Wear and Surface Roughness of Three Different Composite Resins after Simulated Toothbrushing: An in vitro Study

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ABSTRACT

Aim: To assess the influence of toothbrushing on wear and surface roughness of three commercially available composite resins.

Materials and methods: Ten round specimens per each composite resin (Filtek Bulk Fill, Filtek Z250 Universal Restorative, Filtek Z250XT) (n = 10) to be tested were prepared in an acrylic mold according to the manufacturer’s instructions. The specimens were weighed to determine the mass (M) using an analytic electronic balance followed by surface roughness (Ra) measurement of each specimen using a noncontact profilometer. A brushing sequence of 10,000, 25,000, and 50,000 cycles was performed for all the specimens in a toothbrushing simulator. The surface roughness and mass were determined before and after each brushing sequence. Two representative specimens from each group were examined under scanning electron microscopy to analyze and compare the surface topography before and after toothbrushing.

Results: The mean difference in surface roughness values of Filtek Z250 XT (−0.104) was significantly different from the other two composite resins. The mean difference of surface roughness between Filtek Bulk Fill (−0.072) and Filtek Z250 Universal Adhesive (−0.069) was not significant. Filtek Z250 XT group exhibited highest difference in mass loss values (0.0091) of the specimens after toothbrush abrasion cycles as compared with the other two groups.

Conclusion: All the tested composite demonstrated increased wear and surface roughness after simulated toothbrush abrasion of 50,000 cycles. Filtek Bulk Fill was more resistant to wear among the tested composite resins.

Keywords: Composites resin, Surface roughness, Toothbrushing, Wear.


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INTRODUCTION

The drawbacks of amalgams, in particular the lack of esthetics and presence of mercury have largely contributed to the popularity and increased use of resin-based composites (RBCs) for tooth restorations.1 The RBCs have undergone tremendous research and development in the last 40 years in order to improve their performance, mechanical properties, and clinical handling.2 These developments have primarily focused on improving the mechanical properties, such as hardness, compressive strength, flexural strength, fracture toughness, and reducing polymerization shrinkage.3

Bulk-fill composite resin is among the recent development in dental composites. These composites can be placed in a 4 mm thick bulk in the cavities and cured in one step instead of the current incremental fill technique where the increments of 2 mm is placed and cured.4 Bulk-fill composite does not seem to affect the polymerization shrinkage, cavity adaptation, and degree of conversion (DC %) and reported to have superior physical and mechanical properties to resist high masticatory forces.5,6 Many studies have focused on the mechanical properties of the bulk-fill composites4,6,8 and there is little or no literature about the behavior of these composites to toothbrush abrasion.

Like enamel and dentin, even the restorative materials are subjected to wear especially in the posterior occlusal surfaces, and the wear depends on the type of restorative material.9 The wear of the restorative material in the oral environment can be the result of direct contact between the tooth and the restorations during mastication, oral habits, toothbrushing with abrasive particles, and also due to chemicals in the dietary form.10 They have an adverse effect on the mechanical properties of the materials and also leads to an increased surface roughness.11 The surface roughness may increase the coefficient of friction and the rate of wear.12 Rough surface can also predispose

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to accumulation of dental biofilms, residues, and stains leading to gingival irritation, risk of secondary caries, diminishing the gloss of the restoration and giving rise to discoloration and/or surface degradation.\(^\text{13,14}\)

Despite the fact that toothbrushing plays an important role in oral hygiene, its ongoing action might damage the surface of resin composite restorations, making it rougher and, consequently, prone to staining, plaque accumulations, soft tissue inflammation and recurrent caries.\(^\text{15,16}\) The amount of wear caused by toothbrushing depends mainly on toothbrushing habits, quality of the toothbrush (hard, medium, or soft), and the dentifrice abrasive used.\(^\text{17}\) Moreover, toothbrush abrasion causing changes in surface conditions of restorative materials in any experimental situations can be helpful in predicting the clinical behavior of such materials.\(^\text{18}\) The wear and surface roughness may also have a negative impact on the longevity of the restoration in the oral environment. So it becomes necessary to study the effect of toothbrushing on composite wear and roughness. Therefore, the aims of the present study are:

- To evaluate the wear resistance of three composite resins (Filtek Bulk Fill; Filtek Z250 Universal Restorative; Filtek Z250 XT) subjected to toothbrush–dentifrice abrasion at three different cycle intervals using a toothbrush simulator
- To evaluate the surface roughness of three composite resins (Filtek Bulk Fill; Filtek Z250 Universal Restorative; Filtek Z250 XT) using a profilometer before and after each toothbrush–dentifrice abrasion cycle.

**MATERIALS AND METHODS**

The description of the composites resin used in the study is presented in Table 1.

**Specimen Preparation**

Ten round specimens (12.0 × 2.0 mm) per each resin material to be tested were prepared in a rubber mold. The mold was kept on a microscopic glass slide and the composite resin was placed and condensed in the mold. The upper side of the mold was covered by another microscopic glass slide and was then compressed to make sure that there was a uniform distribution of the material and prevent any air bubble entrapment and also to flush out any excess material. The specimens were light cured for 20 seconds using a visible light-cure unit (Elipar freelight 2, 3M ESPE, Germany) according to manufacturer’s recommendation. After light curing, the specimens were removed from the mold and finished with Flexi snap kit abrasive discs (Edenta AG, Hauptstrasse, Switzerland) in decreasing order of the abrasive material (coarse < medium < fine < ultrafine). After finishing, the specimens were polished using a prophy cup and were kept in distilled water at room temperature for 7 days before the test procedures.

**Surface Roughness Measurement**

The initial surface roughness of each composite specimen was assessed with a three-dimensional (3D) optical non-contact surface profilometer (Bruker Contour GT, Tucson, AZ, USA). This optical profilometer works on contact scanning white light interferometry to evaluate the surface roughness and configurations. The profilometer utilizes a Nanolens Atomic Force Microscopy module with fully automated turret with programmable X, Y, Z movements controlled by Vision 64 application software. The standard 1× camera has a magnification 5×, thereby providing high resolution of the composite surface. The simple vision 64 application software transforms these high-resolution data into accurate 3D images. The specimens were scanned in five randomly selected areas. The mean of the values corresponded to the initial surface roughness value (Ra\(_0\)).

**Determination of Weight using Analytic Balance**

After surface roughness assessment, all the specimens were weighed in an analytic electronic balance (Precisa 138

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**Table 1: Composite materials used in the study**

<table>
<thead>
<tr>
<th>Name</th>
<th>Resin matrix</th>
<th>Inorganic filler</th>
<th>Size</th>
<th>Weight %</th>
<th>Batch number</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filtek Bulk Fill (Nanofiller)</td>
<td>Bis-GMA</td>
<td>Zirconia 0.01–4.5 µm Ytterbium trifluoride 100 nm</td>
<td>64</td>
<td>N722295</td>
<td>3M ESPE, St. Paul, MN, USA</td>
<td></td>
</tr>
<tr>
<td>Filtek Z250 Universal Restorative (Microhybrid)</td>
<td>Bis-GMA</td>
<td>Zirconium/silica 0.01–3.5 µm average particle size is 0.6 µm</td>
<td>82</td>
<td>N749365</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filtek Z250 XT (Nanohybrid)</td>
<td>Bis-GMA</td>
<td>Surface modified zirconia/silica 3 µm nonagglomerated surface modified silica 20 nm</td>
<td>82</td>
<td>N754044</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bis-EMA: Ethoxylated bisphenol A dimethacrylate; UDMA: Urethane dimethacrylate; Bis-GMA: Bisphenylglycidyldimethacrylate; TEGDMA: Triethylene glycol dimethacrylate; PEGDMA: Polyethylene glycol dimethacrylate
EP SM–DR, Precisa Gravimetrics AG, Switzerland) to determine the initial mass in grams (M₀).

**Simulation of Toothbrushing**

The specimens from all the composite resin groups were subjected to toothbrushing simulation after the initial roughness and mass values were obtained. For toothbrushing abrasion test, a toothbrushing simulator (ZM 3, SD Mechatronik, GMBH, Germany) was used. A metal holder with same size of the specimen was placed in the container onto which the specimens were affixed with a drop of glue and pressed hard against the plate to promote good adhesion and prevent any undesired removal of the specimen during toothbrushing. The dentifrice (Colgate Total CLEAN MINT, Colgate Palmolive Arabia Ltd, K S A) was mixed with deionized water in a ratio of 1:1 by weight and made into slurry and filled into the container. Toothbrush with wave-shaped medium bristles (Oral B Classic, Gillette India Ltd, India) was used in the brushing simulator for the abrasion test in combination with the dentifrice slurry. The specimen container was completely filled with the slurry and monitored for any refill during the toothbrushing procedure. Toothbrushing was done in a horizontal direction with forward and backward movement under a load of 200 gm and the stroke rate of 120 cycles/minute with a stroke length of 40 mm. The toothbrushing abrasion test was carried in phases of 10,000, 25,000, and 50,000 cycles. After each cycle phase, the composite resin specimens were carefully removed from the metallic specimen holder with a scalpel, rinsed under tap water, and dried. The surface roughness and mass of the specimens was determined after 10,000 (Ra₁₀), 25,000 (Ra₂₅), and 50,000 (Ra₅₀) toothbrushing cycles for all the specimens.

**Scanning Electron Microscopy**

**Topography Analysis**

Two randomly selected composite specimens from each group before subjecting to abrasion cycles and after 50,000 toothbrushing cycles were examined for surface topographic changes using scanning electron microscopy (SEM; Jeol JSM-5900 LV SEM, Tokyo, Japan) operated at 10 kV in vacuum and with 500× magnification.

**Statistical Analysis**

The data obtained were analyzed using Statistical Package for the Social Sciences version 18.0 (SPSS Inc., Chicago, Illinois). One-way analysis of variance and post hoc multiple comparison tests were used to determine for any significant differences within the composite groups. Paired t-test was used for comparisons between each toothbrushing cycle for each composite group.

**RESULTS**

The mean surface roughness values of the tested composite specimens initial and after each brushing cycles are shown in Table 2 and presented graphically in Graph 1. The paired t-test was used to determine the significant difference in surface roughness values (p < 0.05) among the specimens after each brushing cycles within the group, and Tukey’s test was used to determine any difference (p < 0.05) in surface roughness among the three groups. Filtek Z250 XT group exhibited significantly different surface roughness values as compared with the other two groups. No significant difference in surface roughness values was observed between Filtek Bulk Fill and Filtek Z250 Universal Adhesive. The mean mass values of the tested composite specimens before and after each toothbrushing cycles are shown in Table 3. The paired t-test was
Table 3: Mean mass of the specimens before and after each toothbrushing cycle interval

<table>
<thead>
<tr>
<th>Material</th>
<th>$M_{0}$</th>
<th>$M_{10}$</th>
<th>$M_{25}$</th>
<th>$M_{50}$</th>
<th>Mean difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filtek Bulk Fill</td>
<td>0.4590 a</td>
<td>0.4320 ab</td>
<td>0.4135 bc</td>
<td>0.3887 c</td>
<td>0.0703 A</td>
</tr>
<tr>
<td>Filtek Z250 Universal Adhesive</td>
<td>0.4559 a</td>
<td>0.4206 b</td>
<td>0.4004 bc</td>
<td>0.3710 c</td>
<td>0.0849 B</td>
</tr>
<tr>
<td>Filtek Z250 XT</td>
<td>0.4631 a</td>
<td>0.4246 ab</td>
<td>0.4013 c</td>
<td>0.3640 c</td>
<td>0.0991 C</td>
</tr>
</tbody>
</table>

The values are expressed in grams; Different lower case letters in a row indicate significantly different groups (paired t-test, $p < 0.05$); Different upper case letters in a column indicate significantly different groups (Tukey’s test, $p < 0.05$).

used to determine the significant difference in specimen mass values ($p < 0.05$) among the specimens after each brushing cycle within the group and Tukey’s test was used to determine any difference ($p < 0.05$) in mass values among the three groups. Filtek Z250 XT group exhibited higher mass loss values of the specimens after toothbrush abrasion cycles as compared with the other two groups. There was significant difference in measured mass loss values among all the three groups. The mean difference in weight measured from initial to after final toothbrushing abrasion cycles was 0.0991 gm with Filtek Z250 XT as compared with 0.0849 gm with Filtek Z250 Universal Adhesive and 0.0703 gm with Filtek Bulk Fill composites.

The SEM images of the representative specimen from each group of composite are presented in Figure 1. The SEM images showed a clear demarcation between the images done before and after toothbrushing abrasion. The wear was seen in all the three groups but severe changes in surface topography were observed in Filtek Z250 XT (Fig. 1C) composite resin compared with other two composite resins.

DISCUSSION

The present study evaluated the influence of toothbrushing abrasion on the surface roughness and wear of three commercial composite resins. Out of the three commercial composite resins, two were nanocomposites (Filtek Bulk Fill, Filtek Z250 XT) and one microhybrid (Filtek Z250 Universal Adhesive). Nanocomposites have two variants. Due to small primary filler particles in nanocomposites, the filler and resin matrix wear off together by breaking off individual primary particles during abrasion, whereas in microhybrid composites the relatively soft resin matrix wears off first followed by the inorganic filler.19

Restorative material surfaces in the oral environment are exposed to various factors, which can modify the surfaces. Toothbrushing is one such factor. Toothbrushing using dentifrice is one of the oral hygiene procedures that play a significant role in reducing plaque, caries among other benefits. Previous studies have reported that amount of wear by toothbrush dentifrice abrasion depends on toothbrush quality, toothbrushing habits, type of dentifrice used, the load applied, slurry dilution, and oral temperature.17 It is also reported that wear resistance of a composite depends mainly on shape and size and load of filler and to some extent on the filler features, organic matrix components.20

The mechanical characteristics of the composite resins can be evaluated by wear tests and surface roughness measurements after subjected to simulated toothbrushing.21 The present study evaluated the wear and surface roughness of the composite resins after 1, 2.5, and 5 years of simulated toothbrushing assuming those 10,000 cycles simulate 1 year of toothbrushing.17,22 For our research, we selected the medium type of toothbrush because it
is reported that toothbrush type did not affect the wear when used with a wet medium although some authors report that soft toothbrushes abrades more compared with medium or hard brushes.23

In the present study significant difference was observed between all the three groups of composites tested from initial to final 50,000 toothbrushing cycles. Though the wear was not significant from initial to 10,000 cycles, differences were observed in subsequent cycles. Some studies report that nanocomposites are more resistant to wear than microhybrid composites although the nanocomposites and microhybrid composite fillers have same average cluster size, the nanocomposites abrade by breaking off individual primary filler particles.

Notably in our study, the nanocomposite Filtek Z250 XT demonstrated more wear compared with the microhybrid composites and was in disagreement with the views of Mitra et al.24 In this study, the nanofiller Filtek Bulk Fill composite showed more resistant to wear among the tested composite groups. This could better be explained due to the fact that mean distance between adjoining particles is less than coarse filler particles. This structure favors protection against wear of the matrix and ensures better performance of the material.25

In the present study, there was no significant difference in the final surface roughness of the Filtek Bulk Fill and Filtek Z250 Universal Adhesive but Filtek Z250 XT group had significantly different surface roughness values compared with other two after 50,000 brushing cycles. Filtek Z250 XT had the least roughness at initial 10,000, 25,000 cycles but after final brushing cycles it exhibited the highest surface roughness.

Quirynen and Bollen26,27 reported that surface roughness value in composite materials should be below 0.2 μm to prevent adhesion of plaque and microorganisms. The roughness of the restoration can be detected by measuring the gaps. Quintessence Int 1999 Jul;30(7):490-495.

In the current study, the initial Ra values of all the tested composites were well below the threshold limit of 0.2 μm but after final brushing cycles, all the groups exhibited values above 0.2 μm. Though the filler loading in both Filtek Z250 Universal Adhesive and Filtek Z250 XT was 82% by weight, but it was unclear as to why Filtek Z250 XT exhibited higher surface roughness values. There was a clear correlation between surface roughness and wear in the tested specimens.

In a previous study by Kanter et al29 and Mandikos et al,30 it was concluded that composites which abrades more shows increased surface roughness which was well in agreement with the findings of our study but was conflicting with the outcome of the studies by Wang et al17 and Garcia et al15 which concluded that there was no significant relation between wear and surface roughness. The toothbrush abrasion depends on variety of factors, such as type of composite, the chemistry or method of polymerization of the composites, type of toothpaste, and the nature of the toothbrush used.30,31 So the results of the present study should not be compared with the outcome of other studies.

CONCLUSION

The following conclusions are drawn from the present study:

- All the tested composite demonstrated increased wear and surface roughness after simulated toothbrush abrasion of 50,000 cycles.
- Filtek Bulk Fill was more resistant to wear among the tested composite resins.

REFERENCES


