Mechanical Properties of Denture Base Resins after Exposure to Electron Beam Radiation

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ABSTRACT

BACKGROUND

The mechanical properties of polymers can be improved by electron beam irradiation. The aim of this study is to evaluate the mechanical properties of denture base resins after irradiation with electron beam with an energy dose of up to 25 KGy.

METHODS

In this study, four different denture base resins were used namely, DPI, Trevalon, Trevalon HI, and Meliodent heat cure acrylic resins. Mechanical properties of the denture base resins after exposure to electron beam post-curing were studied. The irradiated denture base resins are compared with untreated control groups.

RESULTS

Our study showed that PMMA-based denture resins improved the mechanical properties after irradiation with electron beam. As the radiation dose increases to 25 KGy, the polymeric structure starts to break down, and C–C bonds are split off during electron beam irradiation.

CONCLUSIONS

Mechanical properties such as flexural strength, impact strength, and hardness of DPI heat cure acrylic resin, Trevalon, Trevalon HI, and Meliodent heat cure acrylic resins can be modified by the lower dosage of electron beam irradiation. Denture base resin is not only used for 'unbreakable' dentures but also to construct of skeletally designed heat cure dentures. This is possibly only with high strength polymers. So, research is continuing for higher strength denture base resin. By comparing the flexural strength and impact strength of all heat cure denture base resins (DPI heat cure acrylic resin, Trevalon, Trevalon HI, and Meliodent heat cure acrylic resins) after irradiation, with flexural strength and impact strength of all heat cure denture base resins before irradiation, it was observed that – irradiated heat cure denture base resins had more impact strength and flexural strength than unirradiated heat cure denture base resins. It was also found that on comparing the hardness of all heat cure denture base resins before and after exposure of radiation, radiated heat cure denture base resins were harder than unirradiated heat cure denture base resins.

KEY WORDS

Electron, Radiation, Denture Base, Flexural Strength.

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BACKGROUND

Acrylic resins are the most commonly used polymeric materials in denture dentistry, the majority of which are Polymethylmethacrylate (PMMA). For more than 50 years, Polymethyl methacrylate (PMMA) resins have dominated as denture base materials. PMMA is used mainly in medical and dental applications. It has good biocompatibility. Polymethyl methacrylate is classified as heat curing, chemical (auto) curing, light curing, or microwave curing according to their mode of the chemical reaction (free radical generation), The basic constituents of PMMA are Methyl esters of methacrylic acid. To get the desired characteristics of Polymethyl methacrylate, several additional constituents are added. The polymerization mechanism involving the conversion of monomers to polymer in both the heat and auto curing reactions. For a heat-activated reaction of polymer, chain propagation initiated by the decomposition of the initiator (primarily dibenzyl peroxide) into free radicals under heat.

Acrylic resin is used as a denture base material in dentistry since 1937. Later it has revolutionized in a big way, Polymethyl methacrylate (PMMA) is used as denture base material. PMMA is used in medical and dental applications. It has exhibited excellent Biocompatibility when, in its bulk, It has excellent colour stability and exceptional aesthetic properties. It can be used for the construction of dentures with a simple technique. The polymerization mechanism involving the conversion of monomers to polymer in both the heat and auto curing reactions. The decomposition of the initiator (primarily benzoyl peroxide at 65^{0}C) into the material. He majority free radicals under heat initiate chain propagation for a heat-activated reaction.[1-6]

The polymerization of chemically curing acrylics is triggered via a redox reaction occurring at the oral temperature, mainly under the influence of an accelerator. Comprising the amine-peroxide redox system. Accelerator used is a primary amine, sulfinic acid, or substituted barbituric acid.

Light curing and microwave curing acrylics are derived partly from the PMMA and partly from urethane dimethacrylate (UDMA and ethylene glycol dimethacrylate [EGDMA]. Two important considerations for biopolymers are residual monomer content and the monomer to polymer conversion. Biopolymers are used in oral tissues. When different types of stresses applied to denture base resins cause a fracture, repeated masticatory forces lead to fatigue phenomena Intra-orally and as a result of dropping the prosthesis extra-orally, high-impact forces may occur.

When small flexural stresses are applied repeatedly on the denture, lead to the formation of small cracks that propagate through the surface of the denture surface, resulting in a fracture. This type of fracture is called fatigue. Material choice and fabrication design fracture of denture occurs.

However, this material does not possess the ideal requirements, namely a good combination of mechanical and biological characteristics, required for dental materials. For designs of dentures, Dentists, and manufacturers searching for ideal materials. But there are still some problems with physical and mechanical properties with these materials.

When different types of stresses are subjected to Denture base resins causes fractures. Repeated masticatory forces lead to fatigue phenomena intra-orally, as a result of dropping the prosthesis, extra-orally high-impact forces occur. Additionally, fracture of denture related to fabrication design and material choice.[7-10]

To improve the mechanical properties of polymers, electron beam irradiation is widely used, normally used polymers are polyethylene, polystyrene, and polycarbonate. In the 1950s, the first Electron beam irradiation of polymers was done, in the industry. This method has been used successfully. However, in publications of dentistry, a few studies can be found. Higher bond strength of polymer after radiation is due to increase the stiffness of polymers as well as the links between polymer chains. The effect of the electron beam can cause two types of irradiation-initiated reactions. The degradation of polymers or breaking chains. Electron -beam irradiation creates free radicals. This free radical can recombine, forming the crosslinks. The degree of crosslinking depends upon the polymer and radiation dose. From many years onwards, this mechanism of crosslinking by irradiation has been studied. However, its exact nature of the mechanism is still not agreed upon. When polymers are cross-linked tensile strength is increased. The overall effect of crosslinking is that the mechanical properties of polymer increased with electron beam radiation.

Exposure of high-energy irradiation is a modern method used to improve the properties of polymers and composites. The mechanism of crosslinking by irradiation has been studied for many years. But Proper reason for improving properties is still not agreed.[11-14] Knowledge of physical, mechanical, chemical, biological, properties is Imperative. The use of unirradiated polymer material with normal fabricated methods shows reasonably satisfactory results.

METHODS

In the present study, DPI heat cure acrylic resin, Trevalon, Trevalon HI, and Meliodent denture base resins are used. 25 samples of each heat cure resins were prepared. Each sample is exposed to different electron beam radiation doses from 5 KGy to 25 KGy. The influence of electron beam post-curing on Mechanical properties of the polymer denture base resins is investigated. Flexural Strength, Impact strength and hardness of each sample after exposure to different electron beam radiation doses are measured

Flexural Strength Measurement

One of the important properties of denture base resins in clinical application is Flexural strength. Different denture base resins, DPI heat cure acrylic resin, Trevalon, Trevalon HI, and Meliodent are taken. 25 samples of each heat cure resins were prepared. After exposed to different electron beam radiation, the Flexural strength of DPI heat cure acrylic resin, Trevalon, Trevalon HI, and Meliodent heat cure acrylic resins was determined. The three-point bend test measures flexural strength. Universal Instron testing machine [Instron 4467, England] at a crosshead speed of 2 mm/min is used for measuring flexural strength by a three-point bend test., the three-point bend test was done for each specimen in this manner.

For flexural strength measurement, the fixture was fabricated with the dimensions of length, 80 mm; width, 30 mm; and thickness, 30 mm in the three-point bend test. On either side, on the top of the fixture, two grooves were made at a distance of 25 mm from the center. In each groove, a roller with a diameter of 4.25 mm was placed. T-shaped stress applying rod with the dimensions of 60 mm x 10 mm was fabricated. Stress is applied in the center of the specimen. The specimen was placed on the rollers in such a way that the center of the distance between the two rollers coincided with the center of the specimen. In the Universal Instron testing machine, the stress-applying rod was fixed in the upper jaw, and the whole unit was mounted on the lower jaw. Until fracture, a load was applied with a T-shaped rod in the center of the specimen. Load at which specimen fractured is measured. Using the following equation, flexural strength is measured.

$$FS = \frac{3\,PL}{2\,BH^2}$$

P = dead load weight
L = span
B = width of test sample
H = depth

Impact Strength Measurement

The strength of denture base resins is evaluated mainly on the impact test. After exposure to different electron beam radiation doses, the impact strength of DPI heat cure acrylic resin, Trevalon, Trevalon HI, and Meliodent heat cure acrylic resins was measured. The impact strength was determined using an Izod impact tester on un-notched specimens. The impact strength of denture base was calculated as follows-

$$\text{Impact strength} = \frac{\text{Energy Absorbed}}{\text{Width} \times \text{Thickness}}$$

Hardness

It can be hypothesized that denser materials will be more resistant to wear and surface deterioration, and the risk of perforation of the material will be decreased. Surface hardness can be studied by density. Structural integrity will be maintained for a longer time. Vickers hardness was measured using a Vickers hardness measurement device. Vickers hardness measurement device B 3212001 (Zwick, Ulm, G) has a pyramid-shaped indenter. A pyramid-shaped loading dies with a weight of 0.5 kg for 60 sec loaded on the sample surface. Applied load and the area of the indention was measured. Proportional applied from these values Vickers hardness (VH) of denture base resin is measured. It is directly loaded and inversely proportional to the area of indentation.

RESULTS

It was observed that as the radiation dosage increases, the flexural strength of denture base resin increases. As the radiation dosage increases from 5 KGy to 25 KGy Flexural strength of DPI Heat cure resin is increased from 83.77 MPa to 94.56 MPa, Flexural strength of Meliodent is increased from 101.45 MPa to 107,33 MPa. Trevalon is increased from 154, 89 MPa to 170. 54 MPa and Trevalon HI is increased from 134.41 MPa to 150.44 MPa. These results are shown in (Table 1).

Impact strength of denture base resins increases as the irradiation dosage increases. As the radiation dosage increases from 5 KGy to 25 KGy Impact strength of DPI Heat cure resin is increased from $5.98*10^{-3}$ N-mm to $7.3*10^{-3}$ N-mm Impact strength of Meliodent is increased from $7.4*10^{-3}$ N-mm to $7.9*10^{-3}$ N-mm Trevalon is increased from $5.2*10^{-3}$ N-mm to $6.1*10^{-3}$ N-mm, and Trevalon HI is increased from $7.5*10^{-3}$ N-mm to $8.3*10^{-3}$ N-mm These results are shown in (Table 2).

It was observed that the Hardness of denture base resins increases as the radiation dose increases. As the radiation dosage increases from 5 KGy to 25 KGy Hardness of DPI Heat cure is increased from 19.4 VHN to 23.58 VHN, Hardness of Meliodent is increased from 21.44 VHN to 29. 42 VHN. Trevalon is increased from 15.42 VHN to 19.70 VHN. And Trevalon HI is increased from 12.67 VHN to 17. 71 VHN These results are shown in (Table 3)

Type of Material Radiation Dose	DPI Heat Cure (MPa)	Meliodent (MPa)	Trevalon (MPa)	Trevalon HI (MPa)
5 KGy	83.77	101.45	154.89	134.41
10 KGy	86.55	103.57	160.47	138.54
15 KGy	90.78	104.66	163.76	142.06
20 KGy	91.86	105.44	164.56	147.93
25 KGy	94.56	107.33	170.54	150.44

Table 1. Flexural Strength

Type of Material Radiation dose	DPI Heat Cure (N-mm)	Meliodent (N-mm)	Trevalon (N-mm)	Trevalon HI (N-mm)
5 KGy	$5.98*10^{-3}$	$7.4*10^{-3}$	$5.2*10^{-3}$	$7.5*10^{-3}$
10 KGy	$6.34*10^{-3}$	$7.4*10^{-3}$	$5.5*10^{-3}$	$7.7*10^{-3}$
15 KGy	$6.8*10^{-3}$	$7.6*10^{-3}$	$5.87*10^{-3}$	$7.8*10^{-3}$
20 KGy	$7.0*10^{-3}$	$7.8*10^{-3}$	$5.89*10^{-3}$	$8.0*10^{-3}$
25 KGy	$7.3*10^{-3}$	$7.9*10^{-3}$	$6.1*10^{-3}$	$8.3*10^{-3}$

Table 2. Impact Strength

Type of Material Radiation Dose	DPI heat Cure (VHN)	ME Liodent (VHN)	Trevalon (VHN)	Trevalon HI (VHN)
5 KGy	19.4	21.44	15.42	12.67
10 KGy	19.8	24.63	14.56	12.98
15 KGy	21.45	25.45	16.73	14.05
20 KGy	22.67	26.95	18.05	15.57
25 KGy	23.58	29.42	19.70	17.71

Table 3. Hardness

DISCUSSION

In industrial products such as machine bodies, cars, and insulators, electron beam irradiation widely used. The most commonly used irradiated polymers are Polyethylene, polystyrene, and polycarbonate. In dentistry, electron beam irradiation of polymers has not been used. The stiffness of polymers, as well as the links between polymer chains, increased after exposure of Electron beam irradiation. It is reported by Behr (Behr et al., 2006). Chain linkage and chain breakage are two types of irradiation-initiated reaction occurs during radiation. Several parameters, such as the structure of the polymer, the energy dose, and residual double bonds (Ungar, 1981; Seguchi et al., 2002; Behr et al., 2005a), dominates this mechanism. It has been observed that the radical build-up of all components of a polymer was initiated by electron beam irradiation (Behr et al., 2006) during the irradiation-initiated reaction, from several distinct points radicals, which induce chain linkage, are initiated. But this chain linkage is not equally distributed in the polymer. Thus the polymeric chain is increasing. When electron beam irradiation, the entire polymer may simultaneously be newly arranged and crosslinked.

On exposure of high-energy ionizing radiation, i.e., electron beam, gamma, or x-ray. E-beam irradiation on polymers, It creates free radicals. These free radicles can recombine, forming cross-linked. Cross-linking and breaking chains are two types of reactions that take place in the polymer when the exposure of electron beam irradiation on the polymer. The degradation of polymers or breaking chains, reducing the molecular weight. Electron -beam irradiation creates free radicals. These free radicals can recombine, forming the crosslinks. The degree of crosslinking depends upon the polymer and radiation dose. The degree of crosslinking controlled by the amount of electron irradiation dose l After irradiation, oxidation can continue. As a result of the oxidation properties of polymer changes with time. The polymer is a thermoplastic material. Electron beam radiation of thermoplastic material enhances mechanical properties. Tensile strength, flexural strength is increased when the electron beam irradiates polymers. This is due to the formation of cross-linkage during exposure to radiation. A conceivable reason for the molecular weight increased by the higher dosage was a crosslinking between free monomers or polymer chains. While the Mn, the value of elastane samples did not change. Formation of cross-linkage during exposure of radiation, Molecular weight increases, or low molecular weight constituent losses. This shows that the surface degradation of polymers occurs in the absence of stress.

Some insight into the influence of electron beam post-curing on polymer PMMA is observed Increased during the analysis of the data in the present study. In the literature, polymethyl methacrylate (PMMA) is often described as a thermoplastic polymer. During electron beam irradiation, chain linkage induced in polymethyl methacrylate (Behr et al., 2005b, c). This shows that after exposure to electron beam irradiation, mechanical properties of mostly PMMA-based denture resins could be improved. Although as the radiation dose increases till 25 KGy. The polymeric structure starts to break down, and C–C bonds are split off during electron beam irradiation. All the denture base resins (DPI heat cure acrylic resin, Trevalon, Trevalon HI, and Meliodent heat cure acrylic resins) in the present study showed the improvement in mechanical properties, but with no effect on solubility and sorption.

CONCLUSIONS

Mechanical properties such as flexural strength, impact strength, and hardness of DPI heat cure acrylic resin, Trevalon, Trevalon HI, and Meliodent heat cure acrylic resins can be modified by the lower dosage of electron beam irradiation. Denture base resin is not only used for 'unbreakable' dentures but also to construct of skeletally designed heat cure dentures. This is possibly only with high strength polymers. So, research is continuing for higher strength denture base resin. By comparing the flexural strength and impact strength of all heat cure denture base resins (DPI heat cure acrylic resin, Trevalon, Trevalon HI, and Meliodent heat cure acrylic resins) after irradiation, with flexural strength and impact strength of all heat cure denture base resins before irradiation, it was observed that – irradiated heat cure denture base resins had more impact strength and flexural strength than unirradiated heat cure denture base resins. It was also found that on comparing the hardness of all heat cure denture base resins before and after exposure of radiation, radiated heat cure denture base resins were harder than unirradiated heat cure denture base resins.

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