:17–28.
[41] Alex G. Universal adhesives: the next evolution in adhesive dentistry? Compend Contin Educ Dent 2015;36:15–26.
[42] Miyazaki M, Tsujimoto A, Tsubota K, Takamizawa T, Kurokawa H, Platt JA. Important compositional characteristics in the clinical use of adhesive systems. J Oral Sci 2014;56(1):1–9.
[43] Cavalcanti AN, Mitsui FH, Ambrosano GM, Mathias P, Marchi GM. Dentin bonding on different walls of a class II preparation. J Adhes Dent 2008;10:17–23.
[44] Van Meerbeek B, De Munck J, Yoshida Y, Inoue S, Vargas M, Vijay P, et al. Buonocore memorial lecture. Adhesion to enamel and dentin: current status and future challenges. Oper Dent 2003;28:215–35.
[45] De Munck J, Van Meerbeek B, Satoshi I, Vargas M, Yoshida Y, Armstrong S, et al. Microtensile bond strengths of one- and two-step self-etch adhesives to bur-cut enamel and dentin. Am J Dent 2003;16:414–20.
[46] Jayasooriya PR, Pereira PN, Nikaido T, Tagami J. Efficacy of a resin coating on bond strengths of resin cement to dentin. J Esthet Restor Dent 2003;15:105–13.
[47] Ferreira-Filho RC, Ely C, Amaral RC, Rodrigues JA, Roulet JF, Cassoni A, et al. Effect of different adhesive systems used for immediate dentin sealing on bond strength of a self-adhesive resin cement to dentin. Oper Dent 2018;43:391–7.
[48] McCabe JF, Rusby S. Dentine bonding–the effect of pre-curing the bonding resin. Br Dent J 1994;176:333–6.
[49] Dietschi D, Herzfeld D. In vitro evaluation of marginal and internal adaptation of class II resin composite restorations after thermal and occlusal stressing. Eur J Oral Sci 1998;106:1033–42.
[50] Ito S, Hashimoto M, Wadgaonkar B, Svizero N, Carvalho RM, Yiu C, et al. Effects of resin hydrophilicity on water sorption and changes in modulus of elasticity. Biomaterials 2005;26:6449–59.
[51] Van Meerbeek B, Lambrechts P, Inokoshi S, Braem M, Vanherle G. Factors affecting adhesion to mineralized tissues. Oper Dent 1992;Suppl 5:111–24.
[52] Zheng L, Pereira PN, Nakajima M, Sano H, Tagami J. Relationship between adhesive thickness and microtensile bond strength. Oper Dent 2001;26:97–104.
[53] Stavridakis MM, Krejci I, Magne P. Immediate dentin sealing of onlay preparations: thickness of pre-cured dentin bonding agent and effect of surface cleaning. Oper Dent 2005;30:747–57.
[54] Magne P, Douglas WH. Porcelain veneers: dentin bonding optimization and biomimetic recovery of the crown. Int J Prosthodont 1999;12:111–21.
[55] Rueggeberg FA, Margeson DH. The effect of oxygen inhibition on an unfilled/filled composite system. J Dent Res 1990;69:1652–8.
[56] Magne P. IDS: immediate dentin sealing (IDS) for tooth preparations. J Adhes Dent 2014;16:594.
[57] Jayasooriya PR, Pereira PNR, Nikaido T, Burrow MF, Tagami J. Effect of a "Resin-coating" on the interfacial adaptation of composite inlays. Oper Dent 2003;28:28–35.
[58] Turkistani A, Sadr A, Shimada Y, Nikaido T, Sumi Y, Tagami J. Sealing performance of resin cements before and after thermal cycling: evaluation by optical coherence tomography. Dent Mater 2014;30:993–1004.
[59] Ruyter IE. Unpolymerized surface layers on sealants. Acta Odontol Scand 1981;39:27–32.
[60] Eliades GC, Caputo AA. The strength of layering technique in visible light-cured composites. J Prosthet Dent 1989;61:31–8.
[61] Erickson RL. Mechanism and clinical implications of bond formation for two dentin bonding agents. Am J Dent 1989;2:117–23.
[62] Bergmann P, Noack MJ, Roulet JF. Marginal adaptation with glass-ceramic inlays adhesively luted with glycerine gel. Quintessence Int 1991;22:739–44.
[63] Moon MG, Jarrett TA, Morlen RA, Fallo GJ. The effect of various base/core materials on the setting of a polyvinyl siloxane impression material. J Prosthet Dent 1996;76:608–12.
[64] Bachmann M, Paul SJ, Luthy H, Scharer P. Effect of cleaning dentin with soap and pumice on shear bond strength of dentin bonding agents. J Oral Rehab 1997;24:433–8.
[65] Magne P, Nielsen B. Interactions between impression materials and immediate dentin sealing. J Prosthet Dent 2009;102:298–305.
[66] Bruzi G, Carvalho AO, Maia HP, Giannini M, Magne P. Are some combinations of resin liners and impression materials not compatible with IDS technique? Am J Esthet Dent 2013;3:200–8.
[67] Khakiani MI, Kumar V, Pandya HV, Nathani TI, Verma P, Bhanushali NV. Effect of immediate dentin sealing on polymerization of elastomeric materials: an ex vivo randomized controlled trial. Int J Clin Pediatr Dent 2019;12:288–92.
[68] Ghiggi PC, Steiger AK, Marcondes ML, Mota EG, Burnett Júnior LH, Spohr AM. Does immediate dentin sealing influence the polymerization of impression materials? Eur J Dent 2014;8:366–72.
[69] Sinjari B, D'Addazio G, Murmura G, et al. Avoidance of interaction between impression materials and tooth surface treated for immediate dentin sealing: an in vitro study. Materials (Basel) 2019;12(20):3454, http://dx.doi.org/10.3390/ma12203454. Published 22 October 2019.
[70] Terata R, Yoshinaka S, Nakashima K, Kubota M. Effect of resinous temporary material on tensile bond strength of resin luting cement to tooth substrate. Dent Mater J 1996;15:45–50.
[71] Ribeiro JC, Coelho PG, Janal MN, Silva NR, Monteiro AJ, Fernandes CA. The influence of temporary cements on dental adhesive systems for luting cementation. J Dent 2011;39:255–62.
[72] Hansen EK, Asmussen E. Influence of temporary filling materials on effect of dentin-bonding agents. Scand J Dent Res 1987;95:516–20.
[73] Woody TL, Davis RD. The effect of eugenol-containing and eugenol-free temporary cements on microleakage in resin bonded restorations. Oper Dent 1992;17:175–80.
[74] Powers JM, Finger WJ, Xie J. Bonding of composite resin to contaminated human enamel and dentin. J Prosthodont 1995;4:28–32.
[75] Schwartz R, Davis R, Hilton TJ. Effect of temporary cements on the bond strength of a resin cement. Am J Dent 1992;5:147–50.
[76] Sailer I, Oendra AEH, Stawarczyk B, Hämmerle CHF. The effects of desensitizing resin, resin sealing, and provisional cement on the bond strength of dentin luted with self-adhesive and conventional resin cements. J Prosthet Dent 2012;107:252–60.
[77] Altintas SH, Tak O, Secilmis A, Usumez A. Effect of provisional cements on shear bond strength of porcelain laminate veneers. Eur J Dent 2011;5:373–9.
[78] Augusti D, Re D, Özcan M, Augusti G. Removal of temporary cements following an immediate dentin hybridization approach: a comparison of mechanical and chemical methods for substrate cleaning. J Adhes Sci Technol 2017;7:1–12.
[79] Özcan M, Lamperti S. Effect of mechanical and air-particle cleansing protocols of provisional cement on immediate dentin sealing layer and subsequent adhesion of resin composite cement. J Adhes Sci Technol 2015;29:2731–43.
[80] Altintas SH, Hamiyet K, Kilic S. Effect of surface treatments to remove temporary cement remnants on the bond strength between the core composite and resin cement. Niger J Clin Pract 2019;22:1441–7.
[81] Carvalho CN, de Oliveira Bauer JR, Loguercio AD, Reis A. Effect of ZOE temporary restoration on resin-dentin bond strength using different adhesive strategies. J Esthet Restor Dent 2007;19:144–52.
[82] Erkut S, Kucukesmen HC, Eminkahyagil N, Imirzalioglu P, Karabulut E. Influence of previous provisional cementation on the bond strength between two definitive resin-based luting and dentin bonding agents and human dentin. Oper Dent 2007;32:84–93.
[83] Fonseca RB, Martins LRM, Quagliatto PS, Soares CJ. Influence of provisional cements on ultimate bond strength of indirect composite restorations to dentin. J Adhes Dent 2005;7:225–30.
[84] Brigagão VC, Barreto LFD, Gonçalves KAS, Amaral M, Vitti RP, Neves ACC, et al. Effect of interim cement application on bond strength between resin cements and dentin: immediate and delayed dentin sealing. J Prosthet Dent 2017;117:792–8.
[85] Ribeiro da Silva CJ, Gonçalves ICS, Botelho MPJ, Guiraldo RD, Lopes MB, et al. Interactions between resin-based temporary materials and immediate dentin sealing. Appl Adhes Sci 2016;4(1), http://dx.doi.org/10.1186/s40563-016-0061-9.
[86] Hayashi K, Maeno M, Nara Y. Influence of immediate dentin sealing and temporary restoration on the bonding of CAD/CAM ceramic crown restoration. Dent Mater J 2019;38:970–80.
[87] Dillenburg AL, Soares CG, Paranhos MP, et al. Microtensile bond strength of prehybridized dentin: storage time and surface treatment effects. J Adhes Dent 2009;11:231–7.
[88] Rocca GT, Krejci I. Bonded indirect restorations for posterior teeth: from cavity preparation to provisionalization. Quintessence Int 2007;38:371–9.
[89] Burrow MF, Inokoshi S, Tagami J. Water sorption of several bonding resins. Am J Dent 1999;12:295–8.
[90] Leesungbok R, Lee SM, Park SJ, Lee SW, Lee DY, Im BJ, et al. The effect of IDS (immediate dentin sealing) on dentin bond strength under various thermocycling periods. J Adv Prosthodont 2015;7:224–432.
[91] Schenke F, Hiller K, Schmalz G, Federlin M. Marginal integrity of partial ceramic crowns within dentin with different luting techniques and materials. Oper Dent 2008;33:516–25.
[92] Kitayama S, Nasser NA, Pilecki P, Wilson RF, Nikaido T, Tagami J, et al. Effect of resin coating and occlusal loading on microleakage of class II computer-aided design/computer-aided manufacturing fabricated ceramic restorations: a confocal microscopic study. Acta Odontol Scand 2011;69:182–92.
[93] Ashy LM, Marghalani H, Silikas N. In vitro evaluation of marginal and internal adaptations of ceramic inlay restorations associated with immediate vs delayed dentin sealing techniques. Int J Prosthodont 2020;33:48–55.
[94] Magne P, Douglas WH. Cumulative effects of successive restorative procedures on anterior crown flexure: intact versus veneered incisors. Quintessence Int 2000;31:5–18.
[95] Magne P, Douglas WH. Design optimization and evolution of bonded ceramics for the anterior dentition: a finite-element analysis. Quintessence Int 1999;30:661–72.
[96] Stappert CF, Ozden U, Gerds T, Strub JR. Longevity and failure load of ceramic veneers with different preparation designs after exposure to masticatory simulation. J Prosthet Dent 2005;94:132–9.
[97] Soares LD, Basso GR, Spazzin AO, Griggs J, Moraes RR. Mechanical reliability of air-abraded and acid-etched bonded feldspar ceramic. Dent Mater 2016;32:433–41.

[98] Spazzin AO, Guarda GB, Oliveira-Ogliari A, Leal FB, Correr-Sobrinho L, Moraes RR. Strengthening of porcelain provided by resin cements and flowable composites. Oper Dent 2016;41:179–88.

[99] Barbon FJ, Moraes RR, Boscato N, Alessandretti R, Spazzin AO. Feldspar ceramic strength and the reinforcing effect by adhesive cementation under accelerated aging. Braz Dent J 2018;29:202–7.

[100] Spohr AM, Borges GA, Platt JA. Thickness of immediate dentin sealing materials and its effect on the fracture load of a reinforced all-ceramic crown. Eur J Dent 2013;7:474–83.

[101] Gresnigt MMM, Cune MS, de Roos JG, Özcan M. Effect of immediate and delayed dentin sealing on the fracture strength, failure type and Weilbull characteristics of lithium disilicate laminate veneers. Dent Mater 2016;32:e73–81.

[102] van den Breemer CRG, Özcan M, Cune MS, van der Giezen R, Kerdijk W, Gresnigt MMM. Effect of immediate dentine sealing on the fracture strength of lithium disilicate and multiphase resin composite inlay restorations. J Mech Behav Biomed Mater 2017, http://dx.doi.org/10.1016/j.jmbbm, 2017.04.002.

[103] Drummond JL, King TJ, Bapna MS, Koperski RD. Mechanical property evaluation of pressable restorative ceramics. Dent Mater 2000;16:226–33.

[104] Dietschi D, Magne P, Holz J. An in vitro study of parameters related to marginal and internal seal of bonded restorations. Quintessence Int 1993;24:281–91.

[105] Van den Breemer CRG, Buijs GJ, Cune MS, Özcan M, Kerdijk W, Van der Made S, et al. Prospective clinical evaluation of 765 partial glass-ceramic posterior restorations luted using photo-polymerized resin composite in conjunction with immediate dentin sealing. Clin Oral Invest 2020, http://dx.doi.org/10.1007/s00784-020-03454-7.

[106] Gurel G, Sesma N, Calamita MA, Coachman C, Morimoto S. Influence of enamel preservation on failure rates of porcelain laminate veneers. Int J Periodontics Restorative Dent 2013;33:31–9.

[107] Çötert HS, Dündar M, Öztürk B. The effect of various preparation designs on the survival of porcelain laminate veneers. J Adhes Dent 2009;11:405–11.

[108] Dumfahrt H, Schäffer H. Porcelain laminate veneers. A retrospective evaluation after 1 to 10 years of service: part II—clinical results. Int J Prosthodont 2000;13:9–18.

[109] Gresnigt MMM, Cune MS, Schuitemaker J, van der Made SAM, Meisberger EW, Magne P, et al. Performance of ceramic laminate veneers with immediate dentine sealing: an 11 year prospective clinical trial. Dent Mater 2019;35:1042–52.

[110] van den Breemer C, Özcan M, Cune MS, Ayres AA, Van Meerbeek B, Gresnigt M. Effect of immediate dentin sealing and surface conditioning on the microtensile bond strength of resin-based composite to dentin. Oper Dent 2019;44(6):E289–98.

[111] Lan WH, Lee BS, Liu HC, Lin CP. Morphologic study of Nd:YAG laser usage in treatment of dentinal hypersensitivity. J Endod 2004;30:131–4.

[112] Kern M, Kleimeier B, Schaller HG, Strub JR. Clinical comparison of postoperative sensitivity for a glass ionomer and a zinc phosphate luting cement. J Prosthet Dent 1996;75:159–62.

[113] Hu J, Zhu Q. Effect of immediate dentin sealing on preventive treatment for post cementation hypersensitivity. Int J Prosthodont 2010;23(1):49–52.

[114] Kumar PAV, Sabnis R, Vinni TK, Vasunni GKV, Krishnan DPC. Effect of immediate dentin sealing in prevention of post-cementation hypersensitivity in full coverage restorations. IOSR-JDMS 2015;14(5):80–4.

[115] Pashley DH. Dynamics of the pulpo-dentin complex. Crit Rev Oral Biol Med 1996;7:104–33.