The effect of erosion and abrasion on surface properties of composite resin

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Abstract. The aim of the study was to evaluate the surface roughness of two commercial composite resins submitted to erosive attack, to abrasive wear and to association of erosive and abrasive challenge. Standardized samples of G-ænial anterior (GC Company) and Essentia (GC Company) composite resins were randomly split in 6 groups. In group 1 the samples were maintained in artificial saliva until the evaluation of surface roughness. In group 2 the samples were submitted only to erosive attack, in group 3 only to abrasive challenge and in groups 4, 5, and 6 the erosive attack was followed by abrasive challenge immediately (group 4), 30 minutes after the erosive attack (group 5) and one hour after the erosive attack (group 6). The specimens were evaluated using surface roughness measuring tester SJ-210 (Mitutoyo Corporation, Japan) and the mean surface roughness values (Ra, µm) of each specimen were registered. A significantly increase of both composite resins surface roughness was recorded after erosive attack and abrasive challenge. Toothbrushing 60 minutes after acidic contact determined no significant differences in surface roughness of composite resins.

1. Introduction

Oral cavity is a complex environment, where the teeth are exposed to acids coming from bacterial metabolism, beverages, food or stomach content or to mechanical wear or to temperature changes [1, 2]. In the latest years an increase in acidic beverages consumption was observed and related to that an increase in the prevalence of dental erosion was reported. Enamel, dentine and cement are prone to chemical dissolution in acidic environment [3]. Except the loss of dental hard tissues, acidic agents can also affect the materials for filling. The contact of erosive factors with the composite resins might lead to degradation of the resin matrix, releasing of filler due to abrasion or chewing forces or alteration of coupling agent [4].

Generally, the abrasive effects in the oral cavity are related to the abrasiveness of toothpastes and toothbrushing technique. Previous studies showed a direct correlation between the size of the filler and the amount of material loss [5, 6]. The shape of the fillers can also influence the resistance of the composite resin to abrasive challenge.

One of the clinical results of these chemical and mechanical phenomena is the increase of the surface roughness of restorative materials. This can lead to higher bacterial colonization due to their
retention in the surface irregularities, which can determine periodontal problems [7]. The surface roughness can be a cause of changes in materials colour and translucency, which might affect the aesthetic aspect of final restorations [8-11].

The aim of the study was to evaluate the surface roughness of two commercial composite resins submitted only to erosive attack, only to abrasive wear and to association of erosive and abrasive challenge.

2. Materials and Methods

2.1. Samples preparation

Two composite resins were chosen for this study: G-ænial anterior (GC Company) and Essentia (GC Company). Thirty samples of each material having 25 mm in length, 7 mm in width and 2 mm in height were obtained by placing the composite resin in contact with a transparent matrix between two glass slabs in order to flatten the surface. The samples were built-up in one increment of 2mm. Every sample was light cured for 40 seconds in one step, using a LED curing light unit (LED B, Guilin Woodpecker Medical Instrument Co., Ltd, China), with an intensity of the light source of 850-1000mW/cm² and a wavelength of 420-480 nm. The samples of each composite resin were equally split in 6 groups. In group 1 the samples were kept in artificial saliva (AFNOR NF S90-701) until the evaluation of surface roughness. In group 2 the samples were submitted only to erosive attack, in group 3 only to abrasive challenge and in groups 4, 5, and 6 the erosive attack was followed by abrasive challenge immediately (group 4), 30 minutes after the erosive attack (group 5) and one hour after the erosive attack (group 6).

2.2. Erosion attack simulation

Each sample of groups 2-6 was immersed in 10 mL of Coca Cola® (Coca-Cola Company) two times a day, 3 minutes each time. Fresh beverage was used for every immersion. Between the immersion periods, the samples were maintained in artificial saliva.

2.3. Abrasion simulation

To simulate the abrasive challenge due to toothbrushing, a device created by the authors was used (figure 1).

Figure 1. Toothbrushing machine.

The device is composed by: 1. the weight that ensures a constant pressure on tooth brushes; 2. tooth brushes support that have the possibility to move on vertical direction on two gripper bars and allow toothbrushes lifting and descending under the pressure during tooth brushing; 3. toothbrushes; 4. tube to inject the dentifrice directly on the tooth brushes head; 5. system for fixing the samples; 6. electric motor having 30W and 50Hz; 7. support table to maintain the motor and the sliding system; 8.
mechanism to transform the rotation movement in forward and back movements; 9. sliding table which is stable in vertical direction but allowes the movements in horizontal direction; 10. fixing and sliding bars; 11. sample fixed in correct position; 12. adhesive bands to prevent scratching of the samples when fixing and releasing the samples; 13. tray to collect the used toothpaste.

The device was design to simulates the forward and back movements during toothbrushing. The amplitude of the movements was 30 mm (15 mm in each direction) and the frequency was 60 cycles/minute. Toothbrushes having medium hardness of the bristles were used in this study (Colgate Classic Deep Clean). The weight applied on every toothbrush was 250 g. Colgate Total toothpaste diluted with water (1:2 by volume) was used as dentifrice. In this study was simulated the toothbrushing for 2 minutes, twice a day, 30 days. On each sample the calculated mean number on toothbrushing cycles during a toothbrushing of 2 minutes was 20.

2.4. Surface roughness evaluation

The specimens were evaluate using surface roughness measuring tester SJ-210 (Mitutoyo Corporation, Japan) (figure 2), having the measuring force of 0.75 mN, traversing speed of 0.5 mm/s and the cutoff length of 0.8 μm. The mean surface roughness values (Ra, μm) of each specimen were obtained from ten measurements from the center of each sample in different directions.

Figure 2. Surface roughness measuring tester.

3. Results

Examples of profiles for some composite resins samples in control and study groups are presented in figure 3.
The mean values of surface roughness (µm) and standard deviation of the samples in all six groups are presented in table 1.

A significantly increase of both composite resins surface roughness was recorded after erosive attack when compared to control group (ANOVA and post hoc Bonferroni statistical tests, p<0.05). Besides, after toothbrushing, the surface roughness of both composite resins increased significantly (ANOVA and post hoc Bonferroni statistical tests, p<0.05). When toothbrushing was simulated immediately after the erosive attack, the highest mean surface roughness was obtained. Toothbrushing at 30 minutes and at 60 minutes after the erosive attack leaded to a lower surface roughness of composite resins when compared to the group where toothbrushing was simulated immediately after the erosive attack. No significantly differences were recorded in the surface roughness values when brushing was simulated at 60 minutes after the acid attack and in the group where only the abrasive challenge was simulated.

G-ænial Anterior composite resin recorded significantly higher surface roughness values when compared to Essentia composite resin, in control group and in all six study groups (ANOVA and post hoc Bonferroni statistical tests, p<0.05).
Table 1. Mean values of surface roughness (µm) ± standard deviation

|                | Group 1     | Group 2     | Group 3     | Group 4     | Group 5     | Group 6     |
|----------------|-------------|-------------|-------------|-------------|-------------|-------------|
| G-ænial        | 0.070±0.02  | 0.142±0.04  | 0.090±0.02  | 0.424±0.02  | 0.159±0.02  | 0.098±0.03  |
| Essentia       | 0.042±0.03  | 0.093±0.03  | 0.056±0.03  | 0.297±0.01  | 0.078±0.01  | 0.061±0.02  |

Similar capital letters in a column represent significant statistical difference between materials according to ANOVA and post hoc Bonferroni statistical tests (p<0.05). Similar small letters in a line represent significant statistical difference between groups, according to ANOVA and Bonferroni tests (p<0.05).

4. Discutions

In our study the two commercial composite resins presented different surface roughness. The amount, size, shape, distribution and hardness of filler particles, resin matrix conversion percentage, together with the interaction with the organic matrix, can explain the differences in composite resins roughness [12]. In control group and in study groups, G-ænial composite resin also presented higher surface roughness when compared to Essentia. G-ænial is a hybrid composite restorative with a combination of two types of pre-polymerized resin fillers (silica and strontium and lanthanoid) having the mean size of 16-17 µm, silica as inorganic filler with more than 100 nm size and fumed silica as inorganic filler with less than 100 nm size.

Degradation of composite resins is in a direct relation with the storage solution [13]. It was showed that the pH of immersion solution can accelerate the erosive wear. A lot of factors have the capability to influence the behaviour of restorative materials in acidic conditions [14-16]. In the present study both composite resins were affected by the contact with acidic beverage. Many studies showed that Coca-Cola or Coca-Cola-like beverages are one of the most aggressive erosive agents. The composite resin degradation in low pH solutions is due to hydrolytic degradation [17, 18]. First step in erosive degradation is represented by water absorption, that can further pass inside the resin matrix, at the interface with the fillers or other defects, compromising their reinforcing effects [19]. Also factors like the cross-link nature of the resin matrix, and the solvent sorption uptake have a direct effect on composite resins degradation [20]. Previous studies showed that the increase of composite resins roughness in acidic solutions is probably due to their soften surface that leaches the resin components and displaces the filler particles [21-23].

In the present study toothbrushing using a toothbrush having medium hardness of bristles and a toothpaste with low relative dentine abrasivity for thirty days leaded to higher surface roughness of both composite resins. Similar results were found in other studies [8, 24-26].

The final surface roughness of both composite resins after erosive attack, abrasion challenge or association of both processes was less then 0.2 mm, that is considered to be critical for bacterial retention [27]. For the patient surface roughness lower then 0.25-0.5 mm are impossible to be detected [28], so we can consider that the behaviour of both studied composite resins is clinically safe.

3. Conclusions

The exposure to acidic beverages like Coca-Cola increases the surface roughness of composite resins. Toothbrushing using a toothbrush having medium hardness of bristles and a toothpaste with low relative dentine abrasivity also increases the surface roughness of composite resins. Abrasive challenge immediately after and 30 minutes after an acidic attack determines the highest alteration of the surface state of composite resin. To a lesser alteration of composite resins surface roughness, toothbrushing 60 minutes after an acidic challenge is recommended.

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