A three-dimensional evaluation of microleakage of the class V cavities restored with flowables

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ABSTRACT

Aim To evaluate the dye leakage of three flowables with a new “three dimensional” method.

Methods Three groups of twelve premolars have received Class V cavities of uniform standardized dimensions. The cavities were restored with: Clearfil liner Bond 2 with adhesive SE Bond (group I), Definite flow with Etch & Prime 3.0 (group II) and, the Tetric flow with Syntac Single Component (group III). The teeth were immersed in a contrast dye for 24 hours, rinsed and immersed in the 5% nitric acid for 72 hours. The teeth were acid-softened and the fillings were pulled out of their cavities. The inner surfaces of extracted fillings were photographed in three different rotated positions (3 x 120°). The photographs were transferred to a computer image and the deepest point and the area of the leaked surface were determined.

Results All restorative systems showed leakage at the adhesive level. The statistical analysis showed significant differences between group I and group III in the number of leaked samples, in the depth of leakage and in the leaked surface. Best results in all three ways of leakage evaluation were obtained in group I (Clearfil liner Bond 2 with adhesive SE Bond).

Conclusion In this study, flowable Clearfil liner Bond 2 with adhesive SE Bond had leaked in all three ways of evaluation significantly less than Tetric flow in combination with Syntac Single Component.

Key words: microleakage, dye leakage, class V restorations, flowable resins
INTRODUCTION

Restorative materials and procedures often fail to produce an intact marginal integrity (1). The cervical region cavities are burdened with a highly stressful position and with a non-homogeneous tooth structure (2). The cervical cavities have also a stressful cavity configuration and are usually restored with resin restoratives which exhibit shrinkage during polymerization causing failures (3). Marginal gaps between restoratives and the cavity walls are a consequence of such a failure, thus causing leakage (4). Nonetheless the properties of flowable composites make them suitable as a restorative material for this highly stressful region (5,6).

The researches of marginal leakage usually describe a two-dimensional, linear and very unclear pattern of microleakage (7). Dye leakage is the oldest and most common method of detecting a leakage in vitro. The main disadvantages of this method are its qualitative nature and the fact that damage to the sample occurs due to sectioning, eventually leading to false results (8,9). The ideal way of understanding would be if we could somehow extract the filling undamaged from its cavity and see the leakage in its full physical appearance.

The aim of this study was to investigate and evaluate the leakage of three flowables with a new "three dimensional" method which enables the extraction of the filling out of the cavity and the direct measurement of the died surface and maximum depth of the leakage. Thus the dye leakage becomes a fully quantitative method.

MATERIALS AND METHODS

Thirty-six intact premolars, extracted for orthodontic reasons were randomly divided in three groups of twelve each. All teeth have received buccal cervical Class V cavities of uniform standardized dimensions (3 x 2 x 1.5 mm) with margins in enamel and cementum. These cavities were prepared with a diamond-coated bur (# 811 031 4,2ML, Diatech – SDI, Switzerland) mounted on a water-cooled air-driven handpiece. The specific shape of the bur enabled easy, almost automatic, preparation of the cavity simply by pressing the rotating bur at the previously determined cervical buccal position of each tooth. The same bur was used for 12 cavities and replaced with a new one. Following the preparation prior to the restoration groups 1 and 2 required no additional etching because of the self-etching primer included in their adhesive systems. Cavities of the group 3 were additionally etched for 20 seconds with 37% orthophosphoric acid. All cervical cavities were restored according to the manufacturer’s instructions. Restorative material used in this research consisted of three groups of adhesive restorative systems produced by three different manufacturers. Each group was restored with the - respectively - same-producer flowable restorative and same-producer adhesive system, as follows:

Group I SE Bond (Lot.41116) and Clearfil liner Bond 2 (Lot 0045A) (Kuraray, Osaka, Japan);
Group II Etch & Prime 3.0 (Lot. 22005C) and Definite flow (Lot.12003B) (Degussa, Hanau, Germany);
Group III Syntac Single Component (Lot D33562) and Tetric flow (Lot. E38161) (Vivadent, Schaan, Liechtenstein).

The cavities were restored in one single injected layer of flowable composite and subsequently polymerized for 40 seconds all with the same-type Elipar II (ESPE, Germany) halogen light device. All restorations were finished and polished.

The specimens were then thermally cycled for 1000 cycles in cold (5° C) and warm (55° C) baths with dwell times of 60 s and the transfer time of 10 s. After thermocycling, the root surfaces and the adjacent enamel were coated with two layers of nail varnish, except the filling surface and the area 1 mm around the filling. The specimens were then immersed in a contrast liquid (acid resistant - Rotring Ink, Stanford GmbH, Hamburg, Germany) for 24 hours, rinsed with tap water, and immersed in 5% nitric acid. After 72
hours the teeth were softened enough to pull the fillings out from their cavities with ease, just with a sharp excavator. The extracted fillings have thus become the specimen ready for observation. Leakage pattern was observed and measured through a dissecting microscope equipped with a digital camera (Olympus SZX-12 and Olympus DP-12, Olympus Optical Co.GmbH, Hamburg, Germany). Photographic images of the inner surface (tooth-faced) of the specimens were taken in three different positions, the different position meaning a one-third rotation (for 120°) in order to encompass the entire filling mantle (360°). The photographs were then transformed into computer images. A CAD (computer-aided design) computer program was used to observe the leakage pattern and to measure died surfaces.

The first method of assessment was to measure the maximum depth point of leakage, and ordinal rating scores or levels - ranging from 0 to 3 - were attributed to the marginal dye leakage. The ordinal rating scores are defined as follows (Figure 1):

- score 0 – no leakage;
- score I – leakage deep up to 1/3 of internal surface (up to 0.71 mm);
- score II – leakage deep up to 2/3 of internal surface (up to 1.42 mm);
- score III – leakage deep through entire lateral surface and filling’s bottom (up to 2.14 mm).

The second method of leakage evaluation was to measure the inner surface of the filling colored with the contrast dye on three different surfaces of each specimen. The colored surface was measured in mm² and the total inner surface of (specimen’s) filling’s mantle was totaling 15.1 mm².

For the statistical analysis of the depth of microleakage the highest (maximal) result measured in one specimen was used. For the analysis of surface of microleakage the sum of the leaked area from all three differently angled images was calculated. As a post-hoc test Kruskal-Wallis with Mann-Whitney U tests were used.

**RESULTS**

The observation showed that all restorative systems had leaked at the adhesive level, e.g. between the restorative material and the walls of the prepared cavity (Figure 2). The values of the deepest point and the area of leakage of all tested samples and materials are shown in Table 1.

In Group I only one (1) restoration (8%) had leaked, in Group II four (4 viz. 33%) restorations, and in Group III seven (7 viz. 58%) restorations...
out of total of 12 respectively. Comparing the frequency of leaked samples, a statistically significant difference was found between Group I and Group III ($\chi^2 = 6.75; \text{df} = 1; p = 0.009$).

Considering the area of the leaked surface, a statistically significant difference was found between the groups ($\chi^2 = 6.34; \text{df} = 2; p = 0.042$). The Mann-Whitney test showed a significant difference between Group I and Group III ($U = 3; Z = 2.58; p = 0.010$). The ranking of the groups according the mean range of the Kruskal Wallis test showed the best range of the Group I ($\text{s.r.} = 13.88$), then Group II ($\text{s.r.} = 18.67$) and, as the last, the range Group III ($\text{s.r} = 22.96$). This means that Group III had a larger area of the leaked surface than Group I, but it could not be said of the leaked area of Group II to be larger than Group I or smaller than Group III.

Comparing the three groups of material according to the deepest point of leakage, the Kruskal Wallis test showed a difference between the groups ($\chi^2 = 5.99; \text{df} = 2; p = 0.050$). The Mann-Whitney test showed the statistically significant difference between group I and III ($U = 36.5; Z = 2.44; p = 0.015$). The differences between Group I and Group II, and Group II and Group III were not statistically significant. The ranking of groups according to the mean range of the Kruskal Wallis test showed the best range of the Group I ($\text{s.r.} = 14.04$), then Group II ($\text{s.r.} = 18.58$) and, as the last, Group III ($\text{s.r} = 22.88$).

**DISCUSSION**

Adhesive restorative dentistry today has not - in the clinical environment - accomplished its goal i.e. the optimal adhesion that would totally endure the stress forces generated in the cervical area of the tooth (8,9). The capability of the restorative materials to seal the restoration borders is influenced by the resin composition and the filler, the material’s plastic deformability and ability to flow, the thermal expansion coefficient, the Young modulus, the choice of the enamel-dentin adhesive system and restorative technique used, the mechanical stress due to the cavity shape (8), and eventually the quality of the hard dental tissue (8,9).

<table>
<thead>
<tr>
<th>Flowable restorative material</th>
<th>Specimen that leaked</th>
<th>Leaked surface (mm²)</th>
<th>Total leaked surface (mm²)</th>
<th>Deepest point of leakage (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Surface 1</td>
<td>Surface 2</td>
<td>Surface 3</td>
</tr>
<tr>
<td>Group I</td>
<td>Spec. No. 1</td>
<td>0.36</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spec. No. 2</td>
<td>0.09</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spec. No. 3</td>
<td>0.38</td>
<td>3.89</td>
<td>0.54</td>
</tr>
<tr>
<td>Group II</td>
<td>Spec. No. 6</td>
<td>3.66</td>
<td>1.29</td>
<td>4.95</td>
</tr>
<tr>
<td></td>
<td>Spec. No. 7</td>
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<tr>
<td></td>
<td>Spec. No. 1</td>
<td>0.08</td>
<td>0.08</td>
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<tr>
<td></td>
<td>Spec. No. 2</td>
<td>0.23</td>
<td>0.23</td>
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<tr>
<td></td>
<td>Spec. No. 3</td>
<td>0.38</td>
<td>0.38</td>
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<tr>
<td>Group III</td>
<td>Spec. No. 4</td>
<td>0.89</td>
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<td></td>
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<tr>
<td></td>
<td>Spec. No. 5</td>
<td>1.06</td>
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<td></td>
<td>Spec. No. 7</td>
<td>0.70</td>
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</tr>
</tbody>
</table>

*the maximal depth of microleakage used for statistical analysis*
The flowable composite, because of its injectability in the cavity, surpasses one of composite's clinically less practical characteristics (stickiness for example) (10,11). It is a kind of material capable of flowing like honey with a lower Young modulus (11) which combines the good characteristics of the hybrid composites and their applicability (10). The material is therefore recommended for Class V restorations (12,13). The reason for this recommendation in the tooth-neck area is the non-directional loading of the occlusal and articulation forces. On the other hand, the cervical area is highly burdened depending on the stressed cavity configuration and the flexional forces (because of the tooth deflection). It is indicated because of its favorable mechanical properties of the flowables during and after the polymerization process (lower modulus, lower rigidity of the hardened material). The material's property to flow during the pre-gel phase reduces the overall tension on the hybrid layer, on the polymerized material itself, and finally on the cavity walls.

The leakage of oral fluid, together with bacteria and their by-products, happens in the majority of the present-day restorations (7,14) regardless of their adhesive mediators. The microleakage comprehension and its evaluation is important because of the ability of the process itself to weaken and - finally - get the restoration lost during its clinical lifetime.

The microleakage and nanoleakage research more or less objectively confirm the presence of a leakage but do not show how severe the leakage is influencing the final evaluation of a certain restorative system or material (8,15). A great part of laboratory researches objectively observe and prove the leakage by a contrast-fluid penetration (4,13). The “reading” of the leakage is a two-dimensional process based on the fact that a specimen is mostly sectioned or broken, or prepared to obtain several cuts thru the cavity and restoration surface, in order to see and measure the leakage. However, it is not objective, no matter how precisely it is done. The specimen used in a three-dimensional method of research (8,9) shows higher a quality of evaluation of the microleakage thru the tissue-restoration margins bond. This method enables the «reading» of the leakage of the contrast dye through marginal microcraks. Of course, there is a certain danger of non-objectivity in the use of the mentioned two-dimensional procedure and the fact that a partial picture of the leakage is taken as the measure of the evaluation of a restorative material and therefore conclusions of this kind could be misleading for a reader.

Further, the observation and measurement of microleakage routinely requires a dissecting microscope with a mounted digital camera (13). The leakage is measured in two ways: a maximum depth point of leakage with the associated rating scores or levels, ranging from 0 to 3, and the other way is to measure the surfaces colored with the contrast dye leak. An alternative could be to measure the concentration of the contrast dye with a spectrophotometer (4) or a similar device. This data is to be statistically analyzed and qualified conclusions to be drawn. All of the aforementioned researches are similar for the most part in their respective procedures. In order to evaluate leakage a most objective method is needed. One part of this mosaic is surely the need to understand the problem of the marginal cracks. The essential defining characteristics of the three-dimensional method is to bring the elevated and more realistic value of the results because of the possibility to observe the leakage rather clearly, and because of the combination of two methods of evaluation and subsequent quantification of the leakage. The pattern of microleakage according to the research could be superficial with only slight marginal coloring. But this slight superficial marginal coloring could penetrate from this margin into the deep dentinal surfaces near the pulp with all consequences (8). This understanding of different patterns of leakage justifies the use of the two different methods of leakage-measurement, in order to find the most objective way to evaluate the quality of a certain material. If we were to apply only one of the aforementioned methods, for example, a small edge-superficial leakage could mean only a small irrelevant dam-
age to a restoration. On the other hand, it could mean a deep thin highway straight down into the pulp. So clarified a picture of leakage enables in vitro research making better use of the contrast dye which could leave better traces on the inner surface of the restoration investigated by making it easier to observe and “read”. Improvement could be achieved by a better observation of the aforementioned leaked surfaces (a digital three-dimensional scanner instead of a three-angled digital photography of each filling) and subsequent transfer of the data to a computer, in order to get a best-quality computer-image of the inner-restoration surfaces.

The results of this research are hardly comparable to other related researches because of the difference in the methods applied. The analysis of the results of this study, according to the dual criteria, showed that statistically-significant better flowable-restoratives were Clearfil liner and ormocer Definite flow. Between these two flowables there were no statistically significant differences, although the former had showed a lesser leakage, the least of all. The question is how a resin flowable material indicated to be a lining material would eventually behave as a definitive restorative material in terms of its physical and mechanical properties. That is the reason why we give the advantage to the Definite flow ormocer definitive flowable resin. Significantly less successful was Tetric flow restorative in comparison to the Clearfil flow liner, but not when compared with the ormocer Definite flow. Regardless of the method of research, our results are similar to those of other related research investigating the resin composites (16,17) attributing good properties to the composites, but different from the results of those research where other materials had been more successful (18). According to Eliades (19) the clinical relevance of the formulation and testing of the dentine bonding systems is not clear and not always comparable to the clinical situation, but certainly significant and necessary as a part of the mosaic of evaluation and recommendation of restorative systems, and therefore a good indicator for the convenience of both the manufacturers and clinicians (7,14,19, 20). The quality-marks of different restoratives are vital in the clinical restorative dentistry and are the results of both in vitro and in vivo researches and the data so obtained. According to this, and by the rules prescribed by various dental associations (ADA, IADR, CRA), a clear picture of a given restorative is made. More research is needed to better illustrate the marginal leakage and to give an evaluation of the investigated flowable restoratives.

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REFERENCES


