©Operative Dentistry, 2017, **42-4,** E111-E120

Clinical Performance of Different Solvent-based Dentin Adhesives With Nanofill or Nanohybrid Composites in Class III Restorations: Five Year Results

M Demirci • S Tuncer • HS Sancaklı • N Tekçe • C Baydemir

Clinical Relevance

The clinical performance of different solvent-based dentin adhesives with nanofill or nanohybrid composites in Class III restorations was satisfactory. Marginal discoloration and marginal integrity deterioration were reasons for the failure of the self-etch adhesive systems in Class III cavities.

SUMMARY

Purpose: To evaluate the clinical performance of water, acetone, ethanol, and ethanol-water solvent-based dentin adhesives with nanofill or nanohybrid composites in Class III restorations.

Methods and Materials: A total of 22 patients aged between 14 and 48 years (mean age: 25.2 years) participated in the study. Each patient received four Class III restorations, which were performed using water (Scotchbond Multipurpose), acetone (Prime&Bond NT), ethanol (XP Bond) and ethanol-water (Xeno V) solvent-based dentin adhesive systems with a nanofill (Filtek Supreme XT) or nanohybrid composite (CeramX Duo). Two experienced examiners evaluated the restorations with regard to retention, color match, marginal discoloration, wear/loss of anatomic form, caries formation, marginal adaptation, and surface texture at baseline and at one-, two-, three-, four-, and five-year recalls.

Results: The five-year survival rates were 100% for Scotchbond Multipurpose, Prime&Bond

Mustafa Demirci, DDS, PhD, professor, Faculty of Dentistry, Department of Restorative Dentistry, Istanbul University, Istanbul, Turkey

*Safa Tuncer, DDS, PhD, associate professor, Faculty of Dentistry, Department of Restorative Dentistry, Istanbul University, Istanbul, Turkey

Hande Şar Sancaklı, DDS, PhD, associate professor, Faculty of Dentistry, Department of Restorative Dentistry, Istanbul University, Istanbul, Turkey

Neslihan Tekçe, DDS, PhD, assistant professor, Kocaeli University, Faculty of Dentistry, Department of Restorative Dentistry, Kocaeli, Turkey

Canan Baydemir, PhD, associate professor, Kocaeli University Faculty of Medicine, Department of Biostatistics and Medical Informatics, Kocaeli, Turkey

*Corresponding author: Çapa, 34390 Istanbul, Turkey; e-mail: tuncers@istanbul.edu.tr

DOI: 10.2341/16-326-C

NT, and XP Bond and 81.2% for Xeno V–bonded restorations. Only three Xeno V–bonded restorations failed. With the exception of marginal discoloration, there were no statistically significant differences among the four adhesive-bonded restorations in any of the evaluation periods in terms of the evaluation criteria.

Conclusions: With the exception of marginal discoloration and marginal integrity deterioration of Xeno V–bonded restorations, all four adhesive-bonded restorations exhibited good long-term results. However, adhesion strategy (such as self-etch or etch-and-rinse) is more important than the solvent content of dentin adhesive systems in the success of Class III restorations.

INTRODUCTION

Bonding to enamel and dentin occurs through the replacement of minerals removed from the hard dental tissue by resin monomers, which become micromechanically interlocked in the newly created porosites.[1] Adhesives are classified according to their underlying adhesion mechanism into "etch & rinse," "self-etch," and "resin-modified glass ionomer adhesives, in addition to the number of application steps."[2]

Solvents are key elements of adhesive systems. The low viscosity of primers and primer-adhesive resins is in part caused by the dissolution of monomers in a solvent, which improves the diffusion ability in the porous substrate. Therefore, solvents are important to ensure the diffusion of monomers into demineralized dentin.[3] However, polymerization may be jeopardized, voids created, and the permeability of the adhesive may be increased as a result of the dilution of monomers; therefore, any remaining solvent must be removed from the adhesive after diffusion.[4,5] Water, ethanol, and acetone are the most frequently used solvents in adhesives.[6] Water is an indispensable compound of self-etch adhesives for ionizing acidic monomers.[6] In etch-and-rinse adhesives, water has the ability to re-expand the collapsed and shrunken collagen network.[7,8] Water is not an ideal solvent for organic compounds because they are typically quite hydrophobic; however, the addition of secondary solvents such as ethanol or acetone helps to negate this problem. Water's higher boiling point and low vapor pressure make its removal from adhesive solutions difficult after use,[6] and ethanol's higher vapor pressure enables superior evaporation in air-drying. Ethanol is usually used alongside water as a co-solvent. Thus, the occurrence of hydrogen bonds between water and ethanol molecules provides greater evaporation of water-ethanol aggregates than is obtained with pure water alone.[6] Acetone also combines hydrophobic and hydrophilic components. Its main advantage is its high vapor pressure; however, acetone-containing adhesives may have shorter shelf lives because the high volatility of acetone may cause rapid evaporation.[6] Acetone is often used alone as a solvent, but it is used as a co-solvent with water in self-etch adhesives.[6]

A new category of composites resins, known as nanocomposites, has been developed.[9] There are several nanocomposite products on the market, including Filtek Supreme (3M ESPE, St Paul, MN, USA), which contains nanometric particles (nanomers) and nanoclusters, and CeramX (Dentsply-De-Trey, Konstanz, Germany), which contains glass fillers.[10] Nanocomposites enable increased filler loading and reduce the resin requirement, thereby reducing shrinkage during polymerization while simultaneously maintaining esthetics and strength.[10] Knowledge of the composition, characteristics, and mechanisms of each adhesive system used in etch-and-rinse or self-etch systems is crucially important in the creation of ideal bonding strategies in the clinical setting.[3] Nanocomposites with solvent-containing adhesive systems have been extensively used in Class III cavities. However, few clinical studies have been conducted to investigate their clinical performance in such cavities.[9] The aim of this study was to evaluate the clinical performance of water, acetone, ethanol, and ethanol-water solvent-based dentin adhesives with nanofill or nanohybrid composites in Class III restorations.

METHODS AND MATERIALS

Study Design

Approval for the study was granted by the local ethics committee of Istanbul University Medical Faculty (#32859). The brands, chemical compositions, and manufacturers of the materials used are shown in Table 1. The restorations were performed between July 2008 and January 2010 in the Department of Restorative Dentistry, Faculty of Dentistry, Istanbul University. A total of 22 patients (nine males, 13 females) aged between 14 and 48 years (mean age: 25.2 years) participated in the study. The inclusion criteria included the following: patients with four primary caries in the approximal area on the maxillary anterior teeth; patients who displayed good oral hygiene and had no active periodontal or pulpal diseases and were willing to

Table 1: *Materials, Compositions, and Application Steps*

Adhesive	Compositions	Application Steps	Manufacturer
Scotchbond Multipurpose	Etchant: 35% H_3PO_4, water, and silica Primer: 2-hydroxyethylmethacrylate, polyalkenoic acid, copolymer, water Adhesive: 2-hydroxyethylmethacrylate, Bis-GMA, photoinitiator	Apply the conditioner for 15 s. Rinse the surface for 15 s and dry the surface slightly, leaving a visible moist surface. Apply the primer and dry gently for 5 s. Apply the bond and light-cure for 20 s.	3M/ESPE, St Paul, MN, USA
Prime&Bond NT	Etchant: 36% phosphoric acid (DeTrey conditioner 36 gel) PENTA, UDMA resin, resin R5-62-1, T-resin, D-resin, nanofiller, initiators, stabilizer, cetylamine hydrofluoride, acetone	Gently extrude conditioner to cavity surface, at least 15 s for enamel, 15 s or less for dentin. Rinse the surface for at least 15 s. Remove water from cavity with a soft air blow. Avoid desiccating the dentin; leave a moist surface. Apply the adhesive and leave undisturbed for 20 s. Air blow gently for at least 5 s. Light cure for at least 10 s.	Dentsply DeTrey, Konstanz, Germany
XP Bond	Etchant: 36% phosphoric acid PENTA, TCB, UDMA, TEGDMA, HEMA, camphorquinone, DMABE, butylated benzenediol, tert-butanol	Apply conditioner to the dentin surface for 15 s. Rinse thoroughly for 15 s and air-dry. Apply the adhesive and leave undisturbed for 20 s. Air blow for a minimum of 5 s. Light-cure for 20 s.	Dentsply DeTrey, Konstanz, Germany
Xeno V	Bifunctional acryl resin with amide function, acryloylamino alkylsulfonic acid, “inverse” functionalized phosphoric acid ester, acrylic acid, camphorquinone, coinitiator, butylated benzenediol, water, tertiary butanol	Apply Xeno V sufficiently, wetting all cavity surfaces uniformly. Then gently agitate the adhesive for 20 s. Air blow with air until there is no more movement of the adhesive, but for at least 5 s. Light-cure for a minimum of 20 s.	Dentsply DeTrey, Konstanz, Germany
Filtek Supreme XT	Bis-GMA, UDMA, TEGDMA, Bis-EMA, silica, filler, zirconia, filler, aggregated zirconia/silica, cluster, filler	Tooth color to be restored selected from a Vitapan classical shade guide before isolating the tooth. The corresponding body shade was selected. In 2-mm layers or less increments of body shade applied. Each increment light-cured 20 s.	3M/ESPE, St Paul, MN, USA
CeramX Duo	Methacrylate modified polysiloxane, dimethacrylate resin, fluorescence pigment UV stabilizer, camphorquinone, ethyl-4(dimethylamino)benzoate, barium-aluminum-borosilicate glass, methacrylate functionalized silicon dioxide nanofiller, iron oxide pigments and titanium oxide pigments and aluminum sulfo silicate pigments	Tooth color to be restored selected from a Vitapan classical shade guide before isolating the tooth. The corresponding combination of CeramX Duo enamel and dentin shade was selected. In 2-mm layers or less dentin shade applied and light-cured for 40 s. Then enamel layer in 2-mm layers or less applied and light-cured 10 s.	Dentsply DeTrey, Konstanz, Germany

Abbreviations: BIS-EMA, ethoxylated bisphenol A glycol dimethacrylate; Bis-GMA, bisphenol A diglycidyl methacrylate; DMABE, ethyl-4-(dimethylamino)benzoate; H_3PO_4, phosphoric acid; HEMA, 2-hydroxyethyl methacrylate; PENTA, dipentaerythritol pentaacrylate monophophate; UDMA, urethane dimethacrylate; TCB, butan-1,2,3,4-tetracarboyxlic di-2-hydroxyethylmethacrylate ester; TEGDMA, triethylene glycol dimethacrylate.

Table 2: *Distribution of Class III Composite Restorations According to Adhesives/Composite Combination and Tooth Number*

Dentin Adhesive/Composite	n	Tooth No.					
		11	12	13	21	22	23
Scotchbond Multipurpose/Filtek Supreme XT	22	8	4	1	6	2	1
XP Bond/CeramX Duo	22	9	1	0	8	4	0
Prime&Bond NT/CeramX Duo	22	8	4	0	6	4	0
Xeno V/CeramX Duo	22	2	7	1	5	6	1
Sum of restorations	88	27	16	2	25	16	2

return for follow-up examinations as outlined by the investigators. Exclusion criteria included the following: patients with uncontrolled parafunction; those presenting with insufficient oral hygiene; those presenting with spontaneous pain or pain to percussion; patients who were pregnant or nursing; and patients who had periodontal or gingival disease.[11-13] Each patient received four restorations for primary caries of the anterior teeth prior to evaluation; there were 88 restorations in total. The distribution of Class III restorations according to adhesives/composite combination and tooth number is presented in Table 2. All teeth had contact from opposing and adjacent teeth.

Treatment Protocol

Each patient received four Class III restorations: a water (Scotchbond Multipurpose), acetone (Prime&Bond NT), ethanol (XP Bond), and ethanol-water (Xeno V) solvent-based dentin adhesive system with nanofill composite (Filtek Supreme XT) or nanohybrid composite (CeramX Duo). Randomization was performed by first selecting the water solvent–based dentin adhesive and tooth number by flipping a coin, followed by the selection of acetone, ethanol, ethanol-water, and tooth number, also accomplished by the flip of a coin.

Restoration Procedure

All teeth were cleaned using pumice-water slurry and a rubber cup to remove the pellicle and residual dental plaque. Cavity preparation was limited to the removal of caries. The incisal margins of the cavities were cervical to the incisal edge of the teeth, and the cervical margins were at/or incisal to the cemento-enamel junction and extended.[14] In addition, the cavity margins could extend onto the facial or/and lingual surface depending on the amount of tooth structure missing. If possible, the outline form did not include the entire proximal contact area, extend onto the facial surface, or become extended subgingivally.[15] For etch-and-rinse adhesive systems (Scotchbond Multipurpose, Prime&Bond NT, and XP Bond), all enamel margins were beveled 0.5-1.0 mm at approximately 45° to the external cavosurface using a high-speed, water-cooled, rotary hand-piece, with a medium-grit diamond bur. For the self-etch adhesive system (Xeno V), enamel margins were not beveled and the acid-etching procedure was not performed. After the cavities were prepared, the manufacturer's instructions were closely adhered to regarding cavity treatment and placement of the restorative materials (Table 1). Isolation was achieved with cotton rolls and saliva ejectors.[14] Cavity treatment and application and polymerization of dentin adhesives were performed by the same practitioner (HS), who was experienced with the materials in the present study. Polymerization was performed using a halogen curing unit (VIP; Bisco Inc, Schaumburg, IL, USA). The composite shade was chosen using the relative composite guide or composite samples. All cavities were restored using a Mylar strip and wooden wedge to rebuild the anatomic form and proximal contacts of the teeth. With restorations having depths of more than 2 mm, composite was applied incrementally. The first composite layer was light-cured after being applied to the pulpal walls; this was followed by a second layer, which was cured in the same manner as the first. The composite was placed in a single increment in shallow cavities.[14] Light curing, contouring, and finishing were performed as described in our previous publication.[13]

Evaluation

Two experienced examiners evaluated the restorations using a dental explorer and mirror, in accordance with the modified Ryge criteria (Table 3).[16,17] Examiners were not involved with the operation and insertion of restorations and were fully blinded to the experimental protocol. For consistency, both examiners were provided photographs as reference instruments to illustrate scoring for each criterion. The examiners then clinically evaluated 20 Class III restorations with two days' separation between the

Table 3: *Direct Clinical Evaluation Criteria (Modified Ryge Criteria)*

Rating	Aspect	Method
Color match		
Alpha (A)	There is no a mismatch in color, shade, and/or translucency between the restoration and the adjacent tooth structure.	Visual inspection
Bravo (B)	There is a mismatch in color, shade, and/or translucency between the restoration and the adjacent tooth structure, but the mismatch is within the normal range of tooth color, shade, and/or translucency.	Visual inspection
Charlie (C)	The mismatch is between restoration and adjacent tooth structure outside the normal range of tooth color, shade, and/or translucency.	Visual inspection
Cavosurface marginal discoloration		
Alpha (A)	There is no discoloration anywhere on the margin between the restoration and the tooth structure.	Visual inspection
Bravo (B)	There is discoloration anywhere on the margin between the restoration and the tooth structure, but the discoloration has not penetrated along the margin of the restorative material in an enamel direction and can be polished away.	Visual inspection
Charlie (C)	The discoloration has penetrated along the margin of the restorative material in an enamel direction.	Visual inspection
Wear/anatomic form		
Alpha (A)	The restoration is not undercontoured: that is, the restorative material is not discontinuous with existing anatomic form.	Visual inspection and explorer
Bravo (B)	The restoration is undercontoured: that is, the restorative material is discontinuous with existing anatomic form, but sufficient restorative material is not missing so as to expose the enamel or base.	Visual inspection and explorer
Charlie (C)	Sufficient restorative material is missing so as to expose the enamel or base.	Visual inspection
Caries		
Alpha (A)	There is no evidence of caries contiguous with the margin of the restoration.	Visual inspection
Bravo (B)	There is evidence of caries contiguous with the margin of the restoration.	Visual inspection
Marginal adaptation		
Alpha (A)	There is no visible evidence of a crevice along the margin into which the explorer will penetrate.	Visual inspection and explorer
Bravo (B)	There is visible evidence of a crevice along the margin into which the explorer will penetrate. The enamel or base is not exposed.	Visual inspection and explorer
Charlie (C)	There is visible evidence of a crevice along the margin into which the explorer will penetrate. The enamel or base is exposed.	Visual inspection and explorer
Delta (D)	The restoration is fractured or missing in part or *in toto*.	Visual inspection and explorer
Surface texture		
Alpha (A)	Surface of restoration is smooth.	Explorer
Bravo (B)	Surface of restoration is slightly rough or pitted, can be refinished.	Explorer
Charlie (C)	Surface deeply pitted, irregular grooves (not related to anatomy), cannot be refinished.	Explorer
Delta (D)	Surface is fractured or flaking.	Explorer

examinations. These restorations were not included in the present study. The evaluation phase of study was initiated when at least 85% intra- and interexaminer agreement was achieved in the calibration phase.[18] Color match, wear or loss of anatomic form, marginal discoloration, caries, marginal adaptation, and surface texture were evaluated at baseline and at one-, two-, three-, four-, and five-year recalls. Restorations were scored as Alpha (A) = ideal clinical condition; Bravo (B) = acceptable; Charlie (C) = unacceptable, replacement required; and Delta (D) = fractured, mobile, or missing restoration, immediate replacement required. Scoring conflicts were resolved by consensus.[16,18]

Statistical Analysis

All analyses were performed using SPSS for Windows version 20.0 (SPSS, Chicago, IL, USA). Data obtained were statistically analyzed using the Friedman test to evaluate changes over the five-year study period. Comparisons of data among the four dentin adhesives were performed using the Mann-Whitney *U*-test and Kruskal-Wallis one-way analysis of variance and the Dunn post hoc test. When a statistically significant difference was identified for any criterion, the Dunn post hoc test was used for multiple comparisons between each recall time interval for each composite. Kaplan-Meier survival analysis was used to determine the probability of clinical survival of the composites. Statistical significance was considered at $p < 0.05$. Cohen kappa was used to examine inter- and intraexaminer agreement.

RESULTS

During the five-year evaluation, six patients with 24 restorations (six Scotchbond Multipurpose–bonded restorations, six Prime&Bond NT–bonded restorations, six XP Bond–bonded restorations, and six Xeno V–bonded restorations) left the study (Figure 1). The cumulative recall rate was 72.7% at the end of five years.

Cohen kappa (0.89) exhibited strong agreement between the examiners ($p>0.05$). The results of the Kaplan-Meier survival analysis displayed as follows: At one-year recall, one Xeno V–bonded restoration was lost (95.5% success rate). A 100% success rate was observed at the two- and three-year recalls for Scotchbond Multipurpose, XP Bond, and Prime&Bond NT, and a 95.2% success rate was observed for Xeno V–bonded restorations. At the end of four years, two Xeno V–bonded restorations failed as a result of marginal discoloration with Charlie rating (82.4% success rate). There were no restoration failures at the end of the fifth year with Scotchbond Multipurpose, Prime&Bond NT, or XP Bond (100% success rate), and Xeno V–bonded restorations were 81.2% successful.

With the exception of three failed Xeno V–bonded restorations, no restorations were clinically unacceptable with regard to retention, color, wear or loss of form, caries formation, marginal adaptation, or surface texture after the fifth-year evaluation. Other than marginal discoloration, there were no statistically significant differences among the four restorations in any of the evaluation periods with regard to the evaluation criteria. There was, however, a statistically significant difference between four years or five years and baseline marginal discoloration rates for Xeno V.

After the fifth year, 93.8% of Scotchbond Multipurpose–bonded restorations, 87.5% of the Prime&Bond NT– and XP Bond–bonded restorations, and 84.6% of Xeno V–bonded restorations showed clinically ideal (Alpha) color-match rates. At the end of five years, 6.3% of XP Bond–bonded restorations and 30.8% of Xeno V–bonded restorations exhibited marginal discoloration (Bravo). However, this discoloration was superficial, anywhere along the margin, did not penetrate toward the pulp along the margin of the restorative material, and could be polished away. On the other hand, 12.5% of the Xeno V–bonded restorations showed marginal discoloration at Charlie rating and had to be replaced after four years. With regard to wear and anatomic form, 100% of Scotchbond Multipurpose–, XP Bond–, Prime&Bond NT–bonded restorations and 92.3% of Xeno V–bonded restorations achieved an Alpha rating after five years. With respect to marginal adaptation rates, 100% of XP Bond– and Prime&Bond NT–bonded restorations and 93.8% of Scotchbond Multipurpose–bonded restorations were clinically ideal at the end of five years. One Xeno V–bonded restoration (4.5%) was lost after one year; this restoration therefore received a Delta score for marginal adaptation. After five years, 100% of Scotchbond Multipurpose–, XP Bond–, Prime&Bond NT–, and Xeno V–bonded restorations were rated an Alpha with regard to caries and surface texture.

DISCUSSION

The prevalence rate of Class III restorations has fallen along with the reduction of proximal caries.[19] However, a large demand for Class III restorations has been observed, and resin composites accompanied by different dentin adhesive system types have been extensively used in Class III cavities. There are limited data regarding the effect of adhesive systems on long-term clinical performance of Class III restorations.[20] Therefore, we evaluated the five-year clinical performance of water (Scotchbond Multipurpose), ethanol (XP Bond), acetone (Prime&Bond NT), and ethanol-water solvent-based (Xeno V) dentin adhesives with nanofill (Filtek Supreme XT) or nanohybrid composites (CeramX Duo) in Class III restorations.

According to our findings, the five-year survival rates were 100% for Scotchbond Multipurpose–, XP Bond–, and Prime&Bond NT–bonded restorations and 81.2% for Xeno V–bonded restorations. Scotchbond Multipurpose, XP Bond, and Prime&Bond NT showed the same excellent success rates. In agreement with our findings, identical (100%)[21] or slightly lower (96%)[22] success rates have been reported in Class III/IV or Class III restorations, respectively, after five years. Also, in a 20-year clinical study,[23]

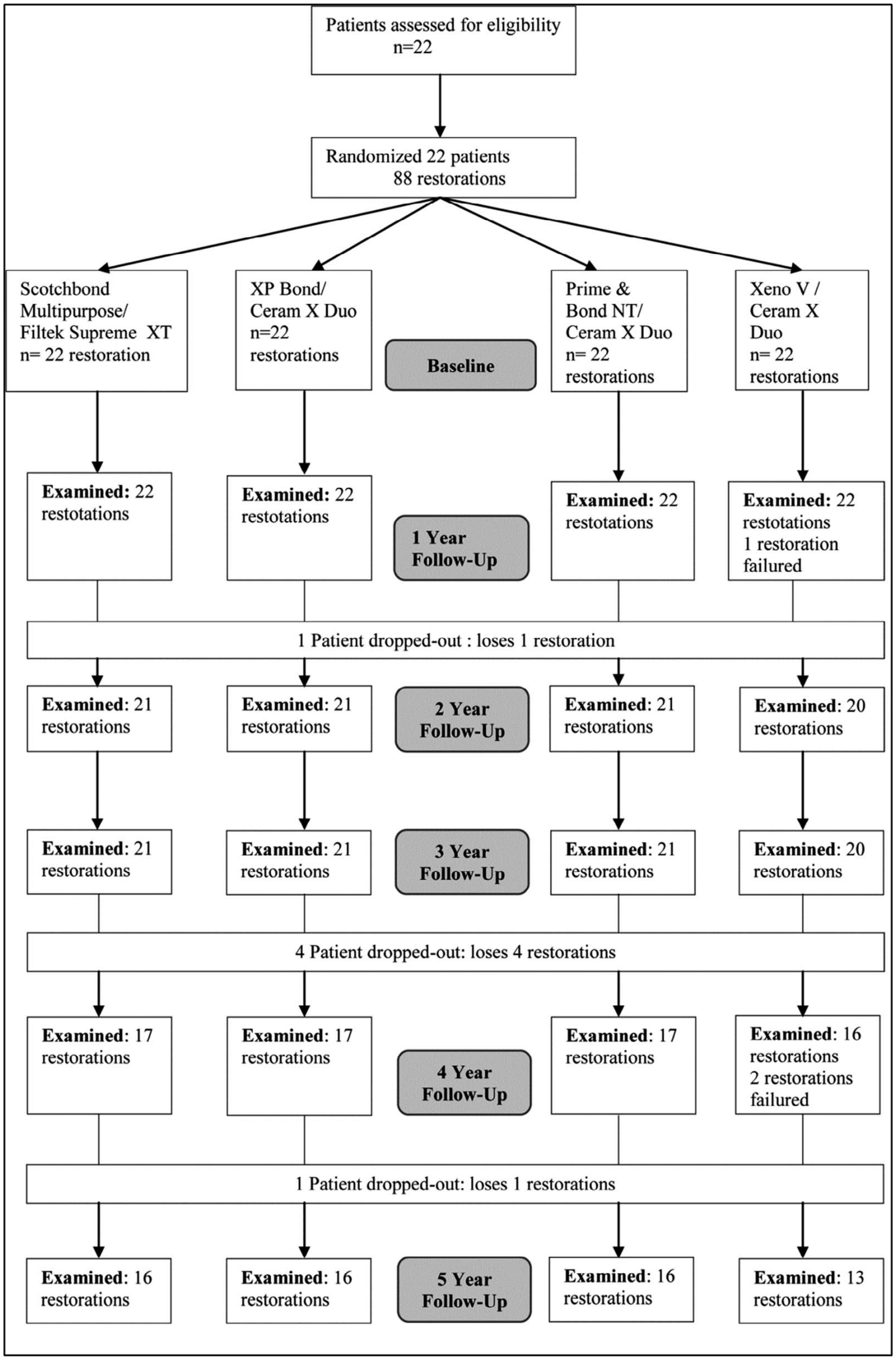

Figure 1. *Flow diagram history of restorations.*

survival rate was 100% for five-year periods in anterior restorations, which included Class III and IV restorations. In a meta-analysis,[19] 10-year survival rates for Class III and Class IV restorations were 95% and 90%, respectively, which corresponded with the annual failure rates of around 0.5% and 1%. A systematic review[24] involving long-term survival of anterior restorations, including Class III and Class IV restorations, showed annual failure rates varying between 0% and 4.1%. In another study,[25] in accordance with the findings of the present study, the success rate after three years was found to be 100% in Class III cavities with additional acid-etching. In contrast, Moura and others[26] reported a lower survival rate (91.8%) after three years for Class III restorations than was obtained in the present study. However, in their study restorations were placed by undergraduate dental students; the main cause of failure was the loss of restoration due to limited adhesiveness. The authors[26] stated that the debonding of the restorations may have been due to operator inexperience with the adhesive technique. In our study, there were no significant differences between the four dentin adhesives with regard to survival rates. On the other hand, Xeno V exhibited lower survival rates than did Scotchbond Multipurpose, XP Bond, and Prime&Bond NT, which are etch-and-rinse adhesive systems; Xeno V is a self-etch adhesive system. Self-etch systems are more user friendly. These adhesives eliminate the etch-and-rinse step, which not only reduces the clinical application time but also significantly minimizes the technique sensitivity or the risk of making errors during application.[2] In addition, it was revealed[14,19] that beveling of enamel did not significantly affect the clinical outcome variables in direct anterior restorations. Therefore, enamel margins were not beveled and etched with phosphoric acid. For etch-and-rinse adhesive systems, enamel margins were beveled and etched with phosphoric acid. Beveling enamel provides more exposed enamel rod ends and makes the enamel prisms more reactive to acid conditioning and produces an additional area for bonding.[27,28] Therefore, with any preparation that utilizes the acid-etch technique, such as etch-and-rinse systems, it is important to expose as many enamel rod ends as possible to increase resin retention.[28] Contradictory to this finding, although different dentin adhesives were used in the present study, Van Dijken and others[22] found no difference in the survival rates of three adhesives that were investigated after five years. The authors[22] did not confirm their hypothesis that use of bonding systems improved the durability of Class III restorations. Also, it was shown[25] that there was no difference in the retention rates of these two applications in Class III cavities when a self-etch adhesive was applied with and without acid-etching after three years. In agreement with the findings of the present study, although a one-step self-etch adhesive was shown[29] to have a higher cumulative failure rate than a two-step etch-and-rinse adhesive after 48 months, there was no significant difference between these two adhesives in Class III cavities. On the other hand, in Class III cavities, the two-step self-etch adhesive with etch group showed a significantly lower survival compared with the non-etch group and two-step etch-and-rinse adhesive groups.[20]

In the present study, self-etch (Xeno V) –bonded restorations exhibited significantly higher marginal discoloration than did three etch-and-rinse adhesive-bonded restorations. The reason for the failure of two of the three Xeno V failed restorations was marginal discoloration at the Charlie level. However, with respect to marginal adaptation, there were no significant differences between the four adhesive-bonded restorations. Only one Xeno V restoration was lost as a result of marginal adaptation at the Delta level. In agreement with these findings, it was reported[29] that a one-step self-etch adhesive showed higher marginal discoloration and lower marginal integrity than a two-step etch-and rinse adhesive in Class III/IV cavities after four years. On the other hand, marginal discoloration was not found as a reason for failure associated with three dentin adhesives in Class III cavities pretreated with oxalic or phosphoric acid.[22] Moreover, additional etching of the enamel margins was reported[25] to improve the marginal quality of mild two-step self-etch adhesives by protecting against small marginal defects and superficial marginal discolorations in Class III cavities after three years. A clear tendency for marginal staining has been reported with self-etching primers compared with enamel etching. The marginal seal of direct restorations can only be measured clinically through the evaluation of marginal discoloration and detectable margins.[19] The bond with enamel is vital to protect against marginal discoloration and for a good seal because almost all of the visible margin of Class III/IV restorations is in the enamel.[19] The best current method for establishing a microretentive pattern that permits good bonding to ground enamel is achieved through etching with 37% phosphoric acid.[19,30] Less discoloration was observed when enamel was etched with phosphoric acid compared with restorations performed with alternative conditioning systems.[19] In addition, in support of our findings related to marginal adaptation and marginal discolorations, it was reported[19] that the marginal integrity did not depend on the system or method of tooth conditioning because no differences were found between acid-etching and no etching in Class III restorations; detectable margins do not always result in stained margins.

After five years, there was no statistically significant difference among the four adhesive bonded restorations with respect to color match. However, nanofill composite restorations (Filtek Supreme XT) with Scotchbond Multipurpose exhibited more ideal restorations than did nanohybrid composite restorations (CeramX) with XP Bond, Prime&Bond NT, and Xeno V. It was stated that the initial gloss of many restoratives was quite good, but in hybrid composite (microhybrids, nanohybrids) plucking of the larger fillers caused loss of gloss. In contrast, nanoclusters shear at a rate similar to that of the surrounding matrix during abrasion in nanofilled composites, which allows restorations to retain a smoother surface for long-term polish retention.[31] This was likely the reason why we obtained more ideal nanofill composite restorations (Filtek Supreme XT) with respect to color match after five years.

In the current study, no caries were observed adjacent to the restoration margins in any of the four products tested, and all showed ideal (Alpha rate) surface texture. During the five-year observation period, 92.3% of the CeramX restorations and Xeno V (7.7%) restorations were ideal (Alpha) for wear and anatomic form, and only 1.2% of the restorations were at clinically acceptable (Bravo) levels for wear and anatomic form. On the other hand, the other three adhesive bonded restorations were ideal for wear and anatomic form. This finding was similar to the findings of our previous study,[13] in which the same composites were used to restore space closure by build-up restorations on anterior teeth. The use of nanotechnology-based composites may account for the greater number of ideal restorations.

CONCLUSIONS

Adhesion strategy, such as self-etch or etch-and-rinse, is a more important factor than solvent content of dentin adhesive systems in the success of Class III restorations. With the exception of marginal discoloration and marginal integrity deterioration of Xeno V–bonded restorations, modern composites such as nano-composites and nanohybrids could provide high-quality restorations and good long-term results.

Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the University Ethical Committee of Istanbul University. The approval code for this study is 32859.

Conflict of Interest

The authors of this manuscript 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.

(Accepted 7 January 2017)

REFERENCES

1. Van Meerbeek B, Vargas M, Inoue S, Yoshida Y, Peumans M, Lambrechts P, & Vanherle G (2001) Adhesives and cements to promote preservation dentistry *Operative Dentistry* **26(Supplement 6)** 119-144.
2. Van Meerbeek B, De Munck J, Yoshida Y, Inoue S, Vargas M, Vijay P, Van Landuyt K, Lambrechts P, & Vanherle G (2003) Buonocore memorial lecture. Adhesion to enamel and dentin: Current status and future challenges *Operative Dentistry* **28(3)** 215-235.
3. Silva e Souza MH Jr, Carneiro KG, Lobato MF, Silva e Souza Pde A, & de Góes MF (2010) Adhesive systems: Important aspects related to their composition and clinical use *Journal of Applied Oral Science* **18(3)** 207-214.
4. Ikeda T, De Munck J, Shirai K, Hikita K, Inoue S, Sano H, Lambrechts P, & Van Meerbeek B (2005) Effect of evaporation of primer components on ultimate tensile strengths of primer-adhesive mixture *Dental Materials* **21(11)** 1051-1058.
5. Jacobsen T, & Söderholm KJ (1995) Some effects of water on dentin bonding *Dental Materials* **11(2)** 132-136.
6. Van Landuyt KL, Snauwaert J, De Munck J, Peumans M, Yoshida Y, Poitevin A, Coutinho E, Suzuki K, Lambrechts P, & Van Meerbeek B (2007) Systematic review of the chemical composition of contemporary dental adhesives *Biomaterials* **28(26)** 3757-3785.
7. Carvalho RM, Yoshiyama M, Brewer PD, & Pashley DH (1996) Dimensional changes of demineralized human dentine during preparation for scanning electron microscopy *Archives of Oral Biology* **41(4)** 379-386.
8. Carvalho RM, Mendonça JS, Santiago SL, Silveira RR, Garcia FC, Tay FR, & Pashley DH (2003) Effects of HEMA/solvent combinations on bond strength to dentin *Journal of Dental Research* **82(8)** 597-601.
9. Loguercio AD, Lorini E, Weiss RV, Tori AP, Picinatto CC, Ribeiro NR, & Reis A (2007) A 12-month clinical evaluation of composite resins in Class III restorations *Journal of Adhesive Dentistry* **9(1)** 57-64.
10. Chen MH (2010) Update on dental nanocomposites *Journal of Dental Research* **89(6)** 549-560.
11. Wolff D, Kraus T, Schach C, Pritsch M, Mente J, Staehle HJ, & Ding P (2010) Recontouring teeth and closing diastemas with direct composite buildups: A clinical

evaluation of survival and quality parameters *Journal of Dentistry* **38(12)** 1001-1009.

12. Gresnigt MM, Kalk W, & Ozcan M (2012) Randomized controlled split-mouth clinical trial of direct laminate veneers with two micro-hybrid resin composites *Journal of Dentistry* **40(9)** 766-775.
13. Demirci M, Tuncer S, Öztaş E, Tekçe N, & Uysal Ö (2015) A 4-year clinical evaluation of direct composite build-ups for space closure after orthodontic treatment *Clinical Oral Investigations* **19(9)** 2187-2199.
14. Demirci M, Yildiz E, & Uysal O (2008) Comparative clinical evaluation of different treatment approaches using a microfilled resin composite and a compomer in Class III cavities: Two-year results *Operative Dentistry* **33(1)** 7-14.
15. Roberson TM, Heymann HO, Ritter AV, & Pereira PNR (2002) Classes III, IV, and V direct composite and other tooth-colored restorations In: Sturdevant CM (ed) *The Art and Science of Operative Dentistry* **4th edition** C.V. Mosby Co, St Louis, MO 501-536.
16. Ryge G (1980) Clinical criteria *International Dental Journal* **30(4)** 347-358.
17. Barnes DM, Blank LW, Gingell JC, & Gilner PP (1995) A clinical evaluation of a resin-modified glass ionomer restorative material *Journal of the American Dental Association* **126(9)** 1245-1253.
18. Cvar JF, & Ryge G (2005) Reprint of criteria for the clinical evaluation of dental restorative materials *Clinical Oral Investigations* **9(4)** 215-232.
19. Heintze SD, Rousson V, & Hickel R (2015) Clinical effectiveness of direct anterior restorations—A meta-analysis *Dental Materials* **31(5)** 481-495.
20. Kubo S, Kawasaki A, & Hayashi Y (2011) Factors associated with the longevity of resin composite restorations *Dental Materials Journal* **30(3)** 374-383.
21. Deliperi S (2008) Clinical evaluation of nonvital tooth whitening and composite resin restorations: Five-year results *European Journal of Esthetic Dentistry* **3(2)** 148-159.
22. van Dijken JW, Olofsson AL, & Holm C (1999) Five year evaluation of Class III composite resin restorations in cavities pre-treated with an oxalic- or a phosphoric acid conditioner *Journal of Oral Rehabilitation* **26(5)** 364-371.
23. Baldissera RA, Corrêa MB, Schuch HS, Collares K, Nascimento GG, Jardim PS, Moraes RR, Opdam NJ, & Demarco FF (2013) Are there universal restorative composites for anterior and posterior teeth? *Journal of Dentistry* **41(11)** 1027-1035.
24. Demarco FF, Collares K, Coelho-de-Souza FH, Correa MB, Cenci MS, Moraes RR, & Opdam NJ (2015) Anterior composite restorations: A systematic review on long-term survival and reasons for failure *Dental Materials* **31(10)** 1214-1224.
25. Ermis RB, Temel UB, Celik EU, & Kam O (2010) Clinical performance of a two-step self-etch adhesive with additional enamel etching in Class III cavities *Operative Dentistry* **35(2)** 147-155.
26. Moura FR, Romano AR, Lund RG, Piva E, Rodrigues Júnior SA, & Demarco FF (2011) Three-year clinical performance of composite restorations placed by undergraduate dental students *Brazilian Dental Journal* **22(2)** 111-116.
27. Schroeder M, Reis A, Luque-Martinez I, Loguercio AD, Masterson D, & Maia LC (2015) Effect of enamel bevel on retention of cervical composite resin restorations: A systematic review and meta-analysis *Journal of Dentistry* **43(7)** 777-788.
28. Moore DH, & Vann WF Jr (1988) The effect of a cavosurface bevel on microleakage in posterior composite restorations *Journal of Prosthetic Dentistry* **59(1)** 21-24.
29. Häfer M, Schneider H, Rupf S, Busch I, Fuchß A, Merte I, Jentsch H, Haak R, & Merte K (2013) Experimental and clinical evaluation of a self-etching and an etch-and-rinse adhesive system *Journal of Adhesive Dentistry* **15(3)** 275-286.
30. De Munck J, Van Meerbeek B, Satoshi I, Vargas M, Yoshida Y, Armstrong S, Lambrechts P, & Vanherle G (2003) Microtensile bond strengths of one- and two-step self-etch adhesives to bur-cut enamel and dentin *American Journal of Dentistry* **16(6)** 414-420.
31. Sakaguchi RL, & Powers JM (2012) *Craig's Restorative Dental Material*s Elsevier Mosby, Philadelphia, PA.