Radiopacity of flowable resin composite

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Abstract

Aim: The aim of this study was to measure the radiopacity of seven flowable composite resins (FCRs). ***Methods:*** The radiopacity values of Tetric EvoFlow®A3 (Ivoclar Vivadent), PermaFlo®A1 (Ultradent), Filtek Supreme XT®A3 (3M ESPE), wave®A3 (SDI), StarFlow®A2 (Danville Materials), els flow®A3op (Saremco Dental AG) and SYNERGY Nano Formula®A2/B2 (Coltène Whaledent) were determined with reference to an aluminium step wedge and an equivalent thickness of the enamel and dentine. ***Results:*** Tetric EvoFlow®A3 had radiopacity values significantly greater than the radiopacity of enamel. All tested materials had radiopacity values greater than the radiopacity of dentine and higher than a 1 mm thickness of aluminium. ***Conclusions:*** In the future, FCRs should have higher radiopacity values than the radiopacity of dentine and ideally be similar to or higher than that of the enamel in order to improve their clinical detection.

Key Words: Radiopacity, Flowable Composite Resin, Dental Radiographs

Introduction

The first generation of flowable composite resins (FCRs) was introduced in 1996, just before condensable composite resins [1]. The low filler content of FCRs (41-53% by volume and 56-70% by weight) led to inferior mechanical properties, higher polymerisation shrinkage [1] and low radiopacity compared to the traditional hybrid composites. The development of FCRs was based on their flowable viscosity but clinical evidence of their success for specific applications needs more investigation [1].

The placement of FCRs into the proximal boxes of Class II restorations in permanent teeth may contribute to the reduction in microleakage at the cavosurface margin when compared to the placement of an injectable glass ionomer [2]. Ferdianakis (1998) [3] reported reduction in microleakage from Class I restorations when using FCRs. The use of restorative materials with a low modulus of elasticity is generally accepted in order to reduce the cervical gap formation and marginal leakage [4]. Unterbrink and Liebenberg (1999) suggested the combination of a single-component adhesive as a dentine primer with a highly radiopaque flowable resin composite as a filled adhesive, in order to achieve better sealing of cavity margins [5].

Radiographic assessment is frequently used to detect interstitial and recurrent caries. Restorative materials of low radiopacity are difficult to distinguish from dental caries *(Figure 1).* It has therefore been suggested that FCRs with a low density should be avoided in Class II restorations in order to prevent confusion when assessing the possibility of recurrent caries [6]. Many studies have reported that to improve their clinical detection, the minimum radiopacity level of composite resin restorations should be higher than that of dentine or slightly in excess than that of enamel [7,8]. However, the

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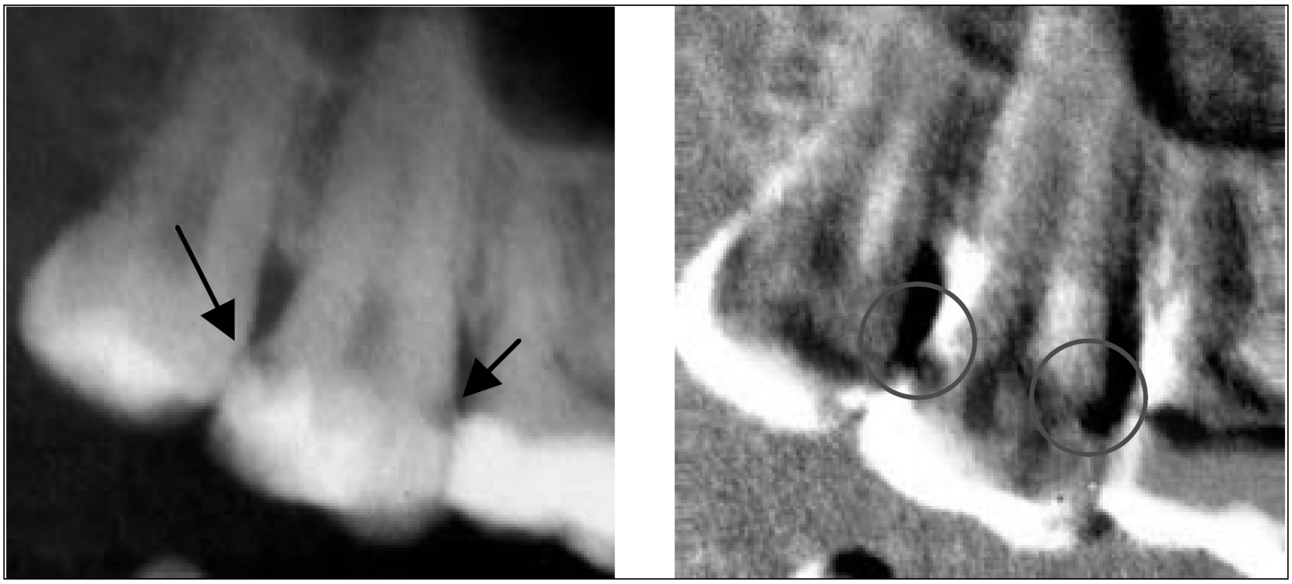

Figure 1. *Lack of radiopacity of a flowable composite-based resin in the proximal box of a Class II restoration.*

results of previous studies have suggested that a number of commercially available FCRs lack the necessary radiopacity [9,10].

Aim

The aim of this study was therefore to analyse the radiopacity of seven FCRs and to compare them with the radiopacity of enamel and dentine. The null hypothesis was that there is no difference in radiopacity of FCRs, enamel or dentine.

Materials

Seven FCRs commonly used in clinical practice in Romania were investigated in this study *(Table 1)*.

Table 1. Flowable resin composite investigated in this study. Information as provided by the manufacturers.

Nr.	Product	Manufacturer	Shade	Composition
1	Tetric EvoFlow	Ivoclar Vivadent	A3	Bis-GMA, UDMA, Dimethacrylate, Decandiol, Prepolymers, Additives, Stabilizers and catalysts, Pigments, Barium glass filler, Ytterbium trifluoride, Silicon oxide, Mixed oxide 57.5% wt inorganic filler 30.7% vol. inorganic filler
2	Filtek Supreme XT	3M ESPE	A3	Bis-GMA, Bis-EMA, TEGDMA, Silica nanofilller, Zirconia nanofiller and zirconia/silica nanocluster 65% wt inorganic filler 55% vol. inorganic filler
3	SYNERGY Nano Formula	Coltene Whaledent	A2/B2	Bis-GMA, Bis-EMA, TEGDMA, Strontium glass, Amorphous silica, Hydrophobed 55% wt inorganic filler 32% vol. inorganic filler
4	els flow	Saremco Dental AG	A3op	Barium glass silanizen, Bis-GMA, Bis-EMA, catalyst, inhibitors and pigments
5	StarFlow	Danville Materials Inc.	A2	61% wt inorganic filler
6	wave	SDI	A3	35% wt multifunctional methacrylic ester 65% wt inorganic filler
7	PermaFlo	Ultradent	A1	Methacrylate monomer, Alkylamino methacrylate, CQ, 68% wt inorganic filler

Bis-GMA: Bisphenol A diglycidylmethacrylate; **Bis-EMA**: Bisphenol A polyethylene glycol diether dimethacrylate; **UDMA**: Urethane dimethacrylate; **TEGDMA**: Triethylene glycol dimethacrylate; **CQ**: Camphorquinone.

Methods

Specimen preparation

Four disks of each of the seven FCRs measuring 8 mm in diameter and 1 mm in thickness (±0.01) were light-cured for 60 seconds using a XL3000 photocuring source (3M Dental Products, St Paul, MN, USA) with a power density >550 mW/cm^2. Samples were measured with a micrometer. Those samples with higher thickness were sanded, using # 800 carbide paper, until their thickness was 1mm (±0.01). Specimens with voids were excluded from the study. Two freshly extracted human molar and one premolar tooth extracted for orthodontic purposes that on visual examination were free from caries, hypoplastic defects or cracks were selected for the current study. Extracted teeth were stored in buffered formal saline for 24 hours post-extraction and then in water at room temperature (23±1°C). One tooth section mesiodistally from each of the three teeth was obtained by a rotary cutting machine to obtain 1 mm thick samples of enamel and dentine. In addition to these samples, pure aluminium samples consisting of 1 to 5 mm thick steps were prepared as controls with which the FCRs, enamel and dentine could be prepared. Samples of the FRCs and tooth slices were placed with aluminium step wedges on radiographic films. Radiographs were taken with a dental radiographic machine (X-Mind; Satelec) at 60 kv, 7 mA, and with a 0.32-second exposure time, at a target-film distance of 40 cm. All the dental films (Kodak D-Speed) were from the same batch. They were automatically developed in a Dürr XR 24 processor (Dürr, Bietigheim-Bissingen, Germany) at 28°C and were then digitalised using a flatbed scanner (Umax Astra 2400s). The resulting images were exported as uncompressed images in 8 bit TIFF files (500 d.p.i. resolution). The TIFF-scanned radiographs were analysed using an Image J (version 1.37V) image analyser (Wayne Rasband, National Institutes of Health, Bethesda, MD, USA) and an average grey value was recorded for every sample. For each radiograph image, a calibration curve generated by the grey scale values as a function of the aluminium thickness was calculated *(Figure 2).* The radiopacity values of the samples were expressed in terms of the equivalent thickness of aluminium per 1 mm unit thickness of the material.

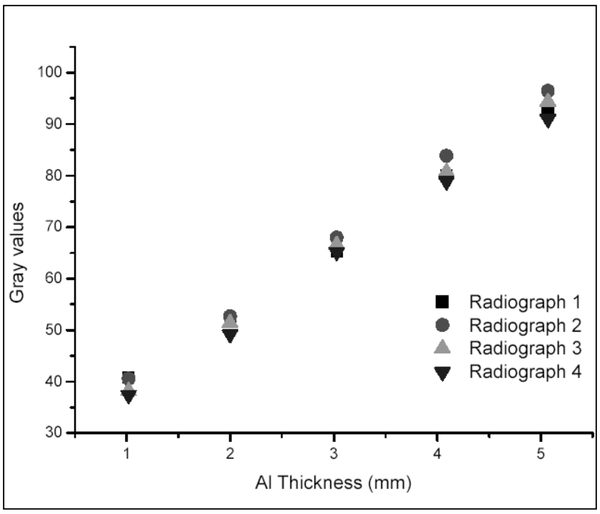

***Figure 2.** Calibration curve generated of the grey scale values versus the thickness of the aluminium.*

Statistical analyses

Data were statistically analysed by one-way analysis of variance (ANOVA) and by Tukey's test with the level of significance set at 0.05 in order to determine the significant differences between the mean values of the tested materials.

Results

Figure 3 shows the mean of radiopacity values of the materials investigated. There were statistically significant differences between materials when the results were compared using the one-way ANOVA test *(P*<0.05). All the FCRs tested had radiopacity values greater than the radiopacity of dentine. Only one—Tetric EvoFlow (A3)—was more radiopaque than the enamel sample and statistically different to enamel *(P*<0.0001) and dentine *(P*<0.0001); radiopacity values of PermaFlo (A1) and Filtek Supreme XT (A3) were lower than the radiopacity of enamel but not statistically different from that of enamel. However, there was a statistically significant difference between the radiopacity of these two FCRs and that of dentine at the *P*>0.0001 level. In contrast, Wave (A3), StarFlow (A2), els flow (A3op) and SYNERGY Nano Formula (A2/B2) had radiopacity values lower than the radiopacity of enamel. Although they were more radiopaque that the dentine samples, there was no statistically significant difference.

Discussion

According to the International Organization for Standardization ISO-4049 [11], FCRs should have a radiopacity value equal to or greater than that of

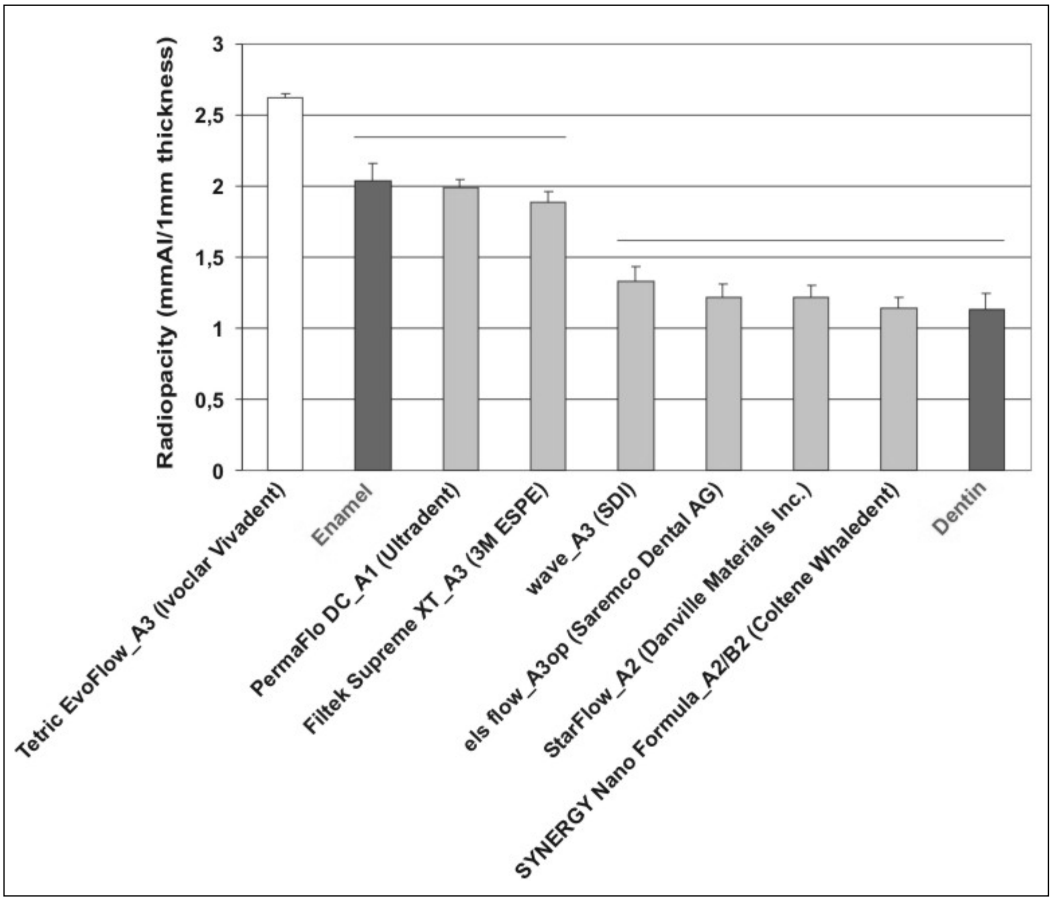

Figure 3. *Mean (SD) radiopacity of flowable resin composites, compared to dentine and enamel. (Horizontal bars indicate means values not statistically significant different from each other, compared using the Tukey test.)*

the same thickness of aluminium. As mentioned in the introduction, some publications have suggested that for improved clinical detection the minimum radiopacity values for FCRs should be higher than the radiopacity of dentine or slightly in excess of that of the enamel [7,8]. Bouschlicher *et al* (1999) [9] investigated the radiopacity of some FCRs and found that if ‘acceptable radiopacity’ is defined as greater than the radiopacity of enamel, only two products—Flow-it (Jeneric/Pentron Inc) and Tetric Flow (Ivoclar Vivadent)—met this standard. In the current study, all seven FCRs had radiopacity values higher than the radiopacity of dentine and a 1 mm thickness of aluminium and thus met the standard of ISO-4049 [11]. Tetric EvoFlow (A3) was found to be the most radiopaque of the seven FCRs and the only one with radiopacity higher than that of enamel. This finding could be explained by its contents, which include barium glass filler and ytterbium trifluoride, both of which have high atomic numbers and a high filler volume fraction [12] thus making them more radiopoque. The finding for Tetric EvoFlow (A3) is in agreement with that of a previous study [6]. The results for the radiopacity values of PermaFlo (A1) and Filtek Supreme XT (A3) (between enamel and dentine, with no statistical difference to enamel) indicate that radiographically it can easily be differentiated from dentine. The results for Wave (A3), StarFlow (A2), els flow (A3op) and SYNERGY Nano Formula (A2/B2), which had radiopacity values that were not statistically different from those of the dentine sample, suggest that these four materials could be improved to allow better radiographic diagnosis.

As all seven FCRs were more radiopaque that the dentine sample, but the difference was not statistically significant; the null hypothesis that there would be no difference in radiopacity of the FCRs that were tested, enamel or dentine was rejected.

The most important factor that can influence the radiopacity of dental materials is the atomic number of the elements in their constituent materials and the proportion of these elements in composition of the materials [13,14]. From information provided by some of the manufacturers, it can be seen that barium, ytterbium trifluoride, zirconium, and strontium are present in the filler of at least some of the seven FCRs that were assessed. A higher percentage of fillers with high atomic numbers in dental composites leads to increased radiopacity [13]. Other dental composites are available and contain elements with high atomic numbers such as barium, strontium, zirconium, zinc, ytterbium, titanium, tantalum, lanthanum, and indium [13-17]. These elements may be present in a wide range of concentrations and combinations. The radiopaque elements are generally found in fillers but can also sometimes be found in monomers [18]. A radiopacity value for dental composites higher than that of enamel can be achieved with a filler volume greater than 70% and when the mass percentage of radiopaque oxide in filler particles exceeds about 20% [14]. The incorporation of too much metal oxide in fillers may be disadvantageous because barium or strontium ions can disrupt the alumino–silicate network [19] and can increase the solubility and degradation of dental composites [19,20].

In clinical practice, it is not unusual to encounter patients who have FCRs of low radiopacity present in their mouths (such as seen in *Figure 1).* Cruvinel *et al.* (2007) have suggested that for this reason clinicians should be careful in selecting FCRs because there are not many on the market that exhibit a radiopacity equal to that of the enamel [21].

Voids in dental composites can decrease radiopacity and they also may structurally weaken a restoration. They should therefore be avoided at all costs. FCRs generally have low viscosity because of a relatively low powder content. This increases the possibility of the production of bubbles during the application of the material. In the current study, any samples with bubbles were detected radiographically and excluded from testing.

It has been suggested that low radiopacity values of FCRs can cause a problem if they are used as liners in Class II restorations [6]. In this context, any radiolucent cement used as base will show up as a separate layer [22] if its radiopacity is lower than that of the dentine and of the restorative materials. On one hand, radiopacity of dental materials can permit the radiographic detection of secondary caries [8] along with the recognition of faulty proximal contours, voids, marginal adaptation, and interfacial gaps [13]. On the other, it can be interpreted as caries when none exists.

The radiopacity of amalgam, gold or other metal restoration is much greater than that of tooth tissue; in fact, it is too radiopaque, and there is the risk that caries and defects adjacent to it can remain undiagnosed hidden in the 'shadow' of amalgam or under a metal restoration [7,8].

The use of an aluminium step wedge as a reference, which transforms readings of light transmission in the radiograph into an equivalent thickness of aluminium, was first described by Eliasson and Haasken (1979) [23]. The purity of the step wedge used in this study, measured by optical emission spectroscopy, was 99.52% aluminium, with 0.22 % iron and 0.001% copper and was in agreement with the recommended International Standard [24].

Various common methods have been used for the evaluation of radiopacity. They include using conventional radiographic film and reading by densitometers [9] and the use of spectrophotometers [25]. Recent alternative techniques to film-based radiography measurement have included a sensor, called CCD (charge-couple device), and storage phosphor technology [26]. The clinical advantages of these more recent techniques include low patient exposure to ionising radiation, ease of use and the possibility of image manipulation during interpretation, ease of image storage and exchange of data, and environmental protection [27].

Conclusions

The seven FRCs that were investigated in this study were found to have radiopacity values higher than the radiopacity of the dentine and a 1 mm thickness of aluminium. The radiopacity value of Tetric EvoFlow (A3) was significantly higher than that of enamel whereas PermaFlo (A1) and Filtek Supreme XT (A3) were found to have radiopacity values lower than the radiopacity enamel but not statistically different to those of enamel. Wave (A3), StarFlow (A2), els flow (A3op) and SYNERGY Nano Formula (A2/B2) had a radiopacity value higher than a 1 mm thickness of aluminium and dentine but it was not statistically different to that of dentine. It is recommended that in order to improve their clinical detection, future FRCs have a higher radiopacity value than that of dentine and perhaps ideally similar to or higher than that of the enamel. Digital imaging could be an alternative to transmission densitometry for the evaluation of the radiopacity of dental composites.

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