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Effect of ionizing radiation on properties of restorative materials

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ABSTRACT

Objective. To evaluate the effect of ionizing radiation from high energy X-ray on properties of restorative materials.

Methods. Study materials (3M-ESPE) were: Z250—microhybrid resin-based composite (Filtek Z-250); Z350—nanofilled resin-based composite (Filtek Z-350XT); VIT—resin-modified glass ionomer cement (Vitremer); and KME—conventional glass ionomer cement (Ketac Molar Easymix). Sixty bar-shaped and cylinder-shaped specimens were fabricated from each material. Specimens were light activated (980 mW/cm^2, Radii, SDI) for 60 s (3×20 s for Z250 and Z350) and 120 s (3×40 s for VIT) and thirty specimens from each shape were irradiated (IR) with 1.8 Gy/day for 39 days (total IR = 70.2 Gy). IR and non-irradiated (NI) specimens were evaluated for flexural strength (σ, n = 30) followed by fractography (SEM), diametral tensile strength (DTS, n = 30), hardness (H, n = 10), surface roughness (R_a, n = 10) and chemical composition (n = 3). The IR effect on each material property was statistically analyzed using Student's t test ($\alpha = 0.05$). Data from σ and DTS were also analyzed using Weibull statistics.

Results. IR significantly increased the mean σ values of VIT and KME and the mean DTS value of VIT ($p < 0.05$). IR increased R_a and H values for VIT and decreased H value for Z-250 ($p < 0.05$). The remaining materials and properties were not significantly affected by IR ($p > 0.05$). There was no significant change on materials composition after IR.

Significance. The recommended radiotherapy protocol for head and neck cancer altered some material properties, mainly for glass ionomer cements. Such variations on material properties are not related to chemical composition changes.

1. Introduction

Dental care for cancer patients subjected to head and neck radiotherapy is an increasing demand at hospital practice. Radiotherapy, using ionizing radiation to destroy tumor cells, is used either as a sole treatment or associated to surgery and/or chemotherapy [1]. This treatment may cause sequelae or complications in the oral cavity (e.g., mucositis, xerostomia, osteoradionecrosis, and radiation caries), especially on tissue cells from salivary glands, dentition, periodontium, bones, muscles and joints [2–5]. In addition, radiation may also affect restorative materials causing clinically relevant alterations, which are material dependent [6,7].

Resin-based composites and glass ionomer cements are widely used as restorative materials because of their adequate

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Table 1 – Materials used in the present study.

Material[a]	Composition
Z-250—Filtek™ Z250	Microhybrid resin-based composite: resin matrix (bis-GMA, UDMA, bis-EMA and TEGDMA) and 60 vol% of zirconia/silica particles.
Z-350—Filtek™ Z350 XT	Nanofilled resin-based composite: resin matrix (bis-GMA, UDMA, bis-EMA, TEGDMA and PEGDMA) and 78 wt% (or 59 vol%) of zirconia/silica particles and non-agglomerated silica particles.
VIT—Vitremer®	Resin-modified glass ionomer cement: fluoroaluminosilicate crystal powder, potassium persulfate, ascorbic acid, and pigments; liquid containing polyalkenoic acid, methacrylate groups, water, HEMA, camphorquinone.
KME—Ketac™ Molar Easymix	Conventional glass ionomer cement: powder containing aluminum fluorosilicate glass, lanthanum and calcium, polyacrylic acid, eudragit, tartaric acid, sorbic acid, benzoic acid, and pigments; liquid containing water, acrylic acid copolymer and maleic acid, tartaric acid, and benzoic acid.

[a] Restorative materials are from same manufacturer (3M-ESPE, St. Paul, MN, USA).

clinical performance [8]. However, several factors can influence on material's properties and contribute to early structural failures [9]. Ionizing radiation may be one of these factors [10].

Physicians often recommend dental treatment to patients just before head and neck radiotherapy [11–13]. Such treatment usually requires replacement of metal-based restorations by polymer-based restorative materials [10,12,14].

Ionizing radiation interacts with metallic materials such as amalgam, intensifying the radiation in the surroundings of the material. This secondary irradiation mostly depends on the atomic number from the material's components [14]. Therefore, this effect should be reduced in polymer-based materials since they absorb radiation. The free radicals produced in resin-based materials may induce chemical reactions, with ions, free radicals, and excited molecules mutually interacting to promote material stabilization. These interactions may also affect material properties, influencing on their sealing ability and restoration longevity [6,14].

Therefore, the objective of this study was to evaluate the effect of ionizing radiation from high energy X-ray on properties of restorative materials, assessing flexural strength, diametral tensile strength, hardness, surface roughness and chemical composition, testing the hypothesis that changes on material's property caused by ionizing radiation depend on the type of restorative material.

2. Materials and methods

Sixty bar-shaped (25 mm × 2 mm × 2 mm) and 60 cylinder-shaped (height: 5 mm; diameter: 6 mm) specimens from each material (Table 1) were produced using Teflon molds and following the 4049:2009 ISO standard [15]. Thirty specimens from each shape and material were irradiated (IR) and the remaining specimens (30) were used as control, non-irradiated (NI).

A polyester strip was placed under each Teflon mold before inserting the material to ensure a standard surface texture for the specimens. Material insertion and light activation (light unit: Radii, SDI, Bayswater, Victoria, Australia; 980 mW/cm^2) were performed according to manufacturer's recommendations. A polyester strip followed by a glass slide were placed on top of the inserted material before light activation. Bar-shaped specimens were fabricated in a single increment and light activated for 20 s (Z250 and Z350) and for 40 s (VIT) on four contiguous surface regions slightly overlapping each other, ensuring light activation to full length of the specimen (total activation time: 60 s for Z250 and Z350, and 120 s for VIT). Three material increments (thickness: 1 mm, 2 mm, 2 mm from bottom to top) were used to fabricate the cylinder-shaped specimens. Each increment was light activated for 20 s (Z250 and Z350) and for 40 s (VIT). The conventional glass ionomer cement (KME) was allowed to set for 5 min. Any material excess was carefully removed from specimen edges using #1200 SiC metallographic paper. Specimen dimensions were verified using a digital caliper (Mitutoyo Corp., Tokyo, Japan) with a precision of 0.001 mm.

Specimens (n = 30) were irradiated (IR) simulating a radiotherapy procedure applied to patients with head and neck cancer. Radiation was performed in a hospital environment using a linear accelerator (Primus 3D 3903, Siemens, Concord, USA). The following recommended protocol (Agency for Healthcare Research and Quality — AHRQ) was used [16–18]: a total dose of 70.2 Gy divided in 39 daily applications of 1.8 Gy (180 cGy). Specimens were placed in an acrylic phantom that was filled up with distilled water. Each specimen was identified by the radiotherapist using the FocalSim software (Elekta Inc., Atlanta, USA) and radiation dose was calculated (Xio planning software, version 4.2.0, Computerized Medical Systems Inc., Maryland Heights, USA) to ensure same radiation dose to all IR specimens.

NI and IR specimens were stored in 37 °C distilled water for 90 days before testing.

2.1. *Three-point flexural strength (σ)*

Bar-shaped specimens (n = 30) were subjected to three-point flexural strength (σ) test until fracture in 37 °C distilled water. Water temperature was controlled using a water circulator and thermostat [19]. Specimens were placed on the supporting rollers using a double-sided adhesive tape to avoid underwater fluctuation [19]. Testing set-up was attached to a universal testing machine (EMIC-2000 DL, São José dos Pinhais, PR, Brazil) and a compression load was applied with a cross-head speed of 1 mm/min. Specimen cross section dimensions (h and b) at fractured area were recorded. Fractured specimens were carefully stored for fractographic analysis. The σ values (in MPa) were calculated using the following equation (ISO 4049:2009) [15]:

$$\sigma = 3Fl/2bh^2 \quad (1)$$

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