ABSTRACT

Background and Aim: The goal of research developments in adhesive materials has been to achieve good and optimal bond strength during treatment and also enabling easy debonding and clean up procedures at the end of the treatment. Hence this study was designed to evaluate the effect of exposure to electron beam radiation on shear bond strength of two commonly used adhesives in Orthodontics. Materials and methods: Light cure composite and self cure adhesive was used for the purpose. 200 upper 1st premolars extracted for orthodontic purpose was selected. In each group, upper 1st premolar; SS brackets were bonded with corresponding adhesive systems. The bonded specimens were subdivided into five groups for evaluation of bond strength before and after irradiation with 2kGy, 4kGy, 8kGy and 10kGy. The shear bond strength of the bonded specimens was tested using Universal Testing Machine. The data obtained was statistically evaluated using One-Way ANOVA. Results: When comparing before and after irradiation, the light cure adhesive had the shear bond strength significantly increased after irradiation with 4kGy and in Self cure adhesive the shear bond strength after irradiation significantly decreases. Conclusion: The electron beam irradiation had negative effect on the shear bond strength of self cure and light cure orthodontic adhesive; except for the radiation dose of 4kGy in case of light cure adhesive.

KEYWORDS: Shear Bond Strength, Electron Beam Radiation.
INTRODUCTION

Direct bonding first described by Newman in 1965 was a major improvement in orthodontic practice. However the presently available adhesives have limitations such as bond failures of brackets which can significantly increase chair side time, treatment time, and efficiency. Therefore much effort has been put into improving the quality of the adhesive systems for direct bonding. Bond strength can be influenced by various factors such as light curing device, etching time, composition of the adhesive, bracket base design and bracket material.\(^1\)

The goal of research developments in adhesive materials has been to achieve good and optimal bond strength during treatment and also enabling easy debonding and clean up procedures at the end of the treatment without causing iatrogenic damage such as cracks and loss of enamel.\(^2\)

The process of bonding is technique sensitive and several factors influence the bond strength which include the nature of the enamel surface, enamel conditioning procedures, the shape and design of bracket base and also the moisture contamination.\(^3\)

The study and evaluation of the adhesive potential of a specific bonding system are complicated, as there are multiple variables that can influence the survival or longevity of the bracket-enamel interphase. The two primary tests used for evaluating the strength of the orthodontic adhesives measure shear and tensile bond strengths. In the shear test, the force is directed parallel to the long axis of the tooth and as closely as possible to the bracket-tooth interface. In vitro studies have shown that orthodontic brackets must be able to sustain loads from 5.9 to 7.8 mega-Pascals (MPa) of shear bond strength (SBS) to be considered clinically successful for orthodontic purposes.\(^4\)

Electron beam processing or electron irradiation is a process which involves using electrons, usually of high energy, to treat an object for a variety of purposes. This may take place under elevated temperatures and nitrogen atmosphere. Possible uses for electron irradiation include sterilization and to cross-link polymers.\(^5\)

Electron-beam irradiation can be used to influence the properties of polymers. Electron beams cause cross-linking that enhances the molecular mass of the polymer; this leads to branched chains until, ultimately, a 3-dimensional network is formed. Electron-beam post
curing improved the Vickers hardness and fracture toughness of polymers with lower mechanical properties.\(^6\)

E-beam radiation is a form of ionizing energy that is generally characterized by its low penetration and high dosage rates. The beam, a concentrated, highly charged stream of electrons, is generated by the acceleration and conversion of electricity. The electrons are generated by equipment referred to as accelerators which are capable of producing beams that are either pulsed or continuous.\(^7\) Electron beam radiation is a high energy beam of electrons which when focused on resin monomer is capable of converting it polymer. There is a possibility that by this high energy beam there can be more curing of monomers thus improving the physical and chemical properties of the resin composite.\(^8\)

As the product/material being sterilized passes beneath or in front of the electron beam, energy from the electrons is absorbed. This absorption of energy alters various chemical and biological bonds within the product/material. The energy that is absorbed is referred to as the “absorbed dose.” It is this absorption of energy – or “dose delivery” – that destroys the reproductive cells of microorganisms by destroying their DNA chains.\(^7\)

Behr et al stated that the mechanical properties of dental composites could be influenced by electron-beam irradiation. Haque et al described UDMA as a polymer that showed improved hardness and reduced abrasiveness after heavy ion irradiation (640 Gy, 290 MeV). Thompson et al showed that electron-beam irradiation of Bis-GMA increases the degree of cross linking of the polymer and that the residual double bond content decreased as dosages increased during irradiation. However, it was described that polymers could suffer chemical degradation after electron-beam postcuring. Behr et al reported decreased fracture toughness and color changes using electron-beam irradiation as the postcuring method.\(^6\)

However, in another study, Behr investigated the influence of electron-beam post curing on dental composites. Different composites were evaluated after electron-beam irradiation with increasing energy doses. They found that irradiation caused a significant change in the mechanical properties. It was shown that increased resistance against wear could be measured. The mechanical properties of all the investigated polymers seemed to benefit from low-energy electron-beam irradiation (25 kGy).\(^9\)
With the background of review of literature, this study was planned and designed to evaluate, the effect of exposure to electron beam radiation on shear bond strength of two commonly used adhesives in Orthodontics.

**MATERIALS & METHODS**

This study was designed to evaluate the effect of electron beam radiation on the bond strength of commonly used adhesives in orthodontic practice. Lightcure composite (3M Transbond XT)* and Self cure Adhesive (3M Unite)* were used for the purpose.

Two hundred upper 1st premolars extracted for orthodontic purpose were selected and stored in artificial saliva to prevent dehydration and bacterial growth. The criteria for tooth selection included intact buccal enamel not subjected to any pre-treatment chemical agents, with no cracks and no caries. Teeth with morphological defects, restorations and severe attrition were not included in the study. These teeth were divided into two groups of hundred samples each.

To mount the teeth in Universal Testing Machine, these teeth were fixed in a self cure acrylic block. The teeth were mounted on acrylic blocks such that the roots were completely embedded in the acrylic up to the cement enamel junction leaving the crown exposed.

The tooth surfaces were cleaned and brushed with nonfluoride pumice and a rubber cup for 10 seconds, sprayed with water, and dried with compressed air. Before bonding, the surfaces were etched with 37% phosphoric acid. In each group, upper 1st premolar, SS brackets(3M)* were bonded with corresponding adhesive systems as per the manufactures instruction. Using the standardized procedure, the brackets were positioned on the least-curved surface and kept under a constant load applied by a plunger-type loading device. To simulate the effects of moisture and temperature to conditions, the specimens were be stored in artificial saliva at 37°C for 24 hours after bonding. The bonded specimens were subdivided into five groups for evaluation of bond strength before and after irradiation with 2kGy, 4kGy, 8kGy and 10kGy. (Table 1).

*: 3M Unitek Orthodontic Products, Monrovia, USA.

**Irradiation of Bonding Adhesives**

Electron beam processing or electron beam irradiation (EBR) is a process which involves using electrons, usually of high energy, to treat an object for a variety of purposes. This may
take place under elevated temperatures and nitrogen atmosphere. Possible uses for electron irradiation include sterilization and to cross-link polymers.\cite{5}

The Bonding adhesives were placed in polypropylene (PP) tubes and exposed to electron beam at a distance of 30 cm from the beam exit point of the Microtron accelerator at a dose rate of 72 Gy/min. Based on the cytotoxic and genotoxic studies we have taken 2-10 kGy for irradiation.\cite{5}

**Bond Strength Testing**

The shear bond strength of the bonded, stored specimens were tested using Universal Testing Machine; MultiTest 10-i. The acrylic block mounted with the specimen was secured to the lower grip of the machine (fixed head) and a custom made blade was fixed in the upper grip (movable head) connected to load cell. The blade was positioned in such a way that it touched the bracket. (Figure 1). The test samples were stressed for debonding at a cross head speed of 2 mm per min and 500 Newton load cell. The force at which the bracket debonded was recorded in the monitor. The force required for debonding was recorded in Newtons and converted into MPA. Surface area of base of the bracket was to be 9.806mm² as provided by manufacturer. (3M Unitek, USA).

**Statistical Analysis**

One-Way ANOVA was used to compare the mean shear bond strength between different study groups and Tukey-Honestly Significant Difference test is used in conjunction with an ANOVA to find means that are significantly different from each other.

**RESULTS**

The mean and standard deviation of shear bond strengths of the two adhesives used for bonding in orthodontics were calculated before and after irradiation and compared with each other.

The mean shear bond strength of two groups before irradiation was calculated. (Table 2) It was found that self-cure adhesive had the higher shear bond strength than the light cure adhesives which was found to be statistically significant.

When comparing before and after irradiation, the light cure adhesive had the shear bond strength significantly increased after irradiation with 4kGy. Whereas 10kGy, 2kGy and 8kGy irradiation had the shear bond strength lesser than that of before irradiation. (Graph 1).
The Self cure adhesive had the highest shear bond strength before irradiation which was statistically found to be significant. The shear bond strength after irradiation significantly decreases and showed variations. It was observed that irradiation with 8kGy had the highest bond strength followed by irradiation with 4kGy, 2kGy and 10kGy. (Graph2).

Table 1: Groups

<table>
<thead>
<tr>
<th>Group I (Light cure composite Transbond XT) N:100</th>
<th>Subgroup</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before radiation</td>
<td>2kGy</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>4kGy</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>8kGy</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>10kGy</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group II (Self cure composite) N: 100</th>
<th>Subgroup</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before radiation</td>
<td>2kGy</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>4kGy</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>8kGy</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>10kGy</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 2-Comparison of the Groups before & after irradiation

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>F/ Statistics</th>
<th>Mean Square/DF2</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Transbond XT</td>
<td>20</td>
<td>6.523</td>
<td>0.454459</td>
<td>114.166</td>
<td>44.004</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Self cure</td>
<td>20</td>
<td>6.7255</td>
<td>0.466053</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2kGy Transbond XT</td>
<td>20</td>
<td>4.8275</td>
<td>0.076287</td>
<td>13907.43</td>
<td>42.272</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Self cure</td>
<td>20</td>
<td>1.9375</td>
<td>0.06758</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4kGy Transbond XT</td>
<td>20</td>
<td>8.349</td>
<td>0.156336</td>
<td>7674.879</td>
<td>45.838</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Self cure</td>
<td>20</td>
<td>3.297</td>
<td>0.068526</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8kGy Transbond XT</td>
<td>20</td>
<td>3.925</td>
<td>0.119274</td>
<td>53752.53</td>
<td>44.214</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Self cure</td>
<td>20</td>
<td>5.9775</td>
<td>0.106863</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10kGy Transbond XT</td>
<td>20</td>
<td>6.4395</td>
<td>0.07126</td>
<td>37019.43</td>
<td>46.793</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Self cure</td>
<td>20</td>
<td>1.4075</td>
<td>0.06051</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Graph 1-Comparison of the bond strength of Light cure adhesive before & after irradiation

Graph 2-Comparison of the bond strength of the Self cure adhesive before & after irradiation

Figure 1: Legend to Figures: Figure 1-Universal Testing Machine
DISCUSSION

The orthodontist has always endeavored to engineer “a handle” on teeth since the beginning of orthodontic sciences that, teeth can be moved more efficiently. The most common medium through which orthodontic forces are applied are through stainless steel bonded brackets. An extremely fastidious bracket placement in order to achieve excellent treatment result is a primary requisite for any orthodontic bracket system. Bonded attachment failure during orthodontic treatment is an unpleasant experience for both the patient as well as the orthodontist.\textsuperscript{[10]}

A typical bonding procedure is based on alteration of the enamel surface by acid etching followed by application of adhesive primer and resin. The reduction of the number of steps for bonding procedures, reducing harm to the enamel surface, and minimizing bond failures during orthodontic treatment are of important clinical concerns.\textsuperscript{[11]}

The bond strength of orthodontic brackets should be enough not to cause bonding failure and delay in treatment and it also should have adequate resistance against chewing forces and stresses from archwires. On the other hand, easy debonding of the brackets without any damage to the teeth needs sufficient and safe bond strength.\textsuperscript{[12]}

If the bond strength is very high during a SBS test, the inner shear stress of all parts will increase. Increasing shear stress cannot be transferred to the contact area between the adhesive and alloy. This results in an increased inner stress of the opaquer and/or the composite cylinder. Therefore, the inner strength in the opaquer and composite is responsible for the breaking strength and not the adhesive properties of the resin–alloy bond. It is expected that cohesive fractures will occur.\textsuperscript{[13]}

Electron beam processing or electron beam irradiation (EBR) is a process which involves using electrons, usually of high energy, to treat an object for a variety of purposes. This may take place under elevated temperatures and nitrogen atmosphere. Possible uses for electron irradiation include sterilization and to cross-link polymers.\textsuperscript{[5]}

In polymers, an electron beam may be used on the material to induce effects such as chain scission (which makes the polymer chain shorter) and cross linking. The result is a change in the properties of the polymer which is intended to extend the range of applications for the material.\textsuperscript{[14]}
When polymers are crosslinked, the molecular movement is severely impeded, making the polymer stable against heat. This locking together of molecules is the origin of all the benefits of crosslinking, including the improvement of the following properties: Thermal: resistance to temperature, aging, low temperature impact, etc. Mechanical: tensile strength, modulus, abrasion resistance, pressure rating, creep resistance, etc. Chemical: stress crack resistance, etc.\textsuperscript{[15]}

In the previous studies in vitro investigation was performed using Haemolysis assay, MTT assay, comet assay and DNA Diffusion agar assay on human lymphocytes from 200Gy-12kGy. Based on the cytotoxic and genotoxic studies we have taken 2-10 kGy for shear bond strength.\textsuperscript{[5]}

After irradiation of self cure adhesive, it was found that the shear bond strength has significantly reduced when compared to before irradiation. The highest shear bond strength of 5.97Mpa was recorded after irradiation with 8kGy which makes the composite clinically not viable.

The light cure bonding adhesive recorded a significant increase in the bond strength when irradiated with 4kGy, whereas the shear bond strength decreased when irradiated with 2kGy, 8kGy, 10kGy doses.

This suggests that irradiation of light cure orthodontic adhesive with 4kGy may be considered as an option for increasing the shear bond strength of composite. However other factors such as biotoxicity of the adhesive and structural integrity needs to be assessed before the procedure can be employed in routine orthodontic practice.

Further studies with larger sample size, variety of adhesives are required to ascertain the usefulness of irradiation of adhesives in orthodontic practice. Among the two adhesives tested for shear bond strength before and after irradiation, the light cure composite Transbond XT significant increase in bond strength after Electron Beam Radiation, the other adhesive (self cure) showed significantly reduced shear bond strength after irradiation with Electron Beam Radiation. These variations could be attributed to the composition and polymerization and the large variation observed in shear bond strength among the groups at different irradiation dose need to be further analysed. Based on this study it is not possible to indicate
definite favorable outcome in Shear Bond Strength for orthodontic bonding adhesives and further research is required for conclusive inferences.

CONCLUSION

- The electron beam irradiation had negative effect on the shear bond strength of self cure and light cure orthodontic adhesive; except for the radiation dose of 4kGy in case of light cure adhesive.
- However further research is required in order to arrive at a conclusive inference regarding the usefulness of electron beam radiation to increase the shear bond strength of orthodontic bonding adhesives.

REFERENCES


