IN VITRO STUDY OF DENTAL COMPOSITE ROUGHNESS AND MICROLEAKAGE OF REPAIRED OBTRUATIONS BY VARIOUS TECHNIQUES

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ABSTRACT
Tooth restoration is one of the most common procedures in dental practice. The replacement of the whole restoration leads to loss of tooth structure and it’s weakening. According to the minimally invasive approach when minimal defects have occurred, or the diagnosed defect is localized only in one region of the restoration, the repairmant is a better choice than the total replacement of the restoration.

The aim of the present study is to investigate the roughness of the surface of dental composites processed by different technics as well as to assess the micro-leakage between a cavity and composite walls and between old and new material after repairment.

In our study, 28 extracted human teeth (premolars and molars without visible cavity) were used for micro-leakage assessment. Class 5 cavities were prepared and obturated with the decision concerns restoration of their own, the restoration is operative removal. Recently published a cross-sectional study from a dental practice based research network showed that still 75% of all posterior restorations were replaced and 25% were repaired [2]. The replacement of the whole restoration leads to loss of tooth structure and it’s weakening, there is a risk of pulp injury, it’s time and cost consuming. This consecutive change of the restorations with weakening, there is a risk of pulp injury, it’s time and cost consuming. This consecutive change of the restorations with

For roughness measurements 20 samples (10 mm diameter and 4 mm thickness) were manufactured of micro-hybrid filling light curing material Essentia Universal (GC). The composite resin was put in a special plastic mold, then the surface was treated by different techniques and the surface roughness was measured by profile meter Mitotoyo SJ-210.

Our study showed that the different types of surface treatments of dental composites lead to different roughness, with the highest values being obtained after laser treatment, followed by turbine application and air abrasion. Microleakage in repaired obturations is influenced not only by the roughness of the surface of the “old” material but also by the chemical composition and physical properties (viscosity) of the used primer and adhesive. The smallest microleakage was obtained in group A, where the “old” composite was treated with a turbine, etched and applied only G-Premio Bond.

Keys: dental composite, repairment, microleakage, composite roughness

INTRODUCTION
Tooth restoration is one of the most common procedures in dental practice. Over 60% of all restorative dentistry is repair or replacement of restorations [1, 2]. The defective restoration could present with marginal staining, fracture, loss of anatomic form, marginal detachment, degradation/wear or secondary caries [3]. Concerning dental amalgam restorations, the most frequent reasons for replacement are caries and fractures of the filling or the tooth itself [4]. Besides this reasons, composite restorations fail because of poor aesthetics as a consequence of material degradation and discoloration, loss of marginal integrity due to breakdown and often causing pain and discomfort [5].

Traditionally, the accepted treatment strategy for restorations exhibiting signs of deterioration and failure is a total replacement. This was based on the concept that the best way of treatment of caries and deficiencies in restorations is operative removal. Recently published a cross-sectional study from a dental practice based research network showed that still 75% of all posterior restorations were replaced and 25% were repaired [2]. The replacement of the whole restoration leads to loss of tooth structure and it’s weakening, there is a risk of pulp injury, it’s time and cost consuming. This consecutive change of the restorations with larger and more complex ones has been called the restorative cycle, spiral or staircase [6].

According to the minimally invasive approach when minimal defects have occurred, or the diagnosed defect is localized only in one region of the restoration, the repairment is a better choice than the total replacement of the restoration [7]. Unfortunately, dentists usually don’t consider this treatment option. A practice-based research study found that only practitioners who assess caries risk, who have graduated recently and such as those who practiced in non-fee service settings preferable repair restorations [3], when the decision concerns restoration of their own, the restoration is on molars and includes multiple surfaces [2]. Unfortunately, in the literature, there is no much information about
the criteria when restoration should be repaired instead of replaced, and even the new books contain relatively little information on this topic [8, 9]. May be this is one of the reasons why in such high percent of the cases dentists change and do not repair defect restorations [10].

The quality of bonding between materials depends on their surface morphology [11, 12, 13]. The rougher is the surface of the composite, the more the adhesive will penetrate the roughness and will make a better connection with the new composite material added to the repaired. The roughness of the composite surface can be used as an indicator for adhesion strength or for the degree of micro-leakage respectively between old and new material when repairs are made.

To over increase the surface roughness and improve the connectivity between two materials, different methods are used in clinical practice. The most frequent methods are with low or high speeds diamond burs, air abrasion with solid particles, surface treatment with acid - orthophosphoric, hydrofluoric, etc., as well as laser etching.

Based on the data obtained from studies we may conclude that repairment of restorations as a treatment method in cases of localized restoration defects is known and applied by dental practitioners [14].

AIM

The aim of the present study is to investigate the roughness of the surface of dental composites processed by different technics as well as to evaluate the micro-leakage between cavity walls and composite material and between old and new material after repairment.

MATERIALS AND METHODS

Roughness measurements

20 samples (10 mm diameter and 4 mm thickness) were manufactured of micro-hybrid filling light curing material Essentia Universal (GC). The composite resin was put in a special plastic mold (Fig. 1-a) and smooth only by spatula, after that it was polymerized for 40 s.

Fig. 1. a) – samples and  b) – profile meter for surface roughness measurements

Depending on the treatment of their surfaces, the samples were divided into five groups with 4 samples in each group: The first group is a control group with no surface treatment; The surface of the second group was treated using turbine diamond burr with green ring in high speed (80 000-200 000 rpm);

The third group was treated with low speed diamond burr (5000-8000 rpm); The surface of the fourth group was air abraded with Air flow (EMS) powder (Al₂O₃ 27 µm) using PrepStar (Danville Engineering) equipment. The surface of the fifth group was treated by high-energy laser LITE TOUCH using program for tooth etching with the following parameters: 300mJ/18 Hz, 5.40 W.

The surface roughness was measured by profile meter Mitotoyo SJ-210 (Fig. 1-b). Before each measurement, the surface of the samples was cleaned with isopropyl alcohol. After roughness measurements, the surfaces of the samples of the first four groups were etched with 37% orthophosphoric acid for 30 s, washed for 30 s and dried. Then, the surface roughness was measured again. In all experiments, the average arithmetic deviation Ru of the surface roughness was evaluated. The average Ra value of 10 measurements of each sample was calculated, and data were processed using Excell software.

Microleakage test

In our study, 28 extracted human teeth (premolars and molars without visible cavity) were used. After the extraction, the teeth were stored in distilled water. To exclude fractures, cracks and other defects, the teeth were pre-screened under the Olympus SZ51 microscope with an x 12x magnification (Fig. 2).

Fig. 2. Preliminary view and choice of the teeth for testing (12x).

The teeth were divided into four groups of 7 pieces each. In each group, we made 22 cavity class 5 on the vestibular and/or lingual surfaces, approximately 3x2x2 mm with conventional technique – diamond burs with a green rings for a high speed handpiece under water-air cooling. After the experiment, the teeth were again examined for defects, cracks and fractures under the microscope and prepared for obturation (Fig. 3-a).

The cavities were cleaned with a 70% alcohol and dried, followed by etching the enamel with 37% orthophosphoric acid for 10 seconds, washing for 20 seconds, gently drying and applying Premio Bond (GC) over the entire surface of enamel and dentine. Then all the cavities were obturated with composite resin - the micro-hybrid Essentia Universal (GC) with application technique - incrementally (Fig. 3-b). For artificial aging, the teeth were thermocycled under the following regimen: 500 cycles at a temperature of 5-50 °C with a residence time of 15 sec.

We removed half of the restoration material- approximately 1.5x2x2 mm (Fig. 3-c), using diamond burs with green rings for a high speed handpiece. After removing half of the restoration of the thermocycled teeth, they were divided in groups A, B, C and D, in which the surface of the remaining material was treated differently before the obturation was made, by the addition of the "new" material (Table 1).
In Group A, before the repairment of the obturation, the cavity and the aged material were treated only with etching and adhesive, using the same as for the original obturation. The repairment was done with the same composite material on the same protocol. We etched the enamel for 10 seconds and the material for 30 seconds. Then we applied adhesive and composite material and light cured, according to the manufacturer’s instructions, for 15 seconds and for a minimum of 20 seconds each portion of the composite.

In Group B, after etching the old composite material Composite Primer (GC) was applied on the surface of the old composite to be bonded to the new one, and light cured for 10 seconds according to the manufacturer's instructions. Then Adhesive and Composite material were applied.

In Group C, the surface of the old material was subjected to air abrasion with solid particles, followed by cavity treatment as described above - etching, adhesive application and composite material incrementally.

In Group D, the surface of the composite material was subjected to air abrasion, after which a composite primer was applied. Enamel etching, bonding and composite filling are done in the same way for all experimental groups of teeth.

After obturation, imitating a repairment, the teeth were isolated with contrasting varnish except for the cavities and 2 mm around (Fig. 3-d). They were placed in a colorant - 2% methylene blue solution for 24 hours, then washed, cut horizontally through the crown with diamond separators and re-examined on a microscope with a magnification of x8 x15 and x30. The degree of penetration of the dye between the wall of the tooth and the composite and the boundary between the two materials was evaluated by measuring the penetration depth using the TourView program. Data were processed using Excell software.

**Table 1. Scheme of the experiment organization**

<table>
<thead>
<tr>
<th>Samples’ group</th>
<th>Treatment before repairment</th>
<th>Repairment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>- Etching - Adhesive Composite</td>
<td>- Adhesive Composite</td>
</tr>
<tr>
<td>Group B</td>
<td>- Etching Composite primer Adhesive Composite</td>
<td></td>
</tr>
<tr>
<td>Group C</td>
<td>Air abrasion Etching - Adhesive Composite</td>
<td></td>
</tr>
<tr>
<td>Group D</td>
<td>Air abrasion Etching Composite primer Adhesive Composite</td>
<td></td>
</tr>
</tbody>
</table>

**RESULTS**

*Surface roughness*

The results obtained (Fig. 4) have shown that the surface treatment of the composite samples with diamond burs leads to increasing of their roughness 6-8 times compared to the control group. The high-speed turbine treatment is more effective – its average $Ra$ value is nearly twice higher than the treatment with low speed diamond bur taking into account that the tools are with the same abrading ability ($Ra=6.387 \mu m$ and $Ra=3.650 \mu m$ respectively). Treatment of the surfaces with air abrasion also leads to significant increase of their roughness - $Ra=5.131 \mu m$, as its average value is higher than that of the low speed bur, but lower than the high-speed turbine bur treatment. The most effective is the laser surface treatment causing the highest roughness $Ra=13.756 \mu m$ which is nearly 20 times higher comparing to the control group and more than two times higher than the high-speed turbine bur treatment.
Fig. 4. Surface roughness of the samples treated by different techniques.

Etching with 37% orthophosphoric acid resulted in a slight increase in the mean arithmetic deviation of the roughness $Ra$ in all groups (Fig. 4). It is well known that etching procedure is used for increasing the surface roughness of the hard teeth tissues (HTT), thus increasing the adhesion strength between HTT and the composite material [11, 12, 13].

Microleakage
For Group A, the average microleakage between cavities and material was about 42% (41.99% and 42.71%), in group D - about 50% (48.42% and 50.82%) (Fig. 5 and Fig. 6). It is noteworthy that the microleakage of dye between the cavity walls and the KM is most pronounced in Group B and C teeth - 54.25% and 58.23% for group B and 66.97% and 72.87% for group C (respectively between new material and cavity and between cavity and old material) (Fig. 7). These are also the highest microporous values measured in our study.

Fig. 5. Micro-leakage of dye to different parts of the cavity.
Fig. 6. Cavity A 20 in different magnifications: a) – x8, b) – x15, c) and d) – x30.

Fig. 7. a) – Pictures of cavity B14 (x15), b) – cavity C3 (x15) and c) – cavity D11 (x15).

The distribution according to the number of cavities with zero or total microleakage between old and new material, we obtained: in Group A there are none, in Group B - 1 cavity with 0% microleakage and 7 with 100%; Group C again has the highest score - 8 cavities are 100%, and none with no leakage, ie. by 0%; in group D, 6 the cavities are without permeation and only 1 is 100% (Fig. 8). Comparing the penetration of dye between cavity walls and “old” and “new” materials, again in group C, the highest score was observed - 11 cavities were 100% leaky. For group B their number is 9, and not quite expected in group D 7 the cavities are totally permeated. In group A, the number of zero and also 100% percolation is small, respectively 3 and 2.
Fig. 8. Quantity of cavities with no (0%) or total (100%) micro-leakage of dye along wall/material or new/old material

The cavity depth in all groups is almost the same - on average from 2.07 mm to 2.20 mm, and the Microleakage varies from 0.69 mm for group A to 1.25 mm for group B (Fig. 9).

Fig. 9. Average cavity depth and average dye micro-leakage in all tested groups.

By comparing the values obtained for all four groups, we found the lowest penetration rate of dye between old and new dental material in control group A - 32.07% and by about 10% higher for group D - 41.48%, which were applied air abrasion and primer. Almost twice as high as in control group A is this percentage for Group C teeth in which a composite primer was used - 59.84%. This is also the largest measured value for microleakage between materials in the experiment. For Group C, in which the old material was treated with air abrasion, the average microleakage between the materials was 51.96%.

DISCUSSION

Surface roughness
Our samples were consist of dental micro-hybrid composite material in which the surface of the inorganic filler is treated with silane agents for better bond strength with the organic matrix [11, 15]. As the acid used cannot etch the polymeric matrix, the surface roughness could be increased only by reaction with the inorganic filler, but its silane coating is an obstacle. Therefore, this is the most probable reason for the low influence of the acid etching on the increase of the surface roughness of dental composite.

Microleakage
According to data from the G-Premio Bond adhesive manufacturer and the GC Composite Primer primer, the two materials differ in chemical composition [16, 17]. The adhesive has a total methacrylate content of between 12.5-30%, 25-50% acetone, 5-10% methacryloyloxydecyl dihydrogenphosphate and 1-2.5% diphenyl (2,4,6-trimethylbenzoyl) phosphine oxide. In contrast, the primer
consists predominantly of 70-100% methacrylates, which determines its lower viscosity. The absence of filler in the GC Composite Primer leads to a greater shrinkage in the polymerization process, and there is a possibility of cracking between the cured primer and the old composite. This is most likely the reason for the higher percentile rate in Group C.

On the other hand, abrasion of the surface of the composite after turbine treatment can result in a reduction in roughness by smoothing or deforming the sharp edges obtained by cutting with the diamond pile. As a result of the deformed edges on the abrasion surface and the higher viscosity of the adhesive, it can not completely fill the roughness, there remain air spaces that determine the higher permeation of Group C vs. Group A (51.96% to 32.07% respectively). Because of the greater fluidity of the primer, it successfully penetrates the deformed edges on the abraded surface and causes less leakage in Group D specimens than those of group C.

CONCLUSION
Our study showed that the different types of surface treatments of dental composites lead to different roughness, with the highest values being obtained after laser treatment, followed by turbine application and air abrasion. Microleakage in repaired obturations is influenced not only by the roughness of the surface of the “old” material, but also by the chemical composition and physical properties (viscosity) of the used primer and adhesive. The smallest microleakage was obtained in group A, where the “old” composite was treated with a turbine, etched and applied only G-Premio Bond.

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