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The Survival of Class V Composite Restorations and Analysis of Marginal Discoloration

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Clinical Relevance

Type of resin composite, the presence of occlusal wear facets, and bleeding on probing were associated with the longevity of class V composite restorations. Surface refurbishment and the use of visual magnification are recommended when evaluating aged composite restorations.

SUMMARY

The aims of this retrospective clinical study were to analyze the longevity of class V composite restorations and compare the results obtained from clinical and laboratory evaluation of marginal discoloration. A total of 186 restorations were evaluated with modified US Public Health Service criteria. Longevity and associated variables were analyzed with the Kaplan-Meier method and a Cox proportional hazard model. Restorations with marginal discoloration were additionally evaluated using digital photographs and epoxy resin replicas under a stereomicroscope. The mean survival time was 15.0 years, with five- and 10-year survival rates of 95.5% and 83.1%, respectively. Z250 had a higher risk of failure (hazard ratio=7.01, 95% confidence interval=2.07-23.72) than Z100. In addition, the presence of occlusal wear facets and bleeding on probing were associated with an increased risk of failure of the restorations. However, the use of an adhesive system (Scotchbond Multi-Purpose or Clearfil SE Bond) did not affect the longevity of the restorations. The results of laboratory evaluation were significantly different from clinical evaluation ($p<0.001$, McNemar test). Among 55 restorations rated as Bravo in the clinical evaluation, 24 restorations (43.6%) were determined to have penetrating discoloration on laboratory evaluation. When evaluating aged composite restorations, surface refurbishment and the use of a microscope are recommended, which will be helpful in determining the need for timely repair or replacement.

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INTRODUCTION

Resin composites are effective materials for restoring damaged or decayed teeth, with the advantages of good esthetics, high surface gloss, and clinically acceptable wear resistance.[1,2] Contemporary dental adhesives used with resin composites show favorable immediate results in terms of retention and sealing of the tooth-composite interface.[3-5] However, some clinical studies showed a significant reduction in dentin adhesion over time and reported relatively short lifetimes of failed composite restorations.[6,7]

The tooth-composite interface is the weakest point of composite restorations.[8] None of the current adhesive systems are capable of completely eliminating marginal leakage, at least in the long term.[1,6,8] Marginal deterioration and recurrent caries are the most common causes of failure of composite restorations.[9,10] Adhesion degradation over time commonly manifests as a marginal discoloration. Hayashi and others[11] reported that marginal deterioration and discoloration were important predictors of the failure of composite restorations. Accordingly, the margins should be carefully examined to evaluate the clinical status of the restorations and determine their prognosis.

Visual rating scales are preferred for the clinical evaluation of existing restorations. The US Public Health Service (USPHS) criteria has been used in most clinical studies with slight modifications.[7,12-14] The USPHS criteria include the assessment of marginal discoloration, based on the assumption that penetrating discoloration is associated with microleakage and the development of secondary caries. The assessment of margins is a difficult decision for dental practitioners, but is usually performed with the naked eye in practice. Furthermore, there is a lack of literature on the effectiveness and accuracy of clinical evaluation for marginal discoloration.

Resin composites have been widely used for restoring class V lesions; however, the restoration of class V lesions seems to be rather difficult because class V lesions often have a low retentive cavity shape and cervical margins lying on dentin or cementum that are unfavorable for resin bonding.[15,16] Some researchers have reported unsatisfactory clinical performance of resin composites in class V lesions.[6,7] Although clinical procedures for restoring class V lesions are relatively simple compared with those of class II and III restorations, it has been suggested that the clinical outcome of class V composite restorations is affected by various factors, such as type of resin composite, adhesive system, tooth type, and operator.[3,14]

In this retrospective clinical study, we assessed the survival of class V composite restorations and prognostic factors for their longevity. In addition to clinical evaluation of restorations using modified USPHS criteria, laboratory evaluation using epoxy resin replicas and a stereomicroscope was performed to determine the modes of marginal discoloration. It was hypothesized that there would be no differences between results obtained from the clinical and laboratory evaluations for marginal discoloration.

METHODS AND MATERIALS

Subjects and Clinical Evaluation Procedures

Forty-six patients who had received cervical restorations with resin composites more than 1 year ago at the Department of Conservative Dentistry of the Seoul National University Dental Hospital were recalled between April 1, 2014 and February 28, 2015. The study protocol was approved by Institutional Review Board of the Seoul National University Dental Hospital (IRB No., CRI14007). Written informed consent was obtained from every patient. Previous dental records were examined to collect information about the patients (sex, age, medical and dental history) and restorative materials (adhesive system and resin composite) by one investigator. Patients with severe systemic diseases or dental problems such as severe chronic periodontitis or bruxism were excluded. On the day of clinical examination, two other experienced and calibrated investigators evaluated class V composite restorations using the modified USPHS criteria, which included assessment of retention, marginal discoloration, marginal adaptation, anatomic form, and secondary caries (Table 1). Interexaminer agreement was assessed using Cohen's κ. Clinical evaluations were performed by the naked eye and a dental explorer. In case of disagreement between the investigators, consensus was reached by reexamination and discussion. Clinical photographs of the teeth were taken with a digital camera, and silicone rubber impressions were obtained to make epoxy resin replicas.

Longevity of the Restorations and Associated Factors

Survival rates of the restorations were analyzed using the Kaplan-Meier method. Restorations receiving a score of Charlie for any category of the

Table 1: *Modified USPHS criteria used to evaluate class V composite restorations*

Category	Rating	Criteria
Retention	Alpha	Restoration is present
	Charlie	Restoration is partially or totally lost
Marginal discoloration	Alpha	No discoloration
	Bravo	Superficial staining
	Charlie	Deep staining penetrating in a pulpal direction
Marginal integrity	Alpha	No detectable gap
	Bravo	Detectable gap with an explorer
	Charlie	Marginal crevice requiring replacement
Anatomic form	Alpha	Restoration continuous with existing anatomic form
	Bravo	Restoration discontinuous with existing anatomic form but clinically acceptable
	Charlie	Sufficient material is lost to exposed dentin
Secondary caries	Alpha	No caries present at the margin of the restoration
	Charlie	There is evidence of caries at the margin of the restoration

modified USPHS criteria were counted as a failure, and their lifespan was defined as the period from the date of the initial treatment to the date of examination. When a restoration was replaced or the tooth received further treatment, such as crown and extraction, the lifespan of the restoration was defined as the period from the date of the initial treatment to the date of retreatment. A Cox proportional hazard model was used to identify factors with possible influence on the longevity of the restorations. The following 12 variables were analyzed as possible predictors of the longevity of the restorations: patient sex and age, adhesive system (Scotchbond Multi-Purpose, 3M ESPE, St. Paul, MN, USA, and Clearfil SE Bond, Kuraray, Osaka, Japan), resin composite (Z100 and Z250, 3M ESPE), jaw site (upper or lower), tooth type (incisor, premolar, or molar), occlusal wear facet (present or absent), lateral occlusion scheme (canine-guided or group function), gingival and plaque index (the Silness-Löe index[17]), bleeding on probing (BOP; present or absent), and brushing stroke (horizontal or rolling). All variables were entered simultaneously into the model, and the Wald test was used to assess the significance of covariates. The relative hazard ratios (HRs) with respective 95% confidence intervals (CIs) were determined.

Laboratory Evaluation of Marginal Discoloration Modes

The restorations, which were rated Bravo or Charlie for marginal discoloration in the clinical evaluation, were additionally investigated using digital photographs and epoxy resin replicas under a stereomicroscope (SZ4045, Olympus Optical Co Ltd, Tokyo, Japan) at 40× magnification. Under the microscope, marginal defects were evaluated whether they were a mere chipping or were accompanied by a crevice between the composite and tooth. In addition, the marginal discoloration mode was reevaluated and classified as superficial or penetrating. When a discoloration was observed in association with a marginal crevice or a detached tooth-restoration interface, it was classified as a penetrating discoloration. Statistical comparison between the results of marginal discoloration obtained from the clinical evaluation at the chairside and the laboratory evaluation was performed using the McNemar test (α=0.05). Additionally, the results from the laboratory evaluation were analyzed using the χ^2 test to identify an association between the presence of marginal defect and marginal discoloration modes (α=0.05).

RESULTS

The Cohen's κ statistics showed excellent agreement between the two examiners (κ=0.95). Clinical data were collected from a total of 217 cervical restorations from 46 patients during the survey. One patient and 31 restorations were excluded from the analysis due to loss of restoration (n=24), re-restoration with a full coverage crown (n=3), or tooth loss (n=4) at an unknown date. Finally, 186 cervical restorations from 45 patients were analyzed for the purposes of this study. Twenty patients (44.4%) were male and 25 patients (55.6%) were female. Patient age at treatment ranged from 23 to 76 years, with a mean age of 61.4 ± 9.7 years. Fifty-five (29.6%) restorations were placed on anterior teeth, 100 (53.7%) restorations on premolars, and 29 (15.6%) restorations on molars. Ninety-nine (53.2%)

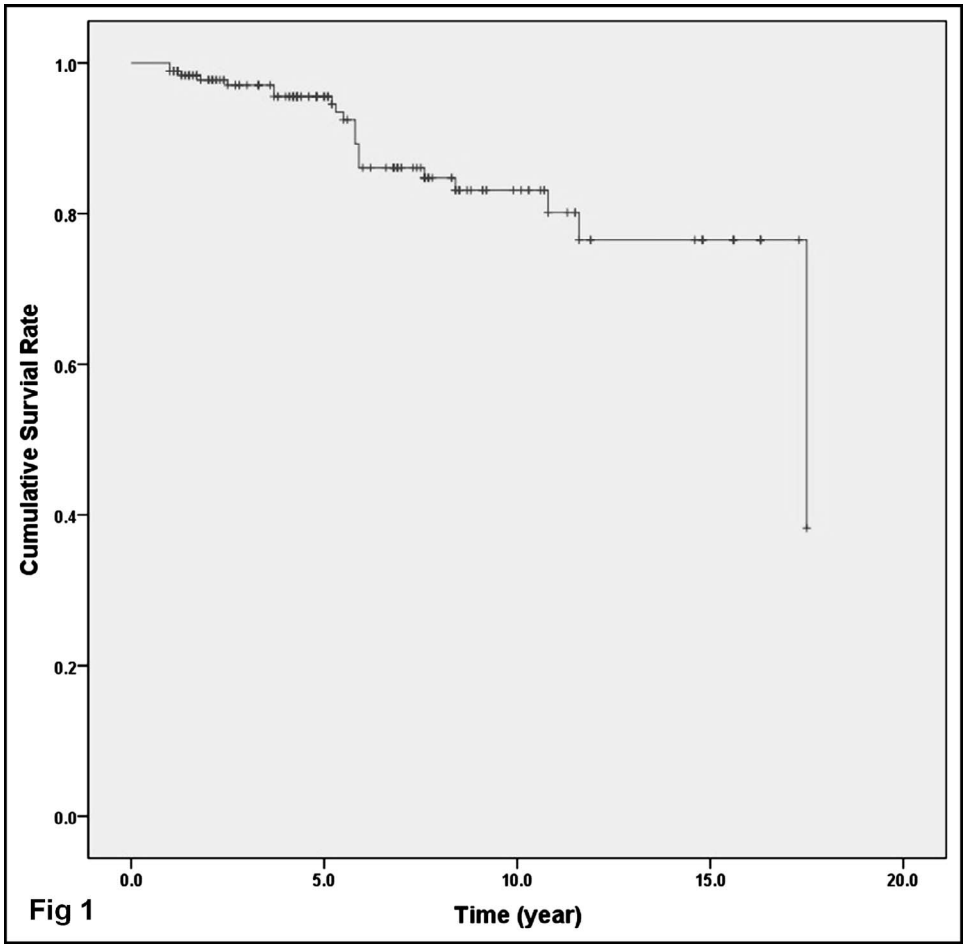

Figure 1. *Cumulative survival estimates of class V composite restorations using the Kaplan-Meier method.*

restorations were placed on upper teeth and 87 (46.8%) restorations on lower teeth.

Thirteen restorations (7.0%) failed and were replaced before the examination. Seven restorations were rated as Charlie for marginal discoloration, and one restoration was rated as Charlie for marginal adaptation. Consequently, 21 restorations (11.2%) were considered failed at the time of examination. Figure 1 shows the cumulative survival rates of the class V composite restorations. The estimated mean survival time of the restorations was 15.0 years (SE=0.53), with estimated five- and 10-year survival rates of 95.5% and 83.1%, respectively.

The Cox proportional hazard model revealed that type of resin composite, occlusal wear facet, and BOP significantly affected the longevity of class V composite restorations (Table 2). Z250 resin composites were more likely to fail than Z100 resin composite, corresponding to a HR for failure of 7.01 (95% CI=2.07-23.72, p=0.002). The restorations of teeth with occlusal wear facets and BOP had 6.65- and 4.58-fold increased risk of failure (95% CI=1.85-23.88, p=0.004 and 95% CI=1.46-14.33, p=0.009,

Table 2: *Prognostic variables affecting the longevity of class V composite restorations and their relative hazard ratio*

Variables	Relative HR	95% CI		Wald	*p*-value
		Lower	Upper		
Resin composite					
Z100	1.00				
Z250	7.01	2.07	23.72	9.791	0.002
Occlusal wear facet	6.65	1.85	23.88	8.425	0.004
Bleeding on probing (BOP)	4.58	1.46	14.33	6.819	0.009

Table 3: *Comparison of results obtained from clinical and laboratory evaluations for marginal discoloration*

Clinical evaluation	Laboratory evaluation		Total
	Superficial discoloration	Penetrating discoloration	
Modified USPHS rating			
Bravo	31	24	55
Charlie	1	7	8
Total	32	31	63

There was a significant difference between results obtained from the clinical and laboratory evaluation ($p<0.001$, McNemar test).

Table 4: *Association between the presence of marginal defects and marginal discoloration modes*

Presence of marginal defect under magnification	Marginal discoloration		Total
	Superficial discoloration	Penetrating discoloration	
No	16	18	34
Yes	16	13	29
Total	32	31	63

There was no association between the presence of marginal defects and marginal discoloration modes ($p>0.05$, χ^2 test).

respectively). However, patient sex and age, adhesive system, jaw site, tooth type, lateral occlusion scheme, gingival and plaque index, and brushing stroke did not affect the longevity of the restorations.

Sixty-three restorations, which were rated Bravo or Charlie for marginal discoloration on clinical evaluation, were evaluated in the laboratory for marginal discoloration mode using the digital photographs and epoxy resin replicas. The results of the laboratory evaluation were significantly different from those of the clinical evaluation ($p<0.001$, McNemar test; Table 3). Among 55 restorations rated as Bravo in the clinical evaluation, 24 restorations (43.6%) were determined to have penetrating discoloration by the laboratory evaluation. On the other hand, 87.5% of restorations rated as Charlie were determined to have penetrating discoloration by the laboratory evaluation. There was no association between the presence of marginal defects and marginal discoloration modes ($p>0.05$, χ^2 test; Table 4).

DISCUSSION

In this retrospective cross-sectional clinical study, we assessed the longevity and clinical status of 186 resin composite restorations. Cross-sectional retrospective studies are less satisfactory compared with controlled prospective trials in terms of methodologic criteria for validity and quality.[9] The major drawback of a cross-sectional design in this case is that various factors associated with restoration procedures such as cavity shape and preparation technique are not well controlled. However, cross-sectional designs are able to examine a large number of restorations in a relatively short survey period. Most prospective clinical studies have included a limited number of cases due to a high research cost and a considerable dropout rate.[18,19] Moreover, a few prospective clinical studies assessed composite restorations over a period of five years.[7,19-22] In the present study, the mean age of the assessed 173 restorations (excluding 13 restorations that failed before the examination) was 6.4 years, with a maximum of 17.5 years based on the date of examination. The medium- to long-term outcomes give more valuable insight into the clinical effectiveness of composite restorations than a short-term clinical trial. Such practice-based studies may reflect the real-life performance of restorative treatment more accurately than a well-controlled trial under ideal conditions.

Kaplan-Meier survival analysis indicated that the mean survival time of the restorations was 15.0 years (SE=0.53), and the estimated 10-year survival rate was 83.1%. Some short- to medium-term clinical trials have reported low retention rates of resin composite restorations over time.[6,7] However, recently, several long-term studies showed high retention rates and excellent clinical performance of class V composite restorations.[4,19,21,22] Wilder and others[19] reported a high retention rate of 89% of class V restorations with a three-step etch-and-rinse adhesive after 12 years. Similar high retention rates of 89.5% were reported for a two-step self-etch adhesive (Clearfil SE Bond) after 13 years by Peumans and others.[22] The excellent clinical performance of composite restorations can be largely attributed to improvement in the formulation of dentin adhesives, which accompanies proper dentin hybridization.

In the present study, we did not find any significant differences between the clinical performance of Scotchbond Multi-Purpose and Clearfil SE Bond. Scotchbond Multi-Purpose, a three-step etch-and-rinse adhesive, includes a water/ethanol-based primer and solvent-free bonding agent. The bonding effectiveness of Scotchbond Multi-Purpose to dentin has been shown to decrease with artificial aging in several *in vitro* studies.[23,24] However, the solvent-free bonding agent provides a stable and durable adhesion to acid-etched enamel and may overcome problems associated with hydrolytic degradation of the adhesive-dentin interface.[1,6] On the other hand,

Clearfil SE Bond is a two-step self-etch adhesive composed of a self-etch primer and a separate hydrophobic resin.[25,26] Clearfil SE bond is less sensitive to hydrolytic and enzymatic degradation of the hybrid layer compared with etch-and-rinse adhesive systems.[27] However, unsatisfactory bonding to enamel has been pointed out as a shortcoming of "mild" self-etch adhesives in several *in vitro* studies.[28,29] Well-controlled clinical studies, however, revealed a good clinical performance of Clearfil SE Bond even on unprepared enamel.[1,22] Considering that it is less technique sensitive and has a lower incidence of postoperative sensitivity compared with that associated with etch-and-rinse adhesives, Clearfil SE Bond should be the material of choice for restoring cervical lesions.

According to the Cox proportional hazard model, the Z250 resin composite had a higher risk of failure (HR=7.01, 95% CI=2.07-23.72) than Z100. Some researchers have claimed that a material with a lower elastic modulus is able to flex with the tooth and as a result shows a higher retention rate for class V restorations than a material with a higher elastic modulus.[30] However, recent clinical trials on class V restorations that compared performance of composites with different elastic modulus revealed no differences in retention rates between materials.[5,13,21] The elastic modulus of Z250 (6.9 GPa) was lower than that of Z100 (11.3 GPa).[31] Thus, the assumption that a material with a low elastic modulus would be favorable for cervical lesions was not supported by the results of the present study, as well as previous clinical studies. [5,13,21] The elastic modulus may be less significant for the retention of cervical restorations with current dentin adhesive systems. On the other hand, a material having mechanical properties similar to that of dentin may form a monolithic structure with the tooth and distribute stress evenly throughout the body of the restoration and the adhesive interface.[32,33] Z100 has an elastic modulus similar to that of dentin (mean, 13.2 GPa) compared with Z250.[34] This is likely to improve the clinical performance of Z100 for the cervical lesion. Another possible explanation for the difference between the clinical performance of Z100 and Z250 could be their chemical composition. Z100 contains a matrix resin consisting of bisphenol A glycol dimethacrylate (Bis-GMA) and triethylene glycol dimethacrylate (TEGDMA), whereas in Z250, the majority of Bis-GMA and TEGDMA is substituted by ethoxylated bisphenol A glycol dimethacrylate (Bis-EMA) and urethane dimethacrylate (UDMA). Several *in vitro* studies reported that UDMA-based composites more easily undergo softening in water or oral simulating fluids than do Bis-GMA–based composites.[35,36] Deterioration of mechanical properties with aging could result in the relatively high failure rate of Z250 restorations. However, well-designed *in vitro* and *in vivo* studies comparing the two composites are required to give an exact explanation of the difference in their clinical performances.

Class V restorations of teeth with occlusal wear facets had a 6.65-fold increased risk of failure than those of teeth without wear facets (95% CI=1.85-23.88). Occlusal wear facets are associated with heavy occlusal or parafunctional forces, which concentrate at the cervical region. Repetitive compressive/tensile stresses caused by tooth flexure promote marginal breakage and dislodgement of cervical restorations.[30,37] According to studies that reported associations between occlusal interferences and non-carious class V lesions, occlusal adjustment may reduce the failure of class V restorations.[37,38] However, the effectiveness of occlusal adjustments is not supported by substantial evidence. Occlusal adjustment should be considered in cases where interferences are clearly present.

Interestingly, teeth with BOP had an increased risk of failure for class V composite restorations (HR=4.58, 95% CI=1.46-14.33). Cervical restorations are contiguous with the marginal gingiva and thus would have an effect on periodontal health. Well-finished and contoured composite restorations are clinically biocompatible and do not adversely affect the marginal gingiva.[39] However, the deterioration of marginal adaptation and gap formation are associated with increased plaque accumulation and gingival inflammation.[40] The association between BOP and an increased failure of class V restorations can be explained by marginal deteriorations of the restorations, which result in bacterial accumulation and persistent gingival inflammation manifested by BOP. Regular checkups to correct marginal defects and smooth the surfaces of the composite restorations will improve the longevity of the restorations and overall periodontal health.

A considerable number of clinical trials have used the USPHS criteria with slight modifications and demonstrated their validity and usefulness.[1,7,13,14,19,38] However, there is a concern regarding examination rating accuracy, in particular for marginal discoloration. Marginal discoloration is a major reason for replacement of composite restorations; thus, an accurate evaluation of marginal discoloration is of the utmost importance.[9,11] Evaluations of existing

restorations have been performed chairside with the naked eye in most clinical studies. In the present study, we were able to determine modes of marginal discoloration by carefully inspecting the location of discoloration and the status of tooth-restoration interfaces in laboratory evaluation. Laboratory evaluation revealed that 43.6% of restorations rated Bravo for marginal discoloration had penetrating discoloration (Table 3). In contrast, with regard to restorations rated Charlie, the results of laboratory evaluation were consistent with those of clinical evaluation. No alterations such as polishing or refurbishing were done before the clinical evaluations. The underestimation of marginal discoloration status could be attributed to the fact that plaque and/or superficial staining interfere with detecting the presence of penetrating discoloration. When evaluating aged restorations, the use of magnifying equipment, such as eye loupes and operating microscopes, and removal of surface stains are recommended for improving the differential diagnosis between superficial staining and penetrating discoloration; the latter is a predictor for failure of restorations and requires intervention such as replacement.

Based on the results of the laboratory evaluation, there was no association between the presence of marginal defects and marginal discoloration modes (Table 4). Most marginal defects were a clinically acceptable chipping fracture at the thin margin of the composite rather than a crevice between the tooth and composite. This result implies that marginal discoloration is not necessarily associated with marginal microleakage, which is mainly characterized by the presence of penetrating discoloration. In the case of marginal chipping with no evidence of microleakage, repair or refurbishment instead of total replacement can be a conservative treatment option for a defective restoration. Total replacement readily leads to loss of a significant amount of tooth structure.[41] In addition, at the restorative stage of class V lesions, avoiding composite flash or overhang extending over the preparation margin may help to reduce chipping fractures at the margin.

CONCLUSIONS

Within the limitations of the present study, the Z250 resin composite had a sevenfold increased risk of failure compared with Z100 (95% CI=2.07-23.72), whereas the type of adhesive system (Scotchbond Multi-Purpose and Clearfil SE Bond) did not affect the longevity of the restorations. Occlusal wear facets and BOP were associated with an increased risk of failure of class V composite restorations. There was a significant difference between the results of the clinical and laboratory evaluations for marginal discoloration. Microscopic examination and refurbishment of aged restorations should be considered before determining their prognosis and treatment options for repair or replacement.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of Seoul National University Dental Hospital. The approval code for this study is CRI14007.

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.

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