ROUGHNESS VARIATION OF A NANOHYBRID COMPOSITE RESIN SUBMITTED TO ACID AND ABRASIVE CHALLENGES

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Abstract

The present study aimed at assessing the surface roughness of a nanohybrid composite after finishing and polishing, and at evaluating the roughness variation of the material after submitting it to the action of hydrochloric acid and toothbrushing. The material used in the study was Filtek Z550 (3M ESPE). 15 cylindrical samples were randomly divided into three groups, corresponding to three different systems (SofLex, Optrafine, Astropol). The samples were subjected to hydrochloric acid in two one-hour cycles, then immediately submitted to toothbrushing in three consecutive cycles (1,000, 2,000, 4,000 cycles). The results showed variations in surface condition after each step. The surface condition of restorations is related to the type of finishing system. Hydrochloric acid influences the surface roughness of a composite resin restoration, changing its values, even at limited exposure. The effect of brushing after acidic challenge increases the surface roughness of the composite resin.

Keywords: *nanohybrid, roughness, finishing, acid, brushing.*

1. INTRODUCTION

Over the last few years, composite resins have benefited from significant improvements, especially in terms of color matching, surface polishing, strength, wear resistance and handling [1]. All these advances aimed at obtaining a universal material that mimics most faithfully the dental hard tissues [2]. However, the development of materials introduced in dental practice composite resins with nanometric particles and nanoclusters included in a resin matrix. Nanoparticle-based composites offer remarkable results in terms of wear resistance and aesthetic capacities, due to their surface polishing. [3]

In order to achieve a long-lasting clinical success, composite resin restorations must have an as smooth as possible surface, to avoid accumulation of bacterial plaque or of extrinsic dyes, a result achieved by performing the polishing and finishing steps [4]. However, obtaining a perfectly smooth surface is impossible, as both the organic and the inorganic matrix have different coefficients of hardness and wear resistance. [5,6]

Several gastroesophageal diseases, such as the reflux, are characterized by the release of hydrochloric acid, which can lead to damage of either dental tissues or restorative materials. Composite resins can be affected by degradation of the organic matrix and exposure of inorganic particles, which leads to changes in the surface condition of restorations. [7]

Toothbrushing, the most common method of oral hygiene, represents a daily ritual among populations in developed countries [7,8]. However, it can be a detrimental factor for composite restorations as, by its abrasive action, it erodes the organic matrix, creating an irregular surface. The combination of toothbrushing with the acidic action of hydrochloric acid leads to continuous degradation, which will cause long-term clinical failure [8,9].

The aim of the study is to assess the surface roughness of a nanohybrid composite resin after finishing and polishing, using three different systems, and also to evaluate the roughness variation of the material after submitting it to the action of hydrochloric acid and to the abrasive action of toothbrushing.

2. MATERIALS AND METHODS

The material used in the study was a photo-activated, nanohybrid composite resin, Filtek Z550 (3M ESPE, St. Paul, MN, USA). The manufacturer, type and chemical structure of the material used are listed in Table 1.

Table 1. Details on the material tested in the study

Name	Filtek Z550
Manufacturer	3M ESPE, St. Paul, MN, USA
Type	Nanohybrid
Lot number	NA447448
Shade	A3
Matrix	Bis-GMA, UDMA, Bis-EMA, TEGDMA, PEGDMA
Filler	zirconia/silica fillers 3,000 nm (3 µm or less), non-agglomerated/ non-aggregated silica particles 20 nm
Filler loading	82 wt%, 68 vol%

Bis-GMA: Bisphenol A diglycidyl ether dimethacrylate; UDMA: urethane dimethacrylate; TEGDMA: Triethyleneglycoldimethacrylate; bis-EMA: ethoxylated bisphenol-A dimethacrylate; PEGDMA: Polyethyleneglycoldimethacrylate

Sample preparation

In this *in vitro* study, an A3 shade of Filtek Z550 (3M ESPE, St. Paul, MN, USA) was used to obtain 15 cylindrical samples, measuring 2 mm in height and 6 mm in diameter. A cylindrical acrylic mold was used to this end. The mold was placed on a glass plate, and a celluloid matrix was inserted between them, for obtaining a smooth surface. The mold was filled with composite resin, and its surface was covered with a celluloid matrix and a glass plate. It was then compressed with a 500 g load for 30 seconds, to leak out the excess material, to remove the air voids and to obtain parallel surfaces. The samples were then light-cured for 40 seconds, using a curing lamp Bluephase 20i (Ivoclar, Vivadent) with a light intensity of 1,200 mW/cm^2, according to manufacturers instructions.

After photo-polymerization, the samples were randomly divided into three groups, each composed of five samples. The groups corresponded to each finishing system used in the study, as follows:

Group A: SofLex (3M ESPE, St Paul MN, USA)

Group B: Optrafine system (Vivadent-Ivoclar, Vaduz, Liechtenstein)

Group C: Astropol system ((Ivoclar Vivadent, Schaan, Liechtenstein)

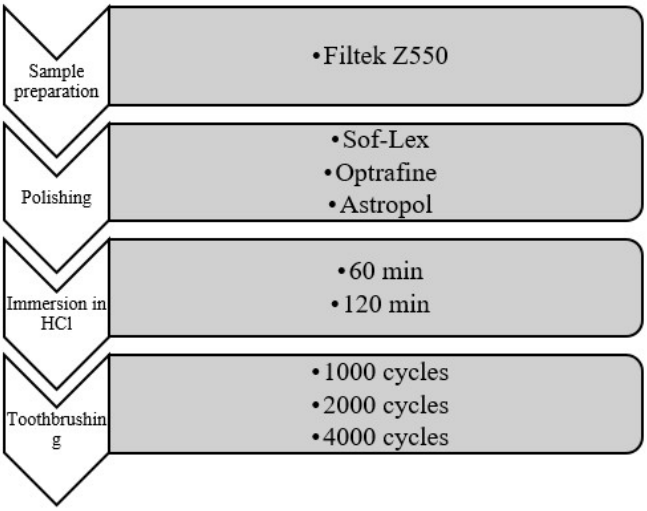

Fig 1. Schematic illustration of the steps followed in the study

Polishing procedure

The Sof-Lex Contouring and Polishing Disc System is composed of four color-coded discs, where color corresponds to the grit size, as follows: black for course discs, dark blue for fine discs, light blue for medium discs, and medium blue for extra fine discs. The procedure involved finishing with water and no paste, for 1 min (15 seconds for each disc), using the contra angle hand piece at a speed of 10,000-20,000 rpm, according to the recommendations of the manufacturer.

Optrafine is a polishing system formed of an assortment of polishers with different shapes (flame, cups, discs and brushes) of different colors, that differentiate the degree of abrasiveness, as follows: light blue (coarse grit), dark blue (fine grit), and brushes for final polishing. The procedure involved finishing with water and no paste, for 1 minute (20 seconds for each polisher), using a contra angle hand

piece at a speed between 10,000-20,000 rpm, according to manufacturers recommendations.

Astropol is a finishing and polishing system containing three grit sizes (coarse – blue, fine – green, extrafine – pink) and four differently shaped polishers: Small Flame, Large Flame, Cup, Disc. The finishing and polishing procedures were performed using flame-shaped polishers for 1 minute (20 seconds for each grit size), using the contra angle hand piece, at a speed of 10,000-20,000 rpm, with water spray and no paste.

For every sample, each of the three polishing and finishing systems was used in two perpendicular directions. In order to remove the residues, the samples were immersed in de-mineralized water for 10 hours, then dried with the air-spray.

Acid attack

All specimens were immersed in 10 ml of solution that simulates gastric acid (Hydrochloric Acid with 2.12 pH and Potassium Chloride buffer) and placed in an incubator at 37 °C for 1 hour. After this step, all samples were taken out of the acid, rinsed with de-mineralized water, dried and analyzed. Immediately after measurements, the samples were submitted for one more hour to the acidic action of the hydrochloric acid, in order to simulate the acidic action of the gastric juice [7], after which the specimens were rinsed again with de-mineralized water and dried with the air-spray.

Tooth brushing simulation

Immediately after the acidic challenge, the specimens were submitted to the action of a multi-station toothbrushing machine, equipped with ten lines of toothbrush heads with reciprocal movements. The holders with the composite samples were placed under the toothbrush heads. [8] The abrasive action was simulated with 1,000, 2,000 and 4,000 cycles of brushing, at a frequency of 100 cycles/min and a constant load of 200 g. Toothbrushes with medium bristles hardness and a toothpaste slurry with a ratio volume of 1:3 (Prodent Cool Mint, Amersfoort, NL) and distilled water were used. At the end, all specimens were rinsed with running water and cleaned using the air-water spray for 2 min for removing the residues.

Profilometry

The surface roughness of all samples was assessed using a non-contact profilometer (Proscan 2100, Scantron Ltd.) with a cut-off of 0.4 mm, and the arithmetical mean of roughness (Ra) was recorded.

Surface roughness was assessed in the initial stage (T1), after polishing (T2), after immersion in hydrochloric acid for one (T3) and two hours (T4), and also after toothbrushing with 1,000 (T5), 2,000 (T6), 4,000 cycles (T7)

3. RESULTS

The mean values of initial surface roughness (T1) for all tested samples were 0.062, with a standard deviation of 0.024 µm.

After polishing (T2), significant differences were recorded in the Ra mean value among the three polishing systems. The Optrafine system showed the highest mean value (0.36 ± 0.06 µm), while the Sof-lex system - the lowest (0.14 ± 0.03 µm) and the Astropol system reached a medium value (0.22 ± 0.02 µm).

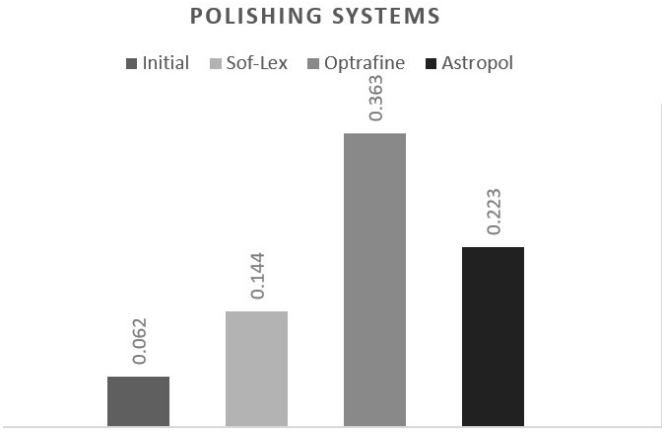

Fig. 2. Mean Ra values after finishing and polishing procedure with three different systems

Submission of specimens to the acidic action of hydrochloric acid for 1 hour (T3) also produced changes in the mean roughness values. The group finished with the SofLex system recorded a mean value of 0.165 µm, with a standard deviation of 0.047 µm, the samples finished with

Optrafine system recorded a mean value of 0.353 with a standard deviation of 0.065, whereas the specimens subjected to the action of Astropol system showed a Ra value of 0.250 and a standard deviation of 0.042.

After subjecting the samples to the hydrochloric acid action for two hours (T4), all roughness values increased. The lowest value was reached by the group finished with SofLex system, namely a Ra of 0.198 µm ± 0.074, followed by Astropol - with a roughness mean value of 0.272 µm ± 0.041, and finally by the group with the Optrafine system, with a roughness mean value of 0.373 µm ± 0.043.

The brushing process also produced differences in the mean values of surface in all groups. In Group A, the mean Ra value of T5 (1,000 cycles of brushing) decreased, compared with the previous procedure (T4), reaching a value of 0.164 µm ± 0.052. The mean values continuously increased for the next procedures, as follows: for ΔT6 (2,000 cycles of brushing), the mean Ra value recorded was 0.214 µm ± 0.063, while for T7 (4,000 cycles of brushing) the roughness reached a mean value of 0.305 µm ± 0.114. In Group B, the mean Ra decreased compared to T4, recording a value of 0.343 µm ± 0.043 for T5 and of 0.300 µm ± 0.032 for T6, and an increase for T7 (0.340 µm ± 0.060). The samples in Group C evidenced an increased value after brushing with 1,000 cycles T5 (0.248 µm ± 0.057), followed by a decrease in T6 (0.277 µm ± 0.065) and an increase in T7 (4,000 cycles of brushing), up to a value of 0.362 µm ± 0.047.

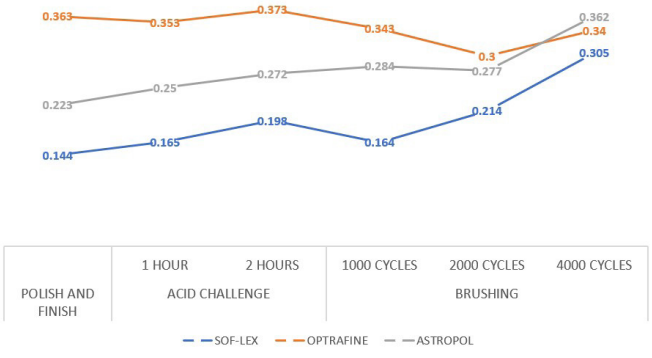

Fig. 3. Variation in the roughness of the Filtek Z550 composite resin following finshing and polishing with different systems (Sof-Lex, Optrafine, Astropol), acid challenge for one and two hours and brushing with 1,000, 2,000 and 4,000 cycles

4. DISCUSSION

The finishing and polishing step has a defining role in the dental restorative treatment as, through this procedure, a smooth and unretentive surface should be obtained, for preventing bacterial plaque and exogenous colorants accumulation. [10]

Organic matrix and inorganic fillers have a massive impact in terms of the surface condition of restoration, which makes the finishing and polishing step dependent on the microstructure of the restorative material. The efficiency of a finishing system depends on the type of material used (organic matrix and fillers), type and shape of the abrasives used, time spent, pressure exerted during this step and orientation of the movements [11]

Different finishing and polishing systems determine different mean Ra values, which should explain why three different systems (Sof-Lex, Optrafine, Astropol) were used in this study. Among them, the Sof-Lex system recorded the lowest Ra values, followed by the Astropol system, and finally by the Optrafine one, a result agreeing with previous studies performed on such finishing systems. [12-14]

A method to simulate gastric acid exposure *in vitro* studies in order to mimic the clinical condition is not well-established yet. In the present study, the exposure of samples to hydrochloric acid was performed for one and two hours, thus simulating an immediate attack and not a long-term acidic challenge. As generally known, acids are neutralized by saliva in about three minutes. In this study, we chose a pH value of the hydrochloric acid of 2.12, higher than that of the gastric juice, considering that, in case of gastroesophageal reflux, acidity will decrease until it comes into contact with the dental tissues or with the restorative materials. [9,15,16]

The mean values of surface roughness of all samples subjected to the acid attack have been modified, comparatively with those recorded after the polishing and finishing procedures, which demonstrates the capacity of the acid to degrade the restorative materials, by eroding the organic matrix and by exposing

or even losing the filler particles from the matrix. [16-18]

In our study, samples were subjected to 1,000, 2,000 and 4,000 brushing cycles, representing a short-term exposure of the composite material to the abrasive action of toothbrushing. [17] Brushing was performed using a toothpaste with a medium RDA (Prodent Cool Mint, Amersfoort, NL).

Toothbrushing has been incriminated for altering the balance between the organic matrix and fillers, for destroying the connection between these two components of the material, or for exposing or even losing filler particles. [19] This was also demonstrated in the present study. An interesting aspect to be mentioned is that, at the end of the last brushing cycle, the mean roughness values recorded in all three groups were almost similar, which could be a topic for future investigations.

Therefore, the present study demonstrated changes in the surface condition of a nanohybrid composite after the finishing step, using three different systems, and after the acidic action of hydrochloric acid, combined with the exposure to the abrasive action of brushing and toothpaste. It has been shown that the acid and abrasive attack acts synergistically, degrading the organic component of the composite resin. [20-22]

5. CONCLUSIONS

The surface condition of the restorations is related to the type of finishing system. Finishing with the Sof-Lex system led to lowest values of surface roughness. Hydrochloric acid influences the surface roughness of a composite resin restoration, changing its values, even at limited exposure (one or two hours). The additional abrasive action of brushing to acidic challenge increases the surface roughness of the tested nanohybrid composite resin.

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