บทวิทยาการ
Original Article

ผลของการเคลือบปิดผิวเนื้อฟันทันทีด้วยสารยึดติดระบบเซลฟ์เอตช์ต่อความแข็งแรงยึดดึงระดับจุลภาคของเรซินซีเมนต์ในงานบูรณะโดยอ้อมด้วยคอมโพสิต

Effect of an Immediate Dentin Sealing Technique Using Self-Etch Adhesives on Micro-Tensile Bond Strength of Resin Cement in Indirect Composite Restorations

พัชนี ชูวีระ[1], สิริวัธน์ วัฒนพาณิชย์[1], จินตนา อิทธิเดชารณ์[1], ชูชัย อนันต์มานะ[2]
[1]สาขาวิชาทันตกรรมทั่วไป ภาควิชาทันตกรรมครอบครัวและชุมชน คณะทันตแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่
[2]ภาควิชาทันตกรรมประดิษฐ์ คณะทันตแพทยศาสตร์ มหาวิทยาลัยมหิดล
Patchanee Chuveera[1], Siriwat Wattanapanich[1], Chintana Itthidecharon[1], Chuchai Ananmana[2]
[1]Department of Family and Community Dentistry, General Dentistry Branch, Faculty of Dentistry, Chiang Mai University
[2]Department of Prosthodontics, Faculty of Dentistry, Mahidol University

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บทคัดย่อ

วัตถุประสงค์ในการศึกษาเพื่อประเมินผลของการเคลือบปิดผิวเนื้อฟันทันที โดยใช้สารยึดติดระบบเซลฟ์เอตช์ 2 ขั้นตอน (Clearfil SE Bond) หรือระบบขั้นตอนเดียว (Single Bond Universal Adhesive) ต่อความแข็งแรงยึดดึงระดับจุลภาคในงานบูรณะโดยอ้อมด้วยคอมโพสิต ด้วยวิธีการยึดติดด้วยเรซินซีเมนต์ชนิด Panavia F 2.0 เปรียบเทียบกับวิธีการยึดติดด้วยเรซินซีเมนต์ตามคำแนะนำของบริษัทผู้ผลิต ซึ่งเป็นวิธีที่ใช้กันโดยทั่วไป ทำการประเมินรูปแบบของการแตกหักของชิ้นงาน

Abstract

The purpose of this study was to evaluate the effect of immediate dentin sealing, using either a two-step self-etch adhesive system (Clearfil SE Bond) or one-step self-etch adhesive system (Single Bond Universal Adhesive), on micro-tensile bond strength of indirect composite restorations luted with Panavia F 2.0 resin cement compared to that without immediate dentin sealing. The fracture patterns of the bonded surfaces were

Corresponding Author:

พัชนี ชูวีระ
ผู้ช่วยศาสตราจารย์ ทันตแพทย์หญิง สาขาวิชาทันตกรรมทั่วไป ภาควิชาทันตกรรมครอบครัวและชุมชน คณะทันตแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่ 50200

Patchanee Chuveera
Assist Prof., Department of Family and Community Dentistry, General Dentistry Branch, Faculty of Dentistry, Chiang Mai University, Chiang Mai 50200, Thailand.
E-mail: ***patchanee.ch@cmu.ac.th***

ในการศึกษาครั้งนี้ เป็นการศึกษาระบบสารยึดติดเนื้อฟัน 2 ชนิด คือ Clearfil SE Bond (Kuraray Medical, Tokyo, Japan) ซึ่งเป็นระบบ 2 ขั้นตอน และ Single Bond Universal Adhesive (3M, ESPE) ซึ่งเป็นระบบขั้นตอนเดียว ในการเคลือบปิดผิวเนื้อฟัน ทำการศึกษาโดยใช้ฟันกรามน้อยบนที่ถอนออกจากช่องปาก จำนวน 30 ซี่ แบ่งออกเป็น 3 กลุ่ม กลุ่มละ 10 ซี่ ได้แก่ กลุ่มควบคุมซึ่งไม่มีการทาสารยึดติดเคลือบปิดผิวเนื้อฟัน และกลุ่มทดลอง 2 กลุ่มที่ทาสารยึดติดระบบ 2 ขั้นตอนและระบบขั้นตอนเดียวเคลือบปิดผิวเนื้อฟัน ทำการกรอตัดฟันด้านบดเคี้ยวจนถึงชั้นเนื้อฟัน ขัดด้วยกระดาษทรายน้ำ ความละเอียด 600 grit ในกลุ่มทดลอง 2 กลุ่ม ทำการเคลือบทับผิวฟันที่กรอตัดแล้วด้วยสารยึดติดชนิด Clearfil SE Bond และ Single Bond Universal Adhesive ทันทีก่อนที่จะปิดทับด้วยวัสดุอุดชั่วคราวชนิด Cavit G ส่วนกลุ่มควบคุม ปิดทับผิวฟันที่กรอตัดแล้วด้วย Cavit G โดยไม่ทาสารเคลือบใด ๆ นำตัวอย่างทุกชิ้นงานแช่ในน้ำกลั่น เป็นเวลา 24 ชั่วโมง หลังจากนั้น รื้อวัสดุอุดชั่วคราวออก ขัดด้วยผงพัมมิสผสมน้ำ นำชิ้นงานคอมโพสิตมายึดด้วยเรซินซีเมนต์ชนิด Panavia F 2.0 ทำการตัดฟันที่มีชิ้นงานคอมโพสิตยึดติดให้เป็นแท่งเหลี่ยมจำนวน 12 ชิ้น พื้นที่หน้าตัดประมาณ 0.8 มม.^{2} - 1.0 มม.^{2} ทดสอบความแข็งแรงยึดดึงระดับจุลภาคในกลุ่มทดสอบทั้ง 3 กลุ่ม โดยใช้เครื่องทดสอบสากล หลังจากนั้น ประเมินรูปแบบความล้มเหลวด้วยกล้องจุลทรรศน์อิเลคตรอนชนิดส่องกราด

ผลการทดสอบ พบว่า ความแข็งแรงยึดดึงระดับจุลภาคของกลุ่มทดลองที่เคลือบปิดผิวเนื้อฟันด้วย Clearfil SE Bond (18.61±3.01 MPa) มีค่ามากกว่าและแตกต่างอย่างมีนัยสำคัญ เมื่อเปรียบเทียบกับกลุ่มที่เคลือบปิดผิวเนื้อฟันด้วย Single Bond Universal Adhesive (12.94±5.43 MPa) และกลุ่มควบคุมที่ไม่ได้เคลือบสารปิดผิวเนื้อฟัน (9.34±4.21 MPa) และในสองกลุ่มหลังไม่มีความแตกต่างอย่างมีนัยสำคัญ การวิเคราะห์รูปแบบของความล้มเหลวภายหลังทดสอบความแข็งแรงยึดดึงระดับจุลภาค พบความล้มเหลวชนิด การยึดไม่ติด (adhesive failure) มีอุบัติการณ์ที่สูงในทุกกลุ่มทดลองของการศึกษานี้ ภายใต้ข้อจำกัดของการศึกษา สามารถสรุปผลได้ว่า การ

also evaluated.

Thirty extracted human upper premolars were randomly allocated into three groups of ten teeth each according to the surface treatments before placing temporary restorations. The occlusal surface of each tooth was cut to expose a flat dentin surface, and polished with 600 grit silicon carbide paper. Two adhesive systems were used as an immediate dentin sealing agent after tooth preparation in the two tested groups. For the control group, no immediate dentin sealing material was used. After dentin surface treatments, Cavit G was placed on the surface of each tooth as a temporary restoration. The prepared tooth specimens were kept in distilled water for 24 hours. Then the temporary material was removed and the surface was cleaned with pumice slurry. Each tooth was then bonded to an indirect composite rod with Panavia F 2.0 resin cement. The tooth-indirect composite assemblies were then sectioned into match-stick liked microbeams for micro-tensile bond strength testing. Twelve representative microbeams with a cross sectional area between 0.8 mm^2 and 1.0 mm^2 from each group were selected for micro-tensile bond strength testing using a universal testing machine. After testing, the failure modes of the specimens were evaluated under a scanning electron microscope.

Among the three approaches, the micro-tensile bond strength of the Clearfil SE Bond group (18.61±3.01 MPa) was significantly higher than the Single Bond Universal Adhesive group (12.94±5.43 MPa) and the control group (9.34±4.21 MPa). The micro-tensile bond strength of the Single Bond Universal Adhesive group and control group were not significantly different. Failure mode analysis showed adhesive failure in all specimens. Within

ใช้ Clearfil SE Bond ซึ่งเป็นสารยึดติดระบบ 2 ขั้นตอนเคลือบปิดผิวเนื้อฟันก่อนปิดทับด้วยวัสดุอุดชั่วคราวและยึดชิ้นงานคอมโพสิตโดยอ้อมด้วยเรซินซีเมนต์ชนิด Panavia F 2.0 จะมีความแข็งแรงยึดดึงระดับจุลภาคมากกว่าการใช้ Single Bond Universal Adhesive ซึ่งเป็นสารยึดติดระบบขั้นตอนเดียว และการเคลือบปิดผิวเนื้อฟันทันทีด้วยสารยึดติดก่อนปิดทับด้วยวัสดุอุดชั่วคราว มีแนวโน้มจะเพิ่มความแข็งแรงยึดดึงเมื่อยึดชิ้นงานด้วยเรซินซีเมนต์ชนิด Panavia F 2.0 เมื่อเปรียบเทียบกับการยึดชิ้นงานด้วยวิธีที่ใช้กันโดยทั่วไป

คำสำคัญ: การเคลือบปิดผิวเนื้อฟันทันที การเคลือบด้วยเรซิน สารยึดติด สารยึดติดระบบเซลฟ์เอตช์

the limitations of this study, it may be concluded that Clearfil SE Bond provided a higher bond strength when used as an immediate dentin sealing agent than did Single Bond Universal Adhesive in the same self-etch mode. In addition, sealing the prepared dentin surface immediately with dentin adhesives before placing a temporary restoration showed a tendency to improve the bond strength of the luting resin cement compared to the conventional cementation technique when Panavia F 2.0 resin cement was used.

Keywords: immediate dentin sealing, resin coating, universal adhesive, self-etch adhesive

Introduction

When preparing teeth for indirect bonded restorations, temporary filling materials or provisional restorations with temporary cements are usually placed on the freshly prepared tooth surface to cover the exposed dentin until the final restoration is placed. However, temporary cements may contaminate the freshly cut dentin and reduce its capacity to bond with adhesive systems leading to a reduction in bond strength(1). Besides, the close relationship between dentin and vital pulp via the extension of odontoblastic processes into the dentinal tubules prompts the optimal and timely sealing of prepared dentin to protect the pulp tissue. As a result, the idea that the exposed dentinal tubules should be sealed immediately after tooth preparation with resin-based dentin bonding agents has been proposed(2-5). "Resin Coating Technique"(3,6-8) and "Immediate Dentin Sealing (IDS)"(5,9,10) are the terms used in the literature to represent this alternative cementation idea. Magne and colleagues(5,9,10) introduced the commonly called "Immediate Dentin Sealing" or "IDS" technique by which freshly cut dentin is sealed using a three-step total-etch dentin bonding agent prior to impression taking. Their studies show a significantly improved bond strength for immediate dentin sealing compared to delayed dentin sealing using the same adhesive system for cementation(5,9).

Earlier reports using the term "Resin Coating Technique"(3,4,6,8) usually applied a combination of a dentin bonding agent together with a low-viscosity micro-filled flowable resin composite on freshly prepared dentin before impression taking and the final restoration would be luted later with a resin cement. This technique has been reported to achieve a greater bond strength than conventional cementation technique in a few studies(3,4,8).

Different adhesive systems and their compatibility with the luting cements used in the resin coating technique have been found to affect the bond strength. In 2003, Nikaido and colleagues(8) evaluated four dual-cured resin cements (Panavia F, Link Max, Bistite II, and Rely-X) and found that resin coating significantly improved the strength of the bond between the resin cement and dentin with Panavia F and Link Max but not with Bistite

II or Rely-X. For the four adhesive systems tested (Clearfil SE Bond, Unifil Bond, One-Up Bond F, and Single Bond) the combination of Clearfil SE bond and a low-viscosity micro-filled resin, Protect liner F, provided the highest bond strength when Panavia F was used as a resin cement for indirect composite restorations. Jayasooriya and colleagues[4] compared two dentin adhesive systems, Clearfil SE Bond and Single Bond with and without a flowable resin composite as resin coating agents and found that the application of Clearfil SE Bond, both with and without a layer of flowable resin composite, significantly improved the strength of the bond between the resin cement and the dentin, whereas coating with Single Bond using a total etch strategy without flowable resin composite did not increase the bond strength. On the other hand, de Andrade and colleagues[11] found a significantly lower bond strength when the combination of Single Bond adhesive with a low viscosity composite, Protect Liner F, was applied as a resin coating agent than when only a luting cement (Rely X ARC) was applied without a resin coating step. They explained that the addition of layers of resin-based agents resulted in a thick layer on the pulpal wall surface, which probably compromised the bond strength[11]. Moreover, Oliveira and colleagues[12] investigated cuspal deflection of teeth restored with composite resin inlays using two different coating protocols and reported that immediate dentin sealing with Clearfil SE Bond allowed a favorable cuspal deflection comparable to that of a sound tooth, whereas the additional layer of the low viscosity resin composite, Protect Liner F, on the Clearfil SE Bond did not contribute to a decrease in cuspal deflection. Based on the assumption that a strong bond between two substrates would result in a small cuspal deflection, that study[12] suggested that the bond strength might be higher when Clearfil SE Bond was used without an additional layer of Protect Liner F.

Mange and colleagues[5,9,10] introduced a thin coating technique using a dentin bonding agent without an additional layer of a low viscosity resin composite called the "Immediate Dentin Sealing Technique". Various adhesive systems used as sealing agents have been investigated[4,7,13-16]. Clearfil SE Bond, a clinically well-accepted two-step self-etch adhesive system, has been found favorable for used as an immediate sealing agent in a few studies[9,12-14].

A new dentin adhesive system classified as a "universal adhesive" has recently been introduced to provide a single product for all situations and can be applied either in a self-etch or etch-and-rinse mode.[17] At present, there is only sparse literature reporting on the efficacy of universal adhesives.

The purpose of this study was to evaluate the effect of the immediate dentin sealing technique using either a clinically well-accepted, two-step, self-etch adhesive system (Clearfil SE Bond, Kuraray Co., Ltd., Tokyo, Japan) or a recently-introduced, single-bottle, multipurpose, universal adhesive product (Single Bond Universal Adhesive, 3M ESPE, Seefeld, Germany) on the micro-tensile bond strength of indirect composite restorations luted to dentin with Panavia F resin cement compared to a conventional cementation technique without an immediate sealing step. The fracture patterns of each bonded surface in each group were also evaluated after micro-tensile bond strength testing.

Materials and Methods

This was a comparative experimental study to compare the mean micro-tensile bond strength of the two tested dentin adhesive systems as immediate dentin sealing agents and a control group without immediate dentin sealing.

A total number of 30 upper premolar teeth, which were extracted for orthodontic reasons, were anonymously collected for this study. All teeth were free of carious lesions and restorations and had complete root formation. The teeth were stored in 0.1% (weight/volume) thymol solution after extraction. The storage period was one to four months prior to the bonding process. The teeth were randomly allocated into three groups of 10 in order to obtain at least 12 sections of microbeam specimens in each group for the micro-tensile bond strength testing. Two dentin adhesive systems, Clearfil SE Bond (Kuraray Medical, Tokyo, Japan), and Single Bond Universal Adhesive (3M, ESPE, Seefeld, Germany), were used as the immediate dentin sealing agents in this study. Material details are presented in Table 1.

Tooth surface preparation

The occlusal surface of each maxillary premolar was removed at approximately 2 mm below the original central groove to get rid of any remaining enamel using a model trimmer with a diamond disc under copious water cooling to expose a clear, flat dentin surface. The roots were removed at 2 mm below the cemento-enamel junction by the same means. To standardize a smooth dentin surface, the cut dentin surface was further finished with 600 grit silicon carbide abrasive paper (Fuji Star brand, TOA Paint (Thailand) Co., Ltd., Samut Prakan, Thailand) under water by a single operator with the same protocol of 30 strokes for each tooth. The teeth were then cleaned ultrasonically in distilled water for two minutes and blotted dry with cotton pellets. The dentin surface was then treated.

The dentin surface treatment for each group is described as follows:

Group A The freshly prepared dentin surface was coated with Clearfil SE Bond adhesive in a two-step, self-etch manner according to the manufacturer's instructions.

Group B The freshly prepared dentin surface was coated with Single Bond Universal Adhesive according to the manufacturer's instructions for use in a "self-etch" manner.

Group C No dentin bonding agent was applied on the freshly cut tooth surface in this group. The exposed tooth surface was covered directly with Cavit G temporary material.

All treated tooth surfaces were then covered with a 5 mm thick layer of Cavit G over the occlusal surface and a 2 mm extension of Cavit G around the margin to retain the temporary material to the specimen.

All specimens were stored in distilled water for 24 hours prior to the luting application.

Table 1 *Materials used in this study.*

Material	Type	Manufacturer	Composition
Clearfil SE Bond (LOT#01488A)	Two-step, self-etched adhesive	Kuraray Medical, Tokyo, Japan	Primer: MDP, HEMA, hydrophilic dimethacrylate, photo-initiator, water Bond: MDP, HEMA, Bis-GMA, hydrophobic dimethacrylate, photo-intiators, silanated colloidal silica
Single Bond Universal Adhesive (LOT#412387)	One-bottle, universal adhesive	3M ESPE, Seefeld, Germany	MDP,Dimethacrylate resins, HEMA, Vitrebond™copolymer, filler, ethanol, water,silane,initiator
Cavit G	Non-eugenol, water setting temporary filling material	3M ESPE, Seefeld, Germany	Zinc oxide, sulfuric acid, calcium salt hydrate, ethylene bisoxyethylene diacetate, zinc sulfate, polyvinyl acetate
Panavia F 2.0 (exp. date 10/2013)	Dual-cured resin cement	Kuraray Medical Tokyo, Japan.	*ED primer A*: HEMA, MDP, 5-NMSA, accelerator *ED primer B*: 5-NMSA, initiator, water *A paste*: Silanated silica, microfiller, MDP, dimethacrylate, photo/chemical initiator *B paste*: Silanated barium glass, surface treated NaF, dimethacrylate, chemical initiator

MDP: 10-Methacryloyloxydecyl dihydrogen phosphate
HEMA: hydroxyethyl methacrylate
5-NMSA: N-methacryloyl 5-aminosalicylic acid

Indirect composite rods preparation

SR Adoro (Ivoclar Vivadent, Schaan, Principality of Liechtenstein, lot number 04628), a heat curing composite system, was used for indirect composite rods fabrication. Composite rods with a diameter of 0.6 cm and 1.0 cm long were cured under Lunamat-100 furnace (Ivoclar Vivadent, Schaan, Principality of Liechtenstein) for 25 minutes. The fitting surfaces of the indirect composite rods were finished with 600-grit silicon carbide abrasive paper (TOA Paint (Thailand) Co., Ltd.) under water by a single operator with the same protocol of 30 strokes for each rod. The rods were then cleaned ultrasonically in distilled water for two minutes and blotted dry with cotton pellets before cementation.

Cleaning and Luting procedure

After the tooth specimens had been immersed in water for 24 hours, the temporary filling material was carefully removed from the surface with a spoon excavator. The surface was cleaned with a mixture of water and pumice using a rotary rubber cup mounted to a handpiece at 1000 rpm in a brushing motion for 10 seconds. Each specimen was then rinsed and dried thoroughly. The prepared tooth surface was cemented to the fitting surface of the composite rod manually by one operator using a dual-cured resin cement, Panavia F 2.0, according to the manufacturer's instructions. All cemented specimens were wrapped in moist cotton pellets and placed in a sealed plastic bag for 24 hours before undergoing micro-tensile bond strength testing.

Micro-tensile bond strength testing

The cemented specimens were sectioned perpendicular to the pulpal wall with a slow speed Isomet wheel saw (Buehler, Lake Bluff, Illinois, USA) under water to obtain slabs of approximately 0.8-1.0 mm thick. The slabs were further sectioned vertically, perpendicular to the first direction, into beams, similar to a match-stick pattern, to get a cross-sectional area of approximately 0.8-1.0 mm^2. Specimens that failed before actual testing were excluded from statistical analysis.

The beams to be tested were fixed to a modified Bencor-Multi t testing assembly (Danville Engineering Co., Danville, California, USA) using cyanoacrylate adhesive. The specimens were pulled to failure under tension, using a universal testing machine (Instron 5566, Instron Corp., High Wycombe, Buckinghamshire, UK) at a crosshead speed of 1 mm/min. Schematic representations of the bonded interfaces in each group are presented in Figure 1.

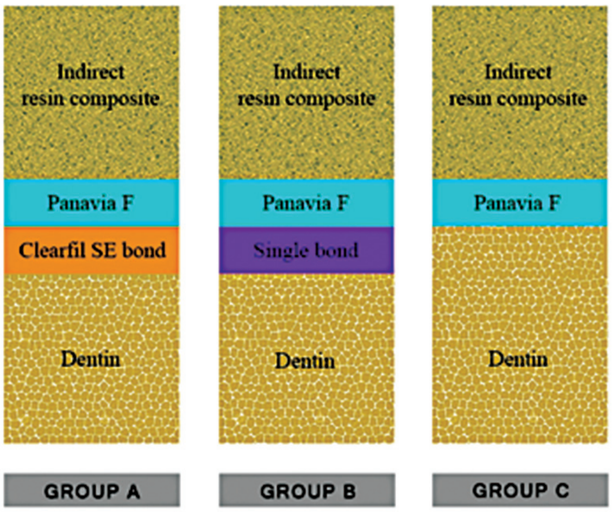

Figure 1 *Schematic representations of bonded interfaces in each group.*

Mode of failure analysis

The dentin sides of the fractured beams from all groups were prepared for scanning electron microscope examination. A scanning electron microscope (JEOL, JSM+6610LV, JEOL Ltd., Tokyo, Japan) was used to evaluate failure modes. Failure modes were classified as cohesive failure if the failure occurred within dentin or indirect resin composite, and adhesive failure if the failure occurred at the interface between the adhesive and dentin or between the resin cement and dentin.

Results

Micro-tensile bond strength

Twelve microbeams from each group with a cross sectional area between 0.8 mm^2 and 1.0 mm^2 were included for analysis. The mean micro-tensile bond strength results are presented in Table 2. The ANOVA test at the 0.05 significance level demonstrated a difference between the groups tested (df=2, F=13.962, p< 0.000) that was further compared with the Tukey HSD test to show significant differences between Group A and Group B (p=0.008), and between Group A and the control (p<0.000). There was no significant difference between Group B and the control (p=0.119). The highest mean micro-tensile bond strength (18.61 ± 3.01MPa) was found in the group immediately sealed with Clearfil SE Bond and was significantly higher than in the Single Bond Universal group and the control group. The mean micro-tensile bond strength in the immediate sealing with Single Bond Universal Adhesive group (12.94 ± 5.43 MPa) was higher but not significantly different from that in the non-coated control group (9.34 ± 4.21 MPa).

Table 2 *Mean micro-tensile bond strength (MPa) of different dentin sealing approaches.*

Group: dentin sealing approach	n	Micro-tensile bond strength (Mean± SD) (MPa)
Group A: immediate dentin sealing with Clearfil SE Bond	12	18.61 ± 3.01
Group B: immediate dentin sealing with Single Bond Universal	12	12.94 ± 5.43
Group C: control, non-immediate dentin sealing	12	9.34 ± 4.21

Mode of failure analysis results

In the control group with the conventional resin cement luting technique, typical adhesive failures between dentin and resin cement were observed with open dentinal tubules on dentin sides (Figure 2). In the group immediately sealed with Clearfil SE Bond and the group immediately sealed with Single Bond Universal Adhesive, more complicated adhesive failures were observed. Most of the specimens from the immediately sealed groups showed remnants of the resin cement on the dentin surface after failure (Figure 3). However, some specimens from the group coated with Clearfil SE Bond showed residual bonding and resin cement together with bonded indirect composite on the dentin surface (Figure 4). A typical cohesive failure within dentin or indirect resin composite rod was not presented in any investigated fragments.

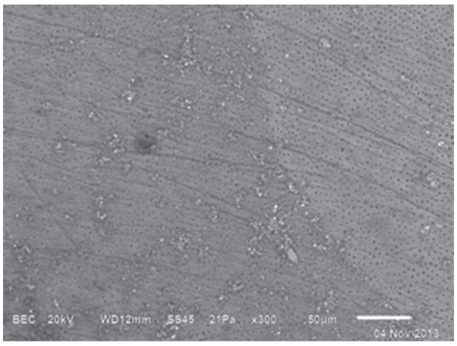

Figure 2 *SEM photograph of an adhesive failure from the non-immediate dentin sealing control group. Fracture surface shows dentine surface at the magnification of 300X.*

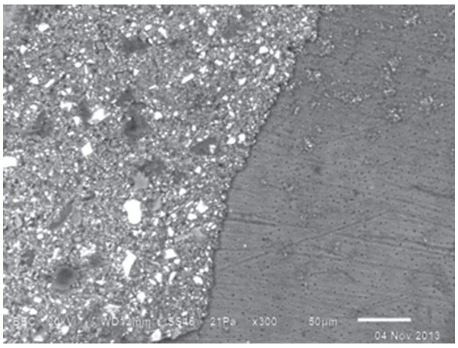

Figure 3 *SEM photograph of a fracture surface of a specimen from the immediate dentin sealing with Single Bond Universal Adhesive group showing dentine surface (right side) and the remnant of the resin cement (left side)*

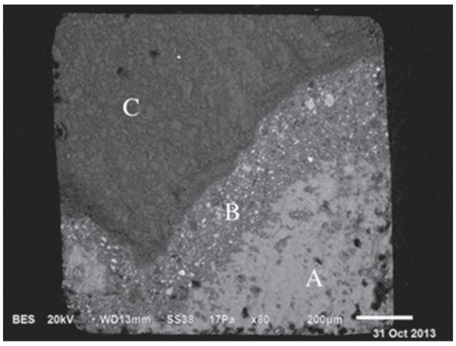

Figure 4 *SEM photograph of a fracture surface of a specimen from the immediate dentin sealing with Clearfil SE Bond group showing: (A) dentine surface (B) residual bonding and resin cement (C) indirect resin composite*

Discussion

In our study, a two-step, self-etch system, Clearfil SE Bond, and a newly introduced universal adhesive system, Single Bond Universal Adhesive, were used as immediate dentin sealing agents and were compared to the conventional cementation technique using Panavia F as a resin cement. Clearfil SE Bond is a widely-used, clinically well-accepted, two-step, self-etch, adhesive system manufactured by Kuraray Co., Ltd., Tokyo, Japan, while Single Bond Universal Adhesive is a recently-introduced, single-bottle, multipurpose, universal adhesive manufactured by 3M ESPE, Seefeld, Germany. It is called a "universal" adhesive because it can be used in etch-and-rinse and self-etch modes[18,19]. Our study used Single Bond Universal Adhesive in a one-step, self-etch mode in order to compare it with the two-step, self-etch Clearfil SE Bond. It is noted that Clearfil SE Bond is a reference for all other self-etch adhesives when it comes to dentin bond strength[20]. We found that immediate dentin sealing with Clearfil SE Bond significantly improved micro-tensile bond strength, with a mean bond strength of 18.61±3.01 MPa, compared to immediate dentin sealing with Single Bond Universal Adhesive, with a mean bond strength of 12.94±5.43 MPa, and the non-immediate dentin sealing conventional cementation technique, with a mean bond strength of 9.34±4.21 MPa. The group immediately sealed with Single Bond Universal Adhesive showed higher micro-tensile bond strength but without statistically significant difference from the conventional cementation technique. However, these higher mean bond strength values from both adhesives applied as immediate dentin sealing agents were suggestive of a positive effect of the immediate dentin sealing technique in improving the strength of the bond between Panavia F resin cement and dentin in luting indirect resin composite restorations. Magne[10] offered reasons for the improved bond strength by immediate dentin sealing that the precuring of dentin bonding agent could have prevented the collapse of the hybrid layer caused by pressure during seating of the restorations, and that the delayed placement of the restorations allows a stress-free situation for dentin bonding to completely polymerize and develop bond strength over time. Immediately sealed freshly cut dentin might have also prevented dentin from contamination with temporary material, which can reduce the dentin potential for bonding[1,10].

The improved bond strength values from immediate sealing with Clearfil SE Bond were also aforementioned in a few studies,[4,9,14] where Clearfil SE bond was applied without additional low viscosity resin composite. It was also suggested by Oliviera et al[12] that immediate dentin sealing using Clearfil SE Bond in composite resin inlay restorations when adhesive luting with Panavia F was used, also yielded a favourable cuspal deflection comparable to that of a sound tooth.

Regarding the compositions of adhesives used, the major ingredients of each share some similarities, as displayed in Table 1. The 3M ESPE manufacturer claimed that the three main ingredients responsible for the so-called true-versatility, all-in-one-bottle, Single Bond Universal Adhesive, include Vitrebond™ Copolymer, MDP monomer, and silane. The functions of these ingredients are presented in Table 3.

***Table 3** Main ingredients and their functions in Single Bond Universal Adhesive*

Ingredient	Main functions
Vitrebond™ Copolymer	Provides a consistent bonding to dentine under moist or dry conditions.
MDP Monomer	Optimizes self-etching performance, provides chemical bonding to zirconia, alumina and metals without a separate primer, and increases shelf stability so that no refrigeration is needed.
Silane	Allows the adhesive to chemically bond to glass ceramic surfaces without using a separate ceramic primer.

As a matter of fact, 10-methacryloyloxydecyl dihydrogen phosphate monomer (MDP) was first introduced by Kuraray Medical Inc (Okayama, Japan)(19). Only recently have other manufacturers introduced new MDP-containing adhesives to the dental market(19). MDP allows the acidity for the self-etching capability and has been proven to provide an effective chemical bond to dentin by forming a stable nano-layer at the adhesive interface and a stable MDP-Ca salt deposition yielding high bond stability(21). In our study, MDP was presented in all adhesive materials, Clearfil SE Bond, Single Bond Universal Adhesive, and Panavia F. The minor difference is that MDP has been incorporated in both the primer and bonding solutions of Clearfil SE bond, whereas in Single Bond Universal Adhesive, because of its all -in-one nature, it was included only in one solution. However, studies(21,22) have shown that Clearfil SE Bond resulted in nano-layering within the hybrid layer and into the adhesive layer while Scothbond Universal Adhesive (a similar product line to Single Bond Universal Adhesive from the same 3M, ESPE manufacturer) resulted in nano-layering only at the tubule orifices, where the adhesive infiltrated the residual smear layer.

Single Bond Universal Adhesive contains a unique ingredient called "Vitrebond copolymer", a polyalkenoic acid copolymer first used in Vitrebond glass ionomer cement of the 3M, ESPE manufacturer and therefore is also known as Vitrebond copolymer, or VCP(22). Vitrebond copolymer was first introduced with Scotchbond Multi-Purpose adhesive to yield a system that was very resistant to the detrimental effects of varying humidity that can affect the bond strength(23). However, without containing this unique copolymer, our result showed a higher bond strength using Clearfil SE bond. This finding is in agreement with a recently published study by Munoz et al(18) in which the micro-tensile bond strength of Clearfil SE Bond was superior to that of Scotchbond Universal Adhesive(3M,ESPE) using a self-etch strategy. It has been postulated that the presence of polyalkenoic acid copolymer may compete with the MDP by binding to the calcium of the hydroxyapatite(18,21). Moreover, the copolymer could have prevented monomer approximation during polymerization due to its high molecular weight(18). However, these observations should be further investigated.

In the present study, air-blocking was not applied after sealing the dentin surface with adhesive systems in order to focus on the role of immediate dentin sealing. However, it has been reported that the oxygen and solvent inhibitor effects (a slower solvent evaporation) in the photopolymerization were found to be higher for water/ethanol based adhesives(24). As a result, Single Bond Universal Adhesive, which is a water/ethanol based adhesive may require an air-blocking step or a double coating to avoid a layer that is too thin to compensate for the oxygen-inhibited layer, resulting in incomplete polymerization and poor bond strength. Future studies involving Single Bond Universal Adhesive should consider including the effect of oxygen inhibition.

The micro-tensile bond strength test allows for a more homogeneous distribution of stress than do simple tensile bond tests and the use of small testing jigs insures an application of pure tensile force[25]. However, a high incidence of premature failure in specimens has been reported[26]. We found a high incidence of pretesting de-bond while sectioning the tooth-indirect composite assemblies with a low speed saw in all groups of our specimens, a problem which might have been caused by the relatively low bond strength of our bonded specimens.

Failure mode analysis of specimens after micro-tensile bond strength testing showed a high incidence of adhesive failure in all groups of our study, whereas typical cohesive failure within dentin was not observed. This result is in line with the relatively low bond strength data obtained in the present study. It has been stated elsewhere that when the prevailing failure mode is adhesive, the bond strengths are generally low, while cohesive failures are more often associated with high bond strengths[20,27]. However, in the present study, partial failure within the resin cement layer was seen in the immediate dentin-sealing groups, whereas typical adhesive failure between resin cement and dentin was mainly found in the non-immediate dentin sealing control group. The remnants of the resin cement on the dentin surfaces of the immediate dentin sealing groups could possibly favor the protection of dentinal tubules after failure.

Other aspects of performance and effectiveness of the immediate dentin-sealing technique using simplified adhesive systems should be investigated in future studies. Examples of such aspects include interfacial adaptation, sealing ability, effects of different adhesive systems and modes of application, and clinical performance.

Conclusions

Within the limitations of the present study, the following conclusions may be drawn:

1. Using a self-etch strategy, the new, one-component, universal adhesive, Single Bond Universal Adhesive, showed a lower performance in terms of micro-tensile bond strength when used as an immediate dentin sealing agent prior to placement of a temporary restoration and luting indirect composite restoration to prepared dentin with Panavia F resin cement than using the two-step, self-etch Clearfil SE Bond.

2. Sealing the prepared dentin surface immediately with dentin adhesives before placement of a temporary restoration showed a tendency to improve bond strength of the luting resin cement compared to the conventional cementation technique when Panavia F resin cement was used.

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