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The Clinical Effectiveness of Various Adhesive Systems: An 18-Month Evaluation

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Clinical Relevance

The clinical effectiveness of three different adhesive systems including a self-etching and two etch-and-rinse adhesives was acceptable in noncarious cervical lesions subsequent to 18-month evaluation.

SUMMARY

The aim of this clinical trial was to compare the clinical performance of three different adhesive systems over 18 months in noncarious cervical lesions (NCCLs). Thirty patients, with at least three noncarious cervical lesions, were enrolled in the study. One operator randomly restored a total of 90 lesions with resin composite (Herculite XRV). The restorations were bonded with either Optibond FL (OF), three-step total-etch; Optibond Solo Plus (OS), two-step total-etch; or Optibond All-In-One (OA), one step self-etch. The restorations were clinically evaluated at baseline and after six, 12, and 18 months using the eight United States Public Health Services criteria. Data were analyzed using Friedman and Wilcoxon signed ranks tests ($p<0.05$). After 18 months, the retention rate was (OF) 96.5%, (OS) 93.1%, and (OA) 89.7%. Differences among the three adhesive systems for evaluated criteria were not observed in comparison of the mean Alfa score percentages. There was a significant increase in marginal discoloration for (OA) adhesive after 18 months compared with baseline ($p=0.011$). Other restoration criteria had no statistically significant differences among the three adhesives ($p>0.05$). With the exception of marginal discoloration, the clinical effectiveness of three types of adhesive systems in NCCLs was acceptable after 18 months. However, using the one-step self-etch adhesive may lead to some marginal discolorations.

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INTRODUCTION

Noncarious cervical lesions were used as clinical models to evaluate the performance of adhesive systems because 1) they involve both enamel and dentin margins, 2) they present no macromechanical retention and require at least 50% bonding to dentin, 3) they are widely available and usually found in premolars and anterior teeth with good clinical access, 4) they have the worst long-term prognosis because of their mixed cavity margins and high stress buildup in the cervical area, and 5) preparation and restoration of these lesions are relatively easy, reducing practitioner variability.[1–3] In the restoration of these lesions, a variety of materials such as resin-based composites with diverse bonding characteristics have been used. An important factor in the success of the resin-based composite restorations is the properties of adhesive bonding agents. Resin-based adhesive systems can be classified as either etch-and-rinse systems or self-etch systems. The disadvantages of the etch-and-rinse systems are the technique sensitivity and the likely discrepancy between the extent of demineralization and monomer infiltration and subsequent degradation of these adhesives when they are exposed to the oral environment during passing time.[4–6] The key advantages of self-etch adhesives are their easy and fast application procedures.[7] This approach significantly reduces technique sensitivity. Infiltration of adhesive occurs simultaneously with the etch process; therefore, discrepancy between both processes is low and less time-consuming.[8–10] Knowing the success and longevity of various adhesives enables practitioners to choose the most appropriate material for clinical use. The information on bonding effectiveness of adhesives in laboratory conditions indicates that bond strength of the all-in-one systems to enamel and dentin are not as high as other adhesive systems.[11,12] However, the high success rate of one-step self-etch adhesives in recent clinical trials has been reported.[7,13,14] The proper test to evaluate the dental adhesive is its clinical performance under functional and natural situations.[15] Therefore, this study evaluated the 18-month clinical effectiveness of the one-step self-etch adhesive Optibond All-In-One, the two-step total-etch adhesive Optibond Solo Plus, and the three-step total-etch adhesive Optibond FL in noncarious cervical lesions.

METHODS AND MATERIALS

Patients and Lesions Selection

The participants in this study were 30 patients aged 20 to 50 years who had at least three noncarious, nonsclerotic cervical lesions. The selected teeth had healthy periodontium and contacted the opposing teeth with a normal occlusal relationship. No more than 50% of the lesion's cavosurface margins involved enamel. In the present study, the extension of noncarious cervical lesions in the selected teeth was limited to the buccal surface of teeth without extension into the proximal surfaces, and the teeth had no previous restoration or carious lesion in other surfaces. The depth of the cavities was not more than 2 mm as measured by a probe. In addition, the operating area could be isolated. Patients with severe medical complications, poor oral hygiene, extreme caries susceptibility, or heavy bruxism were excluded from the study. The proposal was approved by the Regional Medical Research Ethics Committee with the registration code of IRCT138709301509N1, and all patients signed a written consent form.

Material Selection

Ninety cervical lesions were restored either with Optibond FL (OF; Kerr Corporation, Orange, Calif, USA), Optibond Solo Plus (OS; Kerr Corporation), or Optibond All-In One (OA; Kerr Corporation). Composition and application procedures of the three adhesives are shown in Table 1. All lesions were restored with a universal microhybrid composite (Herculite XRV, Kerr Corporation).

Restorative Procedures

One experienced operator, who followed standard procedures, placed all restorations. The distribution of the materials and tooth locations were randomized (Table 2). For measuring tooth sensitivity, the teeth were prepared without local anesthesia injection. The cervical lesions were first cleaned using a rubber cup with pumice-water slurry to remove the dental plaque. The internal walls were lightly roughened with a diamond bur (Diatech Dental AG, Swiss Dental Instruments, CH-9435Heerbrugg). Isolation of the tooth was achieved by cotton rolls and retraction cords. Tooth preparation did not include retentive grooves or enamel bevels. No liners or bases were applied. The adhesive systems were applied according to the manufacturer's recommendations (Table 1). The composite resin Herculite HRV (shade A2) was placed in two increments from cervical to incisal and cured using an Optilux 500 light-curing unit (Demetron LC, Kerr Corporation) with a light output of 500 mW/cm^2. Each composite resin layer was polymerized for 20 seconds. After curing, finishing was accomplished using fine-grit diamond burs (Brasseler, Savannah, GA, USA) and

Table 1: *Adhesives Used in the Study and Application Mode According to the Manufacturer's Instructions*

Adhesive	Composition (Batch Number)	Application Mode
Optibond FL (Kerr Corporation, Orange, CA, USA)	Etchant: 37.5% phosphoric acid Primer: HEMA, GPDM, PAMM, CQ, ethanol, water (3093079); adhesive: TEGDMA, UDMA, Bis-GMA, HEMA, GPDM, filler, CQ (3096500)	Etch with 37.5% phosphoric acid for 15 s, rinse for 15 s and dry for 5 s, apply primer with light brushing motion for 15 s, air-dry for 5 s, apply adhesive with light brushing motion for 15 s, air-dry for 3 s, and light cure for 20 s
Optibond Solo Plus (Kerr Corporation, Orange, CA, USA)	Etchant: 37.5% phosphoric acid; adhesive: Bis-GMA, HEMA, GDMA, GPDM, ethanol, CQ, ODMAB, BHT, fumed silicon dioxide, A174, barium aluminoborosilicate, Na2Si6F (31513)	Etch with 37.5% phosphoric acid for 15 s, rinse for 15 s and dry for 5 s, apply the adhesive and rub for 15 s, dry for 3 s, and light cure for 20 s
Optibond All-In-One (Kerr Corporation, Orange, CA, USA)	Uncured methacrylate ester, ethyl alcohol, water, acetone, monomers, inert mineral fillers, ytterbium fluoride, photoinitiators, accelerators, and stabilizers (3075076)	Shake the bottle for 10 s, apply the adhesive and rub for 20 s, repeat the procedure, air-dry lightly for 5 s, and light cure for 10 s

Abbreviations: A174, gamma-methacryloxypropyltrimethoxysilane; BHT, 2,6-Di-tert-butyl-4-methylphenol; Bis-GMA, bisphenol A glycidyl methacrylate; CQ, camphorquinone; GDMA, glycerol dimethacrylate; GPDM, glycerol phosphate dimethacrylate; HEMA, 2-hydroxyethyl methacrylate; ODMAB, 2-(ethylhexyl)-4-(dimetylamino) benzoate; PAMM, phthalic acid monoethyl methacrylate; TEGDMA, triethyleneglycol dimethacrylate; UDMA, urethane dimethacrylate.

the Sof-lex polishing disc system (Sof-Lex, 3M ESPE, Dental Products, St. Paul, MN, USA) under water cooling to obtain a smooth surface.

Clinical Evaluation Criteria

All restorations were evaluated using the United States Public Health Services (USPHS) criteria (Table 3). Evaluation criteria included color match, marginal discoloration and adaptation, recurrent caries, anatomic form, postoperative sensitivity, retention, and surface roughness. The restorations were examined at baseline (one week later) and six, 12, and 18 months by two calibrated evaluators who were blinded to the adhesive used per lesion and patient. When disagreement occurred during the evaluation, the final decision was made by consensus of both examiners. Tooth sensitivity was assessed by a visual analog scale by questioning the patients after a three-second air blast directed at the restoration site from a distance of 1 cm. After that, scores greater than 2 were accepted as the presence of tooth sensitivity. Tooth vitality and gingival response tests were recorded with a pulp tester and visual inspection and probing at the gingival margins, respectively. Digital color photographs were taken at each recall.

Statistical Analysis

The clinical outcome and durability of the three adhesive systems were compared and analyzed using

Table 2: *Distribution of the Adhesives Among Dental Arches and Postoperative Sensitivity*

Adhesive	Maxillary		Mandibular		Total	Postoperative sensitivity
	Anterior	Posterior	Anterior	Posterior		
Optibond FL	13	3	6	6	28	14
Optibond Solo Plus	18	2	6	6	32	17
Optibond All-In-One	14	4	7	5	30	16
Total	45	9	19	17	90	47

Table 3: *Using the United States Public Health Services Criteria for Restoration Evaluation*

Criterion	Inspection Method	Score
Color match	Visual inspection with mirror at a distance of 45 cm	Alfa: No mismatch in room light in 3 to 4 s
		Bravo: Perceptible mismatch but clinically acceptable
		Charlie: Esthetically unacceptable (clinically unacceptable)
Marginal discoloration	Visual inspection with mirror at a distance of 45 cm	Alfa: No discoloration anywhere along the margins
		Bravo: Superficial staining (removable, usually localized)
		Charlie: Deep staining (not removable, generalized)
Caries formation	Visual inspection with explorer, mirror, and radiographs	Alfa: No evidence of caries
		Charlie: Evidence of caries along the margins of the restorations
Anatomic form	Visual inspection with explorer and mirror, if needed	Alfa: The restoration is continuous with existing anatomic form
		Bravo: Generalized wear but clinically acceptable (50% of margins are detectable, catches explorer going from material to tooth)
		Charlie: Wear beyond dentino-enamel junction (clinically unacceptable)
Marginal adaptation (marginal integrity)	Visual inspection with explorer and mirror, if needed	Alfa: Undetectable crevice along the margin
		Bravo: Detectable V-shaped defect in enamel only
		Charlie: Detectable V-shaped defect in dentino-enamel junction
Retention	Visual inspection with explorer and mirror	Alfa: Retained
		Bravo: Partially retained
		Charlie: Missing
Surface roughness	Visual inspection with explorer and mirror	Alfa: Restoration is as smooth as the adjacent tooth structure
		Bravo: Restoration is rougher than the adjacent tooth structure
		Charlie: Restoration is rougher than the adjacent tooth structure and contains pits and fissures
Postoperative sensitivity	Asking the patients	Alfa: None
		Charlie: Some

Table 4: *United States Public Health Services Criteria Acquired at Each Recall for the Studied Parameters*

Parameters	Score	Baseline			6 Mo			12 Mo		
		Optibond FL	Optibond Solo Plus	Optibond All-In-One	Optibond FL	Optibond Solo Plus	Optibond All-In-One	Optibond FL	Optibond Solo Plus	Optibond All-In-One
Color match	A	30	30	30	28	26	25	28	25	24
	B	0	0	0	0	1	2	0	2	3
	C	0	0	0	0	0	0	0	0	0
Marginal discoloration	A	30	30	30	28	26	23	28	25	21
	B	0	0	0	0	1	4	0	2	5
	C	0	0	0	0	0	0	0	0	1
Marginal adaptation	A	30	30	30	27	27	27	27	27	27
	B	0	0	0	1	0	0	1	0	0
	C	0	0	0	0	0	0	0	0	0
Retention	A	30	30	30	28	27	26	28	27	26
	B	0	0	0	1	0	1	0	0	1
	C	0	0	0	0	2	2	1	2	2
Surface roughness	A	30	30	30	28	27	26	28	27	26
	B	0	0	0	0	0	1	0	0	1
	C	0	0	0	0	0	0	0	0	0

Abbreviations: A, Alfa, B: Bravo; C, Charlie.

the Friedman and Wilcoxon signed ranks tests. In this study, $p<0.05$ was considered statistically significant.

RESULTS

Noncarious cervical lesions were restored in 30 patients at baseline; only 29 patients (96.6%) could be evaluated at every recall during the 18-month period. The reason for dropout was traveling and moving of a participant. The USPHS criteria acquired for the changed parameters in three categories of adhesives after six, 12, and 18 months are shown in Table 4. Differences among the three categories of adhesive systems were not observed when comparing the mean Alfa score percentages ($p>0.05$). Retention rates after 18 months were 96.5% for OF, 93.1% for OS, and 89.7% for OA. The differences in retention rates were not statistically significant ($p>0.05$). There was a significant difference in marginal discoloration for OA adhesive after 18 months compared with baseline ($p=0.011$). Even though other restoration criteria had no statistically

Table 4: Extended.

18 Mo		
Optibon FL	**Optibond Solo Plus**	**Optibond All-In-One**
28	25	24
0	2	3
0	0	0
28	25	20
0	2	6
0	0	1
27	27	27
1	0	0
0	0	0
28	27	26
0	0	1
1	2	2
28	27	26
0	0	1
0	0	0

significant differences among the three adhesives, the three-step total-etch adhesive was found to be superior to the other adhesives after 18 months ($p>0.05$). Gingival inflammation around the restorations was not observed at any recall time.

DISCUSSION

In this clinical trial, a three-step etch-and-rinse, a two-step etch-and-rinse, and a one-step self-etching adhesive from one manufacturer were compared for their clinical effectiveness. All patients received restorations composed of all three adhesives to minimize the influence of the oral environment. At the end of 18 months, the recall rate was 96.6%. Regarding the retention rate, there were no significant differences between the three adhesives. Based on the American Dental Association guidelines, an adhesive material must have a retention failure rate less than 10% at the 18-month recall, and this recall time is sufficient to show the presence of an acceptable seal in clinical tests.[16] In this study, at the end of 18 months, the failure rates were less than the defined border rates in all three adhesives. Optibond FL had the highest retention rate, followed by Optibond Solo Plus and Optibond All-In One. In the clinical study carried out by Reis and others,[17] a higher success rate was recorded for a three-step etch-and-rinse adhesive compared with a two-step etch-and-rinse adhesive, which was in agreement with the results of the present study. Failure rates of adhesives reported by van Dijken and Pallesen[18] were 7.7% in the one-step self-etch adhesive group and 5.6% in the two-step etch-and-rinse adhesive group, respectively. This finding is consistent with our findings that the retention rate of the all-in-one adhesive was lower than other adhesives.

Tooth flexure has been described as either a lateral or axial bending of a tooth during occlusal loading. This flexure produces the maximum strain in the cervical region, and the strain seems to be resolved in tension or compression within local regions, sometimes causing the loss of gingival enamel prisms or failure of bonded class V restorations in preparations with no retentive grooves, the same as tooth preparations in the current study.[19] Another etiological factor for noncarious cervical lesions is the mechanical and chemical wear. Abfraction, abrasion, and erosion are the three main causes of formation of noncarious cervical lesions.[20] Therefore, elimination of the etiological factors along with the restorative procedure is the key to success for treatment of these lesions. Moreover, in incomplete bonded restorations, this flexure may produce changes in fluid flow and microleakage, leading to sensitivity and pulpal inflammation.[13,14,21] In the present study, marginal discoloration was observed only as superficial discoloration (Bravo score) and mostly occurred in the OA group rather than in the OS or OF groups, which is in agreement with the findings of the study by Loguercio and others.[21] They concluded that the higher marginal discoloration in the one-step self-etch adhesives might be due to the inferior etching pattern of these systems. The pH values of OF, OS, and OA adhesives are 1.8, 2.1, and 2.5, respectively.[22] The less acidity of OA could explain the higher marginal discoloration values and

lower retention rate of this adhesive. Some studies have demonstrated that pretreatment using 37% phosphoric acid can improve retention rates.[23,24] An excess or deficiency of the filling material may contribute to the occurrence of marginal staining. Therefore, it is important for the clinicians to follow the basic rules during adhesive materials placement. One explanation for marginal staining is the degree of conversion that does not occur completely in self-etch adhesives because of the existence of water and more hydrophilic monomers in their content.[25] The hydrophilicity, functionality, size of monomers, and filler content in adhesives affect the water sorption, solubility, crosslink density, and degree of conversion.[25,26] The OS adhesive containing glycerol dimethacrylate monomer and filler showed better clinical results in comparison with OA, indicating higher crosslink density along with an increased degree of conversion in the polymer network structure. In the OF adhesive, the presence of fillers and the use of a hydrophobic layer are the two major reasons for the higher performance compared with the other adhesives. Postoperative sensitivity has been attributed to several factors, such as operative trauma, desiccation, leakage, and other sources.[27–30] The ability of the adhesive layer to coat and bond to the tooth structure plays a key role in reducing sensitivity. In the present study, all three adhesives performed the same in this regard. In addition, Perdigão and others demonstrated that self-etch and total-etch adhesives did not differ with regard to postoperative sensitivity.[31] Other evaluation criteria including caries recurrence and marginal integrity were also rated satisfactorily in three adhesive groups. Further long-term clinical studies are required to confirm the results of the present clinical trial, and the evaluation of clinical performance of the one-step self-etch adhesives with various commercial brands are warranted in future investigations.

CONCLUSIONS

Within the limitations of the present study, it can be concluded that restoration of noncarious cervical lesions with the one-step self-etching adhesive can be an appropriate alternative to more complicated adhesives.

Conflict of Interest

The authors certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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