Effect of Ionising Radiation on Micro Hardness Property of Restorative Materials

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Abstract
Patients receiving radiation therapy as source of treatment are commonly known to have restorations on their tooth composed of resin or non-resin restorative materials. Any interaction between ionising radiations and these restorative materials can have adverse effects which can be of clinical significance. Hence in this study we investigated the effects of ionising radiation on 3 restorative materials (Impress Direct, Glass Ionomer Gold Label Type 9 and Te- Econom Plus) by testing their microhardness property. All the 3 composite materials showed increased mean micro hardness values among the radiated groups and was found to be statistically significant (P<0.05). The results obtained indicated that restorative materials has undergone increased degree of polymerisation strengthening the bonds sustaining its stability. Hence the above effect will have no adverse effects on the human health, hence these materials are suitable for endodontic treatment among patients undergoing radiotherapy for head and neck cancer.

Keywords: Ionising radiation, Composites, Restorative materials, microhardness test

Introduction
Head and neck carcinomas are being reported in high numbers all over the globe. The treatment module includes radiation therapy that involves ionising radiation as primary source or as a supplementary regimen [1]. The patients undergoing radiotherapy are usually known to have restored teeth with dental materials. Hence, any interaction between these restorative materials and incident ionising radiation might result in adverse effects. Thus this combined effect may serve as a matter of public health concern if the mechanical properties of these materials are affected. Surface microhardness is one among those properties which is being used to check the resistance against wearing of these materials. This property is an indication of the stability of Restorative materials under various forces applied during mastication process. Since hardness of the material is equivalent to its limits and strength, their physical performance are better distinguished under stress [2-5].

Composites are the mainly used materials in restorative dentistry. Nowadays Glass Ionomer and other Nano-hybrid composites are also used for this purpose. This advancement in the technology has made restorative materials highly durable with increased strength reducing the abrasion [6-10]. The abraded surface leads to plaque deposition and are more prone to post-radiation caries around the restorations.

Dental composite are types of synthetic resins enormously used in dentistry as restorative material or adhesives. They are used in the restorations of anterior and posterior teeth, as sealants for pits, for cementation. Composite materials are composed of 3 main components: fillers, matrix and coupling agents. Matrix is a phase that polymerises to form a solid thereby binding to the tooth structure. It is the
weakest and the wear resistant phase. Composites are often classified by filler size. Fillers determine the surface smoothness where larger filler particles produce rough surface. As the filler content increases resin matrix decreases and thus increases the hardness and abrasion resistance of the composite. Coupling agent is a compound that binds matrix and fillers. It improves the physical and mechanical properties of the whole composite material. It also inhibits leaching by preventing water from penetrating along the resin filler interface [11].

The newer generation of composites are Nano hybrid composites. These have high durability and maintain natural gloss and shine in the restorations for many years. Nano hybrid composites are highly recommended restorative materials in the recent days and the most popular among them is IPS Impress Direct [22]. The unique properties of these composites are attributed by the addition of nanoparticles to the hybrid mixture which has increased its wear resistance and surface finish. They offer numerous advantages to the clinicians as well as to the patients such as wide color range suitable for tooth restoration, glossy finish, durability, high adhesiveness and also requires minimal removal of tooth [23].

Glass Ionomer Cements (GIC) are the unique restorative materials widely used in dentistry. They are chemically bonded to Enamel and Dentine providing caries protective fluoride release at the border line of restorations. The most distinctive properties of GIC is moisture resistance, which has made it accessible in clinical applications. These cements are known to undergo self-setting acid base reaction created by mixing an ion-leachable (fluoride ion) fluoroaluminosilicate glass (powder) with an aqueous polyacrylic acid or polycarboxylate acid (liquid). The higher viscosity of the compounds have resulted in improvements in tensile strength, compressive strength, fracture toughness, greater wear resistance and higher fluoride release [24].

Literature on the properties of restorative materials effected by non-ionizing radiation is available [12, 13]. But very limited studies have been carried out to study the effects of ionising radiation on surface and bulk properties of these materials. Hence this study is focused on investigating the effect of ionising radiation on mechanical strength of restorative materials by determining their surface microhardness.

Radiation dosage of 70 Gy is been used in the present study based on the treatment regimen for Head and Neck Cancer patients which depends on the tumor size [26]. For early stages it varies from 66-74 Gy (2.0 Gy/ fraction; daily in 7 week). In cases of post-operative radiation treatment, the doses range from 60-66 Gy (2.0 Gy/ fraction, < 6 weeks) [25]. The purpose of this study was to analyse the changes occurring in restorative materials by testing its mechanical strength after radiation treatment. This result will be useful for clinicians to sustain or remove these restorative materials during the radiation treatment period from the endodontically treated tooth.

Materials and Methods
The Three materials used in this study are Te-Econom Plus (Ivoclar Vivadent, Bendererstr, Schaan, Liechtenstein) Impress Direct (Ivoclar Vivadent, Bendererstr, Schaan, Liechtenstein) and Glass Ionomer Type 9 (GC Asia Dental Pte Ltd, Loyang Way, Singapore). The product details are given in the Table 1.

<table>
<thead>
<tr>
<th>Brand</th>
<th>Manufacturer</th>
<th>Type</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Te-Econom Plus</td>
<td>Ivoclar Vivadent Schaan, Liechtenstein</td>
<td>Radiopaque Hybrid</td>
<td>ytterbium trifluoride, Bis-GMA, urethane dimethacrylate, triethylene glycol dimethacrylate</td>
</tr>
<tr>
<td>Impress Direct</td>
<td>Ivoclar Vivadent Schaan, Liechtenstein</td>
<td>Nano Hybrid</td>
<td>Ba-Al-fluorosilicate glass, Dimethacrylate, Ytterbium trifluoride, Pre polymer, Silicon Dioxide, Barium glass Filler- 0.4-0.7</td>
</tr>
<tr>
<td>Glass Ionomer Cement, Gold label, Type 9</td>
<td>GC Asia Dental Pte Ltd, GC Corporation, Loyang Way, #06-27 Singapore</td>
<td>Non resin based, Type 9, radiopaque, Posterior Restorative</td>
<td>Powder- Fluoro-alumino silicate glass Polyacrylic acid powder Liquid - Distilled water Polyacrylic acid</td>
</tr>
</tbody>
</table>
12 specimens of each material were prepared using Teflon mold of 2mm depth and 6mm diameter. The specimens were grouped into 2 categories: non-radiated and radiated (6 samples each). The composites were light-cured using Heliolux light curing unit (Vivadent, Amherst, NY, USA). The samples were stored in artificial saliva at 37°C to stimulate the oral environment. 6 specimens of each material were irradiated with Cumulative radiation dosage of 70 Gy (2gy/fraction for 35 days) using Electron beam Irradiator in Microtron Center, Mangalore University.

The irradiated and non-irradiated samples were then subjected to hardness testing using a Micromet microhardness tester (Matzusawa Co Ltd, Model MMT XA, Toshima, Japan). On each sample surface, three indentations were made using a 300 gf load for 15 seconds (Fig 1-2). The average of these 3 indentations were considered and the strength is determined by Vickers Hardness Number (VHN) value. The difference in mean microhardness values of radiated and non-radiated groups were analysed by performing Independent ‘t’-test at 5% level of significance. Further Pairwise Comparison by Bonferroni adjustment was determined to find mean differences between the restorative materials.

Results

Table 2: Mean Microhardness values of Restorative materials (radiated and non-radiated groups)

<table>
<thead>
<tr>
<th>Materials</th>
<th>Radiated/ non-radiated</th>
<th>N</th>
<th>Mean microhardness Value</th>
<th>Std. Deviation</th>
<th>Mean difference</th>
<th>95% Confidence Interval of the Difference</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Te- Econom Plus</td>
<td>non-radiated</td>
<td>6</td>
<td>40.3650</td>
<td>.42866</td>
<td>12.34</td>
<td>-12.7915 to -11.8884</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Radiated</td>
<td>6</td>
<td>52.7050</td>
<td>.25042</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impress Direct</td>
<td>non-radiated</td>
<td>6</td>
<td>44.6600</td>
<td>.42048</td>
<td>22.92</td>
<td>-23.4154 to -22.4412</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Radiated</td>
<td>6</td>
<td>67.5883</td>
<td>.33163</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass Ionomer</td>
<td>non-radiated</td>
<td>6</td>
<td>49.1183</td>
<td>.29233</td>
<td>19.39</td>
<td>-19.8012 to -18.9887</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cement</td>
<td>Radiated</td>
<td>6</td>
<td>68.5133</td>
<td>.33762</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The mean microhardness (VHN) values of 3 restorative materials of radiated and non-radiated groups are given in the Table 2 and represented in Fig 3. All the three materials show an increase in microhardness number after radiation. The difference between the radiated and non-radiated groups as evaluated by Independent ‘t’-test was found to be statistically significant at the p value <0.001. The highest mean difference of 22.92 was obtained with Impress Direct material, followed by GIC Gold label, type 9 (19.39) and Te-Econom Plus (12.34) respectively (Table 2).
From the table 3, the highest mean difference of 12.28 was seen between the GIC and Te-Econom plus materials. Impress direct and GIC showed the least Mean difference of 2.69. Hence the test denotes that there is a difference in mean microhardness values between these restorative materials at 5% level of significance.

Table 3 : Results of Pairwise Comparison between the materials

<table>
<thead>
<tr>
<th>Materials (I)</th>
<th>Materials (J)</th>
<th>Mean Difference (I-J)</th>
<th>Sig.</th>
<th>95% Confidence Interval for Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Te- Econom Plus</td>
<td>Impress Direct</td>
<td>9.589</td>
<td>&lt;0.001</td>
<td>(-10.154, -9.024)</td>
</tr>
<tr>
<td>GIC</td>
<td>Impress Direct</td>
<td>12.281</td>
<td>&lt;0.001</td>
<td>(-12.648, -11.914)</td>
</tr>
<tr>
<td>Impress Direct</td>
<td>GIC</td>
<td>2.692</td>
<td>&lt;0.001</td>
<td>(-3.103, -2.280)</td>
</tr>
</tbody>
</table>

* The mean difference is significant at 0.05 level.

From the table 3, the highest mean difference of 12.28 was seen between the GIC and Te-Econom plus materials. Impress direct and GIC showed the least Mean difference of 2.69. Hence the test denotes that there is a difference in mean microhardness values between these restorative materials at 5% level of significance.

Discussion

Tooth restorations are commonly seen among patients with head and neck cancers [27]. Selection of dental restorative materials on such scenario is of paramount importance to prevent adverse effects to the structure. In this context, determination of material on the basis of their mechanical strength against radiation would be beneficial. Thus, in this study the effects of radiation on 3 different restorative materials was evaluated.

The results showed that the mean microhardness of 3 restorative materials increased after subjecting to a cumulative dosage of 70Gy. The increase in microhardness property of the materials can be due to increased polymerisation which occurred after radiation exposure [14,15]. The electron beam radiation used here has high dose rate and has low penetrating power compared to any other ionising radiations. It mainly targets the superficial layer and the strength increases as the energy increases by dosage rate. Hence the high degree of polymerisation is accredited to the high dose of radiation which causes alteration in chemical bonds within the product [16]. Radiation is known to build up components of polymer and also undergo cross linkage of chains during chemical reaction which in turn increases the polymer chain [17]. Mechanical properties of these study materials were enhanced as a result of this kind of polymerisation.

In contrast, some of the studies have shown a decrease in microhardness value after subjecting to radiation treatment [18]. Also some researchers have proved increased hardness upto the radiation dosage of 200kGy [19]. In the present study Glass Ionomer Cement, Gold label, Type 9 showed highest hardness value of 49.1 and 68.7 VHN among Non-radiated and radiated groups respectively. As the material is known for its high wear resistance property, it can be justified for the improvised strength seen in the material. The main component of the material, strontium reacts with the calcium present in the saliva forming strontium hydroxyapatite. Further calcium undergoes fusion with the GIC compound during the process imparting strengthening effect to the compound [20].

The nanohybrid composite, Impress direct showed similar strength as that of GIC with microhardness values of 44.6 and 67.5 VHN in non-radiated and radiated groups respectively. This enhancement in the property of the material is attributed due to the presence of nano-fillers like ytterbium trifluoride and aluminosilicate glass in its composition. Researchers have studied similar property to distinguish various Impress Direct compounds effected by consumption of alcohol and radiation. It has proved that Impress direct, translucent opal shades originally have high mechanical properties and also irradiation is known to increase its mechanical strength [21]. Further, Impress direct has also shown increased degree of polymerisation compared to GIC with the mean difference of 22.92. The Radiopaque composite, Te-Econom plus has also
undergone polymerisation with mean microhardness value of 52.7 VHN in radiated groups compared to 40.23 VHN in non-radiated groups. The pair wise comparison has proven that GIC and Te Econom plus has the highest mean difference of 12.28. However, the nano hybrid composites showed better degree of polymerisation, thus it could be termed as more clinically suitable restorative material.

Conclusion

The present study has shown that ionising radiation,

\[ \text{Radiotherapy} \]

References

15. Hu X, Marquis PM, Shortall AC. Two-body in vitro wear study of some (Electron Beam Radiation) increases the mechanical strength of the restorative materials. Hence these materials are considered safe for endodontic treatment among head and neck cancer patients. The nano hybrid composite, Impress direct has shown better degree of polymerisation compared to Glass Ionomer Cement and Te- Econom Plus, thus proving to be a clinically suitable restorative material.

References