Comparison of Fracture Toughness between Four Different Types of Heat Activated Denture Base Resins before and after Exposure to Electron Beam Irradiation: An Invitro Study

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Abstract: Electron beam irradiation can be used to improve the physical and mechanical properties of polymers. The aim of this study was to investigate the influence of electron beam irradiation with an energy dose up from 5 to 50 kGy on the Fracture toughness property of polymer denture base resins. The four different denture base resins used in study are DPI, Trevalon, Trevalon HI and Meliodent heat activated acrylic resins. The influence of electron beam post-curing on Fracture toughness of the polymer denture base resins was investigated. The irradiated denture base resins were compared with untreated control groups. It has been demonstrated that the Fracture resistance of mostly PMMA-based denture resins could be improved using electron beam irradiation only up to 25 kGy, although as the radiation dose increases above 25kGy toughness get reduced. It appears that during irradiation, C–C bonds are split off and the polymeric structure starts to break down after certain dose of radiation. The findings of the present study demonstrate that all the investigated denture base resins show improvement in mechanical properties that is fracture toughness.

Keywords: Electron beam Irradiation, Denture base resins, Fracture Toughness, Fracture Resistance, Polymers, Toughness, Heat Activated, Radiation

1. INTRODUCTION:

The introduction and use of acrylic resin as a denture base material for more than 70 years majority of which embrace the Polymethylmethacrylate (PMMA). It can be heat activated, chemical activated or Light activated denture base resins. Heat activated is commonly used in denture fabrication applications and has exhibited outstanding mechanical and Physical properties and can be used with a simple technique for the creation of Removable complete or partial dentures. The polymerization reaction involving conversion of monomers to polymer, in both the heat, Light and chemical curing reactions Benzoyl peroxide initiator break down into free radicals under heat, initiates chain reaction for a heat activated acrylic resins.[1-5] Many different materials have been used for denture bases. Historically materials such as bone, wood, ivory, and vulcanized rubber were utilized; now poly methyl methacrylate (PMMA) is used.[6-10] New materials such as polystyrene and light-activated urethane dimethacrylate have been developed, but PMMA remains the preferred material for removable complete and partial prostheses. Some materials rely on high levels of crosslink resin and heat activated initiators to maximize the physical properties of the processed materials. Other formulations like Lucitone 199 employ a PMMA polymer modified by adding a rubber compound to improve shock resistance and improve strength properties.[11]

The ideal requirement of denture base material should include physical, Mechanical and chemical properties. Some of these properties include biocompatibility, esthetics, good bond strength with acrylic denture teeth, Fracture and Fatigue resistance, ease of repair, and should possess color stability over period. The denture base st be strong enough to allow the prosthesis to withstand occlusal masticatory forces.[12]

Causes of denture fractures are more often related to design errors rather than problems with the resin itself. Denture failures can occur in excessively thin areas or weakened flanges around frenal notches.[13]Midline fractures of denture base resins are especially troublesome, leading some to recommend selectively increasing the bulk of material in regions subject to deformation and fractures. These locations include the palatal incisal junction, the posterior palatal midline, and the mandibular incisal area adjacent to the lingual and labial frenal attachments. Increasing bulk, however, can lead to other problems. A denture base that is too thick can cause gagging or dislodgement of the denture when the patient opens wide or yawns.[14-16]

A variety of mechanical properties can be used to assess the strength of denture materials. The most common tests include flexural strength, the force needed to deform the material to fracture or irreversible yield; and flexural modulus, a measure of the stiffness of a material. In addition, the distance a material specimen can be deformed (yield distance) before failure also is an indication of the toughness of a material. Because of the risk of fracture should a patient drop their denture by mistake, high Fracture toughness is a desirable property. Given the function of a denture base in a removable complete or partial prosthesis, high flexural modulus would help resist torsional forces in function leading to a longer life for any type of the prosthesis. The purpose of this study was to determine flexural modulus of four different types of denture base resins.[17]

A modern method to improve the properties of polymers and composites is use of different type of radiation. Microwave, Ionizing and electron beam radiation has been used in different studies.

Electron beam irradiation had been used recently to study its effect on polymers. The mechanism of cross-linking and chain breakage by irradiation has been studied by different authors. However, there is still no agreement as to its exact nature.[18]

The Purpose of this study is to find the fracture toughness of different heat activated denture base resins and effect of Electron beam irradiation at different dosage level by comparing between irradiated and non-radiated samples

2. MATERIALS AND METHODS-

Type of Heat cure acrylic resin	DPI heat cure	Trevlaon HI	Trevalon	Meliodent
Total sample size(n-10)	80	80	80	80

Table 1 (Type of material and Sample size

Four different varieties of heat cure acrylic resins were taken 40 samples of heat cure acrylic resins were prepared (80 for each DPI heat cure, Trevalon HI heat cure, trevalon heat cure and meliodent heat cure) with dimensions of 65 * 10 * 2.5 mm. All these types were mixed according to ADA specification no. 12 and placed in brass mold with dimensions of 65 * 10 * 2.5 mm, then these samples were bench cure for 30 minutes. Then they were placed in acrylizer for 2 hours. Further samples were bench cooled for 30 minutes. Finally, finished and polished using sandpaper and pumice powder. Then samples were stored in water for 7 days and sent for exposure to electron beam irradiation at a dose of 5, 10, 15, 20, 25, 35 and 50KGy with energy of 7.7MeV and current of 400Ma with pulse width of 10 micro-second. Then samples were stored in water for 7 days and sent for measurement with help of Instron machine

In each of test following dosage and time of exposure was done-

Property	DOSE	MONITORING UNIT	TIME OF EXPOSURE (seconds)
Fracture Toughness	5kGy	7156MU	353
	10kGy	14312MU	701
	15kGy	21468 MU	1054
	20kGy	28624MU	1404.7
	25kGy	35780MU	1752.8
	35kGy	50092MU	2444.5
	50kGy	71560MU	3501.1

Table-2(Radiation Unit dose)

Three-Point Bending Test A series of three-point bending tests were performed on all specimens, following the ISO 20795-1:2013 [20] in a climate-controlled environment. The ISO required the standardised application of a pre-crack in the middle of each specimen. Thus, a 0.5-mm-wide notch, 3.0 mm in length, was machined in the center of each specimen and then sharpened using a razor blade to extend the notch another 0.1 to 0.2 mm.

Fracture toughness measurements were carried out in a universal testing machine. The maximum stress intensity factor (KI,max) was calculated using the following formula28: KI,max*f Pmax/(B W½), where Pmax is the maximum load, B is the specimen thickness, W is the specimen width, and f is a geometrical factor depending on the ratio a/W. KI,max was expressed in MPa.m1/2

3. RESULTS AND DISCUSSION –

The Fracture toughness was measured in MPa.m1/2and further analysis was done in which mean value and P value was calculated.

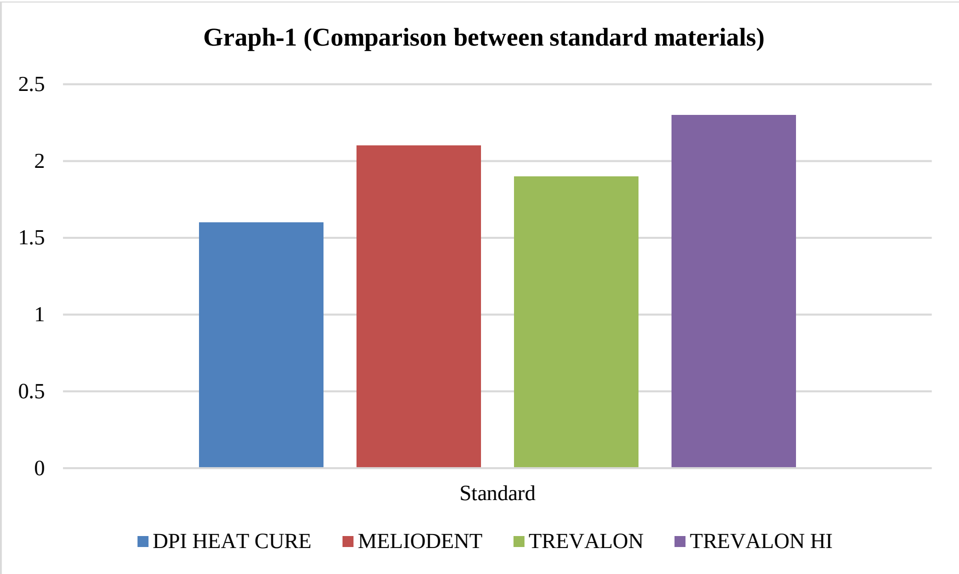
It was found that between four different types of Standard material Trevalon HI is showing highest fracture toughness, but DPI Heat cure resin shows least toughness. These results are shown in (Graph 1).

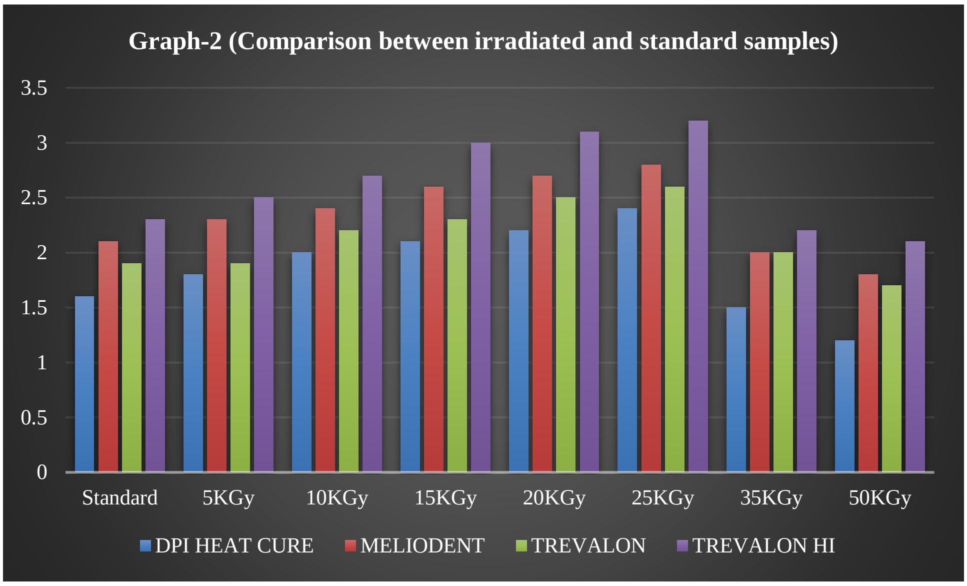
Further as the radiation dosage increases, the Toughness of all different material increases at different levels. As the radiation dosage increases from 5 KGy to 50 KGy maximum increase was seen at 25kGy. These results are shown in Graph 2).

Among all different type of materials Trevalon HI shows maximum increase at 25 kGy. These results are shown in (Table 2).

TYPE OF MATERIAL	DPI HEAT CURE	MELIODENT	TREVALON	TREVALON HI
Standard	1.6	2.1	1.9	2.3
5KGy	1.8	2.3	1.9	2.5
10KGy	2.0	2.4	2.2	2.7
15KGy	2.1	2.6	2.3	3
20KGy	2.2	2.7	2.5	3.1
25KGy	2.4	2.8	2.6	3.2
35KGy	1.5	2.0	2.0	2.2
50KGy	1.2	1.8	1.7	2.1
Fracture Toughness MPa.m1/2				

Table No.3





Fracture toughness (the ability of a material to resist crack propagation,) is an important property for denture base resins, preventing or reducing the incidence of denture fracture, thus decreasing patient discomfort and reducing the number of appointments for denture replacement or repair.

The fracture toughness test was selected for this study because Lee HH measured various mechanical properties of acrylic denture base resins, including flexural modulus, flexural strength, fracture toughness, Barcol and Vickers hardness and their related properties, and to investigate correlations between different mechanical properties. In general fracture toughness revealed strong negative correlations with the flexural parameters and hardness values. Results of correlation tests for the different parameters can be used for estimation of mechanical performance of acrylic denture bases in clinical situation and for quality control purposes.[18] In an another study by Finoti LS evaluated the fracture toughness (FT) of one denture base (Lucitone 550 - L) and four hard reline resins[Ufi Gel Hard (UH), Tokuyama Rebase II (TR), New Truliner (NT) and Kooliner (K)], and the effect of long-term water storage on this property. The denture base resin L showed higher FT mean values than the reline resins. Long-term water storage increased the FT of L, UH and K, reduced the FT of NT and did not influence the FT of TR.[19] **According to** Stafford GD et al. Two types of fracture toughness specimen, the tapered cleavage (TC) and single edge notch (SEN), are compared. The SEN specimens proved capable of distinguishing between the fracture toughness characteristics of the four types of denture base acrylics and proved easy to fabricate. The TC specimens proved difficult to fabricate requiring specialized equipment; however, once made, the specimens revealed more of the fracture process than did the SEN specimens. The higher level of residual monomer may also contribute to the findings since the unreacted monomer that remains within the polymerized material may compromise it`s mechanical properties.[20]

Despite PMMA's wide use as a main component of denture bases, this material will sometimes fracture during clinical use. One of the factors that can lead to fracture is low resistance to impact, flexural or fatigue, [4] or poor fabrication technique.[5]

All these factors increase the need to improve the strength of denture base materials and to fabricate strong dentures, which have increased clinical longevity Despite PMMA's wide use as a main component of denture bases, this material will sometimes fracture during clinical use. One of the factors that can lead to fracture is low resistance to impact, flexural or fatigue, [4] or poor fabrication technique. [5]

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Based on this study Trevalon HI has highest fracture toughness among four and DPI Heat cure has least fracture toughness. Trevalon HI can be considered for various clinical implications being rubber reinforced resins for patients who had a history of repeated denture fractures, shallow palate cases, and patients with high labial frenal attachments.

There are different ways to improve the mechanical properties of PMMA. These ways include replacing PMMA with an alternative material; chemically modifying it; and reinforcing the PMMA with other materials. Also, different denture designs have been made to decrease stress such as increasing the thickness of the denture base. However, use of different radiation like microwave had also improved properties of denture base resins. Based on that Electron beam Irradiation is used because of it advantages when used with varieties of Polymers.[23]

Electron beam irradiation is widely used in manufacturing products such as machine bodies, cars, and insulators. Polyethylene, polystyrene, and polycarbonate are the most irradiated polymers. However, until now, using low dose of electron beam irradiation for post curing of heat activated denture base resins has not been used in dentistry. Electron beam irradiation is reported to increase the stiffness of polymers as well as the links between polymer chains (Behr et al., 2006). Two types of irradiation-initiated reaction can be defined: chain linkage and chain breakage. Which mechanism dominates depends on several parameters, for instance the structure of the polymer, the energy dose, and residual double bonds (Ungar, 1981; Seguchi et al., 2002; Behr et al., 2005a). During chemical reaction, radicals, which induce chain linkage, are initiated from several distinct points. The polymeric chain then increases, but the chain linkage is not equally distributed in the polymer. It has been demonstrated that irradiation initiates the radical build-up of all components of a polymer (Behr et al., 2006). For that reason, the entire polymer may simultaneously be newly arranged and crosslinked when irradiated.[24]

The free radicals can recombine establishing the crosslinks. The degree of crosslinking be contingent upon the polymer and radiation dose. One of the assistances of using irradiation for crosslinking is that the degree of crosslinking can be effortlessly controlled by the amount of dose. Furthermore, oxidation can continue after irradiation instigating changes in properties with time. Electron beam processing of thermoplastic material also consequences in an array of enhancements, such as an intensification in tensile strength once polymers are cross-linked.[25]

Analysis of the data in the present study offers some insight into the influence of electron beam post-curing on polymer PMMA. Nevertheless, polymethyl methacrylate (PMMA) is often described in the literature as a thermoplastic polymer, which tends towards chain breakage during irradiation (Behr et al., 2005b, c).[24] It has been demonstrated that the mechanical properties of mostly PMMA-based denture resins could be improved using electron beam irradiation, although as the radiation dose increases above 25 kGy properties get reduced. It appears that during irradiation, C–C bonds are split off and the polymeric structure starts to break down beyond 25 kGy. The findings of the present study demonstrate that all the investigated denture base resins show improvement in fracture toughness up to 25 kGy beyond which properties get reduced because of bond split off and it break down the structure.

4. CONCLUSION-

The findings of the present study demonstrate following things

1. The Fracture toughness of Trevalon HI is highest among all because of reinforcement of Rubber in it.
2. The DPI heat cure has least Toughness being conventional in nature
3. The fracture toughness of heat activated denture base resins can be modified by electron beam irradiation but at lower dosage upto 25kGy

4. There is little effect on toughness beyond 25 Kilo gray of radiation dose on mechanical properties of denture base resins.

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6. REFERENCES:

[1] Grajower R and Goultschin J., J. Oral Rehabil , 11 (1984) 237.
[2] Ozlem Gurbuz, Fatma Unalan, Idil Dikbas. OHDMBSC, vol 9, issue 1 (2010) 21. H. Sotobayashi,
[3] F . Asmussen, K. Thimm, W. Schnabel, H. Betz And D. Einfeld, Polym. Bull. 7 (1982) 95.
[4] A.Faltermeier, M. Behr, M. Rosentritt And G.Handel, J. Dent. Res. 82 Spec Iss C (2003) 367.
[5] Thomas R, Meng, Jr. DDS, Mark A Latta, Journal of Contempory practice, 6, No.4 (2005)15.
[6] Diwan R. Materials Prescribed in the Management of Edentulous Patients. In: Zarb G, Bolander CL. (ed): Prosthodontic Treatment for Edentulous Patients. ed 12.
[7] St. Louis, C.V. Mosby, 2004: 190-207. 2. Shklar G, Chernin D (ed). Chapter 22, Dental Science and Practice in the Twentieth Century, Part 2. A Sourcebook of Dental Medicine.
[8] Wabam, Maro Publications, 2002. 3. Supplee SH. Notes on the Evolution of Complete and partial dentures. In: Boucher CO (ed): Swenson's Complete Dentures. ed 6.
[9] St. Louis, C.V.Mosby, 1970: 561-569. 4. Boone ME. New materials and techniques in Prosthodontics. Dent Clin North Am 1983; 27: 793-803. 5.
[10] Phillips RW (ed). Skinner's Science of Dental Materials, ed 10. Philadelphia, W.B. Saunders, 1996: 1-12.
[11] Phillips RW (ed). Skinner's Science of Dental Materials, ed 10. Philadelphia, W.B. Saunders, 1996: 237-300
[12] Phoenix RD. Denture Base Materials. Dent Clin North Am, 1996; 40: 113-120.
[13] Stafford GD, Huggett R, MacGregor AR, et al. The use of Nylon as a Denture-base Material. J Dent 1986; 14: 18-22.
[14] Nandal S, Ghalaut P, Shekhawat H. New era in denture base resins. Dent J Adv Stud. 2013; 1:3.
[15] Beyli MS, von Fraunhofer JA. An analysis of causes of fracture of acrylic resin dentures. J Prosthet Dent 1981; 46: 238-41.
[16] Rodford R. The development of high impact strength denture-base materials. J Dent 1986; 14: 214-17.
[17] Rodford R. Further development and evaluation of high impact strength denture-base materials. J Dent 1990; 18: 151-57.
[18] Lee HH, Lee CJ, Asaoka K. Dent Mater J. 2012 Feb 3;31(1):157-64. Epub 2012 Jan 21. Correlation in the mechanical properties of acrylic denture base resins.
[19] Finoti LS, Machado AL, Chaves CA, Pavarina AC, Vergani CE. Gerodontology. 2012 Jun;29(2):e858-64.Effect of long-term water immersion on the fracture toughness of denture base and reline resins.
[20] Stafford GD, Huggett R, Causton BE.J Biomed Mater Res. 1980 Jul;14(4):359-71.Fracture toughness of denture base acrylics.
[21] Bucknall CB. Toughened Plastics. London: Applied Science Publishers; 1977. p. 7-8.

[22] Murphy WM, Bates JF, Huggett R, Bright R. A comparative study of 3 denture base materials. Br Dent J 1982; 152:273-6.
[23] Pavan Sabrina, Arioli Filho, Santos Poulo, Henrique Dos, Mollo J.R. Effect of microwave treatments on dimensional accuracy of maxillary acrylic resin denture base. Brazilian Dental Journal, 2005; 16(2): 119-123
[24] Behr M, Rosentritt M, Faltermeier A, Hande G. *Materials In Medicine*, **16** (2005) 175.
[25] Faltermeier A, Behr M, Rosentritt M.Acta odontolo scand 2007 Jun;65(3):171-6