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Effect of sterilization with gamma radiation on feldspathic ceramics

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ABSTRACT

Sterilization by gamma radiation is the latest and perhaps the most available methods. However, the effect of gamma radiation on structure and physical properties of dental materials that have been recently developed and introduced to the dental market were not investigated. The aim of our research was to investigate the effect of high energy gamma radiation on microstructure, surface hardness and surface roughness of dental porcelain. Matrix microstructure of dental porcelain changed after exposure to gamma radiation doses. Surface hardness of dental porcelain decreased but surface roughness increased after exposure to gamma radiation doses. Surface dental porcelain color (white) changed into dark color.

INTRODUCTION

Dental ceramics are able to mimic natural teeth due to their excellent physical properties such as esthetics, biocompatibility, low thermal conductibility and wear resistance[1-3]. Because of these features, dental ceramics have been extensively used in several rehabilitation procedures, including inlays, onlays, crowns, and porcelain veneers[4]. Surface smoothness is an important consideration for all fixed dental prosthesis as it has been shown to that the gingiva responds best when it is in contact with a smooth surface[5]. Increasing awareness of infectious diseases and considerations to eliminate cross contamination between the dental operatory and the dental laboratory requires that dental prostheses be disinfected before sending to the laboratory and before delivery to the patient[6-10]. Previous studies have reported the presence of microorganisms transmitted to dental laboratories[11, 12]. Both the American Dental Association (ADA) and Centers for Disease Control and Prevention have established guidelines for cleaning, disinfecting, and handling of dental prostheses transported between dental offices and laboratories[13]. Studies have demonstrated that materials such as topical fluoride preparations can affect the glaze and surface roughness of metal-ceramic restorations[14, 15]. If disinfectants do promote surface roughness, restoration esthetics as well as periodontal health may be harmed. The surface roughness of ceramic would play an important role in initial plaque adhesion[16-18]. Studies have been conducted to assess the surface roughness and methods for disinfecting fixed prosthodontics materials prior to their cementation[19, 20]. Diamond burs and rubber wheels that are used for developing grooves in porcelain materials and for manual polishing[21, 22] can be associated with cross-contamination. Because non damaging methods of sterilization may not be possible, the alternative method is to disinfect the prostheses by immersing in chemical disinfectants[7, 23-25]. Recommendations from the ADA Council on Scientific Affairs on prosthetic materials include spray or immersion with hypochlorite, iodophor, and gluteraldehyde. The choice of disinfectants depends on the type of surface to be disinfected. Incorrect application of disinfectants may affect the physical and or mechanical properties of materials undergoing the disinfection process[26, 27]. However, other study reported that no significant difference in surface roughness of different glazed ceramic specimens disinfected and sterilized with chemical disinfection and autoclaved, respectively. The available disinfection methods for fixed partial dentures are still controversial because they may alter some material properties and clinical features. Ionizing radiation is currently used for the sterilization of heat-sensitive medical devices, pharmaceutical packaging and raw materials[29]. It has also been used to sterilize bone[30]. The resulting damage to the radiated material is proportional to the amount of energy absorbed, which is referred to as the 'dose' and measured in units of energy/kilogram. The SI unit of dose is the Gray (Gy), which is defined as an absorbed radiation dose of 1 J/kg. A dosage of 2.5 megarads kills all bacteria, fungi, viruses and spores[29]. However; no researches were conducted to evaluate the effect of gamma radiation on the surface and microstructure of dental ceramics. Clinical implications: Infection control procedures are indispensable steps before cementation of prostheses. The purpose of this study was to evaluate whether sterilization with ionizing gamma radiation have deleterious effects on the surface texture and color of dental porcelain.

MATERIALS AND METHODS

Porcelain specimens fabrication

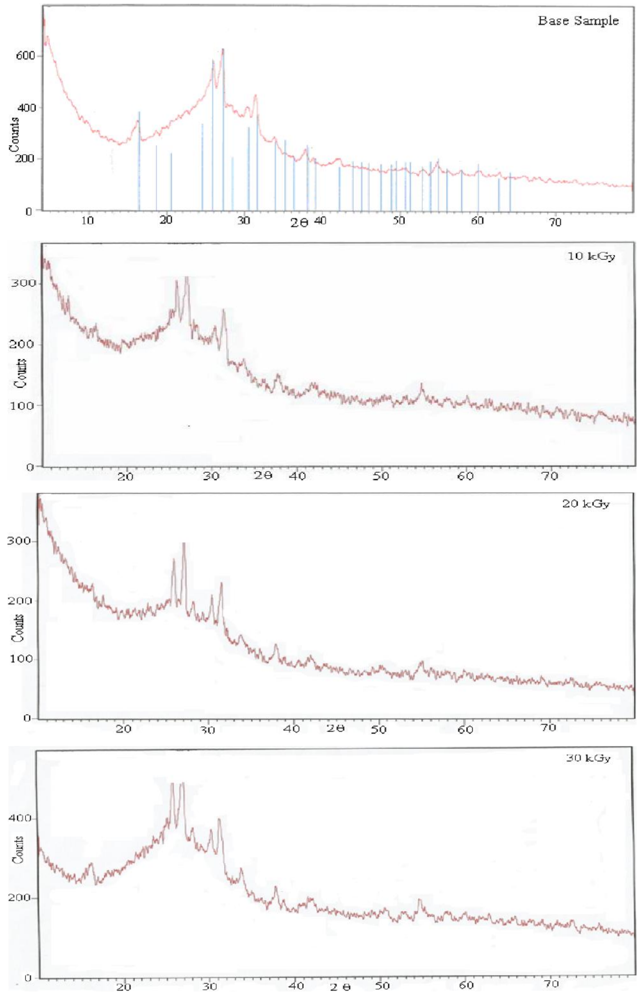
Twenty rectangular-shaped porcelain specimens (Vita VMK, Master, VITA Zahnfabrik, Germany) were prepared in a standardized manner and according to the manufacturer's directions in rectangular stainless steel split mold (40 mm- 5 mm – 3 mm). Porcelain dentine powder and liquid were mixed and then condensed into the mold using vibrator. Tissue was used to absorb excess moisture (Kleenex; Kimberly-Clark, Neenah, Wis). Then porcelain enamel powder and liquid were mixed and condensed into the mold. To compensate firing shrinkage, the amount must have a slightly larger size. The specimens were removed by gentle hand pressure and sintered according to manufacturers' instructions. All specimens were fired in a programmable and calibrated porcelain furnace (Programat P90, Ivoclar-Vivadent, Schaan, Liechtenstein) with the firing cycle. The entire specimens were coated with VITA AKZENT glaze then firing.

Composition of VITA VMK Master

The structure of VITA VMK Master consists of two principal constituents: natural potassium ($KAISi_3O_8$), orthoclase and sodium bicarbonate feldspars ($NaAISi_3O$; albite) constitute the largest proportions and are frequently referred to as tectosilicates in literature since they form three-dimensional networks in the veneering ceramic. Potassium feldspar, which is essential for manufacturing the VITA ceramics, helps to achieve ideal abrasion on the antagonist tooth and chemical stability for the oral system. Orthoclase melts incongruently, i.e. melt and solid reveal different compositions. When using this type of feldspar, a melt is obtained which forms the glass phase and the leucite ($KAISi_2O_6$) during solidification. Leucite represents the crystalline phase of the VMK materials and is essential for the ceramic materials in two respects: on the one hand, it ensures the stability, i.e. it guarantees that the shape of firing object remains unchanged even at high temperatures. On the other hand, the coefficient of thermal expansion (CTE) of the veneering ceramic is controlled by the proportion of leucite. Moreover the crystals cause increased strength of the veneer and reduce crack propagation. With 15 - 25%, quartz is another main constituent and is added to increase the proportion of the glass phase and hence the traslucency. Metal oxides are also added to the veneering ceramics to optimize the optical properties. Accordingly, metal oxides are used as opacifiers and thus the translucency and the opalescence are adjusted. In addition to the metal oxides, pigments are added to the VITA metal ceramics, which are produced in a special fritting process; these pigments are not burned and remain unchanged over the years but determine the final shade of the fired ceramic and thus provide the restoration with long-term shade stability.

Tests

The specimens used in the present work are dental porcelain. The specimens were prepared in convenient shape for all tests such as microstructure, Vickers microhardness, and surface roughness. Microstructure of used specimens was performed on the flat surface of all specimens using an Shimadzu X–ray Diffractometer (Dx–30, Japan) of Cu–Kα radiation with λ=1.54056 Å at 45 kV and 35 mA and Ni–filter in the angular range 2θ ranging from 0 to 90° in continuous mode with a scan speed 5 deg/min. Microhardness test of used specimens were conducted using a digital Vickers microhardness tester, (Model FM–7, Tokyo, Japan), applying a different loads for different indentation time via a Vickers diamond pyramid. The arrangement of hand surface (Surfest SJ201.P) which used in measurements of surface roughness in the present work.



Figures 1 : X-ray diffraction patterns of dental porcelain before and after exposure to gamma radiation doses

RESULTS AND DISCUSSIONS

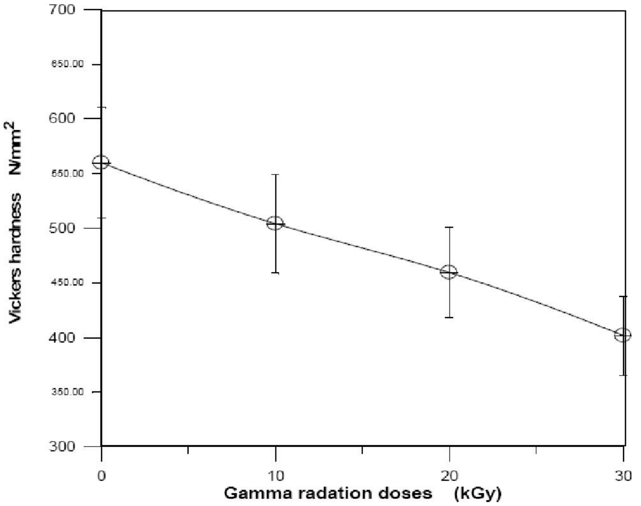
X-ray analysis

Any interactive effects between the incident gamma radiation beam and such dental materials might be of clinical significant if the properties of these dental materials are adversely affected.

Effect of high energy gamma radiation on microstructure was studied by x-ray diffractometer. Figure 1 shows x-ray diffraction patterns of dental porcelain before and after irradiated by different gamma radiation dosage, (10, 20 and 30 kGy). The analysis of x-ray diffraction patterns (intensity, position and orientation) shows a variation in the main matrix peak (amorphous part) and other formed phases (accumulated particles or cluster) due to the interaction of high energy gamma radiation with the dental porcelain matrix.

Vickers hardness

Hardness is a property with a low coefficient of variation when compared with other mechanical properties tested. In general hardness is defined as “Resistance of material to plastic deformation”, usually by indentation. However, the term hardness may also refer to stiffness or temper or resistance to scratching abrasion, or cutting. The microhardness value was conducted using a digital Vickers microhardness tester, applying a load of 100 g for 5 s, for dental porcelain. Vickers hardness value of dental porcelain before and after irradiated by different gamma radiation dosage, (10, 20 and 30 kGy), are shown in Figures 2. Vickers hardness value of dental porcelain decreased after exposure to gamma radiation and that is agree with other pervious results[31, 32]. That is because the high energy gamma radiation could break the established bonds in matrix which results in a



Figures 2 : Vickers hardness of dental porcelain before and after exposure to gamma radiation doses decrease in hardness or promotes simultaneously the linking and breaking the bond. Also gamma radiation affects porcelain matrix structure as shown in x-ray diffraction patterns.

Roughness

The roughness profiles of dental porcelain before and after exposure to gamma radiation doses (10, 20 and 30 kGy) are shown in Figure 3. The average surface roughness parameter Ra along the total sliding distance and other roughness parameters before and after exposure to gamma radiation doses are listed in TABLE 1. From these results, it is clear that the average surface roughness parameter Ra and other roughness parameters are increased after exposure to gamma radiation doses.

TABLE 1 : Average surface roughness parameter ra and other roughness parameters before and after exposure to gamma radiation doses

Roughness parameters	Base	10 kGy	20 k Gy	30 kGy
Ra um	0.74	1.15	0.78	0.78
Rz um	3.01	4.79	3.17	2.81
Rq um	0.91	1.44	0.90	0.98
Rt um	5.74	7.85	5.56	5.92
Rp um	1.20	2.58	1.61	1.30

CONCLUSION

1. Microstructure of dental porcelain changed after exposure to gamma radiation doses
2. Vickers hardness value of dental porcelain decreased but surface roughness parameters increased after exposure to gamma radiation doses
3. The porcelain surface color changed after exposure by gamma radiation doses

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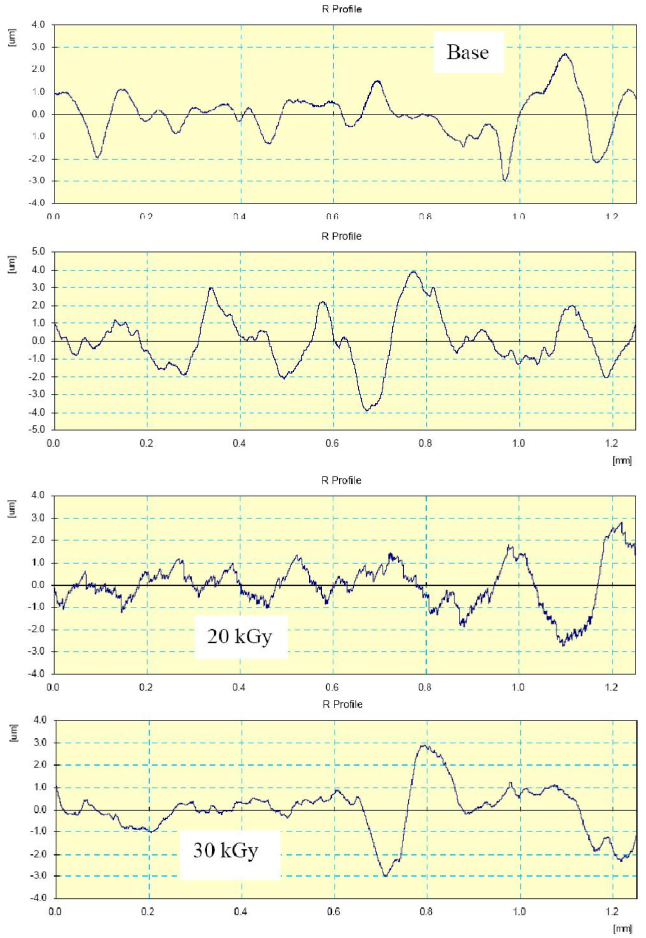

Figure 3 : roughness profiles of dental porcelain before and after exposure to gamma radiation doses

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