Effect of Air Polishing with Glycine and Bicarbonate Powders on a Nanocomposite Used in Dental Restorations: An In Vitro Study

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Air polishing increases the surface roughness of dental restorations, enhancing bacterial adhesion. This in vitro study was the first, to the authors' knowledge, to evaluate the effect of sodium bicarbonate and glycine powders, at different application distances (2 and 7 mm) and times (5, 10, and 30 seconds), on the surface roughness of a nanocomposite material used in restorations. Untreated slides were used as controls. Surface roughness was measured using atomic force microscopy. Air polishing with glycine powder for 5 seconds, at both application distances, determined the lowest surface damage. Even with all the limitations of any in vitro analysis, this study further supports the safety of this method of air polishing. (Int J Periodontics Restorative Dent 2011;31:e51–e56.)

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Several etiologic factors are associated with plaque accumulation. In particular, surface roughness resulting from defects of the different dental structures and restorative materials, or from damage to these structures, contributes to staining, plaque accumulation, and gingival irritation.[1,2] In fact, an increase in surface roughness determines an increase in the surface area accessible for bacterial adhesion.[3]

Hand instruments or oscillating scalers are currently used to remove plaque accumulation.[4] These methods present some disadvantages, since they are time consuming, technically demanding, and may also cause a clinically significant increase in surface roughness.[2,4] Therefore, alternative methods such as air polishing with abrasive powders, water, and pressurized air have been evaluated and are now applied routinely in professional dental cleaning.[5–7] Of note, even air polishing, if not applied properly, can cause surface defects on both tooth and restoration surfaces.[2,8] The choice of working parameters including distance and spraying time, and in particular the choice of abrasive powder, plays a central role in the effectiveness and safety of the air-polishing process.

Sodium bicarbonate powder is largely used for air polishing.[7] In recent years, air polishing with glycine powder has also been tested in several in vitro, ex vivo, and in vivo studies; overall, these studies were consistent in indicating the clinical efficacy and low abrasive effect of glycine powder when sprayed on different dental and gingival structures.[4,6,9–12] However, the evidence regarding the effects of bicarbonate and glycine powders on restorative materials, such as composites, is still quite scant,[2,13] and no study has evaluated the impact of these powders on nanocomposites. Moreover, most studies investigating the effect of air-polishing powders evaluated surface defects either with laser scanners or profilometers. Both of these techniques are able to characterize a large surface area, thus allowing simultaneous observation of regions treated and not treated with air polishing. In this way, it becomes possible to measure the absolute loss of material and mean defect depths after treatment, ie, to evaluate the structural integrity of dental structures.[10] However, laser scanners and profilometers do not permit high-resolution measurement of surface roughness.

Atomic force microscopy (AFM) has recently emerged as one of the most important techniques for surface analysis and characterization.[14,15] This imaging technique allows the scanning of a surface in high resolution (reaching molecular or even atomic scale, in optimal conditions) and allows for a direct quantitative characterization of the surface roughness.[15] AFM has played an increasing role in dentistry; a recent study indicated that data recorded by this method described the surface quality of resin composites with higher resolution than other imaging techniques.[16]

The aim of this in vitro study was to preliminarily evaluate the effect, at different application distances and times, of bicarbonate and glycine powders on the surface roughness of a commercial nanocomposite dental material used in restorations.

Method and materials

Experimental setting

This in vitro study is the first of its kind to the authors' knowledge. The experiment was set in line with previous studies.[2,10] Slides of a nanohybrid composite resin (Venus Diamond, Heraeus Kulzer) were air polished with either sodium bicarbonate powder (Air-Flow Air, EMS) or glycine powder (Air-Flow Subgingival Perio, EMS). All possible combinations of the different air-polishing application times (5, 10, and 30 seconds) and distances (2 and 7 mm) were tested for both powders. These times and distances were chosen according to a previous study[10] after adjusting for different parameters to keep the polished area constant (approximately 25 mm^2).

In total, eight slides (four treated with bicarbonate, four treated with glycine) were prepared for each combination of time and distance. Four untreated slides were used as negative controls.

Preparation of nanocomposite resin

The slides of nanocomposite resin were prepared at standard conditions (approximately 25°C, 1 atm). The composite was placed in rectangular plastic molds (5 × 5 × 2 mm^3) and covered with acetate strips. Excess material was removed by applying pressure over the acetate strips with a quartz slide. The restorations were polymerized, according to the manufacturer's instructions, for 40 seconds through the quartz slide using a photopolymerizing lamp. The completed restorations were stored for 1 week in distilled water at 37°C prior to being subjected to air polishing. The preparation of resin was always performed by the same trained operator.

Air-polishing process

Air polishing was performed using a standard air-polishing unit (Air-Flow Handy, EMS), installed according to the manufacturer's instructions. Working pressure was kept at 1.5 to 2.0 bar. The instrument nozzle was kept perpendicular to the slide surface. Spraying distance was kept constant by holding the nozzle with a clamp. Spraying time was ensured

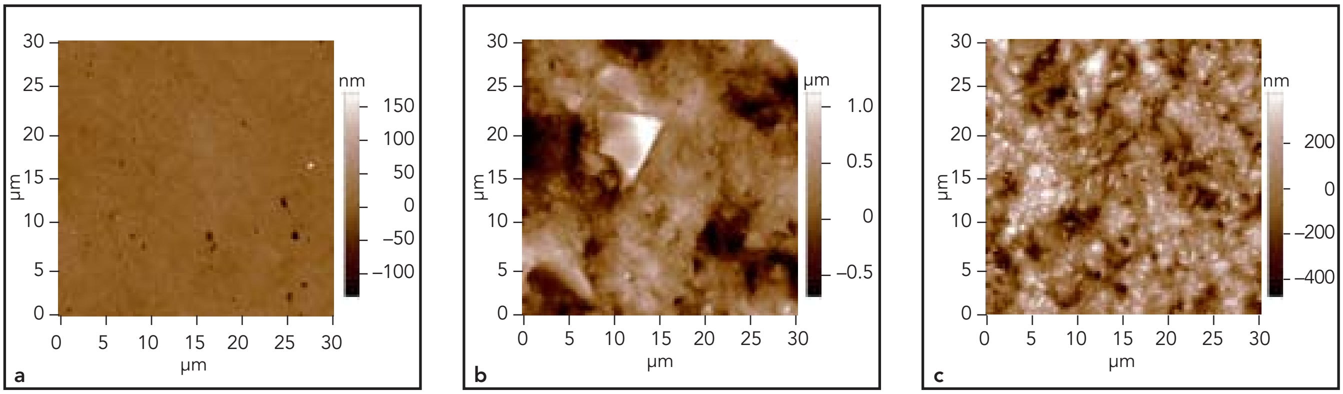

Fig 1 *Typical AFM topography images (scan size, 30 × 30 μm²):* (a) *untreated control nanocomposite slide (height range, 300 nm),* (b) *nanocomposite slide treated with bicarbonate (height range, 2,200 nm) after air polishing for 5 seconds at a distance of 2 mm from the surface, and* (c) *nanocomposite slide treated with glycine powder (height range, 800 nm) after air polishing for 5 seconds at a distance of 2 mm from the surface.*

by an aperture with an electronically controlled opening placed between the tip of the instrument and the slide surface. The air-polishing process was always performed by the same trained operator. The instrument's powder chamber was refilled after each air-polishing period to ensure maximum reproducibility of powder emission.

AFM measurements

The relative height maps of the sample surfaces, both for controls and treated specimens, were acquired in tapping mode AFM with a commercial instrument (MFP-3D, Asylum Research). The used probes (NSG10, NT-MDT) had spring constant and resonance frequency values of approximately 10 N/m and 250 kHz, respectively. All measurements were completed in air with 512 × 512-pixel surface sampling. The scan size was equal to 30 × 30 μm². This area was chosen on the basis of the dimension of the typical bacteria expected to adhere to a composite surface in vivo.

From these images, the surface roughness of each specimen was evaluated as the root mean square (RMS) of the distribution of heights in the three-dimensional AFM topographic images.

Statistical analysis

RMS values were analyzed using descriptive statistics. Comparisons between different combinations of times and distances and comparisons between powders were performed with analysis of variance and the Bonferroni post hoc test using SPSS software (SPSS 14, IBM). A P value < .05 was considered statistically significant.

Results

Some AFM images of representative slides are reported in Fig 1. In particular, Fig 1a shows the typical surface of a control slide, whereas Figs 1b and 1c show the surfaces of nanocomposite slides after air polishing (distance, 2 mm; time, 5 seconds) with bicarbonate and glycine powders, respectively. Overall, it may be qualitatively observed that the control slide was smoother than both air polished slides; moreover, the slide treated with glycine was smoother than the slide undergoing air polishing with bicarbonate. It can also be observed that sodium bicarbonate determined large depressions on the nanocomposite surface (typically 5- to 10-μm wide), while glycine was associated with smaller surface defects (typically 1- to 2-μm wide). These observations were consistent in most combinations of treatment distance and time.

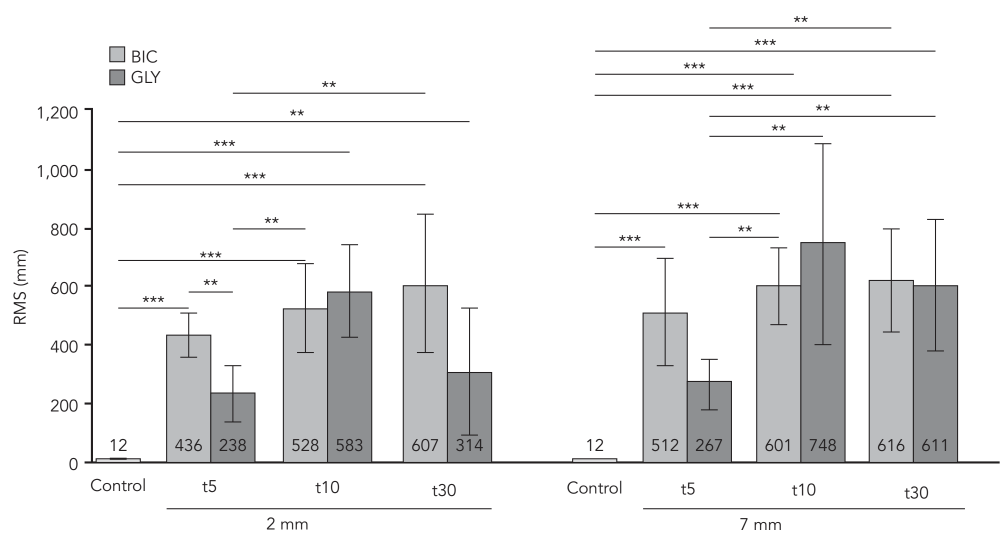

Fig 2 *Surface RMS values for nanohybrid composite slides either untreated (control) or treated with air polishing at different combinations of powder (sodium bicarbonate [BIC] or glycine [GLY]) and time (t), as measured by AFM. **P < .05; ***P < .001.*

The quantitative analysis of RMS values confirmed these findings (Fig 2). For sodium bicarbonate, a trend toward an increase in surface RMS over time was observed. On the other hand, for glycine, the RMS value reached a maximum in 10 seconds, after which it seemed to either decrease (distance, 2 mm) or remain constant (distance, 7 mm).

RMS values resulting from the AFM images after air polishing for different times at a distance of 2 mm from the slide surface are represented in the left half of Fig 2. Overall, RMS values increased in all groups with respect to unpolished controls; this effect was evident after only 5 seconds of treatment. The difference in RMS values between treated slides and controls was significant at all times for both powders, with the exception of glycine sprayed for 5 seconds. The application of glycine for 5 seconds was associated with the lowest RMS value among all treated samples, reaching a significant difference in most comparisons.

Similar findings were observed after air polishing at a distance of 7 mm, as shown in the right half of Fig 2. In particular, the lowest RMS value among treated specimens was reported for glycine sprayed for 5 seconds; all other combinations of powder and time resulted in a significant increase in RMS with respect to controls ($P < .001$ for all comparisons). Spraying with glycine for 5 seconds determined a significantly lower RMS value when compared to both powders sprayed for 10 and 30 seconds ($P < .05$ for all comparisons).

A direct comparison of spraying at 2 mm versus spraying at 7 mm for the same application time did not disclose any significant difference in RMS values, even if a trend toward an increase was observed in association with spraying at 7 mm; a significant difference between 2 and 7 mm was observed only for glycine sprayed for 30 seconds ($P < .05$).

Discussion

This in vitro study suggests that air polishing may result in an increase in surface roughness on a commercial nanohybrid resin used for dental restorations at different combinations of application times and distances. However, it must be observed that an increase in surface roughness, which is directly connected with bacterial adhesion, has been reported for all methods currently in use to reduce plaque accumulation on different dental structures and biomaterials.[2,4,9,10] Therefore, a certain amount of surface damage was expected in association with air polishing using either bicarbonate or glycine powder, as demonstrated by previous studies.[4,9,10,12]

However, although present, surface damage was notably limited for 5-second air polishing with glycine powder, while it was more evident for bicarbonate powder and for glycine at other application times considered. Imaging of slides with AFM showed a higher surface damage for air polishing with bicarbonate for 5 seconds when compared to glycine powder applied for the same amount of time. Visual assessment was confirmed by numeric analysis. In fact, spraying with glycine powder for 5 seconds resulted in the lowest level of damage on the nanohybrid surface. Of note, these effects were observed at both spraying distances considered (2 and 7 mm). Surface damage resulting from air polishing at spraying times equal to 10 and 30 seconds was comparable overall with bicarbonate and glycine. No significant effect of application distance was observed in most cases, differing from what was observed in previous studies, even if a trend toward an increase of surface damage with an increase in distance was observed.[10,12] The lack of a significant difference can be due, at least in part, to the adjustment applied to the experimental parameters to keep the polished area constant.

The efficacy and safety of air polishing with glycine for 5 seconds has already been established in different landmark studies conducted on subgingival and gingival structures, as well as on root cementum.[4,6,9,10] Moreover, glycine powder has been demonstrated to determine less surface erosion than bicarbonate.[9] This effect has been attributed to the smaller particle size of glycine, which is about four times smaller than sodium bicarbonate.[9]

Two different patterns in RMS variation over time for bicarbonate and glycine were observed in the present analysis. In line of principle, and according to a previous study,[12] an increase in surface damage may be expected over time if no loss in power of the air polishing device is observed and the distance is kept constant. This effect has been observed for bicarbonate powder at both considered distances but not with glycine. In fact, at a spraying distance of 2 mm in particular, maximum damage was observed with glycine powder after 10 seconds of air polishing. This effect may be attributed either to a loss in power of the air-polishing device while air polishing with glycine, even if not observed during the current experimental process, or to the small particle size of glycine. The authors speculate, on the basis of visual assessment of AFM images, that bicarbonate removes large portions of the composite surface because of its large particle size, thus resulting in a linear increase of RMS at the scan size adopted. On the other hand, glycine may determine smaller but more diffuse surface defects, associated with a different kinetics of damage. This may determine full surface coverage of defects, and thus a smoothing effect, at the considered treatment time (30 seconds), which is not used in clinical practice.

Other studies have assessed the effects of air polishing with glycine powder on different dental structures.[4,6,9,10,12] These studies, however, have investigated the effect of air polishing using a laser scanner and by measuring mean depths of surface defects to monitor structural damage. The present analysis, although preliminary, confirms the results of these studies and, at least partially, extends them. In fact, the current analysis was the first, to the authors' knowledge, to evaluate the effect of air polishing on a commercial composite, while previous studies mostly considered dental and gingival structures. Moreover, surface damage was measured using surface roughness, a parameter directly associated with bacterial biofilm formation and accumulation, as seen using AFM. This method has recently been proven to be the most reliable method to measure surface roughness.[16]

It must be acknowledged that this study presents several limitations. For instance, the in vitro nature of the present experiment may limit its applicability to clinical practice. However, the authors investigated a commercial composite (ie, an exogenous material) using an experimental setting similar to that used in other in vitro studies.[2,10] As a second limitation, the authors did not investigate the efficacy of air polishing in removing bacterial biofilm from the surface. It must be noted, however, that the efficacy of bicarbonate and glycine has been assessed already.[9,10,11] Therefore, the authors assumed that both powders would be effective in plaque removal at the conditions tested. Finally, while a negative control was included, the present analysis lacked a positive control with a different deplaquing method, such as an oscillating scaler or hand instrument. This could be the subject of forthcoming experimental work.

Conclusions

Air polishing with glycine for 5 seconds is a safe and effective deplaquing technique, as suggested by different studies on dental structures, and is currently used in clinical practice.[9,10,11] Even with all the limitations of any in vitro analysis, this study suggests that air polishing with glycine powder for 5 seconds on a commercial nanocomposite determines the lowest surface damage, as measured using AFM, when compared to the other combinations of powder, time, and application distance tested. The reduced surface damage may result in a lower adhesion of the bacterial biofilm on the treated surfaces, further supporting the safety of this new method of air polishing. It must be observed, however, that air polishing with both sodium bicarbonate and glycine determined an increase in surface damage, with respect to controls. Such damage, however, also was observed in association with other more time-consuming deplaquing methods, such as hand instruments, curets, and ultrasonic scalers,[4] even if a direct comparison was not conducted in the present analysis. Moreover, the increase in surface roughness resulting from any deplaquing technique may be limited if followed by a further repolishing procedure.[2]

Other in vitro and in vivo studies are required to confirm these preliminarily findings and to directly compare air polishing with glycine to other deplaquing methods on composite surfaces used in dental restorations.

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