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Color Change in Composite Resins after Radiotherapy: The Importance of Knowing Dental Materials for the Treatment of Cancer Patients

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ABSTRACT

BACKGROUND

To analyze the influence of radiotherapy (RT) in color change of resin composite restorations.

METHODS

Forty bovine incisors were assigned to four groups: restoration with microhybrid (Z250) or nanohybrid (Z350) composite resins and submitted or not to irradiation. A cavity was made in each specimen, which was later restored by the insertion of composite resin. Then, the initial color measurements were performed. The irradiated specimens received dose of 60 Gy in 30 fractions (2 Gy per day fraction in 6 weeks, 5 consecutive days for week). At the end of the irradiation, the specimens were kept in artificial saliva at 37ºC for 24 hours before final color analysis. The quantitative response of the color stability was performed by examining the L* (luminosity), a* (red-green), b* (yellow-blue) coordinates of the CIE Lab system and by calculating the ΔE, to check the total color difference.

RESULTS

There was a statistically significant difference for ΔE between the non-irradiated and irradiated groups, both in the restorations with the microhybrid resin and in the nanohybrid resin restorations. No difference was found in chromatic coordinate a* but in coordinate L* and b* there were a statistically significant difference between not irradiated specimens and irradiated specimens.

CONCLUSION

RT promoted a significant alteration in the color of composite resin restorations, with a change in the total color and brightness difference of both composite resins.

KEYWORDS

Head and neck cancer; Radiotherapy; Composite resin; Color change

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INTRODUCTION

Radiotherapy (RT) is widely used for head and neck cancer (HNC) treatment, and may be indicated as primary therapy, with chemotherapy combination, adjuvant to surgical treatment, or as palliative treatment in advanced stages of the disease [1]. The goal of RT is to eradicate cancer with minimal adverse effects on surrounding tissues. Although it is beneficial and generally performed in the most conservative manner possible, often the side effects to adjacent tissues are unavoidable. Many are acute and transient, while others may be late or irreversible. The prevalence of dental caries may be 25% higher in patients undergoing RT in HNC [2] and the risk for the development of “radiation caries” will be present not only during treatment and shortly after that, but rather throughout the lifetime of the patient [3]. Studies were carried out to elucidate the direct effects of the irradiation on the dental structure, resulting from the ionizing action of the treatment on the dental tissues, which could favor the occurrence of the caries of radiation. It has been shown that RT can cause changes in enamel and dentin [2,3,4]. This includes altered micro hardness, increased solubility, atrophy of odontoblastic processes and obliteration of dentinal tubules, increased fracture risk [5], reduction of the stability of the dentin junction and destruction of collagen [3].

Dental treatment before the initiation of RT in HNC is advocated by various clinical protocols [6] to improve oral health status by minimizing the risk of acute and long-term adverse events and avoiding potential complications during the treatment period. Since the introduction of composites in dentistry, composite resin restorations are widely performed in dental practice. In general, microhybrid composites, nano hybrid resins and nano particles are the most used [7]. The development of the microhybrid resins allowed a greater translucency of the material, adequate polishing, and improved mechanical properties [8]. Nano hybrid resins further improved mechanical and aesthetic properties and, for this reason, are now considered universal resins [9]. The color stability of a material is a very important property for aesthetics. The
potential for color change, which is a problem for aesthetic restorations, being the central clinical aspect that leads patients to smile dissatisfaction [7].

In this context, it is considering that:

1) Patients with head and neck cancer are admittedly patients with precarious oral conditions and need extensive restorative treatments.
2) Composite resin restorations may be a viable treatment for these patients and are widely used in dentistry;
3) RT causes changes in the oral environment.
4) It acts directly on the restorative materials.

With these aspects in mind, the objective of this study was to evaluate the influence of RT on the color change of composite resin restorations. The null hypothesis of this study is that RT would not change composite restoration color.

MATERIAL AND METHODS

Experimental Design

The experimental sample consisted of 40 permanent bovine incisors, obtained from a refrigerator. The teeth were extracted with a lever, divided into four groups, and restored with composite resin. It is a 2 × 2 factorial study, with the factors being: the composite resin in two levels - microhybrid resin (Z250 - 3M ESPE Dental Products, St Paul, MN, USA) and nanohybrid resin (Z350-3M ESPE Dental Products, St Paul, MN, USA) (Table 1), and irradiation on two levels - present and absent.

This study was performed using a randomized complete block design, with one repetition of each experimental group per block, the quantitative response variable being the color stability, total color variation (ΔE), variation of luminosity (ΔL), red and green color variation (Δa) and yellow and blue color variation (Δb).

Composite	Composition of resin matrix (Charge) *	Average load particle size	Percentage of load	Photo time polymerization	Manufacturer
Filtek Z250 Micro Hybrid Resin	Bis-GMA, UDMA e Bis-EMA (zirconia/silica)	0.01-3.5 μm with mean particle size of 0.6 μm	82% weight (60% weight)	20 seconds	3M ESPE St. Paul – MN – 55144-1000- USA
Filtek Z350 Nano Hybrid Resin	Bis-GMA, UDMA, Bis-EMAs e TEGDMAb (zirconia/silica)	5-20 nm with a mean particle size of 0.4 μm	78.5% weight (59.5 weight %)	20 seconds	3M ESPE St. Paul – MN – 55144-1000- USA

Table 1: Composite resins tested in the present study. **Note:** *Bis-GMA = bisphenol-A-glycidyl-dimethacrylate; UDMA = urethane-dimethacrylate; Bis-EMA = bisphenol-A-polyethylene glycol-diether-dimethacrylate; TEGDMA = triethylene glycol dimethacrylate. *Manufacturer's instruction information.

Experimental Process

For this study, we stored clean bovine incisors in 2% formalin solution, pH 7.0. Teeth with cracks, hypoplastic stains or severe wear were discarded. Initially, the roots were removed with a diamond disc (#7015, KG Sorensen, Barueri, 06454-920, Brazil) in a cutting machine (Minitom, Struers A/S, Copenhagen, DK - 2610, Denmark). The crowns were then fixed on an acrylic plate and then cut to obtain 40 specimens with dimensions of 5x5 mm.

The specimens were taken to a Politriz (DP-9U2, Panambra / Struers, A / S) for enamel preparation. This was accomplished using water sandpapers (Norton Abrasivos Ltda, São Paulo, SP, Brazil) with granulation from 600 to 1200, applied in decreasing order of abrasiveness, under constant cooling. The wear was carried out and, at the end of this process, samples with dimensions 5 mm x 5 mm (width and length) and thickness of 3 mm was obtained, with care to maintain 1 mm of enamel and 2 mm of dentin. Then, using a 333 drill, a cavity was made in theses blocks with a depth of 2 mm and a diameter of 3 mm was made. All these procedures were performed with the aid of a digital caliper (Digimess, São Paulo, SP, Brazil).

The cavity was restored with an etch rinse adhesive system (Adper™ Single Bond Plus - 3M ESP St. Paul - MN - 55144-1000-USA) and direct composite resin (shade B2B). Information regarding composite type, composition and manufacturer is given in Table 1. The material was handled following the manufacturer's instructions and inserted into the cavity in two increments. Immediately after insertion of the second layer of the material, a polyester matrix was placed on which an axial load of 500 gf was applied for one minute to compact the composite resin, making the surface flat with standardized thickness. The material was light-activated by a LeD device (FLASH lite 1401, Discus Dental, Culver City, CA, USA, light intensity ≥ 1100 mW/ cm^2, wavelength in the range between 460 nm and 480 nm), for 20 seconds, according to manufacturer's recommendations. After the specimens were prepared, they were kept in artificial saliva and stored in an oven at 37°C (±1°C).

Workmanship and polishing of test specimens

After 24 hours, the experimental units were submitted to finishing with Super-Snap discs (medium and fine grain, Shofu INC. Kyoto - 605.0983 - Japan) and polishing with disks of felt and diamond paste (KG Sorensen Ind. and Com. Ltda, Barueri, SP, Brazil) with granulation of 6μm and 3 μm.

The specimens were washed with running distilled water, sonicated for five minutes, dried with absorbent paper, and then dipped in artificial saliva for 24 hours in an oven at 37°C. After these procedures, the initial color measurements were performed, and the solution cycle was initiated.

Initial Color Analysis

The initial color measurement was performed after washing with water for ten seconds and drying with absorbent paper for 30 seconds. The specimens were randomly divided into two subgroups: control, maintained in artificial and not irradiated saliva; and the experimental subgroup, maintained in artificial saliva and submitted to irradiation.

Before the start of irradiation, color reading of the specimens was performed according to the CIE Lab system (Commission Internationale de l'Eclairage), against a white background (L^* = XX, a^* = XX, b^* = XX, Gardner Laboratory Inc., Bethesda, MD, USA) in a reflection spectrophotometer (PCB 6807, BYK Gardner, Geretsried, Germany). This equipment is specific for color reading and has 30 LED lamps with 10 different colors arranged circular, measuring geometry 45°/0°, with standard Illuminant D65 and 5 mm diameter of color aperture. The spectrophotometer returned a precise quantitative measurement of surface colors by recording the spectral reflectance/transmittance curve of the specimen. A prism disperses tungsten-filament bulb light into a spectrum of wavelength (5 nm and 20 nm) bands [10-17]. For this reading, the tip of the spectrophotometer was positioned touching the specimens and perpendicular to them.

Specimen Irradiation Procedure

During the irradiation procedure, the specimens were placed on cell culture acrylic plates (Cellstar®, reference 657160, Greiner bio-one GmbH, Frickenhausen, Germany). All specimens received the same direct irradiance per unit area. To maintain a humid environment during radiation, thus simulating the characteristics of the oral cavity, each well was filled with 10ml of deionized, distilled water, completely covering the PVC cylinders.

The irradiation of the specimens from the experimental group went in a 6 MV clinical linear accelerator (Elekta Synergy Platform; Elekta AB Stockholm, Sweden), dose of 60 Gy in 30 fractions (2Gy dose day fraction, for 6 consecutive weeks, in 5 days for week) [4,17,18] at the RT Service of the Centro de Tratamento em Radio-Oncologia (CTR). Plates were aligned equidistant from the center of the bundle and the interior of the cone to ensure a uniform dose rate (400 UM/min) and total dose delivery per fraction. The dose was calculated and administered in the midline of the set, arranged by two parallel and opposite anteroposterior fields. Quality control was performed using Nanodot dosimeters (Landauer, Inc., Glenwood, IL, USA), with the dose readings on the surface of the plates being used to calculate the beam-on treatment times. The dosimeters were placed under the irradiated plates and calibrated according to the beam conditions described above.

At the end of each procedure, the deionized, distilled water was discarded, and the specimens were kept in artificial saliva in an oven at 37°C and 100% humidity until the next irradiation cycle, in a total of 30 renovations during the 6 experimental weeks [18]. Due to the high concentration of ions in artificial saliva, which could interfere with the direct radiation per unit area, artificial saliva was not used during irradiation.

After the end of the RT (cumulative total dose of 60Gy), the specimens were kept in artificial saliva in an oven at 37°C for seven days, for performing the final color analysis. For the control subgroup, the specimens were maintained at 37°C (±1°C), with renewal of the saliva solution, daily, for 30 days.

Final Color Analysis

After the end of radiation cycle, specimens color was measured by the spectrophotometer, as previously described. The colour changes (ΔE) of each specimen were calculated by analyzing the coordinate values. Colour changes were quantified using the following equation [19]: $\Delta E = ((\Delta L^*)2 + (\Delta a^*)2 + (\Delta b^*)2)1/2$, where ΔE^* = color alteration; ΔL^* = lightness difference (L^*), so that the greater L^* values, the higher the brightness of the sample; Δa^* = axis a^* difference; so that positive values for Δa^* means redder samples and negative values, greener; Δb^* = axis b^* difference; so that positive values for Δb^* means yellower samples and negative values bluer, being that: $\Delta L^* = L^*F - L^*I$; $\Delta a^* = a^*F - a^*I$; $\Delta b^* = b^*F - b^*I$, where L^*I , a^*I and b^*I are referred to as the initial color measurement and L^*F, a^*F and b^*F as the final color measurement.

The data were analyzed for their distribution and homogeneity. They were submitted to the verification of the normality and the homogeneity of the variances by the Shapiro - Wilk and Levene tests, respectively. Two-way ANOVA (two-way analysis of variance – resin and radiation) was performed to differentiate the means. Graph Pad Prism 6.0 software (Graph Pad Software Incorporation, San Diego, CA, USA) was used for the analysis. The level of significance was 5%.

RESULTS

The mean values and standard deviations for color stability (ΔE) are presented in Table 2. There was a statistically significant difference ($p < 0.0001$) for ΔE between the not irradiated and irradiated groups, both in the restorations with the microhybrid (Z250) and nanohybrid (Z350) composite resins.

	Z250	Z350
Not Irradiated	0.80(0.63) aA	1.14(0.78) aA
Irradiated	7.71(3.68) aB	9.34(4.23) aB

Table 2: Means (standard deviations) for ΔE values.

About to the intensity of luminosity (L^*), there was statistically significant difference ($p < 0.0001$) between the not irradiated and irradiated groups, both in the restorations Z250 and Z350 (Figure 1a).

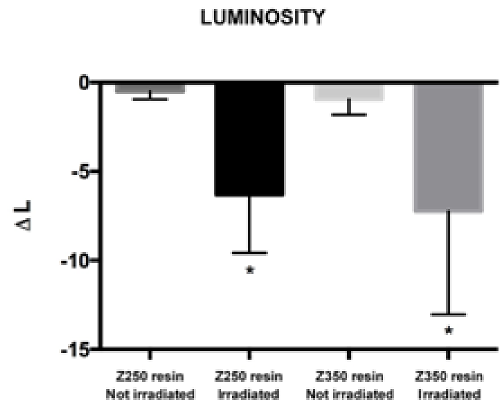

Figure 1a: Comparison of luminosity intensity variation in non-irradiated (control) and irradiated specimens, restored with microhybrid resin (Z250) and nanohybrid resin (Z350).

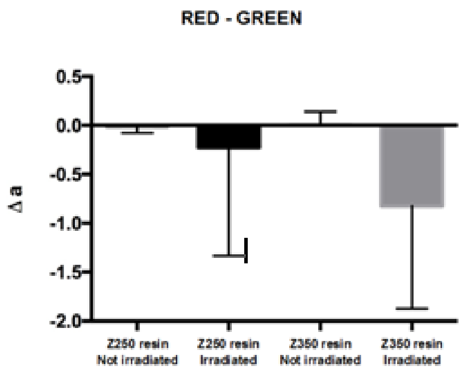

Figure 1b: Comparison of the red-green tonal variation in the non-irradiated (control) and irradiated specimens, restored with microhybrid resin (Z250) and with nanohybrid resin (Z350).

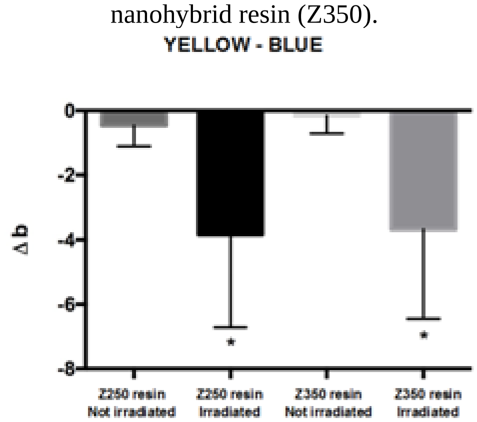

Figure 1c: Comparison of the variation of the blue - yellow tint in the non - irradiated (control) and irradiated specimens, restored with microhybrid resin (Z250) and with nanohybrid resin (Z350).

With regard to the chromatic coordinate a^* (red-green), there was no statistically significant difference ($p = 0.0506$) between the group of not irradiated and irradiated for both composite resins (Figure 1b). For the b^* (yellow-blue) coordinate, there was a statistically significant difference ($p<0.0001$) between the not irradiated and irradiated groups for the two types of resin (Figure 1c).

DISCUSSION

The study aimed to simulate the clinical conditions of the RT in HNC patients, with the main objective of analyzing the influence of RT on the color change (ΔE) of the composite resin restorations since the literature is scarce about this theme. Bovine incisors were used, due to their availability and dimensions, as well as anatomical and histological similarity to human teeth [20,21]. The experimental sample was restored with two types of composite resin, microhybrid (Z250) and nanohybrid (Z350), and submitted to RT protocol, simulating the conventional treatment, and reproducing the characteristics of the buccal cavity.

According to the literature, the color change of the resinous materials is related to several intrinsic and extrinsic factors. The resin matrix composition (structure and characteristics of the charge particles) plays an essential role in the final softness of the restoration, a critical factor in color stability and the susceptibility of extrinsic staining [22]. The charge particles (type, size, and quantity) influence the extrinsic pigmentation of the material since they can alter the quality and affect the surface roughness of the composites [23]. Factors such as wear, chemical degradation or oxidation can promote changes in the resin matrix and at the interface between the matrix and the load, favoring the accumulation of pigments, dehydration, water sorption, infiltration, and changes in surface roughness.

One of key drawbacks these materials are the colour stability [24,25]. Light cured composites contain canphorquinone as photo-initiator which facilitates better control over working time and enhances colour stability [25-28], but discoloration remains the main concern [19]. The ability of the resin matrix to absorb pigments is modulated according to the degree of conversion of the material and by some physical properties, such as, for example, water sorption capacity, which depends directly on the composition of the resin matrix [24]. In addition, the uniform distribution of charge particles in the polymer network minimizes the formation of filler - rich and filler-depleted areas within the composites. This is important in relation to the performance of composites in aqueous environments, such as saliva since void spaces at the interface loading / matrix can increase water sorption of composites [27].

Based on the color analysis performed by the CIE Lab system, it was evident the total alteration of color (ΔE), luminosity (ΔL) and blue-yellow variation (Δb) of the irradiated and restored specimens with the micro hybrid (Z250) and nano hybrid (Z350) resins. Some authors have reported that ΔE values ranging from 1 to 3 are perceptible to the naked eye [6] and ΔE values greater than 3.3 are clinically unacceptable [27]. Considering these concepts; the composite resins tested in the present study demonstrated unacceptable color stability when submitted to irradiation.

Although the radiotherapy treatment is handy, and generally performed in the most conservative manner possible, it is still associated with significant side effects. In addition to its indirect effects on the oral cavity, already known in the literature, recent studies have demonstrated the occurrence of several alterations due to its direct action, in the dental structure [3,4]. However, the effect of RT on dental restorative materials, such as composite resin, was not yet known. The potential for color change of resin restoration, aggravated by the action of radiation, was demonstrated in the present study. However, the lack of published studies makes it impossible to compare directly with our results, besides making it difficult to establish the exact mechanism by which RT directly affects the structure of resinous materials, affecting color stability.

Considering that the composite resin, because it is a low-density material, promotes a smaller dispersion of the energy received during the radio therapeutics treatment, possibly a large part of the emitted radiation is absorbed by this material. Thus, it is suggested that this event is responsible for the changes in the resin matrix and/or the matrix-load interface of this material that probably resulted in the color change. The specific sensitivity of each material may depend, to a lesser extent, on its resinous chemical nature and unwanted chemical changes [16] caused, for example, by irradiation.

Regarding the intensity of luminosity (ΔL^*), it was possible to observe that the specimens of the irradiated group, after the RT treatment, were decrease brightness, both in the restorations with the micro hybrid resin, and in the restorations of nano hybrid resin. As for tonality, about the chromatic coordinate a^* (red-green coordinate), the color of the specimens tended to be green and about the chromatic coordinate b^* (yellow-blue coordinate), the coloring trend was blue. Thus, RT in the head and neck region in addition to affecting oral functions under different aspects alters the total color difference (ΔE) of the restored specimens with composite resins.

In addition to the significance of the ΔE and its coordinates (ΔL^*, Δa^* and Δb^*), it is important to evaluate the clinical color difference; for this purpose, another two thresholds (perceptibility and acceptability) are helpful to clarify the visual and instrumental findings in clinical dentistry, dental research, and subsequent standardization [27,28].

Perceptibility and acceptability distinguish the color difference and show whether this difference is acceptable. For these reasons, visual thresholds have been used for describing the efficacy of bleaching, by making comparisons between visual and instrumental shade matching and other areas related to compatibility, stability, and interaction of colors [27,29,30].

Paravina et al. 2015 [27] found the perceptibility and acceptability's values of thresholds of 1.2 and 2.7, respectively, by using CIE $L^*a^*b^*$ system. These values can be used as a reference in dentistry research. In our study, when the ΔE values were analyzed it could be clearly seen that irradiated and restored specimens with the micro hybrid (Z250) and nano hybrid (Z350) composite resins showed perceptibility and acceptability threshold values respectively than 1.2 and 2.7.

These results confirm that after RT treatment, it is possible to distinguish color changes in the restored specimens with Z250 and Z350 composite resins using appropriate equipment. In general, the evaluation of color differences is of great scientific interest; specifically, color thresholds are very important for the development of new color systems, to contribute to understanding of mechanisms of color vision and consequently, the development of color science [27,31,32].

A study limitation would be to analyze the color change of specimens made with dentin substrate plus composite resin. However, in the context of RT study this binomial is justifiable. The literature shows that irradiation promotes generalized micro-morphological alterations in the dentin, such as fissures in the dentin structure, dentinal tubules obliteration and fragmentation of collagen fibers accompanied by reduced dentin micro hardness [3,4]. These changes may be due to loss of collagen fiber hydration, leaving the tissue dry and friable. Irradiation of proteins causes alterations in their secondary and tertiary structures, with harmful effects on the hydration of collagen fibers by the action of free radicals [32]. These alterations in dentin tissue may influence not only in the color change of the dentin substrate but also of the composite resins used as restorative material.

Due to the high ΔE results after RT, it is possible to consider that the color change of the binomial, dentin substrate + composite resin, is due more to the serious damage caused to the dentin substrate, than to the color variation of the composite resin itself. However, when the patients to finish RT treatment, the aesthetics can be very important aspect for quality of life.

Although the literature presents several protocols regarding the dental conducts of the irradiated patient in the head and neck region, there is still no consensus regarding the ideal management of these patients. The dental surgeon has fundamental participation in the multidisciplinary team from the diagnostic phases to the stages of the RT treatment to reduce or even prevent the collateral effects. However, to guarantee the maintenance of the color stability of the composite resin the ideal treatment would be the removal of all carious tissue and the placement of ionomeric cement, another kind of restorative materials, suitable for temporary dental treatments. This would adjust the buccal environment so that, after the end of the treatment, the final restorations are performed without the risk of color change and, consequently, without harming the self-esteem of this patient who is already debilitated both physically and psychologically.

The present study was conducted under strict laboratory conditions, and we believe that there is a need for further in vivo and ex vivo studies to address the gaps still found in the literature and to elucidate the possible mechanisms of RT action on the structure and composition of resinous materials.

CONCLUSION

The radiotherapy (RT) promoted a significant alteration in the color of composite resin restorations, with a change in the total color and brightness difference of both composite resins, used in the dental treatments. The total color changes were above the perceptibility and acceptability thresholds reported in the literature, with a darkening effect for both composite resins after RT treatment.

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