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# The Effects of Polymerization in Different Light Power Modes on the Radiopacity of Composite Resins

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## Abstract

**Objective:** The aim of this study is to evaluate the effect of polymerization in different light power modes on the radiopacity of six different composite resins (Filtek Z250, Xtrafil, Tetric N Ceram, SureFil SDR Flow, Nova Compo HF, Grandio Flow).

**Methods:** Plexiglass molds (8 mm diameter, 2 mm thickness) were used for the preparation of the samples. Totally ten samples were formed for each composite resin (standard mode; n=5 and extra power mode; n=5). A 2-mm-thickness buccolingual section was obtained from the extracted premolar tooth for enamel and dentin samples. To evaluate the relationship between the density of the samples and tooth structure, an Al step wedge was used as a reference. The mean gray values of each composite resin, enamel, dentin, and Al step wedge were calculated with an image analysis program. Data were analyzed with an independent sample t-test, one-way ANOVA, and Tukey HSD test.

**Results:** All tested composites met ISO standards. Even if the radiopacity values of tested composites changed according to the light power mode, this change was found to be statistically significant only in SureFil SDR Flow (p=0.037). The difference between the radiopacity values of tested composites in both standard power and extra power mode was statistically significant (p<0.01). The highest radiopacity values were produced by the bulk-fill composites in both standard and extra power modes.

**Conclusion:** In this study, all tested composites were found to have sufficient radiopacity for restorations according to the criteria set by the ISO.

**Keywords:** Radiopacity, bulk fill composite resin, flowable composite resin

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## INTRODUCTION

Composite resins are restorative materials used to provide aesthetics in the anterior region. Today, with the importance of dental aesthetics, composite resins have started to be used frequently in the posterior region. As known in the posterior region, the working area is narrow, and the risk of contamination is high. In direct composite restorations, the incremental layering technique is considered as the standard procedure since it reduces polymerization shrinkage stress and provides an adequate depth of cure (1,2). New materials such as highly filled flowable, bulk fill flowable, or non-flowable composites are developed in order to improve the physical and mechanical properties of composite resins and increase the clinical success rate.

Flowable resin composites were first introduced in 1996 (3). These materials have higher flow, easier application, better adaptation, and more elasticity (4,5). Bulk fill composites have lower viscosity compared with conventional composites but show lower polymerization shrinkage compared to flowable composites (6). The biggest advantage of bulk-fill composite resins is that they can be applied in bulk (single layer) with a thickness of 4-6 mm, shortening the clinical study time, showing low polymerization shrinkage, and having a high polymerization degree (7). Other advantages are that it provides ease of application to the dentist, better adaptation of the composite layer, no gap formation between the layers, good abrasion resistance against chewing forces, sufficient radiopacity, increased translucency, surface properties and color matching are clinically acceptable levels (8,9).

It is the polymerization mechanism that significantly affects the physical and mechanical properties of composite resins. The Light intensity of at least 400 mW / $cm^2$ has been recommended for the polymerization of composite resins (10). It is thought that short-term application of high light intensity and long-term application of low light intensity can provide equal polymerization degrees (11,12). Adequate polymerization does not occur in composite resins when light of the appropriate wavelength is not given. In addition, the polymerization reaction is affected by many factors such as layer thickness, type and color of the restorative material, type and intensity of light source used, polymerization time, and the diameter of the light tip. Lack of polymerization of composite resins affects mechanical properties, biocompatibility, volumetric shrinkage, degree of polymerization, and depth of polymerization (13). When composite resins are not sufficiently polymerized, their physical and mechanical properties weaken, and monomer is released into the environment. These residual monomers can cause estrogenic (14), mutagenic (15), genotoxic (16,17), and cytotoxic effects (18,19).

Radiopacity is an essential feature of all restorative materials. The Radiopacity value of restorative dental materials is generally detected by comparing them with enamel, dentin, or aluminum (20,21). It is stated by the International Standards Organization (ISO 4049) that the radiopacity of dental materials is to be equal to or greater than the same thickness of aluminum (22). The radiopacity of restorative dental materials should be both distinguishable from dental tissue and radiopaque enough to be distinguished from a void (23). The adequate radiopacity of the restorative dental material allows the clinician to evaluate and detect secondary caries, voids, overhangs, and open margins and distinguish them from neighboring anatomical structures (24).

The difference in radiopacity of restorative materials results from the difference in monomeric resin formulations and filler properties of dental materials such as type, particle size, and volume of filler. Studies have observed remarkable differences in radiopacity between different restorative materials (25,26). Although a number of studies have been conducted on the radiopacity of bulk fill or flowable composite materials (21,27-31), there was no report in the literature about the effects of polymerization in different light power modes on the radiopacity of composite resins. The aim of the present study was to evaluate the effects of polymerization in different light power modes on the radiopacity of composite resins. The null hypotheses tested were that 1) polymerization in different light power modes would not affect the radiopacity of tested composite resins 2) no difference between the radiopacities of the tested composite resins.

**METHODS**

***Sample Preparation***

This study tested the radiopacity of six different composite resins (Filtek Z250, Xtrafil, Tetric N Ceram, SureFil SDR Flow, Nova Compo HF, and Grandio Flow). In order to determine the number of samples for each composite resin, a Power analysis was conducted by taking into account the study of Tarcin et al. (31). For each composite resin used in the study, a total of ten samples (Power 0.86) were formed according to light power modes (standard mode; n=5 and extra power mode; n=5). A total of sixty samples were prepared. The type, manufacturers, filler type, and filler loading of tested composite resins are listed in Table 1 (8,31-33).

**Table 1.** The type, manufacturers, filler type, and filler loading of tested composite resins

| Composite Resin | Type | Manufacturer | Filler type | Filler loading (% volume) | Reference |
|---|---|---|---|---|---|
| Filtek Z250 | Microhybrid | 3M ESPE, St. Paul MN, USA | Zirconia/silica | 60 | 8 |
| X-tra fil | Microhybrid Bulk fill | VOCO, Cuxhaven, Germany | Barium-boron-alumino-silicate glass | 70 | 32 |
| Tetric® N-Ceram | High-viscosity bulk fill | Ivoclar Vivadent (Schaan, Liechtenstein) | Barium aluminum silicate glass, prepolymer filler | 60 | 33 |
| SureFil SDR Flow | Bulk fill flowable | Dentsply DeTrey, Konstanz, USA | Barium-alumino-fluoro-borosilicate glass, strontium alumino-fluorosilicate glass | 45 | 31 |
| Nova Compo HF | Nanohybrid flowable | Imicryl, Konya, Türkiye | Silanated barium glass, ytterbium, silanated higly dispersed silicon dioxide, silica-zirconia and prepolymer | 55-61 | Manufacturer |
| Grandio Flow | Nanohybrid flowable | VOCO, Cuxhaven, Germany | Barium-alumina borosilicate, silica | 65.6 | 31 |

Plexiglass molds (8 mm diameter, 2 mm thickness) were used for the preparation of the samples to be tested. VALO third-generation LED light cure unit (Ultradent Products Inc., South Jordan, UT, USA) was used for polymerization. According to the manufacturer's instructions, the light was applied for 20 s once in standard mode (1000 mW/cm$^2$) and for 3 s twice in extra power mode (3200 mW/cm$^2$) for the polymerization of each composite resin. The polymerized samples were meticulously removed from the plexiglass mold. Samples were polished with standard procedures. It was checked whether the thickness of the samples was 2 mm using a digital caliper (Altas, 905 model, Istanbul, Turkey). One extracted intact human premolar was used for the enamel and dentine samples. This study was approved by Ordu University Clinical Research Ethic Committee (2021/115). The patient was informed that their tooth was to be extracted for orthodontic treatment.

In addition, written informed consent was obtained from the patient who confirmed that one of the extracted teeth was to be used in this in vitro study. The tooth was cut buccolingual using a slow-speed diamond saw (Mecatome T180, Presi SA, Angonnes, France) under water cooling. One enamel and dentin slab with a thickness of 2±0.2 mm was obtained.

***Radiopacity Analysis***

To evaluate the relationship between the density of the composites and tooth structure, an Aluminum (Al) step wedge (each step made 1mm thick, 4x6mm, 99.5% pure Al) was used as a reference. First of all, a tooth section containing enamel and dentine, an aluminum steep wedge sample polymerized in standard mode, and a sample polymerized in extra power mode from each tested composite were placed on the center of the size 4 photo-stimulated phosphor plate (Carestream CS7600, Carestream Health Inc., Rochester, NY, USA). The phosphor plate was exposed at 70 kVp, 7 mA, 0.3s at a distance of 30 cm and an angle of 90 degrees with a special holder apparatus. On the digital image (Fig. 1) obtained with the scanner (KODAK CR7600, Carestream Health Inc., Rochester, NY, USA), with 50x50 pixels region of interest (ROI) from the samples for each composite, the steps of the Al step wedge, enamel, and dentin were selected (34). The mean gray value (MGV) of each ROI was measured with the histogram function of an image analysis program (ImageJ 1.52a, National Institutes of Health, USA), and after that, the calibration curve creation was performed (34). Average mm Al thicknesses for each composite resin, enamel, and dentin were determined using the calibration curve. These processes were repeated independently for each of the five digital images. The mean mm Al thicknesses were detected for each composite resin, enamel, and dentin.

***Statistical Analysis***

All statistical evaluations were made with SPSS v26 statistical software (IBM Inc., Chicago, IL, USA). $\alpha$ was set as 0.05. The homogeneity of the radiopacity values was checked with The Kolmogorov-Smirnov normality test. To investigate the significant differences in radiopacity values for each composite resin according to light power modes, data were analyzed with an independent sample t-test. To study the significance of the differences between the composites, enamel, and dentin, data were analyzed with one-way ANOVA. The Tukey HSD test was applied for comparisons.

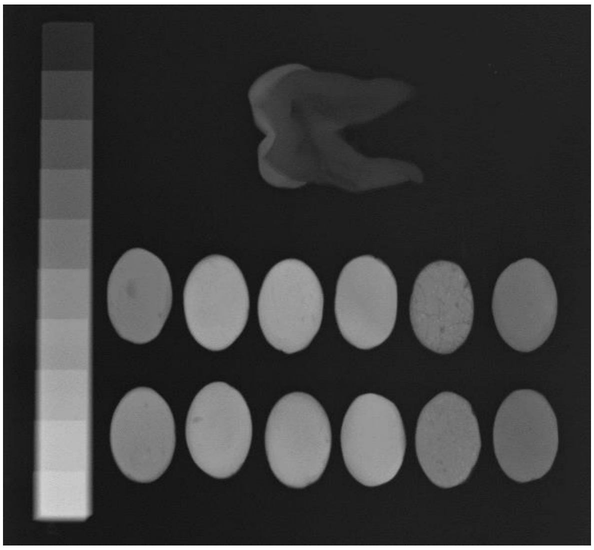

**Figure 1**: Representative radiograph showing of composite resins, Al step wedge, and tooth. Top row from left to right (extra power mode): Filtek Z250, Xtrafil, Tetric N Ceram, SureFil SDR Flow, Nova Compo HF, Grandio Flow.Bottom row from left to right (standard mode): Filtek Z250, Xtrafil, Tetric N Ceram, SureFil SDR Flow, Nova Compo HF, Grandio Flow

**Table 2.** The radiopacity values of tested composites according to light power mode.

| Materials | Mean Radiopacity ±SD (mm eq AL) Standard Mode | Mean Radiopacity ±SD (mm eq AL) Extra Power Mode | p* |
|---|---|---|---|
| Filtek Z250 | 5.41±0.52 | 5.07±0.69 | 0.406 |
| X-tra fil | 6.91±0.76 | 6.75±0.53 | 0.703 |
| Tetric® N-Ceram | 6.35±1.14 | 7.05±0.46 | 0.241 |
| SureFil SDR Flow | 6.62±0.33 | 6.10±0.31 | **0.037** |
| Nova Compo HF | 4.51±0.21 | 4.62±0.38 | 0.590 |
| Grandio Flow | 3.51±0.10 | 3.38±0.46 | 0.538 |

p* Independent sample t test

## RESULTS

All the tested composite resins met ISO standards. Table 2 presents the radiopacity values of tested composites according to light power mode. Even if the radiopacity values of all composites tested changed according to the light power mode, this change was found to be statistically significant only in SureFil SDR Flow (p=0.037). The highest radiopacity values were produced by the bulk-fill composites in both standard and extra power mode. The lowest radiopacity values were produced by the flowable composites in both standard and extra power mode.

The difference between the radiopacity values of all materials in both standard power and extra power mode was statistically significant (p=0.01). A comparison of the radiopacity values of the six composite resins, enamel, and dentin samples are shown in Table 3 for the standard power mode.

**Table 3.** Comparison of the radiopacity of tested composite resins for the standard power mode, enamel and dentin samples

| Materials | Mean Radiopacity ±SD (mm eq AL) |
|---|---|
| Dentin | 2.25 ± 0.21[a] |
| Grandio Flow | 3.51 ± 0.10[b] |
| Enamel | 3.70 ± 0.10[b] |
| Nova Compo HF | 4.51 ± 0.21[bc] |
| Filtek Z250 | 5.41 ± 0.52[cd] |
| Tetric® N-Ceram | 6.35 ± 1.14[de] |
| SureFil SDR Flow | 6.62 ± 0.33[e] |
| X-tra fil | 6.91 ± 0.76[e] |
| **p*** | **0.001** |

p* One way ANOVA
Different superscripts show statistically significant difference according to Tukey HSD multiple comparison test.

The comparison of the radiopacity of tested composite resins, enamel, and dentin samples are presented in Table 4 for the extra power mode. In both standard and extra power mode, the radiopacity of all composites was found to be higher than those of the enamel, except Grandio Flow. In the standard power mode, the highest and lowest radiopacity values were determined as X-tra fil and Grandio Flow, respectively. In the extra power mode, the highest and lowest radiopacity values were determined as Tetric® N-Ceram and Grandio Flow, respectively.

**Table 4.** Comparison of the radiopacity of tested composite resins for the extra power mode, enamel and dentin samples

| Materials | Mean Radiopacity ±SD (mm eq AL) |
|---|---|
| Dentin | 2.25±0.21[a] |
| Grandio Flow | 3.38±0.46[b] |
| Enamel | 3.70±0.10[b] |
| Nova Compo HF | 4.62±0.38[c] |
| Filtek Z250 | 5.07±0.69[c] |
| SureFil SDR Flow | 6.10±0.31[d] |
| X-tra fil | 6.75±0.53[ef] |
| Tetric® N-Ceram | 7.05±0.46[f] |
| **p*** | **0.001** |

p* One way ANOVA
Different superscripts show statistically significant difference according to Tukey HSD multiple comparison test.

## DISCUSSION

Adequate radiopacity of the restorative dental material allows the clinician to evaluate on radiographs. There was no report in the literature about the effects of polymerization in different light power modes on the radiopacity of composite resins. Therefore, this study was conducted.

In the current study, all the tested composites met ISO standards. Even if the radiopacity values of all composites changed according to the light power mode, this change was found to be statistically significant only in SureFil SDR Flow. Therefore, the first null hypothesis was partially rejected. In our study, the difference between the radiopacity of tested composite resins was statistically significant in both standard power and extra power mode (p=0.01). The highest radiopacity values were produced by the bulk-fill composites in both standard and extra power mode. In addition, the lowest radiopacity values were produced by the flowable composites in both standard and extra power mode. Therefore, the second null hypothesis was rejected.

Digital or conventional radiography can be used to measure the radiopacity of restorative materials (23). Digital image analysis is considered as a fast and easy method for the evaluation of the radiopacity of dental restorative materials (35). Digital radiographic systems enable the use of lower radiation doses compared with conventional films. In addition, digital radiographic systems eliminated the potential error related with processing conventional films (23,25,35). Because of these advantages, a digital radiographic system was used in our study.

The most important factor affecting the radiopacity of a restorative material is the composition of the material (26,36). The filler volume and the mass percentage of opacifiers in the filler particles should be more than 70% and 20% respectively to obtain a higher radiopacity value of dental composites than enamel (37). Researchers reported that restorative dental materials with high atomic number filler particles, such as barium, zirconium, and strontium, showed higher radiopacity values (37). However, quartz, lithium-aluminum glasses, and silica are not radiopaque. They are incorporated with other filler particles into the inorganic filler phase of resin composites. According to the results of our study, the difference between the radiopacity values of composites in both standard power and extra power mode was found to be statistically significant ($p<0.01$). The highest radiopacity values were found in bulk fill composite resins. In the standard and extra power mode, the highest radiopacity values were determined as X-tra fil and Tetric® N-Ceram, respectively. X-tra fil and Tetric® N-Ceram bulk fill composite materials contain barium (Ba, atomic number: 56). In addition, filler loading (% volume) of X-tra fil and Tetric® N-Ceram bulk fill composite materials are 60 and 70, respectively. The type and amount of radiopaque filler particles may have contributed to a high level of radiopacity in bulk-fill composite resins.

The radiopacity value of the restorative material should be equal to or slightly higher than that of the enamel. Materials with higher radiopacity than that of enamel are favorable for a true-negative diagnosis (38). In addition, the radiopacity value of the restorative materials should not be lower than that of the dentine in order to be distinguished from decalcified dentine (39). In our study, the radiopacity of all tested composites was found to be higher than those of dentin. However, the radiopacity of only Grandio Flow was found to be lower than those of the enamel. Grandio Flow is a nanohybride flowable composite. Grandio Flow filler loading (% volume) is 65.6. This flowable composite contains barium and silica. Even though barium is radiopaque, silica is not radiopaque. The silica may have caused lower radiopacity than enamel.

In previous studies, different radiopacity values were detected for flowable or bulk-fill flowable composites (21,27-31). Yildirim et al. reported that the radiopacity of SureFil SDR Flow was higher than enamel and dentin. While Gul et al. (28) reported that the radiopacity of Grandio Flow is higher than that of enamel, Dukic et al. (30) reported that the radiopacity of Grandio Flow was similar to enamel with slight deviations at different exposure values. Tarcin et al. reported that while the radiopacity of Grandio Flow was similar to enamel, the radiopacity of SureFil SDR Flow was higher than enamel (31). In our study, the radiopacity of only Grandio Flow was found to be lower than those of the enamel. The differences in radiopacity values for the same restorative material from different studies can result from many factors such as variations in polymerization time, power mode for polymerization, purity of the Al step wedge, using different imaging techniques, different exposure factors, and thickness of the restorative materials.

The total radiant energy is calculated by radiant power (mW) × time (s) (40). In our study, two different modes (standard and extra power modes), which are frequently preferred in clinical applications, were used for the polymerization of composite resins. For the polymerization of composite resin, light is recommended for 20 s once in standard mode (1000mW/$cm^2$) and for 3 s twice in extra power mode (3200 mW/$cm^2$). Even if the radiopacity values of tested composites changed according to the light power mode, this change was found to be statistically significant only in SureFil SDR Flow in the present study. In extra power mode, total radiant energy was 19.2 J/$cm^2$ while it was 20 J/$cm^2$ in standard mode. The fact that the total radiant energy value obtained in these two modes was very close to each other may have contributed to the result. There was no report in the literature about the effects of polymerization in different light power modes on the radiopacity of composite resins.

When the radiopacity value of each composite tested in our study was compared according to the power mode, it was found that the radiopacity decreased in the extra power mode, except Tetric® N-Ceram and Nova Compo HF. Tetric® N-Ceram bulk fill composite contains Ivocerin, an additional photoinitiator that is considered to be more effective than camforoquinone as a photoinitiator. The absorption range of Ivocerin is 390–445 nm (41) and the absorbance maximum is 418 nm (42). Ivocerin in Tetric® N-Ceram may be responsible for the increase in radiopacity by contributing to polymerization depth and degree of conversion of the material in the extra power mode. Even if the radiopacity values of all composites changed according to the light power mode, this change was found to be statistically significant only in SureFil SDR Flow ($p=0.037$). The radiopacity of Surefil SDR Flow is reduced in extra power mode. The differences of the type and amount of radiopaque filler particles, insufficient polymerization, and low polymerization time may have contributed to the low level of radiopacity for extra power mode in SureFil SDR Flow. Polymerization with extra power at a short period of time can affect the polymerization depth, degree of conversion, and radiopacity of composite resins.

This study is considered to have some limitations. First, this study is an in vitro study. Second, thermal cycles or aging procedures applied to simulate the effects of the oral environment were not conducted on the composites tested in our study. Third, the effect of two different power modes of the same light device on radiopacity was tested. Finally, samples were prepared in 2 mm thickness. The results may vary with different parameters such as light device, polymerization time, irradiation parameters, thickness, and oral environments. Additional research should be conducted to evaluate the effect of different parameters on the radiopacity of composite resins.

## CONCLUSION

**1.** All of the tested composite resins met ISO standards.

**2.** Even if the radiopacity of tested composite resins changed according to the light power mode, this change was found to be statistically significant only in SureFil SDR Flow.

**3.** The difference between the radiopacity of tested composite resin materials in both standard power and extra power mode was found to be statistically significant. The highest radiopacity values were produced by the bulk-fill composites in both standard and extra power modes. The lowest radiopacity values were produced by the flowable composites in both standard and extra power modes.

***Ethics Committee Approval:*** This study was approved by Ordu University Clinical Research Ethic Committee (2021/115).
***Peer-review:*** Externally peer-reviewed.
***Author Contributions:*** Concept: CG, ZUE, DO, EUC; Design: CG, ZUE, DO, EUC; Literature Search: CG, ZUE, DO, EUC; Data Collection and Processing: CG, ZUE; Analysis or Interpretation: KE; Writing: CG, ZUE, DO, EUC
***Conflict of Interest:*** No conflict of interest was declared by the authors.
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