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Effect of Gamma Radiation on Mechanical Properties of Tooth Structure

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ABSTRACT

This in vitro study was made to evaluate the effect of gamma radiation on mechanical properties of tooth structure. A total number of 40 human premolar teeth were collected. The teeth were healthy and were freshly extracted and they were stored in distilled water for periods of less than one month the teeth were, free from any apparent caries, macroscopic cracks, and abrasion and staining as assessed by visual examination.

The teeth were divided into 2 groups of 20 teeth each (A and B) The groups were:

1. Group (A) which served as a control.
2. Group (B) which subjected to 60 Gy of γ- radiation.

The result showed the enamel microhardness increased after adose of 60 under the limitation of this study it was found that. The enamel microhardness increased at a dose of 60GY whereas the value of dentin microhardness decreases.

INTRODUCTION

Head and neck cancers exist at high frequencies in the population, with an incidence of 500,000 new cases per year [1]. In Brazil, the National Cancer Institute (Instituto Nacional do Câncer - INCA) has reported more than 9,000 new cases of childhood cancer per year[2]. Although the incidence of head and neck neoplasms in children is low, the peculiarities of treatment,prognosis, and age-inherent toxicities should be considered [3,4].Radiation therapy is a therapeutic modality that is widely used to treat head and neck cancer. Although radiation therapy may promote healing, head and neckirradiated patients are

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susceptible to oral complications,including mucositis, xerostomia, taste loss, trismus,progressive loss of the periodontal ligament, microvascular alterations, soft tissue necrosis, osteoradionecrosis, and dental caries [5].

Radiation-related caries or "radiation caries" is one of the highest indirect and late effects of radiation in the head and neck region [6]. This complication is a complex and destructive disease that causes severe destruction of the tooth enamel and dentin in head and neck-irradiated patients [5,7,8] and has negative effects on their quality of life [8]. Scientific evidence indicates that patients incur a lifelong risk of developing radiation caries following radiation therapy [7].The effects of radiation therapy on the onset and progression of a caries lesion might be direct or indirect [8].The indirect effects of irradiation include changes in the quality and quantity of saliva, difficulty in performing proper oral hygiene, increased intake of cariogenic foods,and changes in the oral microbiota [5,7,9]. Radiation therapy may also exert direct effects on the dental structure,including changes in the crystalline structure, enamel and dentin microhardness, dentinoenamel junction, and acid solubility of the enamel; these effects might be involved in the pathogenesis of the disease [6,10-16]. The direct effects of radiation on the deciduous dentitionare still unknown because studies addressing this issue have only been conducted in bovine teeth and in human permanent teeth. Therefore, the aim of the current study was to perform an in vitro assessment of the effects of radiation therapy on the mechanical and morphological properties of the enamel and dentin of deciduous teeth using microhardness testing.

MATERIALS AND METHODS

Teeth selection

A total number of 60 human premolar teeth were collected for orthodontics reasons. The teeth were sound and were freshly extracted and they were stored in distilled water for periods of less than one month the teeth were, free from any apparent caries, macroscopic cracks, abrasion and staining as assessed by visual examination. The teeth were cleaned, polished, refrigerated, and stored in artificial saliva before beginning the experiment. The teeth were randomly divided into 2 groups (Control and Gamma), each containing 20 teeth.

The groups were:

1. Control group: considered as a control.
2. Gamma group: subjected to 60 Gy of γ- radiation.

Microhardness assessment

Surface microhardness of the specimens was determined using DigitalDisplay Vickers Microhardness Tester (model: Shimadzu HMV) with a Vickers diamond indentor and a 20X objective lens (Fig. 1). A load of 200gm was applied to the buccal surface of the specimens for 20 seconds. Three indentations were equally placed over a cycle of 1 mm diameter at the buccal surface of the enamel and the dentin of the specimens. The diamond shaped indentations were carefully observed under the microscope. Image analysis software allowed accurate digital measurements of their diagonals. Microhardness Vickers values were converted into microhardness values MHV following this equation**:**

MHV=1.854 P/d2

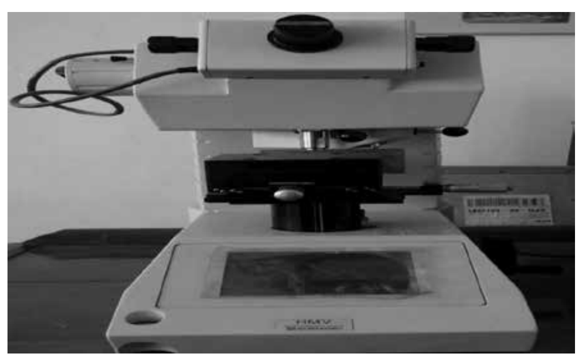

Fig. (1) Vickers Microhardness Tester. A: Eye Piece lens, B: Working table,C: Loading force hand wheel, D: Digital screen

Where;

MHV Vickers microhardness values in Kgf/mm2

P the load in Kgf

D the length of the diagonals in mm

The hardness was measured at baseline, before and after the PH cycling.

Statistical Analyses

All the data were collected, tabulated and analyzed by ANOVA test. Data analysis was performed in several steps. Initially, descriptive statistics for each group results was done. One-way analysis of variance ANOVA test followed Newman-Keuls post-hoc were done for comparing variables affecting mean values. Student t-test was done to detect significance between paired groups. Statistical analysis was performed using Aasistat 7.6 statistics software for Windows (Campina Grande, Paraiba state, Brazil). P values ≤ 0.05 are considered to be statistically significant in all tests.

RESULTS

Table (1) *Comparison of the DTS results (Mean±SD) between* ***Gamma*** *and* ***Control*** *groups*

Variable	Mean±SD	t- test	
Gamma group	9.649 ± 1.9	t-value	P value
Control group	11.89 ± 3.573	2.18	0.0404*

*ns; non-significant (P>0.05) *; significant (P<0.05)*

Table (2) *Comparison of the HV results (Mean±SD) between* ***Gamma*** *and* ***Control*** *groups – Enamel was shown in table (10), figure (15)*

Variable	Mean±SD	t- test	
Gamma group	294.4 ± 14.31	t-value	P value
Control group	261.7 ± 19.67	3.56	0.0031*

*ns; non-significant (P>0.05) *; significant (P<0.05)*

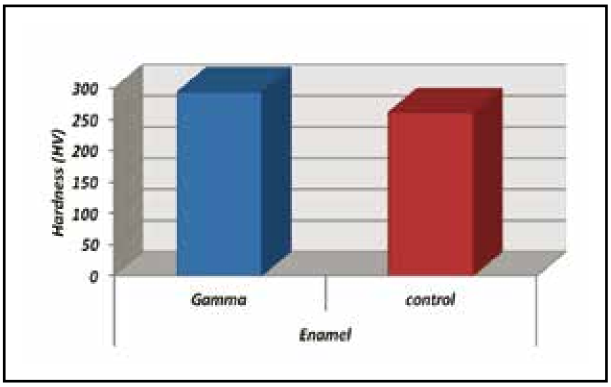

Fig. (2) A column chart comparing HV mean values between ***Gamma*** and ***Control*** groups- Enamel

Laser+gamma group **vs.** ***Control*** **group**

Comparison of the HV results (Mean±SD) between ***Laser*** + gammaand ***Control*** groups - Enamel

It was found that ***Laser+gamma*** group recorded higher HV means value than ***Control*** group.

The t-test analysis showed significant difference between both groups (t= 3.8; P= 0.0017< 0.05).

Table (3) *Comparison of the HV results (Mean±SD) between* ***Gamma*** *and* ***Control*** *groups - Dentin*

Variable	Mean±SD	t- test	
Gamma group	52.00 ± 6.29	t-value	P value
Control group	53.72 ± 3.52	0.62	0.5529ns

*ns; non-significant (P>0.05) *; significant (P<0.05)*

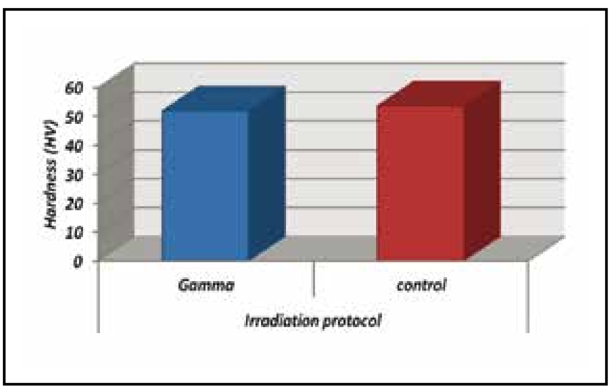

Fig. (3) A column chart comparing HV mean values between Gamma and Control groups- Dentin

DISCUSSION

The results of the present study demonstrate that in vitro irradiation of deciduous teeth altered the micro hardness and structure of both enamel and dentin. Complications from radiation therapy may vary depending on the general condition of the patient, the tumor characteristics (such as the histological type, location and volume), and radiation features (such as the radiation type, dose, and application rate). The doses for cancer treatment in children range from 50 to 70 Gy, depending on the tumor and the hospital routine protocols [17,18]. However, studies have demonstrated that late effects also depend on the fractionation dose [19,20]. Because treatment protocols have changed considerably over the years and because fractionation doses vary within and between patients, the fractionation dose should also be considered in the evaluation of late effects [19]. The daily dose is normally2 Gy/day, 5 days/week, interspersed by 2 days without radiation, such that the healthy tissues adjacent to the tumor can recover[5,7]. The maximal dose of 60 Gy, which is used for radiation therapy of head and neck tumors [21], was chosen in the present study to simulate the clinical conditions of radiation therapy. Additionally, in the current study, the samples were placed in artificial saliva during irradiation to simulate, as precisely as possible, the conditions that are found in the oral cavity [16]. However, other media, including 0.9% saline solution [6,13], distilled water [11,15], or buffered phosphate solution [11], have been used to store teeth in similar studies. Although artificial saliva does not exactly mimic the characteristics of natural saliva, especially in the case of patients undergoing head and neck radiation therapy, who present changes in the flow, secretion, and composition of natural saliva [22], artificial saliva is still considered the most suitable storage medium [16,23].Studies of the structural changes in enamel and dentin following irradiation are controversial [6,11-13,15,16]. The conflicting results that have been observed are most likely due to the lack of standardization of the methodology in the various studies assessing the direct radiogenic damage to the enamel and dentin. These investigations have used dental substrates of either bovine origin[11-13] or human origin [6,7,15,16], which have been subjected to different doses of radiation [14] and different methods of radiation, mostly with fractional irradiation and some without [12,24]. The novel findings of the present investigation demonstrates that ionizing radiation led to a dose-dependent increase in the enamel micro hardness, and a cumulative dose of 60 Gy yielded the highest micro hardness values. These findings contrast with previous investigations of permanent teeth that demonstrated either that the micro hardness of irradiated enamel is lower than that of nonirradiated enamel[28] or that there is no change in micro hardness as a function of radiation[10,11]. However, the present study was conducted using teeth, and these teeth might respond differently to radiation therapy. Furthermore, ionizing radiation may cause restructuring of the crystal structures of mineralized tissues [10] and thereby modify their physical properties, including the structural micro hardness. In the present study, the enamel micro hardness was affected based on the region of the tooth, as the highest values of enamel micro hardness were found near the dentin enamel junction followed by the middle region, with the lowest micro hardness values being observed at the surface. Nondried enamel contains approximately 12% water by volume [12]. In this context, it is noteworthy that this water content is higher in the area of the dentino enamel junction. Radiation may cause a reduced water content in tissues [29], and tissue dehydration leads to increased organic matrix stiffness and, consequently, to increased micro hardness. Specifically, in the dental enamel, this increased stiffness may cause are duced capacity of the tissue to absorb and dissipate the impact energy due to occlusal loading, making the tissue more friable. In clinical practice, this phenomenon has been observed in patients undergoing head and neck radiation therapy, whose enamel appears to detach from the dentin in regions where these tissues connect, namely, the dentino enamel junction, which is the region where the greatest increase in enamel micro hardness is found. Tooth enamel is organized into prisms, the orientation of which determines the anisotropic performance of the enamel and affects its mechanical properties [29]. SEM revealed morphological changes in the enamel structure following cumulative irradiation with 30 and 60 Gy, characterized by an increasingly disorganized prismatic structure as the cumulative dose of radiation increased, as previously described for bovine teeth [10]. This change in the enamel crystalline structure has been suggested to be one of the factors related to the increased risk of dental caries following radiation therapy[21]. Although the enamel composition is essentially inorganic, the initial damages from irradiation occur in the organic portion of the enamel, that is, in the inter prismatic space, via the oxidation of water molecules into hydrogen peroxide and hydrogen free radicals that denature the organic components [24]. Consequently, the mechanical properties and integrity of the enamel are affected [6]. However, we demonstrated in the present study that irradiation also caused changes in the prismatic structure of the enamel, suggesting that the clinically observed radiation effects result from changes in both organic and inorganic compounds in the enamel. The clinical extrapolation of findings from the in vitro or in situ studies that have evaluated the structure,

CONCLUSION

Under the limitation of this study it was found that:

1- The enamel microhardness increased at a dose of 60GY whereas the value of dentin microhardness decreases.

2- However the gamma group showed the lowest value of DTS of dentin.

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