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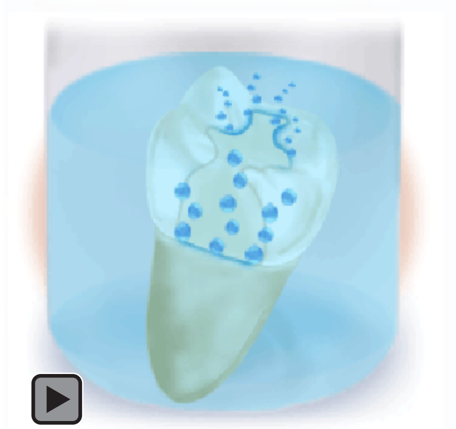
The Leakage of Class II Cavities Restored with Packable Resin-Based Composites

Oya Bala, BDS, PhD; Mine Betül Üçtaşli, BDS, PhD;
İlknur Ünlü, BDS



Abstract

Recently, new resin-based composites, called “packable” or “condensable” resin composites, are being promoted as amalgam alternatives. The purpose of this study was to evaluate leakage in Class II cavities restored with the five packable resin-based composites. On 45 freshly extracted human molars, cavities were prepared following a standardized pattern in which the Class II cavity had a length of 3.0 mm, width of 2.0 mm, and depth of 1.5 mm occlusally. The proximal box had an axial depth of 1.5 mm and a buccolingual width of 4.0 mm. The cervical margin was located 1.0 mm below the cement enamel junction (CEJ). The teeth were randomly divided into five groups of 8 each. The cavity surface was conditioned with 36% phosphoric acid, rinsed, excess water removed, and a dental bonding adhesive (Prime&Bond NT) was used for all the cavities. The teeth were then restored according to the manufacturer’s instructions: Group 1, Surefil; Group 2, Solitaire; Group 3, Alert; Group 4, Filtek P60; and Group 5, Prodigy Condensable. After the restorations were completed, the specimens were finished and polished with an aluminum-oxide-coated disc, thermocycled, stained, sectioned, and viewed under a stereo-microscope for leakage at occlusal/enamel and gingival/dentin margins.

All test groups showed that leakage of gingival/dentin margins were greater when compared with leakage of occlusal/enamel margins. At the occlusal/enamel margins, there were no significant differences between the materials; however, at gingival/dentin margins, Filtek P60 and Prodigy Condensable demonstrated less leakage, while Solitaire demonstrated greater leakage.

Keywords: Packable resin composite, resin-based composite, Class II restorations, leakage

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Introduction

Resin-based restorative composites are used extensively in the restoration of posterior teeth because of esthetic demands by the general public. While the mechanical properties and abrasion resistance of resin-based composites have improved considerably over the years, the placement of posterior resin-based restoration remains very technique sensitive. One of the major disadvantages of restoring posterior teeth with resin-based composites is the lack of adaptation of the material to tooth structure, particularly at the gingival margin.[1,2] Direct Class II resin-based composite restorations can be done to an acceptable standard if the gingival margin is in sound enamel, but the quality of the margin of an adhesive restoration located below the cementoenamel junction (CEJ) is questionable.[1,3-5] Especially when the bond with dentin is weaker, the polymerization shrinkage of the resin-based composite may lead to separation of the resin from the preparation wall and the formation of gaps.[5-7] Furthermore, the differences in the coefficients of thermal expansion of the tooth structure and resin-based composite can lead to different volumetric changes which could directly affect leakage.[8-12]

As a result of leakage, saliva and salivary components penetrate the tooth/restoration interface resulting in marginal staining, breakdown at the margins of restorations, the development of secondary caries at the tooth/restoration interface, postoperative sensitivity, and pulp pathology.[13,14] It can be observed ingress of bacteria is the main cause of the pulpal reactions.[10]

Additionally, placing resin-based composites in Class II cavities includes difficulty in obtaining proximal contact and adhesion to placement instruments.[15,16] Traditional resin-based composites do not offer any resistance to placement forces in their unpolymerized state and tend to be "sticky," resulting in a tendency to pull away from the cavity wall when the placement instruments are withdrawn.[17] The inaccessibility of the cervical area of Class II preparations and the problem of moisture control in the posterior region further hinder good marginal adaptation.[18,19]

The new "packable" or "condensable" resin-based composites promise to eliminate some of these problems.[20,21] They are characterized by a high-filler load and a filler distribution that gives them a different consistency compared with the hybrid restorative composites. Packable resin-based composites are promoted for stress-bearing posterior restorations with improved handling properties such as sculpt ability, better carving properties, and similar handling characteristics to those when condensing and carving amalgam restorations. Easier establishment of physiological interproximal contacts on Class II restorations, the use of a metal matrix band and wooden wedges, and possible bulk curing of the restorations are some of the advantages.[19,21]

The purpose of this study was to investigate the leakage of five different packable resin-based composites, in Class II cavity preparations that extend beyond the CEJ.

Material and Methods

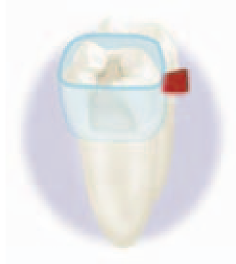
Forty-five extracted sound (non-carious and non-restored) mandibular human molars were selected in this study. The teeth were cleaned, polished using scalers and pumice, and were stored in distilled water until use.

Cavity Preparation

Conservative Class II cavities were prepared with a number 836 cylindrical diamond bur (Diatech diamant AG, Swiss) using a high-speed air/water-cooled turbine. A new bur was used for every five preparations. The cavities were prepared following a standardized pattern in which the Class II cavity had a length of 3.0 mm, width of 2.0 mm, and depth of 2.0 mm occlusally. The proximal box had an axial depth of 1.5 mm and buccolingual width of 4.0 mm. The cervical margin of the proximal box was located 1.0 mm below the CEJ. The specimens were then randomly divided into five experimental groups, with 8 teeth each.

Restorative Procedures

In order to stimulate a clinical situation, the prepared teeth were lined up with proximal contacts in lower jaw models. The teeth were mounted



to the models using dental wax and the missing teeth were completed with plastic teeth. The preparations were cleaned and metal matrix bands (Sectional Matrix Retainer System, 3M, USA) and wooden wedges (Hawe-Neos Dental, Bioggio, Switzerland) were used. All cavities were then etched (enamel and dentin) with 36% phosphoric acid (Conditioner 36 gel, Dentsply DeTrey GmbH, Konstanz, Germany) for 15 seconds. Preparations were rinsed with an air/water spray for 20 seconds followed by gentle drying for 5 seconds. One layer of Prime&Bond NT (Dentsply DeTrey GmbH, Konstanz, Germany), as dentin bonding agent, was applied to the etched tooth surface. Surfaces were gently dried for 10 seconds and light cured (Hilux Ultra Plus, Benlioglu Dental Inc., Turkey) for 20 seconds. The teeth were then restored with Group 1, Surefil (Dentsply, De Trey, 77USA); Group 2, Solitaire (Hereaus Kulzer, Germany); Group 3, Alert (Jeneric/Pentron, USA); Group 4, Filtek P60 (3M Dental Products, USA); and Group 5, Prodigy Condansable (Kerr Corp, USA).

The tested materials were placed into the prepared teeth with an amalgam carrier and condensed using amalgam condensers. The resin-based composites were placed incrementally in three layers, and each layer was cured for 40 seconds from the occlusal direction. After the last increment was placed, the matrix band and wedges were removed. The restoration was also light-cured for 40 seconds from both the buccal and lingual walls.

Thermocycling and Leakage Evaluation

The restored teeth were stored for 24 hours in distilled water. The specimens were then finished and polished with numbers 8379 and 863EF finishing burs (Busch, Germany) on a high-speed hand piece with a light water-spray and aluminum-oxide-coated discs (Sof-Lex, 3M, USA) on a slow-speed hand piece. The teeth were thermocycled for 500 cycles between 5°C and 55°C with a dwell time of 30-seconds in each bath. The apices of the specimens were sealed with sticky wax, and all tooth surfaces were covered with two coats of clear nail polish with exception of 1.0 mm around the tooth-restoration margins and allowed to air dry. All specimens were then immersed in 2% methylene blue dye for 24 hours. After removal from the dye, the teeth were rinsed under running water and the nail polish scrapped off. The teeth were sectioned along the mesio-distal direction, coincident with the center of the restoration, with a water cooled diamond saw.

The dye penetration of the occlusal and gingival margins of each section was evaluated independently by the two observers using a stereomicroscope (Olympus SZ 60, Japan) at a magnification of X10 and scored as follows:

- 0 – No dye penetration
- 1 – Dye penetration up to but not beyond 1⁄2 the occlusal or gingival wall
- 2 – Dye penetration up to but not contacting the axial wall
- 3 – Dye penetration along the axial wall

The Kruskal-Wallis test was used to statistically analyze the results of the five groups. The Mann-Whitney test analyzed the difference between the occlusal/enamel and gingival/dentin region.

Results

The distribution of the leakage scores and the means and standard deviations for all tested materials are shown in Tables 1 and 2.

For the tested materials, leakage was significantly greater at the gingival/dentin margins than at the occlusal/enamel margins. According to the Mann-Whitney U test, there were statistically significant differences between occlusal/enamel and gingival/dentin leakage scores ($p<0.05$) (Figure 1).

There was no statistical difference when the tested resin-based composites were analyzed within the occlusal/enamel margins ($p>0.05$). However, gingival/dentin margins showed a significant difference ($p<0.05$). The group restored with Filtek P60 and Prodigy Condensable demonstrated less leakage at the gingival/dentin margins, while the Solitaire group demonstrated significantly greater leakage at the gingival/dentin margins.

Table 1. The leakage scores of tested groups in occlusal/enamel margin (n=8 Per group).

Groups	Tested Materials	Leakage Scores				Mean	Standard Deviation
		0	1	2	3		
1	Surefil	8	0	0	0	0	0
2	Solitaire	5	3	0	0	0.38	0.52
3	Alert	6	2	0	0	0.25	0.46
4	Filtek P60	8	0	0	0	0.0	0
5	Prodigy Condensable	7	0	1	0	0.25	0.71

Table 2. The leakage scores of tested groups in gingival/dentin margin (n=8 Per group).

Groups	Tested Materials	Leakage Scores				Mean	Standard Deviation
		0	1	2	3		
1	Surefil	2	0	4	2	1.75	1.16
2	Solitaire	0	0	4	4	2.5	0.53
3	Alert	1	3	2	2	1.63	1.06
4	Filtek P60	3	1	4	0	1.13	0.99
5	Prodigy Condensable	3	2	2	1	1.13	1.30

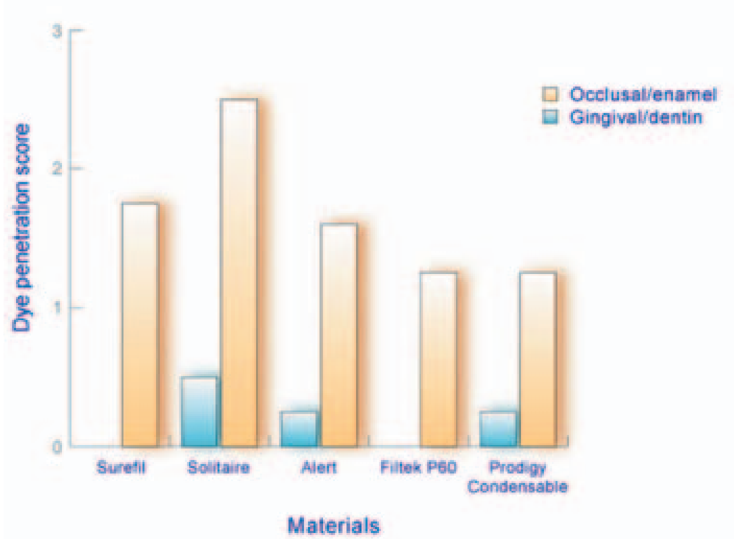


Figure 1. The average values of dye penetration of tested materials.

Discussion

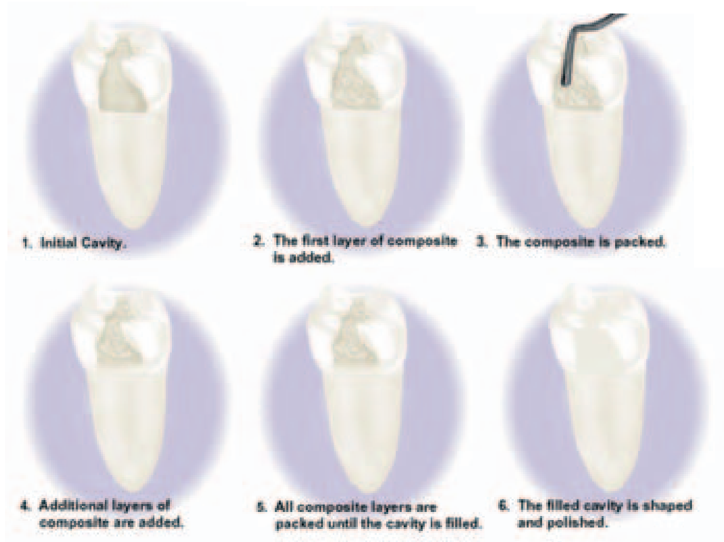
Effective sealing of dentin tubules and, thus, the ability to withstand leakage forms a paramount factor in ensuring the longevity of a restoration.

This study evaluated the sealing ability of five packable resin-based composites in Class II preparations with the gingival floors placed below the CEJ. In this study, gingival/dentin margins showed significantly higher leakage than occlusal/enamel margins in all materials. This was expected as bond strength to enamel is usually higher than bond strength to dentin; dentin is a less favorable bonding substrate and enamel margins of resin-based composite restorations are reported as having less leakage than the gingival/

dentin margins.[3-5,17,22] In extended complex cavities, the gingival wall most frequently reaches the CEJ. The enamel at the gingival surfaces of the cavities might have prevented a gap formation, and as a result, may have formed a perfect sealing surrounding the cavity. Besides the enamel etching, dentin bonding systems are adequate as a lining if they not only infiltrate the substrate but also form a continuous hybrid layer between the restoration and tooth structure.[23]

The quality of the hybrid layer formed by the adhesives has come under question by several investigators.[24,25] These researchers remove the smear layer and expose collagen fibers by decalcification, so leakage may progress within the decalcified dentin layer if resin impregnation of the collagen network is incomplete. On total etch bonding systems adhesion to enamel has become routine and reliable, but dentinal adhesion has proved to be more difficult and less predictable.[26] The heterogeneous structure of dentin also affects the quality of bonding of the current dentin bonding systems.[27] The tubules may branch, particularly near the amelodentinal and cemento-dentinal junctions. Generally, branching of tubules are smaller and more numerous in root dentin than in crown dentin.[28,29] Acid etching of the heterogeneous dentin structure results in different surface chemistries and morphologies. Also, the orientation of dentin tubules can affect the formation of the hybrid layer.[30] In areas with perpendicular tubule orientation, the hybrid layer was significantly thicker than areas with parallel tubule orientation. Therefore, the dentin surface on the gingival floor of Class II preparations may be a surface on which good hybrid layer formation is difficult. This could well contribute to the results of the present study in which substantial leakage occurred.

Another factor that could induce leakage of restoration margins is polymerization shrinkage.[31] This polymerization shrinkage creates contractions stresses in the resin-based composite restoration, which can disrupt the marginal seal between the resin-based composite and the tooth structure.[32] Several clinical techniques have been proposed to minimize the problem of polymerization shrinkage. One way to reduce the effect of contraction stress is the incremental layering of resin-based composites during placement to minimize bridging between cavity walls and to reduce shrinkage stresses through the sequential use of small volumes of material. But, the benefit of the incremental technique for reducing polymerization contraction stress is somewhat controversial.[11,33] Gallo et al.[34] studied leakage of Class II packable resin-based composites using incremental (light-curing between layers in 2 mm increments) or bulk filling techniques and found bulk filling produces similar leakage as incremental filling. However, numerous studies have reported leakage of Class II restorations placed by an incremental technique showed less leakage than when a bulk restorative technique was used.[1] Manufacturer's recommended bulk technique for Alert, SureFil, and Prodigy Condensable, while the manufacturers of Solitaire and Filtek P60 recommend incremental curing techniques. To standardize placement in this study, all tested materials were placed in 2 mm increments.



The fillers of tested packable resin-based composites may be added in the form of fibers (Alert-84% filled by weight, particle size range 0.01-3.0 μm), porous filler particles (Solitaire-66% filled by weight, particle size range 2-20 μm), irregular particles (SureFil- 82% filled by weight, particle size range 0.01-3.0 μm), irregular rounded Zirconia/silica particles (Filtek P60- 61% filled by volume, particle size range 0.01-3.5 μm), and viscosity modifiers (Prodigy Condensable- 78-80% filled by weight, particle size range 0.01-3.0 μm) (Table 3).[34,17] The filler loading and particle size can affect the leakage.

Table 3. Compositional values, physical properties.

Materials	Filler Volume (%)	Average Filler Particle Size um
Surefil	60	0.01-3.0
Solitaire	66	2-20
Alert	70	0.01-3.0
Filtek P60	61	0.01-3.5
Prodigy Condensable	61.7	0.01-3.0

Another factor is that the coefficient of thermal expansion of resin-based composite is greater than the tooth structure.[35] Therefore, the resin-based composite restoration expands and contracts more than the surrounding tooth structure when temperature changes occur, such as during thermocycling, which was used in the present study and intraoral conditions. This process can possibly lead to marginal gap formation and resulting leakage.

One factor that may contribute to the success of these restorations is water sorption. Even though the bond between resin and tooth structure may be disturbed initially during curing because of shrinkage, water sorption can cause gap reduction by hygroscopic expansion over time.[36] This factor may help these restorations achieve a better seal over time and, thus, add to their success and longevity.[34] Also, as bonding systems improve, many of these problems may be overcome or at least diminished.

Conclusion

In summary, the clinical restoration of posterior approximal cavities achieving good contact areas is facilitated by high density, packable materials. However, such materials may not necessarily be conductive to good marginal adaptation, since they do not "wet" the cavity walls easily.[37] Indeed, the so-called "flowable" resin-based composites are now being promoted for initial placement along the external cavity margins, followed by heavily filled "condensable" materials for the bulk of the restoration.

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About the Authors

Oya Bala, BDS, PhD

Dr Bala received her dental education and her PhD at University of Gazi, Faculty of Dentistry in Ankara, Turkey where she now serves as an Associate Professor in the Department of Operative Dentistry and Endodontics.

e-mail: oyabala@gazi.edu.tr

Mine Betül Üçtaşli, BDS, PhD

Dr. Üçtasli received her dental education at University of Ankara, Faculty of Dentistry and her PhD at University of Gazi, Faculty of Dentistry. Currently she serves as an Assistant Professor in the Department of Operative Dentistry and Endodontics of the Faculty of Dentistry at the University of Gazi in Ankara, Turkey.

e-mail: uctasli@gazi.edu.tr

İlknur Ünlü, BDS

Dr. Ünlü received her dental education at the University of Ankara, Faculty of Dentistry. She now serves as a research assistant and is a PhD candidate at the University of Gazi, Faculty of Dentistry in Ankara, Turkey.