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Research Article

Does Consistency of Dental Resin-Composites Influence their Resistance to Microleakage?

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Abstract

Objective: To investigate the influence of consistency of resin-composite restorative materials on microleakage at the restoration/tooth interface.

Materials and Methods: Class V cavities were prepared on the sound facial surfaces of forty recently extracted first and second molars (4 mm mesiodistally, 2 mm occlusogingivally and 2 mm deep). Cavities were thoroughly cleaned using a water spray for 10 s and then dried using an oil-free air spray for 3-5 s. The forty prepared cavities were then randomly divided into four experimental groups (n = 10); Group A: the cavities were incrementally filled with a conventional nanohybrid resin-composite (Filtek^{TM} Z350 XT, 3M ESPE, St. Paul, MN, USA) applied to the dentin surface without adhesive application. Group B: the cavities were incrementally filled with the conventional nanohybrid resin-composite used in Group A but bonded to the dentin surface through an adhesive application (Single Bond Universal, 3M Deutschland GmbH, Germany). Group C: the cavities were incrementally filled with a flowable resin-composite (Vertise Flow^{TM}, Kerr Corporation Orange, CA, USA) applied to the dentin surface without adhesive application. Group D: the cavities were incrementally filled with the flowable resin-composite used in Group C but bonded to the dentin surface through the adhesive used in group B. After 24 h storage in distilled water, specimens were thermocycled for 500 cycles between 5 and 55°C with a dwell time of 1 minute. Specimens were then dried and their root apexes were sealed with small increments of resin-composite. A finger nail polish was applied to all surfaces of the teeth except for the restorations and 1 mm surrounding them. Specimens were then immersed in 1% methylene blue dye for 24 h at room temperature. After 24 h, they were then embedded in a self-curing polymethyl methacrylate (PMMA; Esschem Co., PA, USA) and labelled according to their groups. Each specimen was sectioned longitudinally through the center of the restoration from buccal to lingual surface with an Isomet Precision Saw (Isomet ^{TM} 5000, Buehler, Illinois, USA). A stereo-microscope at 25× magnification was employed to determine the extent of dye penetration.

Results: From the data recorded, it was clear that the highest leakage scores were shown by Group A (1.3) followed by Group B and C (0.8 and 0.7, respectively) and the lowest leakage scores were recorded by Group D (0.3).

Conclusions: Cavities restored after adhesive application exhibited lower microleakage scores compared to those restored without adhesive application. The flowable resin-composite used in the study proved higher ability to resist microleakage than the conventional one.

Keywords: Microleakage, Consistency of dental resin-composites, Polymerization contraction stress, Dental Adhesive Systems.

Introduction

Prevention of marginal microleakage at the restoration/tooth interface is one of the major objectives of modern restorative dentistry [1,2]. As reported in the literature [3], microleakage is defined as the clinically undetectable passage of bacteria, fluids, molecules or ions from the oral environment along the gaps that may exist between a cavity wall and the material applied to it. Hypersensitivity, tooth discoloration, recurrent caries, accelerated deterioration and pulp injury are apparent negative outcomes of microleakage [4].

Poor bonding between a restorative material and the underlying tooth substrate was reported to be one of the most crucial promoters of microleakage [5,6]. Achievement of good bonding or not depends not only on the technique applied or the type of adhesive

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used but also depends to, a great extent, on the histological and morphological characteristics of the tooth substrate to which the restorative material is bonded [7].

Another major factor of microleakage is the residual stress created by the polymerization shrinkage of resin-based restorative materials [8,9]. Upon light activation of resin-based materials, the shrinkage stress generated can compromise the synergism at the tooth/restoration interface. This will increase the potential for mechanical failure by allowing the ingress of bacteria, secondary caries, pulpal inflammation and necrosis [10-12]. Different coefficients of thermal expansion/contraction between the tooth substrate and the applied restorative material, cavity location and C-factor, insertion technique and source of polymerization were reported as potential variables of microleakage [13].

Several approaches were suggested to minimize or totally prevent polymerization stress and subsequent marginal microleakage. One of these ways is to use a more flexible intermediate liner between the dentin and the resin-composite. This way was thought to preserve the dentin bond during polymerization process. This is commonly referred to as "Elastic bonding" or the "Elastic wall concept" [14,15]. It was reported that the application of an intermediate layer of either a low viscosity "flowable" resin-composite or glass ionomer cement between dentin and restorative resin-composite may relieve polymerization contraction stress [16,17]. This was explained on the basis that the lower elastic modulus of flowable resin-composites (1 - 5 GPa) provides a greater ability to flex with the tooth to accommodate the inherent modulus of the tooth, which will eliminate gap formation and subsequent microleakage [18].

Flowable resin-composites have lower filler loading and greater proportion of diluent monomers in their formulation than conventional resin-composites [19,20]. These materials contain the same filler particles of conventional resin-composites but the filler content may be as lower as 20 - 25% than the filler content of non-flowable materials [21,22].

The ability to flow during polymerization reaction is a very useful aspect of these materials. When used as liners under conventional resin-composites, this might provide more contraction stress relaxation and help to reduce the marginal microleakage and debonding at the tooth/material interface [23]. Resin-based restorative materials shrink during polymerization mainly because the monomer molecules of the resin system are located at "van der Waals" distances from one another. After polymerization, in the corresponding polymer, the monomeric units become located at "covalent bond" distances which are far shorter than the van der Waals distances resulting in volumetric shrinkage [24].

Polymerization volumetric shrinkage of resin-composites can be in the range of 2 - 6% [25,26]. As one measure to relieve some of the contraction stress, the restorative material should flow during the early setting so that the tooth/adhesive bond will not be compromised [27]. Despite some studies have revealed that use of flowable resin-composites minimizes restoration microleakage and the occurrence of voids [28,29], others have shown no apparent advantage over conventional materials [30,31].

Therefore, this study was conducted to investigate the influence of resin-composite consistency on microleakage at the restoration/tooth interface. The null hypotheses tested were: i) adhesive application will have no influence on resistance to microleakage and ii) consistency of resin-composites will have no effect on resistance to microleakage.

Materials and Methods

Specimens preparation

Microleakage testing was carried out on forty recently extracted first and second human molars with sound facial surfaces that were selected and stored in 0.1% thymol solution at room temperature for one month. Teeth were then thoroughly cleaned with slurry of pumice and examined to make sure that the facial surfaces were intact.

Using a high-speed diamond bur (8-3 Kiyohara Industrial Park, Utsunomiya, Tochigi, Japan) and a high speed handpiece with a copious amount of water, class V cavities were prepared on the facial surface of each tooth (4 mm mesiodistally, 2 mm occlusogingivally and 2 mm deep) having the occlusal margin in the enamel and the gingival one positioned just above the cervical line so that the whole cavity is in the tooth crown. Care was taken to ensure a standardized cavity preparation in all specimens. To ensure high cutting efficiency, after every five preparations the bur was discarded and replaced with a new one. After finishing cavity preparation, it was thoroughly cleaned using a water spray for 10 s to remove all cut tooth material and then dried using an oil-free air spray for 3-5 s.

The forty prepared cavities were then randomly divided into four experimental groups (n = 10) as follows:

Group A: the cavities were incrementally filled with a conventional nanohybrid resin-composite (Filtek™ Z350 XT, 3M ESPE, St. Paul, MN, USA) applied to the dentin surface without adhesive application. The resin-composite was applied and light-cured according to the manufacturer's instructions.

Group B: the cavities were incrementally filled with the conventional nanohybrid resin-composite used in Group A but bonded to the dentin surface through an adhesive application (Single Bond Universal, 3M Deutschland GmbH, Germany). Adhesive application and filling of the resin-composite were done according to the manufacturer's instructions.

Group C: the cavities were incrementally filled with a flowable resin-composite (Vertise Flow™, Kerr Corporation Orange, CA, USA) applied to the dentin surface without adhesive application. The resin-composite was injected and light-cured according to the manufacturer's instructions.

Group D: the cavities were incrementally filled with the flowable resin-composite used in Group C but bonded to the dentin surface through an adhesive application (the adhesive used in group B). Care was taken to ensure that adhesive application and filling of the resin-composite were done according to the manufacturer's instructions. After preparing all specimens, they were stored in distilled water at room temperature for 24 h before microleakage assessment.

Microleakage assessment

After storage, the restored teeth were thermocycled for

500 cycles between 5 and 55°C with a dwell time of 1 minute. Specimens were then dried with a paper towel and the root apexes of each tooth sealed with small increments of resin-composite. A finger nail polish was applied to all surfaces of the teeth except for the restorations and 1 mm surrounding them. Specimens were then immersed in 1% methylene blue dye for 24 h at room temperature. After 24 h, they were removed, thoroughly rinsed and the nail polish was gently scraped with a scalpel blade. The teeth were then embedded in a self-curing polymethyl methacrylate (PMMA; Esschem Co., PA, USA) and labelled according to their groups. Each specimen was sectioned longitudinally through the center of the restoration from buccal to lingual surface with an Isomet Precision Saw (Isomet ™ 5000, Buehler, Illinois, USA).

A stereo-microscope at 25× magnification was employed to determine the extent of dye penetration and scored according to the following:

Score 0: No dye penetration

Score 1: Dye penetration up to the dentino-enamel junction (DEJ)

Score 2: Dye penetration beyond the dentino-enamel junction

Score 3: Dye penetration up to the axial wall.

Each specimen was evaluated twice: one time to examine which half (Mesial or Distal) exhibited more leakage and another time to see which margin (Occlusal or Cervical) of each half permitted more dye penetration. As the study interested primarily in microleakage at the restoration/tooth interface, the worst score of each specimen was recorded.

The results of microleakage scores were analyzed with Kruskal-Wallis nonparametric analysis followed by the Mann-Whitney U test to determine the differences among the groups. The significance level was established at ($p < 0.05$).

Results

Mean data of microleakage scores for all investigated groups are listed in Table 1 and presented in Figure 1.

The Kruskal-Wallis analysis of variance revealed statistically significant differences among the four groups investigated ($p = 0.001$). Microleakage comparisons between the groups with different restoration approaches were accomplished with the Mann-Whitney U test at a significance level of ($p < 0.05$). There were significant differences between group A and group B ($p = 0.0321$), between Group A and Group C ($p = 0.0283$), between Group A and Group D ($p = 0.0017$), between Group B and Group D ($p = 0.0319$) and between Group C and Group D ($p = 0.0347$). However, there was no significant difference between Group B and Group C ($p = 0.0812$).

From the data recorded, it was clear that the highest leakage scores were shown by the Group A (1.3) followed by Group B and C (0.8 and 0.7, respectively) and the lowest leakage scores were recorded by Group D (0.3). Using an adhesive before the application of restorative filling material markedly reduced microleakage, both in case of conventional as well as flowable resin-composites. Moreover, cavities restored with the flowable resin-composite exhibited more resistance to dye leakage than those restored with the conventional one, both with or without adhesive application.

Discussion

Numerous dental investigations can be conducted both in vivo as well as in vitro. It was reported that laboratory screening tests may have some advantages over clinical trials provided that these laboratory investigations closely simulate the clinical conditions.

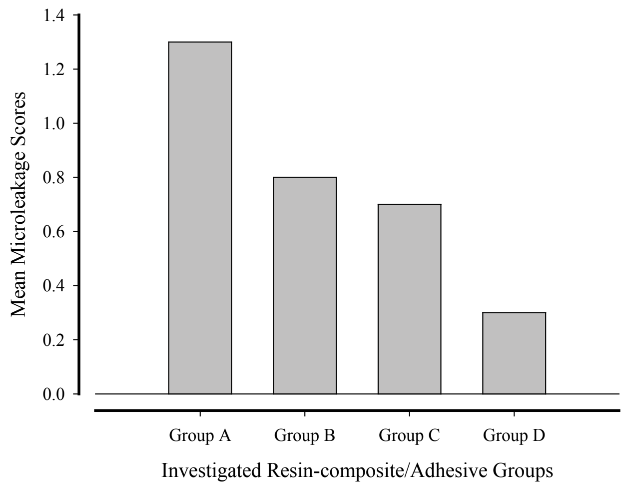

Figure 1: Showing mean data of microleakage scores for all investigated groups.

Table 1: Mean data of microleakage scores for all investigated groups.

Specimen \ Group	Group A (Conventional without adhesive)	Group B (Conventional with adhesive)	Group C (Flowable without adhesive)	Group D (Flowable with adhesive)
I	1	0	0	0
II	3	2	0	0
III	1	1	1	1
IV	0	0	1	0
V	0	1	2	1
VI	2	2	0	0
VII	2	0	1	0
VIII	3	1	1	0
IX	0	1	0	1
X	1	0	1	0
Mean	**1.3**	0.8	0.7	0.3

Some of these advantages include patient-independence, saving money and time, ease of achievement and ability to evaluate the effect of a single variable if other variables are kept constant [32]. However, in case of microleakage evaluation, the in vitro investigation lacks many aspects compared to the in vivo research. Limitations of such an investigation include the inability of the restorative filling materials to stimulate the dynamic intra-oral thermal changes induced by routine eating and drinking. Thermocycling is often employed in laboratory experiments to simulate stresses in the oral cavity. However, the absence of outward flow of the dentinal fluid and the completely altered dentinal surface due to extraction result in a poor correlation between the in vitro and in vivo conditions [18,33].

One more shortcoming is that only thermocycling was used to age and stress the restored teeth, with no load cycling applied, not taking into consideration the effect of repeated load cycling within the physiologic chewing range on resin-bonded restorations [34]. However, in vitro microleakage studies can provide some initial information necessary to evaluate and compare different restorative materials.

Though there are many approaches to evaluate marginal microleakage at the restoration/tooth interface, Methylene blue dye was chosen in this study to evaluate microleakage because it is simple and inexpensive with better penetration results than eosin or other radioisotope traces [35].

Majority of previous microleakage investigations were conducted on a cavity on the buccal surface of molar or premolar teeth with the occlusal border of the prepared cavity located in the enamel and the cervical border in cementum or at the cemento-enamel junction. Almost all authors reported that microleakage at the cervical margin was greater than that in enamel [3,36,37]. This was explained on the basis that wider surface area available for bonding at the occlusal margin (enamel) than at the gingival one which is comprised mainly of dentin or dentin/cementum. The unique characteristics of the dentin substrates, including high organic content, low calcium concentration, tubular structure variations, higher permeability and the presence of outward fluid movement can adversely affect the adhesion between restorative material and dentin wall [9,37].

However, in this study, the cavity prepared has the two margins (occlusal and cervical) located in enamel. This is because the goal of this research was mainly to investigate the efficiency of flowable resin-composites to minimize or totally prevent marginal microleakage. In addition, the difference between enamel, dentin and cementum with regard to microleakage resistance has been reported several times in the literature.

In this study, cavities restored with conventional resin-composites after adhesive application exhibited lower microleakage scores than those restored with the same resin-composite without adhesive application. Similarly, cavities restored with flowable resin-composites after adhesive application recorded lower microleakage scores compared to those without adhesive application. Therefore, the first null hypothesis was rejected.

It has been repeatedly concluded that effective resin adhesion enhances the clinical behavior of restorative materials by blocking, or at least reducing, interfacial microleakage together with rendering it easier to have conservative cavity preparations without traditional mechanical retention [38,39]. On the other hand, lack of adequate adhesion of dental restorative materials to the underlying dental tissues is considered one of the major obstacles in modern restorative dentistry. Thus, application of an effective adhesive system between the restorative material and the tooth structure is a very critical step in dental restorations [40-42].

In addition, cavities restored with flowable materials (either with or without adhesive application) showed greater resistance to microleakage than the corresponding groups of cavities restored with conventional materials. Therefore, the second null hypothesis was rejected as well.

Flowable resin-composites, as previously reported [43], were thought to improve marginal adaptation and create an intimate union with the microstructural defects in the floor and the walls of the cavity preparation. This ultimately minimizes the internal voids and eliminates or reduces marginal leakage. Low modulus of elasticity and increased flexibility of these materials may be helpful in distribution of stresses of polymerization shrinkage and preserve integrity of bond to tooth structure [44]. Regardless of other considerations, particularly from a mechanical view, the application of a low-viscosity material was suggested as a mean of reducing microleakage at the restoration/tooth interface because it can better wet and adapt to the tooth surface [15,16].

Conclusions

- Dental cavities restored with either conventional or flowable resin-composites after adhesive application exhibited lower microleakage scores compared to those restored without adhesive application.
- The flowable resin-composite used in the study proved higher ability to resist microleakage than the conventional one.

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