

## Evaluation of cavity adaptation of low-shrinkage composite resin

Keizo Tanno, DDS,<sup>a</sup> Noriko Hiraishi, DDS, PhD,<sup>a</sup> Masayuki Otsuki, DDS, PhD,<sup>a</sup> and Junji Tagami, DDS, PhD<sup>a,b</sup>

<sup>a</sup>Cariology and Operative Dentistry, Department of Restorative Sciences, Graduate School of Medical and Dental Sciences, and <sup>b</sup>Global Center of Excellence (GCOE) Program; International Research Center for Molecular Science in Tooth and Bone Diseases, Tokyo Medical and Dental University, Tokyo, Japan

**Purpose:** The purpose of this *in vitro* study was to evaluate cavity adaptation of a low-shrinkage composite resin lining with or without a flowable composite resin.

**Materials and Methods:** One-mm-deep dentin and 2-mm-deep enamel-dentin cylindrical class I cavities were prepared and restored with a self-etch adhesive and either of a low-shrinkage composite or a conventional composite resin (1-mm-deep and 2-mm-deep cavities) and with or without a flowable composite (2-mm-deep cavity). Samples were crosscut and evaluated for gap formation using a digital microscope.

**Results:** Slight gap formations were observed at resin-cavity interface in all groups. There was no statistical difference of the gap formation among experimental groups.

**Conclusion:** Cavity adaptation of a low-shrinkage composite resin was comparable to that of a conventional composite resin. Intermediate layer of a flowable composite did not improve the adaptation at resin-cavity interface. (Asian Pac J Dent 2011; 11: 27-33.)

**Key Words:** composite resin, gap formation, low shrinkage

### Introduction

Indications for composite resin restoration have widely expanded as the various properties of the adhesives and the composite resins were improved. Clinical trials demonstrated that composite resin restorations were acceptable for long period.<sup>1-6</sup> As a results, directly placed composite resins serve as standard materials in restorative and esthetic dentistry.<sup>7</sup> The longevity of a resin restoration is affected by not only the properties of adhesives and composite resins, but also the restorative technique.

The factors affected for creating good adhesion are clean surfaces, surface roughness, proper contact angle and good wetting, low viscosity adhesives and adequate flow, resistance to phase separation and adhesive solidification.<sup>8</sup> Impairment of marginal integrity by insufficient adhesion would cause microleakage, post-operative sensitivity, marginal discoloration, restoration loss and pulpal disease which reduce the longevity of the restoration.<sup>9-11</sup> Microleakage is defined as the passage of bacteria, fluids or molecules between a cavity wall and the restorative material applied to it.<sup>9,12</sup>

As the contraction stress developing during polymerization is transferred to the tooth/composite interface, it may cause mikroleakage.<sup>11</sup> Despite the differences among their chemical formulation, all composite resins are essentially characterized by a polymerization reaction occurring between methacrylate groups of monomers, resulting in cross-linking of mobile molecules to form rigid polymers. The main adverse effect of this methacrylate polymerization reaction is volumetric shrinkage, which contributes to stress formation along the bonded interfaces of restorations.<sup>13</sup>

A low-shrinkage resin composite (Kalore, GC, Tokyo, Japan) has been recently developed. This material contains high molecular weight urethane dimethacrylate monomer (DX511) which has low number of C=C double bonds expecting reduce polymerization shrinkage. This composite showed low polymerization contraction and low contraction stress.<sup>14</sup>

Flowable composites can be easily inserted into small cavities and are expected to demonstrate better adaptation to the internal cavity wall compared to the conventional restorative composites which are more

viscous.<sup>15</sup> It has been suggested that flowable composites would be acceptable as filling materials in low-stress applications and in situations with difficult access or those requiring good penetration such as pit and fissure sealing; preventive resin restoration; restoration of air-abrasion preparations; cavity lining; amalgam, composite or crown margin repairs; porcelain repairs; enamel defects; incisal edge repairs in anterior sites; and for small class III and class V restorations.<sup>16</sup> The use of flowable composites as intermediate materials was shown to be effective in reducing voids at the interface between the restoration and the tooth<sup>17</sup> acting as an elastic layer able to absorb the stress generated by the overlying layer of conventional resin-composite materials characterized by higher elastic modulus.<sup>11,18</sup>

The combination with a low-shrinkage composite and a flowable composite as an intermediate material seems to be effective in improving the adaptation of the restoration to the cavity. The purpose of this study was to evaluate the cavity adaptation of a low-shrinkage composite resin with or without a flowable composite resin.

## Materials and Methods

### Adhesive and composites

Materials used in this study and their codes, manufacturer, ingredients and properties are listed in Table 1. One component one-step self-etching light-cured adhesive (G-Bond Plus, GC, Tokyo, Japan) was used in combination with a low-shrinkage composite resin (Kalore, KL, GC), a universal composite resin (Gradia direct, GR, GC) and a flowable composite resin (MI Flow, MI, GC).

**Table 1.** Materials used in this study

Material, Code (Manufacturer)	Ingredients	Lot No	Filler content*	Volumetric shrinkage*
G-Bond Plus (GC)	acetone, distilled water, dimethacrylate, 4-methacryloxyethyl trimellitate anhydride, phosphoric acid ester monomer, silicon dioxide, photo initiator	1003081		
Kalore, KL (GC)	ytterbium trifluoride, urethane dimethacrylate (UDMA), urethane dimethacrylate (DX-511), bisphenol A polyethoxymethacrylate, camphorquinone	0906291	82wt%	1.7%
Gradia direct, GR (GC)	urethane dimethacrylate, silica powder, organic filler, dimethacrylate, camphorquinone	1003011	73wt%	2.7%
MI Flow, MI (GC)	strontium glass, bis-MEPP, urethane dimethacrylate, dimethacrylate, lanthanoid fluoride, silicon dioxide, pigment, photo initiator	1002121		4.4%

\*Data were provided by manufacturer.

### Cavity preparation

Forty-eight extracted intact human third molars were utilized in this study. This research design was subjected to the guideline of the ethical committee, University Hospital, Faculty of Dentistry, Tokyo Medical and Dental University. After cleaning with a scaler, the roots were removed. Occlusal surfaces of sixteen teeth were ground using a model trimmer to obtain flat dentin surfaces, and then polished with a 600 grid silicon carbide paper (Sankyorikagaku, Saitama, Japan). A class I dentin cavity, 2 mm in diameter and 1 mm in depth was prepared in each tooth using a flat-end tapered diamond bur (SB2, GC) with an air turbine handpiece under water spray coolant.

The occlusal surfaces in the remaining 32 teeth were slightly ground to obtain flat enamel surfaces and then

polished. A class I cavity, 2 mm in diameter and 2 mm in depth was prepared in each tooth. In the 2-mm-deep cavities, all cavosurface margins were located within enamel with each cavity wall consisting of approximately 1mm enamel at the top and 1mm dentin in the bottom, with the cavity floor in dentin.

### Restoration

Each cavity was treated with G-Bond Plus according to the manufacturer's instruction. The adhesive was applied for 10 s and dried with air, then irradiated with a halogen light curing unit (Optilux 501, 800 mW/cm<sup>2</sup>, Kerr, CA, USA) for 10 s. The teeth with 1-mm-deep cavities were divided into two groups and those with 2-mm-deep cavities were divided into four groups, with eight cavities in each group. The cavities in all 1-mm-deep groups and those in two of the 2-mm-deep groups were filled with one of the two composite resins in bulk, and light cured for 40 s to make up 1-KL, 1-GR, 2-KL and 2-GR groups with respect to the cavity depth and composite resin. The remaining 2-mm-deep cavities were restored in two increments; with MI in the deeper layer and KL or GR in the surface layer to comprise 2-MI-KL and 2-MI-GR groups respectively. MI was photo-cured for 20 s and KL and GR was irradiated for 40 s.

### Evaluation

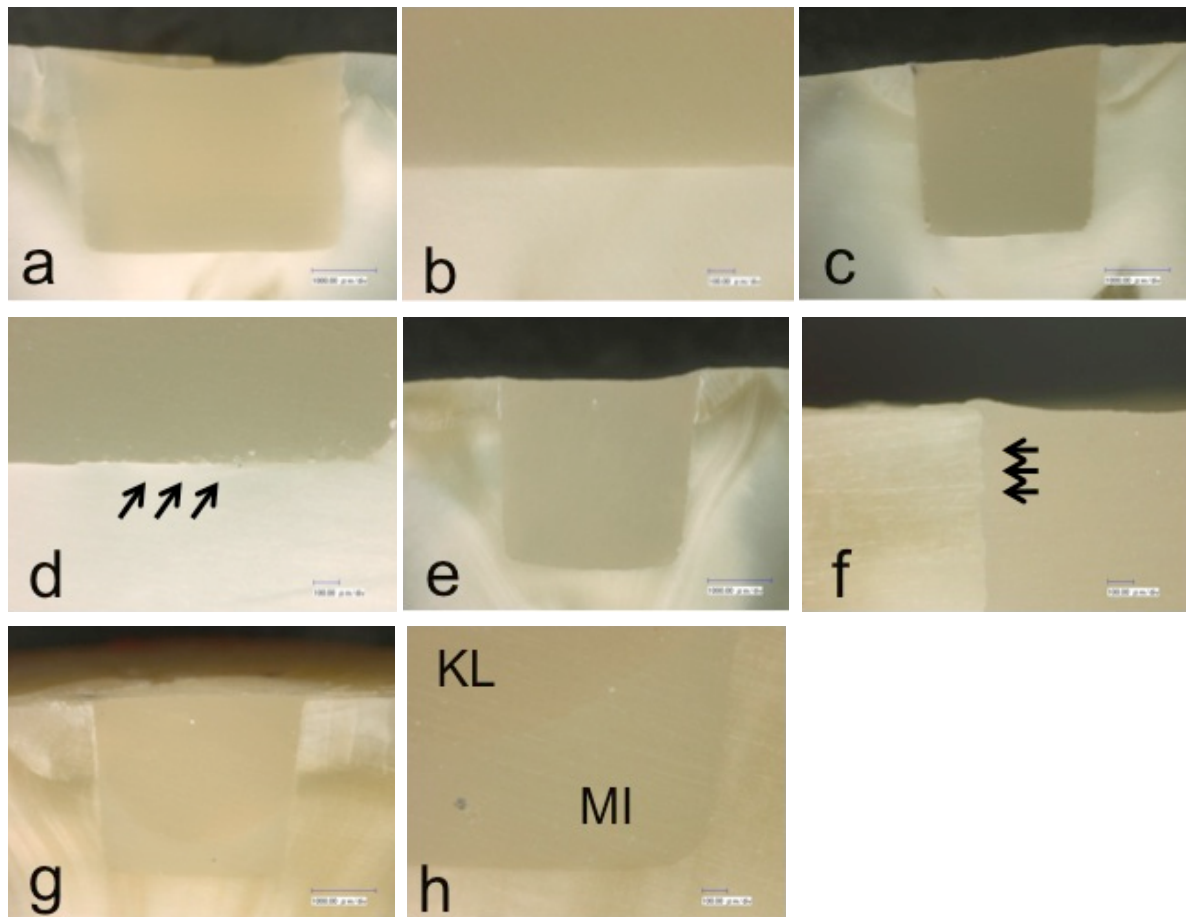
The restored teeth were stored in tap water for 24 hours at room temperature. Each tooth was then bucco-lingually crosscut at the center of cavity, using a low speed diamond saw with copious water. The crosscut surface was polished down to 1,500 grit silicon-carbide paper. The polished surface was observed and the gap formation was evaluated using a digital microscope (VHX-500, Keyence, Osaka, Japan) at 50 to 200x magnifications. The frequency of detection of gap formation in lateral wall and cavity floor was recorded in each group and statistical analysis of the results was performed by the Kruskal Wallis test (significance level  $p < 0.05$ ).

### Results

Representative images of the samples obtained in experimental groups were shown in Fig. 1. The number of the specimens detecting gap formation in the lateral wall and the cavity floor was shown in Table 2. Some slight gap formations were observed at resin-cavity interface in all groups. Comparing Kalore and Gradia Direct groups, statistical difference was not found in gap formation in both lateral wall and cavity floor. Comparing 1-mm-deep and 2-mm-deep cavities, there was no statistical difference. Although the frequency of gap formation in cavity floor of 2-MI-GR group was less than that of 2-GR group, there was no statistical difference.

**Table 2.** Experimental groups and number of samples detecting gap formation

Group	Cavity depth	Material (filling method)	Lateral wall	Cavity floor
1-KL	1 mm	KL (bulk)	3	5
1-GR	1 mm	GR (bulk)	2	2
2-KL	2 mm	KL (bulk)	1	4
2-GR	2 mm	GR (bulk)	2	5
2-MI-KL	2 mm	MI, KL (inclemntal)	1	5
2-MI-GR	2 mm	MI, GR (inclemntal)	2	2



**Fig. 1.** Representative images of the crosscut surfaces  
 a, 2-KL group, gap formation Lateral wall (-), Cavity floor (-);  
 b, Higher power magnification at cavity floor of Fig. 1a;  
 c, 2-KL group, gap formation Lateral wall (-), Cavity floor (+);  
 d, Higher power magnification at lateral wall of Fig. 1c, arrows showed gap formation;  
 e, 2-GR group, gap formation Lateral wall (+), Cavity floor (-);  
 f, Higher power magnification at cavity floor of Fig. 1e, arrows showed gap formation;  
 g, 2-MI-KL group, gap formation Lateral wall (-), Cavity floor (-);  
 h, Higher power magnification of Fig. 1g, MI, MI Flow, KL, Kalore

## Discussion

In this study, there was no difference in gap formation between a low-shrinkage composite and a conventional composite resin with or without a flowable composite resin as an intermediate layer. Adaptation at the resin-cavity interface and bond strength have often been investigated for *in vitro* evaluation of the restorative materials and techniques. For evaluation of the interface, different methods have been employed.<sup>15,19-21</sup> Although microleakage evaluation is one of the most common methods for assessing the sealing efficiency of restorative materials, no gold standard has been established for this method.<sup>19</sup> In this study, the crosscut surface of the restoration was observed using a high-resolution digital microscope according to a previous study.<sup>15</sup> This method has an advantage to avoid the necessity of desiccating the specimens, which may cause the separation of the bonding interface due to the shrinkage of the tooth substrate.

Despite innovative improvements and the excellent acceptance of methacrylate-based restorative dental materials, polymerization shrinkage stress is still considered as their main drawback.<sup>22</sup> Different approaches have been proposed to reduce polymerization shrinkage and the effects of contraction stress in composite resins; such as incremental placement techniques, use of low-modulus intermediate layers and modifications of the

current resin-based composites.<sup>13</sup> Some low-shrinkage restorative composites are BisGMA-based and use high filler levels or do not contain low-molecular weight dimethacrylates as strategies to reduce polymerization shrinkage. Other materials combine conventional dimethacrylates with new high-molecular weight monomers, for example, tricyclodecane-urethane dimethacrylate or dimer dicarbamate dimethacrylate.<sup>23</sup> According to the manufacturer, Kalore employs high molecular weight urethane dimethacrylate monomer (MW 895) and high filler content (82%Wt) to achieve low shrinkage (1.7%Vol).

In this study, the gap formation of Kalore at the resin-cavity interface was comparable to that of a conventional composite resin Gradia Direct. According to the manufacturer, volumetric shrinkage of Gradia Direct is 2.7% which is relatively low among the conventional composite resins. The difference of the volumetric shrinkage between Kalore and Gradia Direct might not be enough to demonstrate the difference of gap formation.

A new category of resin matrix, so called silorane as an alternative to dimethacrylate resins was developed based on ring-opening monomers for a low-shrinkage composite resin.<sup>9,10,13</sup> The silorane molecule presents a siloxane core with four oxirane rings attached that open upon polymerization to bond to other monomers.<sup>23</sup> There are many researches about a silorane-based composite resin. A silorane-based composite resin seems to be one of representatives as low-shrinkage composites.

Mechanical properties of the silorane-based composite were revealed to be comparable to clinically successful methacrylate-based composite materials,<sup>22</sup> and this composite showed better behavior than the methacrylate-based composites in setting shrinkage and marginal adaptation.<sup>24</sup> The microleakage of experimental silorane-based composite was less than commercial methacrylate-based composites in MOD restorations.<sup>25</sup> In order to reduce microleakage problems, silorane-based materials might be a better substitute for methacrylate-based composites.<sup>9</sup>

Even when a silorane-based composite was used, cavity configuration and composite application technique affected the tensile bond strength as well as methacrylate-based composite.<sup>26</sup> The adequate polymerization at the bottom of the cavity is important and a layering technique is still recommended, even for the low-shrinking composite.<sup>26</sup> In a clinical study, a silorane-based composite showed good durability, but not significantly better than the methacrylate-based composite in class II cavities and recurrent caries was the main reason for failure of the restoration.<sup>27</sup> Further researches would be necessary to determine the effect of low-shrinkage composites on contribution of adaptation at resin-cavity interface.

Although the silorane-based adhesive is essential for silorane-based restorative composite materials and is not recommended for use with methacrylate-based systems,<sup>10,25</sup> the monomer of Kalore is compatible with current adhesive and composite products. Compatibility between composites and adhesives are very important clinically for selecting materials.

In this study, incremental filling with a flowable composite and a low-shrinkage composite or a conventional composite did not improve the gap formation statistically. It has been suggested by previous studies that the use of an incremental technique may result in significantly less microleakage compared to the use of a bulk technique. Thus the incremental technique should be an effective restorative technique.<sup>15,19,28,29</sup> Flowable composites have been used as intermediate materials or liners between the adhesive layer and higher-viscosity composite.<sup>30-32</sup> The elasticity of intermediate layer with a flowable composite may absorb the contraction stress generated by the composite resin with higher elastic modulus, thus reducing the tooth/restoration interfacial

stress.<sup>11</sup> However, other studies showed no major improvement in marginal sealing and clinical performance for restorations lined with flowable composites.<sup>32,33</sup>

The uncured paste of a silorane-based composite is rather stiff, and close adaptation to the dentin surface in the narrow cavity may have been problematic. In some specimens of bulk filled with a silorane-based composite, air bubbles were indeed observed at the composite–dentin interface.<sup>34</sup> Kalore used in this study was rather stiff as well as a silorane-base composite and small bubbles were detected occasionally at the interface in some samples.

Filler content has somewhat controversial effects on shrinkage patterns. An increase in filler volume content leads to reduce volumetric shrinkage as the resin volume is minimized, meanwhile high filler volume results in stiff materials with high elastic modulus.<sup>24</sup> Kalore is a stiff paste because of high molecular weight monomer and high filler loading. The stiffness of Kalore might affect the results of gap formation in this study. The stiffness of the composite resin seems to be a significant factor to compromise the adaptation to the cavity wall.

The clinical success of a composite restoration is closely related to the material characteristics like polymerization shrinkage, degree of conversion and mechanical properties.<sup>7</sup> However, other factors, such as operator ability and caries risk of the individual patient, are likely to be more important clinical variables determining the durability of restorations than the polymerization shrinkage stress of restorative composite resin materials.<sup>6</sup> With the limitation of this study, it was possible to conclude that cavity adaptation of a low-shrinkage composite resin was comparable to that of a conventional composite resin for both dentin and enamel-dentin class I cavities. The use of intermediate layer of a flowable composite has not improved the adaptation at resin-cavity interface.

#### Acknowledgment

This work was partially supported by the grant from the Japanese Ministry of Education, Global Center of Excellence (GCOE) Program, “International Research Center for Molecular Science in Tooth and Bone Diseases.”

#### References

1. Kubo S, Kawasaki K, Yokota H, Hayashi Y. Five-year clinical evaluation of two adhesive systems in non-carious cervical lesions. *J Dent* 2006; 34: 97-105.
2. Akimoto N, Takamizu M, Momoi Y. 10-year clinical evaluation of a self-etching adhesive system. *Oper Dent* 2007; 32: 3-10.
3. Opdam NJ, Bronkhorst EM, Roeters JM, Loomans BA. A retrospective clinical study on longevity of posterior composite and amalgam restorations. *Dent Mater* 2007; 23: 2-8.
4. Peumans M, De Munck J, Van Landuyt K, Lambrechts P, Van Meerbeek B. Five-year clinical effectiveness of a two-step self-etching adhesive. *J Adhes Dent* 2007; 9: 7-10.
5. van Dijken JW, Lindberg A. Clinical effectiveness of a low-shrinkage resin composite: a five-year evaluation. *J Adhes Dent* 2009; 11: 143-8.
6. Opdam NJ, Bronkhorst EM, Loomans BA, Huysmans MC. 12-year survival of composite vs. amalgam restorations. *J Dent Res* 2010; 89: 1063-7.
7. Lohbauer U, Zinelis S, Rahiotis C, Petschelt A, Eliades G. The effect of resin composite pre-heating on monomer conversion and polymerization shrinkage. *Dent Mater* 2009; 25: 514-9.
8. Marshall SJ, Bayne SC, Baier R, Tomsia AP, Marshall GW. A review of adhesion science. *Dent Mater* 2010; 26: e11-6.
9. Bagis YH, Baltacioglu IH, Kahyaogullari S. Comparing microleakage and the layering methods of silorane-based resin composite in wide Class II MOD cavities. *Oper Dent* 2009; 34: 578-85.
10. Duarte S Jr, Phark JH, Varjao FM, Sadan A. Nanoleakage, ultramorphological characteristics, and microtensile bond strengths of a new low-shrinkage composite to dentin after artificial aging. *Dent Mater* 2009; 25: 589-600.
11. Cadenaro M, Marchesi G, Antonioli F, Davidson C, De Stefano Dorigo E, Breschi L. Flowability of composites is no guarantee for contraction stress reduction. *Dent Mater* 2009; 25: 649-54.
12. Kidd EA, Beighton D. Prediction of secondary caries around tooth-colored restorations: a clinical and microbiological study. *J Dent Res* 1996; 75: 1942-6.
13. Navarra CO, Cadenaro M, Armstrong SR, Jessop J, Antonioli F, Sergo V, et al. Degree of conversion of Filtek Silorane Adhesive System and Clearfil SE Bond within the hybrid and adhesive layer: an in situ Raman analysis. *Dent Mater* 2009; 25: 1178-85.
14. Takahashi H, Finger WJ, Wegner K, Utterodt A, Komatsu M, Wostmann B, et al. Factors influencing marginal cavity adaptation of nanofiller containing resin composite restorations. *Dent Mater* 2010; 26: 1166-75.
15. Ikeda I, Otsuki M, Sadr A, Nomura T, Kishikawa R, Tagami J. Effect of filler content of flowable composites on resin-cavity interface. *Dent Mater J* 2009; 28: 679-85.

16. Bayne SC, Thompson JY, Swift EJ, Jr., Stamatides P, Wilkerson M. A characterization of first-generation flowable composites. *J Am Dent Assoc* 1998; 129: 567-77.
17. Braga RR, Hilton TJ, Ferracane JL. Contraction stress of flowable composite materials and their efficacy as stress-relieving layers. *J Am Dent Assoc* 2003;134:721-8.
18. Chuang SF, Liu JK, Chao CC, Liao FP, Chen YH. Effects of flowable composite lining and operator experience on microleakage and internal voids in class II composite restorations. *J Prosthet Dent* 2001; 85: 177-83.
19. Yamazaki PC, Bedran-Russo AK, Pereira PN, Swift EJ Jr. Microleakage evaluation of a new low-shrinkage composite restorative material. *Oper Dent* 2006; 31: 670-6.
20. Iwami Y, Hayashi M, Takeshige F, Ebisu S. The accuracy of electrical method for microleakage evaluation by a three-dimensional analysis. *J Dent* 2007; 35: 268-74.
21. Ernst CP, Galler P, Willershausen B, Haller B. Marginal integrity of class V restorations: SEM versus dye penetration. *Dent Mater* 2008; 24: 319-27.
22. Ilie N, Hickel R. Macro-, micro- and nano-mechanical investigations on silorane and methacrylate-based composites. *Dent Mater* 2009; 25: 810-19.
23. Boaro LC, Goncalves F, Guimaraes TC, Ferracane JL, Versluis A, Braga RR. Polymerization stress, shrinkage and elastic modulus of current low-shrinkage restorative composites. *Dent Mater* 2010; 26: 1144-50.
24. Papadogiannis D, Kakaboura A, Palaghias G, Eliades G. Setting characteristics and cavity adaptation of low-shrinking resin composites. *Dent Mater* 2009; 25: 1509-16.
25. Sabatini C, Blunck U, Denehy G, Munoz C. Effect of pre-heated composites and flowable liners on Class II gingival margin gap formation. *Oper Dent* 2010; 35: 663-71.
26. Feng L, Suh BI, Shortall AC. Formation of gaps at the filler-resin interface induced by polymerization contraction stress: Gaps at the interface. *Dent Mater* 2010; 26: 719-29.
27. Soares CG, Carracho HG, Braun AP, Borges GA, Hirkata LM, Spohr AM. Evaluation of bond strength and internal adaptation between the dental cavity and adhesives applied in one and two layers. *Oper Dent* 2010; 35: 69-76.
28. Chi HH. A posterior composite case utilizing the incremental and stratified layering technique. *Oper Dent* 2006; 31: 512-16.
29. Felix SA, Gonzalez-Lopez S, Mauricio PD, Aguilar-Mendoza JA, Bolanos-Carmona MV. Effects of filling techniques on the regional bond strength to lateral walls in Class I cavities. *Oper Dent* 2007; 32: 602-9.
30. Unterbrink GL, Liebenberg WH. Flowable resin composites as "filled adhesives": literature review and clinical recommendations. *Quintessence Int* 1999; 30: 249-57.
31. Jackson RD, Morgan M. The new posterior resins and a simplified placement technique. *J Am Dent Assoc* 2000; 131: 375-83.
32. Chuang SF, Jin YT, Lin TS, Chang CH, Garcia-Godoy F. Effects of lining materials on microleakage and internal voids of Class II resin-based composite restorations. *Am J Dent* 2003; 16: 84-90.
33. Reis A, Loguercio AD. A 24-month follow-up of flowable resin composite as an intermediate layer in non-carious cervical lesions. *Oper Dent* 2006; 31: 523-9.
34. Van Ende A, De Munck J, Mine A, Lambrechts P, Van Meerbeek B. Does a low-shrinking composite induce less stress at the adhesive interface? *Dent Mater* 2010; 26: 215-22.

**Correspondence to:**

Dr. Keizo Tanno  
Cariology and Operative Dentistry, Tokyo Medical and Dental University  
1-5-45 Yushima Bunkyo-ku, Tokyo 113-8549, Japan  
Fax: +81-3-5803-0195 E-mail: keizo19770206@yahoo.co.jp

Accepted May 1, 2011.

Copyright ©2011 by the *Asian Pacific Journal of Dentistry*. Online ISSN 2185-3487, Print ISSN 2185-3479