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Analyzing the radiopacity of dental composite restoratives

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The radiopacity of modern dental restorative materials depends critically on the filler compositions.

In modern dentistry, composite resins—with a variety of physical and mechanical properties—are widely used, and it is therefore important to understand their radiopacity level (i.e., the degree to which they can be distinguished from normal teeth and surrounding structures). Indeed, composite dental restorative materials should be sufficiently radiopaque so that excess material at the cervical margins (the part of the tooth between the crown and the root) and the contours of the proximal surfaces (facing the front of the mouth) can be detected. Excessive radiopacity of a restorative material is undesirable, however, because the composite must be distinguishable from lesions caused by secondary tooth decay (caries) and from a background of enamel and dentin (the dental tissue beneath enamel).[1] Specifically—according to the most recent International Organization of Standardization (ISO) recommendation (ISO 4049:2009)—the radiopacity of a 1mm-thick composite specimen should be equal to, or greater than, a 1mm-thick specimen of pure aluminum (Al). Furthermore, for ideal diagnosis of secondary caries from radiographs (i.e., to ensure non-excessive radiopacity and optimum contrast), the radiopacity of a composite restorative should be slightly higher than, or equal to, that of enamel.[2]

The radiopacity of composite resins is mainly attributed to the addition of radiopaque inorganic compounds as fillers, and modern composites tend to include glass particles with high atomic number (e.g., made from bismuth, ytterbium, lanthanum, barium, zirconium, yttrium, strontium, zinc, or titanium).[3] The precise composition of restorative materials varies greatly, however, and thus gives rise to wide variation in radiopacity levels. For example, it has previously been found that when the filler volume of a composite restorative reaches or exceeds 70%, and the amount of radiopacifying agent is greater than 20%, radiopacity may be higher than that of human enamel.[4] Nonetheless, to date, there have been relatively few studies conducted to evaluate the precise relationship between filler composition and radiopacity of modern composite restoratives. Moreover, radiopacity data provided by manufacturers (usually expressed in terms of equivalent Al thickness,

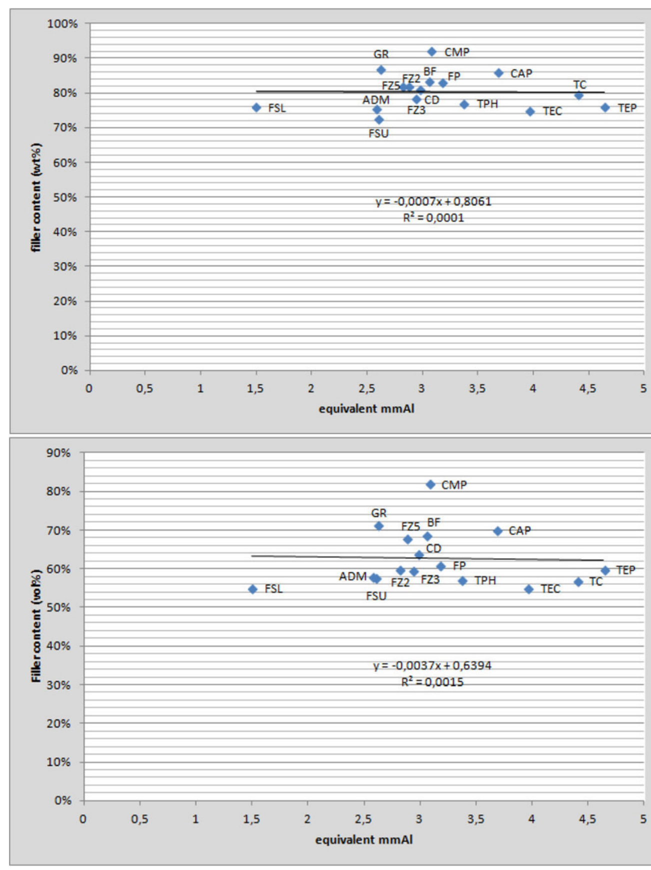

Figure 1. *Regression analysis between the measured radiopacity (in terms of equivalent aluminum thickness, mmAl) and filler content expressed (top) per weight (wt%) and (bottom) per volume (vol%) for the tested composite materials. The equation for the line of best fit and the coefficient of determination (R^2) is given in both cases. The 16 commercially available restoratives are each labeled. ADM: Admira. BF: Beautifil II. CD: Charisma Diamond. CAP: Clearfil AP-X. CMP: Clearfil Majesty Posterior. FZ2: Filtek Z250. FZ3: Filtek Z350 XT. FZ5: Filtek Z550. FSU: Filtek Supreme XT. FSL: Filtek Silorane. FP: Filtek P60. GR: Grandio. TEC: Tetric EvoCeram. TC: Tetric Ceram. TEP: Te-Econom Plus. TPH: TPH Spectrum.*

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Table 1. *Mean and standard deviation radiopacity values for the tested composites and dental tissues as measured from digital radiography and expressed in mmAl. Materials labeled with the same uppercase letters (i.e., A–J) have radiopacity with no statistically significant difference (p>0.05). The specific radiopacifying agents, the difference (%) between the radiopacity value and that of dentin, and the radiopacity in %Al supplied by the manufacturer for each composite are also given. BaO: Barium oxide. YbF_3: Ytterbium trifluoride. ZrO_2: Zirconium dioxide. SrO: Strontium oxide. TiO_2: Titanium dioxide. YF_3: Yttrium trioxide.*

Composite materials	Radiopacity (mmAl)	Radiopacifying agent	% difference compared to dentin	Radiopacity according to manufacturer
Te-Econom Plus	4.64 ± 0.44^{A}	BaO, YbF_3	+307.0%	300% Al
Tetric Ceram	4.40 ± 0.38^{A}	BaO, YbF_3	+286.0%	400% Al
Tetric EvoCeram	3.96 ± 0.28^{B}	BaO, YbF_3	+247.4%	400% Al
Clearfil AP-X	3.68 ± 0.29^{B}	BaO	+222.8%	Radiopaque
TPH Spectrum	3.37 ± 0.36^{C}	BaO	+195.6%	200% Al
Filtek P-60	3.18 ± 0.29^{CD}	ZrO_2	+178.9%	Radiopaque
Clearfil Majesty Posterior	3.08 ± 0.22^{DE}	BaO	+170.2%	250% Al
Beautifil II	3.06 ± 0.26^{DE}	SrO	+168.4%	340% Al
Charisma Diamond	2.98 ± 0.22^{DE}	BaO	+161.4%	218% Al
Filtek Z350 XT	2.94 ± 0.25^{EF}	ZrO_2	+157.9%	250% Al
Filtek Z550	2.88 ± 0.26^{EF}	ZrO_2	+152.6%	250% Al
Filtek Z250	2.82 ± 0.18^{F}	ZrO_2	+147.4%	250% Al
Grandio	2.62 ± 0.18^{G}	TiO_2	+129.8%	250% Al
Filtek Supreme XT	2.60 ± 0.22^{G}	ZrO_2	+128.1%	200% Al
Admira	2.58 ± 0.20^{G}	BaO	+126.3%	300% Al
Enamel	1.95 ± 0.16^{H}	–	+70.2%	–
Filtek Silorane	1.50 ± 0.12^{I}	YF_3	+31.6%	Radiopaque
Dentin	1.14 ± 0.11^{J}	–	–	–

mmAl) sometimes differs from independently measured radiopacity data for the same composites.[5]

We have therefore conducted an in vitro study to evaluate the effect of filler composition on the radiopacity of 16 commercially available modern dental composite restorative materials.[6] In addition, we have compared the 16 restorative materials with tooth enamel and dentin. For this work we have used digital radiography, which presents a number of advantages over conventional radiography in dental practice (e.g., reduced exposure times and the ability to obtain a computer image immediately without the need for chemical processing).[7]

To quantify the radiopacity of the tested materials from digital radiographic images, we used Al wedges ('stepwedges') of equal thickness (varying in uniform in 1mm steps from 1 to 10mm) as a reference. We transferred the resulting images as 8-bit PNG files to a personal computer for further analysis, and then measured (using the ImageJ 1.41o program, from Wayne Rasband, National Institutes of Health, MD[6]) the mean gray values of the composite specimens, tooth fragments, and stepwedges from the digital images. In addition, we analyzed how the composition of the tested materials correlated with their radiopacity, checked if they met the ISO requirement, and compared our results with the manufacturers' data.

We show the correlation between the mean radiopacity and the filler load, per weight (wt%) and per volume (vol%), for the composite restorative materials in Figure 1. We find that there is a very weak correlation between the radiopacity and filler content (wt% or vol%) of the tested composite restoratives (with coefficients of determination of 0.0001 and 0.0115, respectively). The mean and standard deviation radiopacity values we obtained are also given in Table 1.

Our results indicate that radiopacity varies between the commercial dental composite restoratives because of differences in their radiopacifying agents, but that these were within the acceptable range for radiographic diagnosis of deficiencies. For some products, however, we found discrepancies between our measured radiopacity and data from the manufacturers. Product datasheets may therefore not always accurately represent a product's true properties.

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In summary, we found that dental composite restorative materials exhibit great variation in their radiopacity. Although the composition of the material (i.e., the type of radiopacifying agent) has a large influence on the radiopacity, we find that the concentration (per weight or volume) of fillers within the composites has little effect. All the composite restoratives we tested met the ISO radiopacity requirement of resin-based restorative materials. In the next step of this project, we will use various techniques to investigate the radiopacity of additional commercial composite materials. We also plan to publish a map of our results as a reference for dental practitioners.

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