Comparative radiopacity of four low-viscosity composites

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Abstract
The aim of this study was to evaluate the radiopacity of four commercially available low-viscosity composites. The low-viscosity composites used in this study were Natural Flow, Flow It, Filtek Flow and Protect Liner F. Five specimens of each material were made in stainless-steel ring moulds of 10 mm diameter and 2 mm height. One specimen of each material and a 10-step aluminium wedge were radiographed in an occlusal film. The reading of the optical density was performed in five different locations in each radiographed specimen. The net optical density was calculated, and then the mean values were obtained, and related with the equivalent thickness of aluminium. The radiopacities of each composite, in millimeters of aluminium were: Flow It (3.24 ± 0.17); Filtek Flow (2.25 ± 0.17); Natural Flow (1.50 ± 0.13); Protect Liner F (<1 mm/Al). Flow It and Filtek Flow presented an acceptable radiopacity according to the ISO Standard 4049. Natural Flow and Protect Liner F did not supply the requirements for radiopacity, thus, these materials could be confounded with secondary caries in some clinical applications, such as restorations or cavity lining.

Key Words:
low-viscosity composites, X-Ray, densitometry, radiopacity, diagnosis
Introduction

The first generation of low-viscosity composites was introduced in late 1996, just before condensable composites, being developed in response to requests for special handling characteristics, rather than for any performance criteria, and with unknown limitations. These materials were created by retaining the same particle size of traditional hybrid composites, but reducing the filler content and increasing the proportion of diluent monomers in its formulation, reducing its viscosity. They were recommended due to the higher flow, which allowed easier insertion in some clinical situations, an improved adaptation in internal cavity walls, particularly in deeper cavity angles, and greater elasticity than previously available products. Low-viscosity composites have been used for a wide range of applications, from liners and pit/fissure sealants to margin or void repairs, and even for class I and V restorations.

According to the American Dental Association, Council on Dental Materials, Instruments and Equipment, a dental filling must accomplish five basic requirements: high wear resistance; good marginal adaptation; resistance to hydrolytic degradation and other solvents; radiopacity; and easiness of execution.

Radiopacity is an essential property for all restorative materials. In restorative dentistry, a radiopaque filling material would allow the dentist to distinguish, radiographically, existing restorations and primary caries, to evaluate contours, overhangs, and major voids in restorations, and to assist in the identification of recurrent caries.

There are several studies on the radiopacity of composites in the literature, however, few studies are available regarding the radiopacity of low-viscosity composites. Thus, the aim of this study was to evaluate this property in four commercially available low-viscosity composites.

Material and Methods

The materials, manufacturers, compositions and batch numbers for this study are listed in Table 1. The low-viscosity composites were tested for radiopacity in accordance with the International Standards Organization – ISO 4049. A stainless-steel ring mould with an internal diameter of 10 mm and 2 mm height was used to prepare standardized specimens. Five specimens of each material were made by inserting the material slowly into the ring mould using the manufacturer’s syringe tip applier, in order to avoid the occurrence of bubbles inside the specimens after polymerization. After the complete filling of the ring mould, the specimens were polymerized using a visible light-curing unit (Ultralux EL, Dabi Atlante Co. Ribeirão Preto – SP, Brazil) for 60 seconds on the top surface and then inverted and light cured on the bottom surface for an additional 60 seconds. The specimens were finished with 600-grit SiC paper under water, separated from the moulds and individually polished with fine and superfine flexible Soft-Lex discs. The specimens’ thicknesses were verified with a digital micrometer in order to ensure standardization.

After preparation, the specimens were radiographed (Insight, Kodak, Eastman Rochester, USA) to check the porosity content. Specimens with porosities were excluded from the study and replaced. The specimens were then stored in distilled water at 37°C for one week. Then the radiographic procedures were conducted.

One specimen of each material and the 10-step aluminium wedge were placed on an occlusal dental film (Insight, Kodak, Eastman Rochester, USA. Batch 2106666). The X-ray unit (GRD, Heliodent 60B, Siemens, Germany) was set at 65 kVp, using a current of 10 mA, and a 1-second standard exposure time. The focus-film distance was set at 40 cm. The exactness and precision of the X-ray equipment were previously evaluated, with the deviation values lower than 3% for the tension variation applied to the X-ray tube, and for the reproducibility of the radiographs.

A densitometer (M. R. A., Brazil) was then used to record the readings of the radiographic images of the specimens, the 10-step aluminium wedge, and the unexposed part of the film. Five readings were recorded for each film and each material, and the mean was subsequently calculated. The net radiographic density was derived from the following equation: net radiographic density = gross radiographic density – (base + fog).

The aluminium equivalent thickness (mm) for each material was calculated from the linear regression equation of the log of normalized optical density and aluminium thickness (mm) obtained from the 10-step wedge. Table 2 displays the equations resulting from the graphs of each radiographic film exposed for the determination of the radiopacity of each material, expressed in millimeters of aluminium.
Table 1. Low-viscosity composites used in the study.

<table>
<thead>
<tr>
<th>Product</th>
<th>Composition</th>
<th>Batch</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow It</td>
<td>Bis-GMA, TEGDMA, boro-fluoro-silicate glass filler, silica, titanium dioxide</td>
<td>104810</td>
<td>Jeneric/Pentron, Inc., USA</td>
</tr>
<tr>
<td>Filtek Flow</td>
<td>Bis-GMA, TEGDMA, dimethacrylate polymer, zirconium/silica filler</td>
<td>4FU</td>
<td>3M/Espe Dental Products, St. Paul, MN, USA</td>
</tr>
<tr>
<td>Natural Flow</td>
<td>Bis-GMA, dimethacrylate polymer, zirconium/silica filler</td>
<td>0403246</td>
<td>DFL Dental Products, Rio de Janeiro, Brazil</td>
</tr>
<tr>
<td>Protec Liner F</td>
<td>Bis-GMA, TEGDMA, fluoride-methyl methacrylate, silanized colloidal silica, prepolymerized organic filler</td>
<td>0056B</td>
<td>Kuraray Co., LTD, Japan</td>
</tr>
</tbody>
</table>

Table 2. Equations of the optical density curves related with the thickness of aluminium. Y= optical density and X= thickness in millimeters of aluminium.

<table>
<thead>
<tr>
<th>Film</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Y= 1.1705e(^{-0.1322x})</td>
</tr>
<tr>
<td>2</td>
<td>Y= 0.9236e(^{-0.1341x})</td>
</tr>
<tr>
<td>3</td>
<td>Y= 1.0012e(^{-0.1292x})</td>
</tr>
<tr>
<td>4</td>
<td>Y= 0.9745e(^{-0.1347x})</td>
</tr>
<tr>
<td>5</td>
<td>Y= 0.9197e(^{-0.1317x})</td>
</tr>
</tbody>
</table>

Table 3. Mean radiopacity of the composites expressed in equivalent thickness of aluminium.

<table>
<thead>
<tr>
<th>Composite</th>
<th>Mean net density</th>
<th>Standard deviation</th>
<th>Mean radiopacity*</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Flow</td>
<td>0.81</td>
<td>0.08</td>
<td>1.5</td>
<td>0.13</td>
</tr>
<tr>
<td>Flow It</td>
<td>0.65</td>
<td>0.07</td>
<td>3.24</td>
<td>0.17</td>
</tr>
<tr>
<td>Filtek Flow</td>
<td>0.74</td>
<td>0.07</td>
<td>2.25</td>
<td>0.17</td>
</tr>
<tr>
<td>Protect Liner F</td>
<td>0.91</td>
<td>0.12</td>
<td>&lt;1mm/Al</td>
<td>&lt;1mm/Al</td>
</tr>
</tbody>
</table>

* in millimeters equivalent of aluminium.

Results

Table 3 summarizes the mean radiopacity of the materials, the mean equivalent of aluminium thickness as well as standard deviations. Flow It (3.24 mm/Al) was the most radiopaque of the materials evaluated, followed by Filtek Flow (2.25 mm/Al); Natural Flow (1.5 mm/Al) and Protect Liner F, which presented a net density value of lower than the equivalent of 1 millimeter thickness of aluminium.

Discussion

Radiopacity of dental materials has been evaluated by several techniques. Schoenfeld et al.26 developed a theoretical model for predicting materials’ optical densities, when given a set of radiographic variables. Other authors have used the simpler technique of comparing specific thicknesses of composite to aluminium step wedges or aluminium standards under typical radiographic conditions14,18-19,21,27-29. Human tooth tissues may perform better as a standard than aluminium; however, the natural variability between distinct conditions of development, film and exposure may interfere with, and make difficult, comparisons among different studies. In this study, the comparison of radiopacity values was conducted with aluminium as the reference. The literature shows a great variability in the radiopacity of dental tissues, and the mean radiopacity of 2 mm of enamel ranges from 2.5 mm/Al18 to 3.53 mm/Al30, whilst for dentin it ranges from 1.5 mm/Al18 to 1.99 mm/Al21. Restorative materials that present a lower radiopacity, or even equivalent radiopacity, to the tooth structure must be avoided for posterior restorations, since an enhanced radiopacity would enable the easy detection of the interface between the filling and enamel or dentin18,20,22,30. Furthermore, ISO standards25 stipulate that the minimum radiopacity for a restorative material should be equal or higher than its equivalent thickness in aluminium. For this study a 2 mm thickness was used.

Several studies have suggested that the radiographic detection of caries is improved if radiopacity of the restorative material is similar or slightly greater than the enamel’s31-32. According to Goshima20, it would be preferable if the composite resins had a higher degree of radiopacity, similar to amalgam. However, it has been reported that the extreme radiopacity of amalgam does not provide the best conditions for radiographic detection of caries and defects adjacent to restorations, as compared to posterior composites, since its very high radiopacity interferes directly in the contrast, impairs visual acuity and, consequently, diminishes the perception of details17. Thus, the appropriate degree of radiopacity for restorative materials remains open for discussion, since differences in radiopacity values between structures indicate that problems of interpretation may occur in the clinical situation; it is, however, questionable whether a statistical difference in radiopacity between two materials can be seen as contrast on a radiograph. In this respect, radiograph and cognitive factors alike should be taken into account33.

Radiolucent incipient images in enamel are hardly detected by radiographic examination, due to the superposition of healthy enamel, since variations in thickness of materials may influence the resultant radiopacity, although this is less important than its molecular structure34. In fact, this could
result in a difficult visualization of radiolucent images corresponding to small cavities filled with less radiopaque materials than the enamel; thus, when the caries is restricted to enamel, it would be preferable to use a material with higher radiopacity than enamel, and it may be stated that the optical density of materials is critical in small cavities that have a large amount of remaining dental structure, since materials are applied with a lower thickness.

A plethora of new low-viscosity composites have been marketed during the last 8 years, and it could be said that almost all the composite manufacturers have at least one commercially available low-viscosity composite. Many dentists have accepted these flowable composites for a wide variety of uses. These materials have been reported to adapt well to cavity walls, and that this optimal adaptation could result in an improvement in the adhesive performance in composite restorations. Indeed, one of the most recommended applications has been its use as a cavity liner, on the adhesive surface, in order to create a lower elastic modulus intermediate layer along the cavity wall, diminishing the effect of the rigid polymerization shrinkage of the restoring composite. Particularly for this clinical application, the radiopacity of these materials become a decisive factor, since there is a tendency for accumulation in deeper cavity angles, due the material’s high flow, which could lead to misinterpretations in radiographic diagnosis, suggesting lack of material and remaining or recurrent caries. According to Unterbrink and Liebenberg, the use of highly radiopaque low-viscosity composites on adhesive surfaces would avoid misinterpretations during the radiographic diagnosis of composite restorations. Watts found that radiopacity values of higher than those in enamel may be achieved in composites with a filler loading of approximately 70% by volume when the mass percentage of radiopaque oxide in the filler exceeds about 20%. All the low-viscosity composites evaluated in the study presented a lower filler loading (Table 1), and only Flow It (3.24 mm/Al) presented an equivalent or superior radiopacity to the enamel’s. (Table 3)

Flow It, a first-generation low-viscosity composite, with silica and barium boro-fluoro-silicate glass (and a trace amount of aluminium oxide) as its filler, a mean filler particle size of 1 μm and barium boro-fluoro-silicate glass (and a trace amount of aluminium oxide, corroborating the results of Bouschlicher et al. and Murchison et al. This composite presents the highest filler content among the materials investigated by this study and, according to Bayne et al., its physical properties are similar to those of the traditional hybrid composites. Indeed, its higher filler content associated with the high atomic number element barium, and the trace amount of aluminium oxide, improved its radiopacity which is within that recommended by ISO 4049, and meets the values of enamel’s radiopacity reported in the literature. Thus, according to this property, Flow It could be indicated for lining in traditional composite restorations in posterior teeth.

The low-viscosity composite, Filtek Flow, presents a 68% by weight and 47% by volume of zirconium/silica filler, with a mean particle size of 1.5 μm. This filler is the same as the traditional micro-hybrid composites Z-100 and Z-250 of the same manufacturer. Its radiopacity corresponded to 2.24 mm/Al, which is higher than dentin’s radiopacity. Thus, according to ISO 4049, this composite fulfills the requirements for application as a liner in posterior teeth restorations. Natural Flow (1.5 mm/Al) and Protect Liner F (<1 mm/Al) presented lower radiopacities than the correspondent in mm/Al of dentin, and lower than the ISO 4049 recommendations. According to Sabbagh et al., the radiopacity of composite resins is dependent on their fillers (percentage and type). Although Natural Flow presents the same type of filler as Filtek Flow, i.e., zirconium/silica, its lower content (54% by weight and 41% by volume) must have been decisive to its lower radiopacity. Protect Liner F is a microfilled composite, thus its filler particle is silanized colloidal silica and prepolymerized organic filler. Regardless of its filler content which is 42% by weight, the type of filler determined its low radiopacity, and is explained by the unique presence of the low atomic number element silicon in its filler composition. Indeed, materials composed by elements with low atomic numbers, such as silicon, resulted in radiolucent materials, while the addition of elements with high atomic numbers (Barium, Yttrium and Ytterbium), resulted in radiopaque composites. In this case, the use of the low-viscosity composites Natural Flow and Protect Liner F could compromise radiographic diagnosis, leading the clinician to confound them with lack of material, marginal leakage, and remaining or secondary caries.

References
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