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# Effect of Electron Beam Irradiation on Flexural Strength of Two Nanocomposites-an *In vitro* Study

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Author MNH designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors SSS and NDH managed the analyses of the study. Authors SK and AP managed the literature searches and author GS carried out the irradiation of the materials. All authors read and approved the final manuscript.*

***Original Research Article***

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## ABSTRACT

**Aim:** The aim of this study is to investigate whether dental nanocomposite Filtek Z350 XT and Ceram X-duo can benefit from electron beam irradiation in order to achieve increased flexural strength

**Place and Duration of Study:** Department of Conservative Dentistry and Endodontics, A. B. Shetty Memorial Institute of Dental Sciences, Nitte University, Deralakatte, Mangalore, India and Microtron Centre; Department of Physics Mangalore University; Mangalore, India between May 2011 to March 2014.

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**Materials and Methods:** Materials were prepared on rectangular bar shaped specimens of 25-×2-×2-mm according to ISO standard -4049. Electron beam irradiation dose selected for the study were 1KGy, 3KGy and 5KGy. In total, 48 specimens were fabricated and divided into 4 groups based on radiation dose group I (non-radiated), group II (1KGy), group III (3KGy), group IV (5KGy) with 12 specimens in each. After 24 hours, specimens were subjected to 3-point bend test on a universal uniaxial servo mechanical testing machine.
**Statistical Analysis:** Performed using one way ANOVA and inter group comparisons were done using tukeys multiple comparision. 'P' value<0.05 was considered statistically significant.
**Results:** Flexural strength of Filtex Z350 XT before radiation was170.89±9.07.Flexural strength of Filtex Z350 XT after irradiation with 1KGy, 3KGy and 5KGy was found to be 269.06±94.91, 326.53±54.74 and 377.64±74.5 respectively. P value statistically significant (P<0.0001). Flexural strength of Ceram X duo before radiation was120.14±7.12.Flexural strength of Ceram X duo after irradiation with 1KGy, 3KGy and 5KGy was found to be 206.27±76.38, 177.31±67.35 and 229.33±59.15 respectively. P value statistically significant (P<0.0001).
**Conclusion:** It can be concluded that electron beam irradiation can be used as a tool to modify the present day dental materials for enhancing their mechanical properties.

*Keywords: Electron beam irradiation; flexural strength; nanocomposite; filtex; Ceram X-duo; Dental composites; polymerization; cross linking.*

## 1. INTRODUCTION

For more than 100 years dental amalgam and gold alloys, have been used as dental restorative materials which have a long record of clinical success, however, these metallic materials are not esthetic [1]. Dental composites are among the synthetic resins used as adhesives or restorative material in dentistry. However, composites had limited use because of low durability and strength. Clinical performances of restorations mainly relys on the appropriate polymerization of the resin composites [2]. Since their development many attempts have been undertaken to improve the clinical performance of dental resin composites [3].

Nanotechnology has played as an important role in improving the clinical performance of dental resin composites in the last few years with chemical and physical methods to produce nanoscale operational materials which ranging in size from 0.1 to 100 nanometers [4]. Nanomaterial includes nanoparticles, nanocluster, nanocrystals, nanotubes, nanofiber, nanowire, nanorod, etc. Numerous manufacturing approaches are available to synthesize nanomaterial [5]. Nanomaterials may be used to manipulate the structure of materials to provide dramatic improvement in mechanical, physical, chemical, and optical properties [6]. A large amount of examinations is being dedicated to the development of nanocomposites.

Nanocomposites are known for their improved mechanical properties i.e. better compressive strength, diametrical tensile strength, fracture resistance, wear resistance, low polymerization shrinkage, high translucency, high polish retention and better esthetics [1,7,8].

Filtex Z350 XT Universal Restorative is a visible light-activated, radiopaque, nanocomposite designed for use in anterior and posterior restorations. Ceram X is a light curable, radiopaque restorative material for anterior and posterior restorations of primary and permanent teeth. Based on proprietory Nano-Ceramic Technology, Ceram X offers natural aesthetics achieved by an easy procedure, superior handling characteristics and excellent durability. Ceram X is available in two distinct shading systems: Ceram X mono and Ceram X duo.

Electron beam irradiation can be used to influence the mechanical properties of polymers. Even though the mechanism of cross linking polymers by irradiation which involves the splitting-off of a hydrogen atom from a C–H bond has been extensively studied, the exact mechanism is still unknown. In contrast, chain breakage or chain scission can also occur [9-11].

It was the aim of this study to investigate whether dental nanocomposite Filtek Z350 XT and Ceram X-duo can benefit from electron beam irradiation in order to achieve increased flexural strength.

## 2. MATERIALS AND METHODS

The flexural strength of Filtek Z350 XT and Ceram X duo was tested before and after electron beam irradiation.

### 2.1 Composition of the Material

Composition of the material is given Table 1.

**Table 1. Composition of two nanocomposites as given by the manufacturer**

| Material | Composition |
|---|---|
| Filtek Z350 (3M ESPE) | Bis- phenol–a diglycidyl methacrylate (BisGMA),<br>tri ethylene glycol dimethacrylate (TEGDMA),<br>urethane dimethacrylate (UDMA),<br>bisphenol a polyethylene Glycol di ether dimethacrylate. |
| Ceram X duo (Dentsply) | Methacrylate modified polysiloxane<br>dimethacrylate resin<br>fluorescence pigment<br>UV stabilizer<br>camphorquinone<br>ethyl-4(dimethylamino)benzoate<br>barium-aluminium-borosilicate glass<br>methacrylate functionalised silicon dioxide nano filler |

### 2.2 Preparation of test Materials

Materials were prepared on rectangular bar shaped specimens of 25-×2-×2-mm according to ISO standard -4049 by placing in polytetrafluoroethylene molds held between 2 glass slides [12]. After the material setting, Specimens were removed from mold and kept in 37ºC distilled water and stored in the dark until setting.

### 2.3 Standardization of Dose

The materials were radiated using an 8 MeV Microtron at Microtron Centre, Mangalore University, and Mangalore, India. Doses selected for the study were 1kGy, 3kGy and 5kGy.

### 2.4 Groups

In total, 48 specimens were fabricated and divided into 4 groups based on radiation dose.

Group I-Non-radiated (n=12)
Group II-1KGy (n=12)
Group III-3KGy (n=12)
Group IV-5KGy (n=12)

Fabricated dental materials in polypropylene vials were subjected to their respective doses of radiation.

### 2.5 Testing Procedure

#### 2.5.1 Flexural strength

Flexural strength (σ) in megapascals (MPa) combines the forces found in compression and tension. After 24 hours, specimens were subjected to 3- Point bend test on a universal uniaxial servo mechanical testing machine (Model 33R 4467; Instron Corp; 3M ESPE, Bangalore) at a crosshead speed of 0.75mm/min. The maximum load generated on the specimen before failure was captured by Instron's central processing unit.

The flexural strength was expressed as maximum flexural load pre-cross-sectional area of specimen (MPa), according to international standards organization (ISO 4049). The values of flexural strength were obtained from three points bending test, in (MPa), based on the following formula:

Flexural strength= $\frac{3FL}{2bd^2}$

Where *F* is the force load at fracture point (N), *L* is the length of support span (mm), *d* thickness (mm), and *b* the width of specimen (mm).

### 2.6 Statistical Analysis

Statistical analysis was performed using one way ANOVA and inter group comparisons were done using tukeys multiple comparision. 'P' value <0.05 was considered statistically significant.

## 3. RESULTS AND DISCUSSION

Dental composites are materials comprising curable dimethacrylic resins based on hydrocarbon molecular structures (e.g. Bis-GMA, TGDMA, UDMA) and methacrylate functionalised but otherwise non-reactive fillers [13]. Setting occurs due to radical polymerisation of the resins. Traditionally, dental composites are classified according to their filler particle size distribution into subgroups of hybrid, micro-hybrid and microfilled composites.

Fuctionality and esthetic quality are the two prerequisites for an ideal restoration [14]. Dentists are in long search for an universal restorative material the combines the best features of microfills and hybrids [15,16].

Nanotechnology is the production of functional materials and structures in the range of 0.1-100nm [2,17,18] Nanocomposite restorative materials are the latest in clinical dentistry and mainly comprises of nanomers and nanocluster filler materials and is a product of nanofiller technology [14].

Clinically, Composite restorations undergo considerable flexural stress [16]. Therefore materials with high flexural strength are desired to avoid deformation of the material because of masticatory stresses resulting in damage to the marginal seal between the composites and the tooth [17,18].

This study compared and analysed the effect of electron beam irradiation on two nanocomposites-Filtek Z350 XT and Ceram X duo.

Filtek Z350 XT restorative is indicated for use in direct anterior and posterior restorations (including occlusal surfaces), core build-ups, splinting indirect restorations (including inlays, onlays and veneers).

Ceram X comprises organically modified ceramic nano-particles and nanofillers combined with conventional glass fillers of ~1µm. Ceram X merges hybrid composite filler technology with advanced nano-Technology.

Electron beam irradiation is an excellent way to provide structural modification of materials and modification in the properties due to cross linking or chain scission [19-21]. Previously we have studied the effect of 200Gy electron beam irradiation on compressive strength and flexural strength of resin modified glass ionomer luting agent. Relyxluting cement showed increased flexural strength, modulus of elasticity and compressive strength after irradiation [22,23].

In the present study we have selected three doses of radiation i.e., 1KGy, 3KGy and 5KGy after dose standardization based on unchanged technical properties.

Flexural strength of Filtex Z350 XT before radiation was170.89±9.07.Flexural strength of Filtex Z350 XT after irradiation with 1KGy, 3KGy and 5KGy was found to be 269.06±94.91, 326.53±54.74 and 377.64±74.5 respectively. P value statistically significant ($P<0.001$) Fig. 1, Tables 2 and 3. Flexural strength of Ceram X duo before radiation was120.14±7.12.Flexural strength of Ceram X duo after irradiation with 1KGy, 3KGy and 5KGy was found to be 206.27±76.38, 177.31±67.35 and 229.33±59.15 respectively. P value statistically significant ($P<0.001$) Fig 2, Tables 2 and 4. A comparision of flexural strength between Filtex Z350 and Ceram X Duo before and after radiation was also analysed, where Filtex Z350 showed better results Fig. 3.

**Table 2. Flexural strength of two nanocomposites-filtex Z350 XT and ceram X duo before and after electron beam irradiation**

| | Group I | Group II | Group III | Group IV | 'P' value |
|---|---|---|---|---|---|
| Filtex Z350 XT | 170.89±9.07 | 269.05±94.91 | 326.53±54.74 | 377.64±74.58 | P<0.001 |
| Ceram X duo | 120.138±7.12 | 206.27±76.38 | 177.31±67.35 | 229.33±59.15 | P<0.001 |

**Table 3. Tukey's multiple comparison test for filtex Z350 XT**

| Groups | 'P' value |
|---|---|
| Group Ivs Group II | P<0.001* |
| Group I vs Group III | P<0.001* |
| Group I vs Group IV | P<0.001* |
| Group II vs Group III | P>0.05 |
| Group II vs Group IV | P<0.001* |
| Group III vs Group IV | P<0.001* |

In the present study the flexural strength of Filtex Z350 and Ceram X duo increased with increase in radiation dose and was statistically significant .

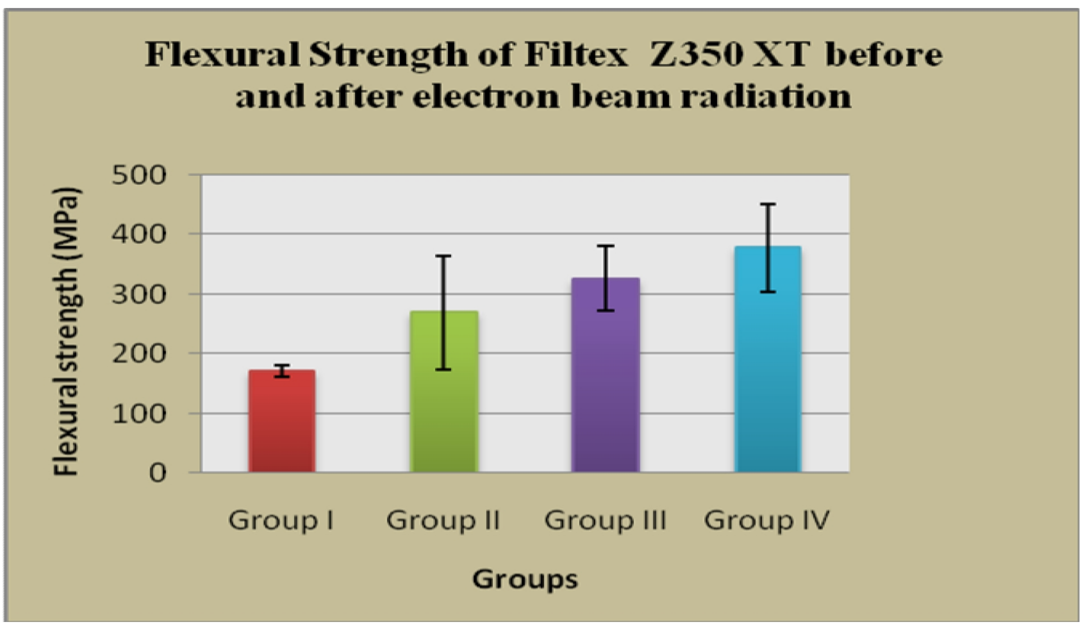


**Fig. 1. Graphical representation of flexural strength of filtex Z350 XT before and after electron beam irradiation**

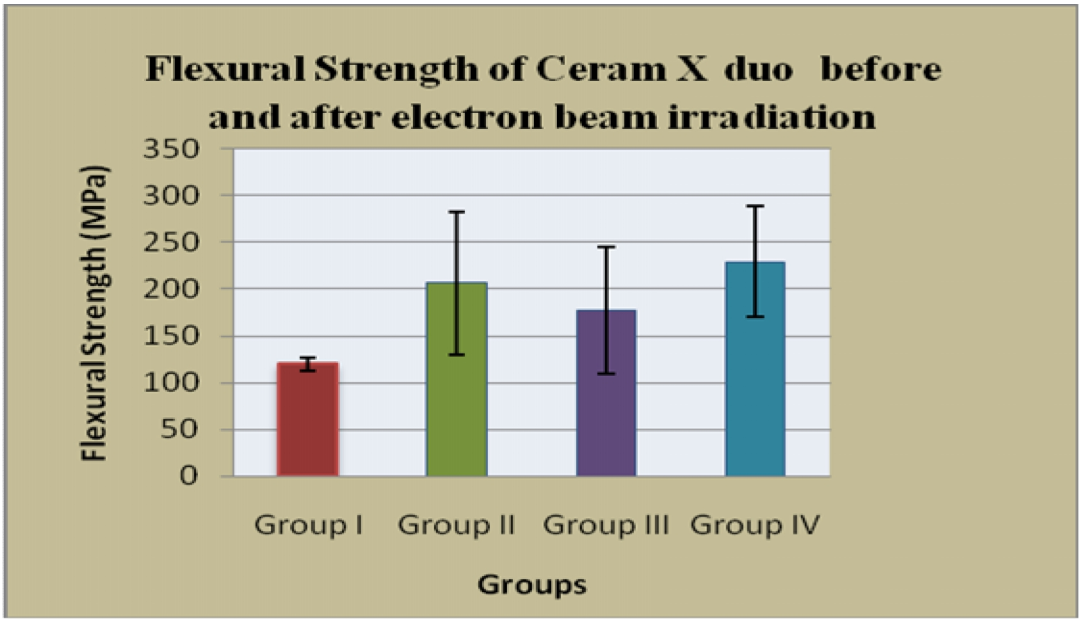


**Fig. 2. Graphical representation of flexural strength of ceram X duo before and after electron beam irradiation**

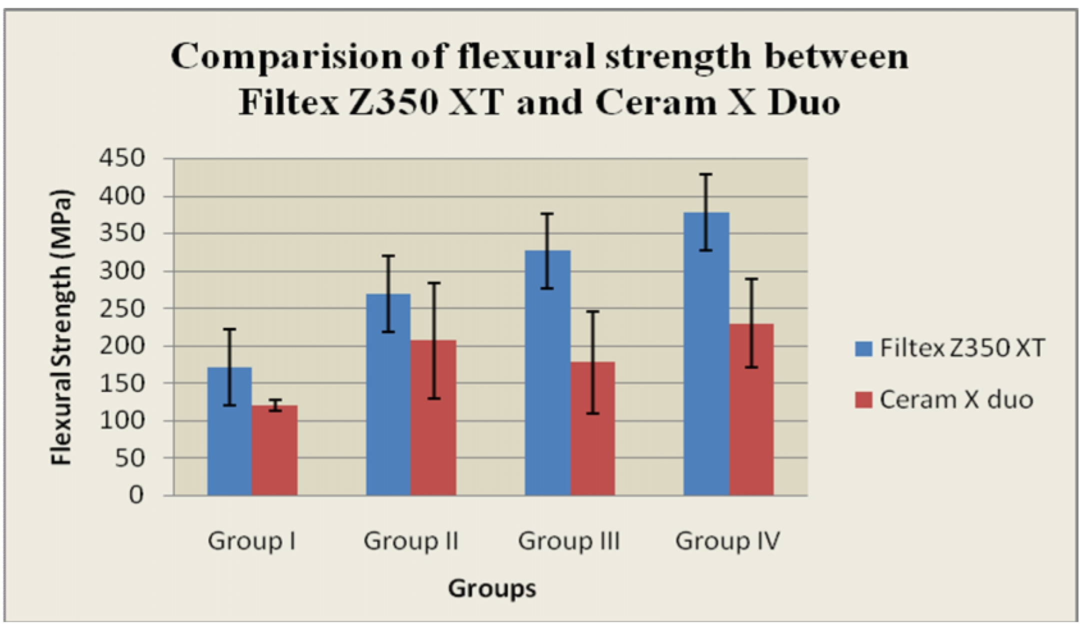


**Fig. 3. Comparision of flexural strength between filtex Z350 and ceram X Duo before and after radiation**

**Table 4. Tukey's multiple comparison test for ceram X duo**

| Groups | 'P' value |
|---|---|
| Group I vs Group II | P>0.05 |
| Group I vs Group III | P>0.05 |
| Group I vs Group IV | P<0.001* |
| Group II vs Group III | P>0.05 |
| Group II vs Group IV | P<0.01* |
| Group III vs Group IV | P<0.001* |

ANOVA of Filtex Z350 results showed that flexural strength of radiated material was higher than the non-radiated material and was statistically significant.

Tukey's comparision test showed statiscally significant results between non-radiated and 1KGy, non-radiated and 3KGy and non-radiated and 5KGy. Stastically significant comparision was also seen between 1KGy and 5KGy and 3KGyand 5KGy. Whereas stastically insignificant results were seen between 1KGy and 3KGy.

Similarly ANOVA of Ceram X-duo showed that flexural strength of radiated material was higher than the non-radiated material and was statistically significant. There was an overall increase in flexural strength after radiation but there was a slight decrease at 3KGy and again an increase at 5KGy.

Tukey's comparision test showed statiscally significant results between non-radiated and 5KGy, 1KGy and 5KGy and 3KGy and 5KGy.

Here the increase in flexural strength after electron beam irradiation may be mainly because of cross linking and polymerization. Cross linking (or cross-linking, cross linking) is a process where the long chains of polymers are linked together increasing the molecular mass of the polymer. In all cases, the chemical structure of the polymer is altered through the cross linking process. Irradiation creates free radicals which will often chemically react in various ways, sometimes at slow reaction rates. The free radicals can recombine forming the cross links. The degree of cross linking depends upon the polymer and radiation dose. One of the benefits of using irradiation for cross linking is that the degree of cross linking can be easily controlled by the amount of dose [24].

Another reason for this increased flexural strength may be the the polymerization reaction. Polymerization reaction may be explained as follows: The number of double carbon links (C=C) present in the monomers, which are converted into single links (C-C) to form the polymeric chain during the polymerization process, is called degree of conversion [25,26]. It is said that the extent to which monomers react to form the polymer during the polymerization reaction has an important effect on the physical and mechanical properties of composites resins [27-30]. Further research is required as to investigate the exact mechanism involved in conferring increased flexural strength on irradiation.

## 4. CONCLUSION

Within the limitations of the study, it can be concluded that electron beam irradiation can change the mechanical properties of dental materials which is evident from the increase in flexural strength of the two nanocomposites studied. Further work on the study of exact mechanism is required in this field of study.

## CONSENT

Not applicable.

## ETHICAL APPROVAL

Not applicable.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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