Effect of different immediate dentin sealing techniques on the microtensile bond strength

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ABSTRACT

This study aimed to compare the effects of different immediate dentin sealing techniques on the bond strength using Optibond FL® (Kerr, USA) as a dentin sealing agent and to analyze their influences on the bonding performance. Twelve caries-free extracted human molars were used. The experimental groups were categorized according to the dentin sealing methods as follows: Immediate Dentin Sealing with Optibond FL® (IDS with OF), Immediate Dentin Sealing with Optibond FL® and Tetric Flow® (IDS with OF + TF), and Delayed Dentin Sealing (DDS). Direct composite restoration was carried out in the control group. After preparing each group with use of different processes, all specimens were subjected to microtensile bond strength testing, and the data were statistically analyzed. A combination of Optibond FL® and Tetric Flow® showed significantly higher bond strength compared with single use of Optibond FL® in the IDS groups. The DDS group showed statistically lowest mean microtensile bond strength. The direct composite group showed statistically higher bond strength than the IDS group using Optibond FL® alone, but there was no significant difference between the direct composite group and the IDS group using Optibond FL® and Tetric Flow®. Compared to the immediate dentin sealing technique using a dentin sealing agent alone, the technique consisting of a dentin sealing agent and a flowable resin composite may improve dentin bond strength, minimize patient discomfort, and consequently have a positive influence on the long-term survival of indirect bonded restorations.

KEY WORDS: Dentin bonding, Restoration, Sealing

Introduction

Composite resin associated with an adhesive system has gained popularity based on the similarity of its elastic modulus to that of the dental structures, and due to its high potential to bond to the enamel and dentin [1]. With the development of improved resin composites, bonding systems, and operating techniques, the use of composite resin esthetic restorations has increased. Composite resins are generally applied by using the direct technique for placement of restorations in anterior and posterior teeth because direct composite restorations require minimal intervention and cavity preparation [2]. However, direct resin composite restorations can cause several problems such as polymerization shrinkage, marginal leakage, and inadequate anatomic form and proximal contacts, especially in case of large restorations and esthetic treatment. As alternatives, indirect composite restorations such as inlays and onlays were shown to present improved clinical conditions with respect to proximal contact, occlusal anatomy and marginal adaptation because all technical procedures for manufacturing and polymerization of the restorations are performed externally and only a thin layer of high flow composite resin (so-called resin cement) is used to lute the restorations [3].

Successful dentin bonding is particularly important in the case of indirect composite restorations because the final strength of the tooth-restoration complex is highly dependent on adhesive procedures. The principle of dentin bonding is to create an interphase or interdiffusion layer, also called the hybrid layer, by the interpenetration of monomers into hard tissues. Once the infiltrating resin is
polymerized, it can generate a “structural” bond somewhat similar to the interphase formed at the dentinoenamel junction [4]. However, during the polymerization of resin cements, tensions could arise, causing a disruption between the restoration and the cavity walls, leading to marginal leakage, especially when the margins are located in dentin. Thus, marginal integrity is directly related to the bond strength between the dentin surface and the resin cement [5].

Tooth preparation for indirect restorations can induce significant dentin exposures, and consequently, sensitivity [3]. In the conventional technique for indirect restorations, dentin is sealed after the provisional phase at the cementation appointment. This method called delayed dentin sealing (DDS); however, it does not provide optimal conditions for bonding procedures. Because freshly cut dentin has been demonstrated to be the ideal substrate for dentin bonding, dentin contamination due to provisional cements could reduce the potential for bonding, leading to lower bond strength, failure during the hybridization process, and post-operative sensitivity [6].

In an attempt to overcome the above mentioned problems, the so-called immediate dentin sealing (IDS) method has been suggested. In this method, dentin is sealed immediately after tooth preparation, prior to impression taking. There are two alternative techniques for immediate dentin sealing. One technique involves the application of a dentin bonding agent immediately following cavity preparation, which appears to achieve increased bond strength, improved restoration adaptation, fewer gap formations, decreased bacterial leakage, and reduced dentin sensitivity [4]. The other technique involves the addition of a thin layer of low-viscosity flowable resin over the bonded dentin. The latter procedure also seems to reduce gap formation at the interface of dentin to resin cement, and to improve the bond strength. Moreover, it could provide a resilient layer between the restorative composite resin and dentin, absorbing the tensions generated by polymerization shrinkage of the resin cement and mastication efforts [3].

Although several studies have investigated the effects of the immediate dentin sealing method on the bond strength, there has been no study comparing the effects of the two alternative IDS techniques, using Optibond FL® (Kerr, USA) as a dentin sealing agent. Optibond FL® is particularly indicated for the application of IDS because of its ability to form a consistent and uniform layer and its cohesive with the final luting composite [7]. This study aimed to compare the effects of different immediate dentin sealing techniques on the bond strength using Optibond FL® as a dentin sealing agent and to analyze their influences on the bonding performance.

### Materials and Methods

The materials used in this study are shown in Table 1. Optibond FL® was used as a dentin sealing agent and Tetric Flow®, a low-viscosity resin, was used as a flowable resin. As a provisional restoration, water soluble release agent, SEP® and resin based temporary filling material, Quicks® were used. ESTELITE Σ® was used in building composite resin blocks.

### Tooth preparation

Twelve caries-free extracted human molars were hand-scaled to remove all soft tissue and were stored in physiological saline solution. After embedding the teeth in self-cure acrylic resin (Orthodontic resin®, Dentsply, USA), the occlusal surfaces were ground flat to expose the dentin surface using a low speed diamond saw (MetSAR®-
Effect of different immediate dentin sealing techniques

Polishing at 600-1000 grit was followed to smoothen the exposed dentin surfaces and to remove contaminations produced by smear layer.

Experimental design

The teeth were distributed into three experimental groups and one control group. Experimental groups were divided according to the dentin sealing methods: Immediate Dentin Sealing with Optibond FL® (IDS with OF), Immediate Dentin Sealing with Optibond FL® and Tetric Flow® (IDS with OF + TF), and Delayed Dentin Sealing (DDS).

IDS groups

1. IDS with OF: Dentin was etched with 37% phosphoric acid for 15 seconds, rinsed with water for 15 seconds, and gently air dried. The primer of Optibond FL® was applied to the dentin surface and thoroughly air dried for 5 seconds to evaporate the solvent. Then the adhesive resin was applied, slightly air dried and light cured for 20 seconds. SEP® was applied to the sealed dentin surface and air dried, and then Quicks® was built up 2 mm high and light cured for 10 seconds.

2. IDS with OF + TF: The same procedure as for IDS with OF was performed, followed by application of a thin layer of Tetric Flow® and light curing for 20 seconds. SEP® was applied to the sealed dentin surface and air dried, and then Quicks® was built up 2 mm high and light cured for 10 seconds.

The DDS group

Quicks® was built up 2 mm high and light cured for 10 seconds. All teeth blocks of the IDS and DDS groups were placed in the saline solution bath for one week.

The control group

The direct composite resin was used for the control group. After tooth preparation, 1-week delay and provisional restorations were not applied to the control group, instead the bonding procedures were followed immediately.

Bonding procedures

After a 1-week delay, provisional restorations were removed and dentin was cleaned with pumice (Zircate®) in the IDS and DDS groups. Following bonding procedures were performed for the specimens in all groups. The exposed dentin surface was etched with 37% phosphoric acid for 15 seconds, rinsed with water for 15 seconds, and gently air dried. The primer of Optibond FL® was applied to the dentin surface and thoroughly air dried for 5 seconds to evaporate the solvent. Then the adhesive resin was applied, slightly air dried and light cured for 20 seconds. After the procedures were performed, composite resin blocks were built with ESTELITE Σ® composite resin shade A2 in all groups. Then 4 mm-high blocks were built up in increments of about 2 mm, and each block was light-cured for 40 seconds with Optilux 501® (Kerr, USA) with an energy level higher than 450 mW/cm², as measured by a curing radiometer. In the experimental groups, the fabricated resin blocks were adhered by using a dual cured luting cement (Duolink™, Bisco. Inc., USA). The test specimens were then stored in 100% humidity for 24 hours at 37°C. All procedures were summarized in Fig. 1.

Preparation for μTBS testing

After storing in distilled water for 24 hours, the teeth were polished at 600-1000 grit was followed to smoothen the exposed dentin surfaces and to remove contaminations produced by smear layer.
were sectioned in the X and Y perpendicular directions with a low speed diamond saw (MetSAW®-MSH-04-112, R&B, Korea) to obtain 8 specimens measuring 1 mm × 1 mm and having a length of 8 mm (n = 24). The ends of each specimen were fixed to the microtensile tester (Bisco Inc., USA) with cyanoacrylate adhesive (ZAPIT base®, Dental Ventures of America Inc., USA) plus an accelerator (ZAPIT accelerator®, Dental Ventures of America Inc., USA). The results were obtained at the moment of specimen fracture and were calculated in MPa.

**Statistical analysis**

The data were statistically analyzed by one-way ANOVA. The Tukey HSD test was used to detect pairwise differences among the experimental groups.

**Results**

The mean microtensile bond strengths for the four groups are listed in Table 2 and Fig. 2. A combination of Optibond FL® and Tetric Flow® showed significantly higher bond strength of 21.69 MPa compared with the single use of Optibond FL® of 18.39 MPa (P = .042). The DDS group showed statistically lowest mean microtensile bond strength of 12.15 MPa (P = .000). The Direct composite group (control group) showed statistically higher bond strength of 22.62 MPa than IDS group using Optibond FL® alone (P = .006), but there was no significant difference between the direct composite group and IDS group using Optibond FL® and Tetric Flow® (P = .863).

**Table 2. Mean microtensile bond strength (n=24)**

| Group                  | Mean (MPa) ± S.D |
|------------------------|-----------------|
| Indirect Composite - experimental |                  |
| IDS with OF            | 18.39 ± 2.51a   |
| IDS with OF + TF       | 21.69 ± 2.33b   |
| DDS                    | 12.15 ± 1.91c   |
| Direct Composite - control | 22.62 ± 3.60b   |

S.D; standard deviation. Mean values followed by the same superscript letter were not significantly different at p=0.05 level according to Tukey HSD post hoc multiple comparisons.

**Discussion**

Direct composite restorations are commonly preferred over indirect composite restorations when treating dental caries, but indirect composite restorations are usually recommended when teeth require large restorations [8]. Successful dentin bonding is significant in indirect restorations because the final strength of the tooth-restoration complex is highly dependent on adhesive procedures. The most important basic principles for the clinical procedure of dentin-resin hybridization are related to problems of dentin contamination and susceptibility of the hybrid layer to collapse until it is polymerized. Considering these essential problems, Pascal Magne [4] presented several rational motives supporting IDS.

Freshly cut dentin is the ideal substrate for dentin bonding, and significant reductions in bond strength can occur when simulating dentin contamination with various provisional cements compared to freshly cut dentin. Precuring of the dentin bonding agent leads to improved bond strength compared to the situation in which the dentin bonding agent and the overlaying composite are cured together. This can be explained by the collapse of the uncured dentin-resin hybrid layer caused by pressure during composite placement or seating of the restoration. Immediate dentin sealing allows stress-free dentin bond development, because of the delayed placement of the restoration and postponed occlusal loading. IDS also protects the dentin against bacterial leakage and sensitivity during provisionalization. Therefore, patients experience improved comfort during provisionalization and reduced postoperative sensitivity, and the need for anesthesia during insertion of the final restoration may be limited [4].

The bonded dentin covered by a thin layer of low-viscosity flowable resin is one of the techniques to perform immediate dentin sealing. According to the results of this study, statistically significant increases in the bond strength were observed when this technique was applied. The addi-
tional application of a low-viscosity resin can protect and promote an improvement of the polymerization of the underlying adhesive, resulting in an increase in bond strength [9]. Application of a flowable resin on the cured adhesive can polymerize the oxygen inhibition layer, which contains uncured resin. The uncured resin of the oxygen inhibition layer may subsequently polymerize by diffusion of free radicals from the flowable resin [10]. Also, the low-viscosity resin layer may protect the adhesive from being torn off at the time of removal of the provisional restoration, and it can act as an absorbing layer protecting the adhesive layer against contraction stress generated during the resin cement polymerization [11].

The success of the IDS procedure might also be attributed to the dentin bonding system, especially the filled adhesives. Magne [4] recommended a three-step total etch dentin bonding agent with a filled adhesive resin for the application of IDS. Among the most reliable contemporary systems, Optibond FL® is particularly indicated for IDS [4]. Although there is a tendency to simplify bonding procedures, recent data confirm that conventional 3-step etch-and-rinse adhesives still perform most favorably and are most reliable in the long term [12]. This was the reason why this specific dentin bonding agent was selected for this study. Optibond FL® allows both dentin hybridization and the formation of a stress absorber with significantly improved adaptation to dentin, especially in the case of posterior bonded restorations [13]. The materials and methods used in this study were selected in an attempt to examine the effects of the most favorable dentin bonding agent combined with different IDS techniques on the bond strength.

Based on the results of this study and the findings obtained in preceding studies, the dentin bonding strength was significantly increased when the IDS method was used compared with when the DDS method was used. Also, with the additional application of a flowable resin over the hybridized dentin, more improved bond strength and increased resistance against stress and damage would be achieved, leading to long-term survival of restorations. The applied low-viscosity resin layer seems to optimize the benefits that we can obtain from immediate dentin sealing. Previous studies have shown that application of a flowable resin composite to the cured adhesive provided perfect sealing of the dentinal margins, even in direct composite restorations [14]. In this study, there was no significant difference between the bond strengths of direct restoration and the IDS technique with additional application of the low-viscosity flowable resin. Therefore, in the case of indirect resin restorations, application of a low-viscosity composite liner over the bonded dentin should be performed to improve the bond strength of resin cement to dentin and to minimize patient discomfort.

This study has its own limitations as the fracture patterns and fractured surfaces were not examined while performing μTBS testing. Besides improving the bond strength and creating a thick sealing film [15], a combination of a dentin bonding system and a low viscosity resin composite can modify the failure pattern. Due to the formation of a stronger hybridization process, the failure pattern tends to preserve the bonded interface area [9].

Previous studies have reported that the bond strength of direct composites was significantly higher than that of indirect restorations, even for the combination of an adhesive system and a flowable resin [2, 8]. The significance of this study lies in the presentation of the indirect resin restoration technique possessing bond strength high enough to show no statistically significant difference from that of direct restorations. As direct restorations are less invasive than indirect restorations, they should be the first choice for posterior restorations. However, in certain situations, such as when large restorations are required, indirect restorations should be selected. As per the result of this study, the IDS method with Optibond FL® and Tetric Flow® should be applied to the exposed dentin surface to improve the bond strength of resin cement to dentin in case of indirect restorations.

To investigate another improved IDS technique showing more enhanced bond strength, future studies should focus on finding the proper combination of an adhesive and a low-viscosity resin, and the most favorable depth of the flowable resin layer. Kitasako et al. [16] emphasized that when a low-viscosity flowable resin is applied over the adhesive resin layer, the cavity design for indirect restorations should be changed because of strong adhesion between the restoration and the prepared tooth [17]. According to their study, the concept of producing square cavities should be changed by limiting cavity preparation to removing only the carious lesion and the accompanying undermined tissue [16]. Further studies on this subject would make the application of indirect resin restorations more conservative and efficient in clinical and practical aspects, by achieving maximum preservation of the tooth structure and saving chair time.
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Conflict of Interest

The authors declare that they have no competing interests.

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