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Influence of powder type, power, angulation and duration in air-polishing on the surface properties of gingiva-colored composites

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Abstract

Background This study evaluated the effects of air-polishing procedures using sodium bicarbonate, glycine, and erythritol powders on the surface microhardness and roughness of gingiva-colored composites (GCCs).

Methods Sixty GCC discs were divided into 12 groups to investigate the differences in air polishing applications based on powder type (E = erythritol, S = sodium bicarbonate, G = glycine), power (F = Full, M = Medium), and angulation (45°; 90°). Surface microhardness and roughness were assessed at baseline (T0), 5 s (T1), and 10 s (T2). Statistical analyses included Independent Sample T-test, Mann–Whitney U test, ANOVA, and Kruskal–Wallis tests.

Results EF45, EM90, SF45, SF90, SM90, and GF90 groups showed a significant decrease in hardness over time ($p < 0.05$). Erythritol exhibited greater hardness compared to sodium bicarbonate and glycine at T2 ($p < 0.05$). Surface roughness increased significantly in the majority of groups at T2 compared to both T0 and T1 ($p < 0.05$). EM45, EM90, SM90, and GM90 exhibited significantly higher roughness at T2 compared to both T0 and T1 ($p < 0.05$). Among the powders, sodium bicarbonate caused a higher increase in surface roughness under all conditions.

Conclusion Erythritol exhibited the lowest abrasive properties and resulting in lowest hardness loss and roughness increase on the GCC surface. Similarly, the medium power mode and 45° angle caused lower increase in surface hardness and roughness. Based on the tested parameters, if a patient has restorations with GCC, the airflow application protocol can be adjusted according to the findings of this study to achieve optimal results.

Keywords Air-polishing, Surface roughness, Microhardness, Indirect composite resins

Background

The maintenance of gingival and periodontal health depends critically on the removal of supragingival and subgingival dental plaque and stains [1]. Air polishing devices are frequently used for easy, fast, and complete removal of stains and bacterial biofilm [2]. Nevertheless, material loss and clinically significant surface degradation could occur from using air polishing on both tooth and restorative surfaces [3]. Moreover, rough surfaces provide a favorable environment for plaque accumulation and discoloration, which can lead to plaque-induced gingivitis and secondary caries [4].

Abrasive powders, water, and air pressure are the three inputs used by air-polishing equipment [5]. A wide range of air polishing powders (APPs) such as aluminum trihydroxide, calcium carbonate, calcium sodium phosphosilicate, glycine, sodium bicarbonate, and erythritol are commercially available [6, 7]. In the literature, studies are evaluating the effect of these powders on tooth surfaces such as enamel, dentin, and cementum [8–10], as well as

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studies investigating the effect on restorative materials used in the mouth [3, 6, 11].

Sodium bicarbonate ($NaHCO_3$), with a particle size of up to 250 µm and a salty and unpleasant taste, was the first product to be launched on the market [12]. Eliades et al. reported that sodium bicarbonate may cause abrasion and dulling effects on cast metal alloys, composites, and glass ionomers [13]. Glycine is a naturally occurring amino acid that has smaller particles [3]. Compared to sodium bicarbonate, glycine was found to cause less roughness on the dentin surface [14]. A sugar alcohol with an even smaller average particle size of 14 µm is erythritol [11]. Sodium bicarbonate significantly increased the surface roughness of resin composites in an in vitro study; however, erythritol was not superior to glycine [12].

Gingival-colored composites (GCCs) are cost-effective and minimally invasive alternatives often used to mask the condition in individuals with gingival recession [15]. In addition, indirect GCCs are frequently used to meet aesthetic demands, especially in veneering tooth and implant supported prosthesis [16]. Since GCCs have better-handling characteristics, acceptable mechanical qualities, and favorable aesthetics, they are increasingly utilized as a practical substitute for gingiva-colored porcelain [17].

To the best of our knowledge, there are no studies in the literature investigating the effect of different air-polishing applications on the surface roughness and hardness of GCCs and exhibits the appropriate method. Therefore, the aim of the present study was to assess the surface roughness and hardness of GCCs after different air-polishing protocols. The null hypothesis was that tested air polishing procedures would not affect the surface roughness and hardness of GCCs.

Methods

The visual flowchart of the study is presented in Fig. 1. The materials used in this study are presented in Table 1. A plastic mold designed with 10 mm diameter holes and 2 mm thickness was prepared to ensure dimensional standardization of the samples. The plastic mold was placed on a glass surface, and indirect GCCs (Crea.lign Gum; Bredent GmbH, Senden Germany) were placed into the cavities with the help of a spatula. The upper surfaces were covered with transparent tape and condensed using finger pressure. Both surfaces of the indirect composite resins were pre-polymerized for 40 s using an LED light device (DTE LUX-E Plus; Guilin Woodpecker Medical Instrument, Guilin, Guangxi, China; 1200 mW/cm^2) [18] following the manufacturer's instructions, and then placed in the Labolight DUO polymerization device (GC Europe NV; Leuven, Belgium) for an additional 3 min of polymerization. The samples were sequentially sanded with 320, 500, 800, and 1200 grit silicon carbide sandpapers (Atlas; Saint-Gobain Abrasives, Istanbul, Turkey). Subsequently, a polishing process was applied using diamond-impregnated polishing discs (Diacomp Plus

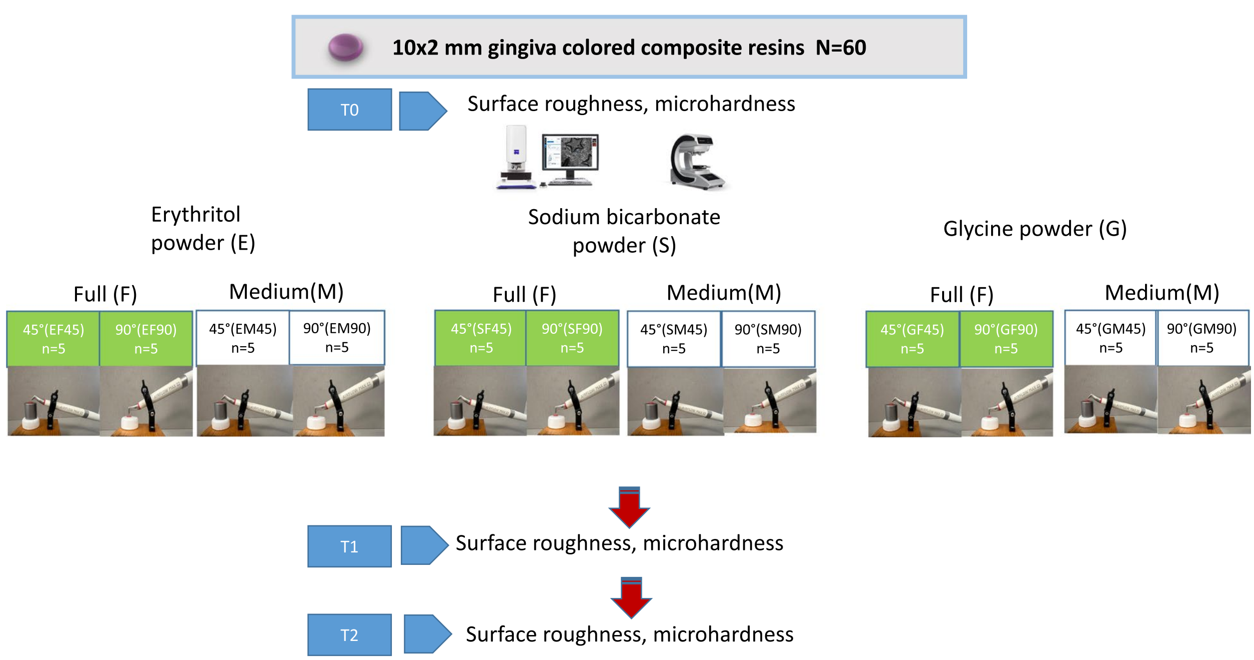

Fig. 1 The visual flowchart of the study

Table 1 Materials used in this study

Material	Brand	Composition	Manufacturer	Lot
Veneering Composite	Crea.lign gum (G3 pink)	BisGMA, UDMA, and aliphatic dimethacrylate resins, inorganic ceramic filler (~ 50%)	Bredent, Senden, Germany	N231752
Photopolymerized surface sealant agent	Optiglaze	PMMA, MMA, silica filler, photo inhibitor	GC Corporation, Tokyo, Japan	2,303,201
Erythritol powder	Airflow® Plus Prophylaxis powder	Erythritol 14 µm, Cetyl Pyridinium Chloride (CPC) 0.05%	EMS, Nyon, Switzerland	2,311,072
Sodium bicarbonate powder	Airflow® Classic powder	Sodiumhydrogencarbonate, hydrophobe modified silica, lemon taste	EMS, Nyon, Switzerland	FB- 143
Glycine powder	Woodpecker Air Polisher Prophylaxis Powder Gentle	Glycine, Amorphous Silica	Guilin Woodpecker Medical Instrument Co., Guangxi, China	P23 A02

Twist Set RA 342; EVE Technik, Pforzheim, Germany) at 10,000 rpm for 20 s. The average thickness of specimens was measured as 2 mm ± 0.05 mm using a caliper (Digital Caliper; Guangxi, China). The samples were then cleaned in an ultrasonic cleaner with distilled water for 10 min and dried with air. The surface irregularities of the indirect composite were removed, and the surface was cleaned. Following the manufacturer's instructions, Optiglaze Color Clear (GC Europe NV; Leuven, Belgium) surface coating agent was applied with a clean brush to the surface of the samples to be measured.. The samples were then polymerized in a Labolight DUO polymerization device (GC Europe NV; Leuven, Belgium) at a wavelength of 380–510 nm for 90 s.

Surface roughness (Ra) measurements of all prepared samples both before and after air-polishing, were made using a 3D optical profilometer (Zeiss Smartproof 5; Carl Zeiss, Jena, Germany). From each sample center, 3 randomized reads were performed by scanning a 500 µm × 500 µm area in fast mode (4 µm) at a total magnification of 20x (C Epiphalan-Apochromat 20x/0.7 DIC; Carl Zeiss, Jena, Germany) in 3D imaging mode [19]. The images were transferred to an automated software analysis program (ConfoMap ST 7.4.8076; Carl Zeiss, Jena, Germany).

Ra values were obtained in accordance with ISO 21920. The arithmetic averages of Ra values taken 3 times each were recorded.

Microhardness measurements of the samples both before and after air polishing was performed using a microhardness tester (HMV-G; Shimadzu, Japan) equipped with a Vickers indenter. A maximum load of 9.807 N was applied, with a hold time of 10 s at the maximum load. The microhardness values were calculated as an average of four measurements taken across the surface of the samples using the tester's software.

Specimens were grouped according to the applied powder type (E = erythritol; S = sodium bicarbonate; G = glycine), degree of power (F = Full; M = Medium), and angulation (45°; 90°).

Accordingly, the twelve different groups (n = 5 per group) were defined as: EF45, EF90, EM45, EM90, SF45, SF90, SM45, SM90, GF45, GF90, GM45, GM90). Surface roughness and surface hardness measurements were done according to these application times (T0 = Initial; T1 = 5 sn; T2 = 10 sn). All measurements were performed by one trained person (Ö.S.A).The EMS Airflow® Prophylaxis Master unit (EMS; Nyon, Switzerland) was used to apply Erythritol and Sodium Bicarbonate powders, while the Woodpecker air-polishing device (PT-A; Woodpecker, China) was used to apply Glycine powder.

An adjustable customized jig was designed, and parts were 3D printed using the stereolithography method with 3D printer (Creality Ender V3; Creality 3D Technology Co., Shenzhen, China). Printed parts were polylactic acid (PLA) resin (FilameX PLA; İstanbul, Turkey), assembled using steel M3 bolts and nuts, and fixed on a wooden block. The tip of the handpiece placed on the prepared stand was directed at 45° and 90° angles, respectively, to the surface of the specimens at a distance of 5 mm. The samples were fixed on a horizontal surface and kept immobile during the process. The samples were treated with the selected powders at specified water and powder levels (level 10 (Full) and level 5 (Medium)) for 5 s and 10 s, respectively. Distilled water was used in all air polishing processes to ensure standardisation. To prevent needless aerosol dispersion, a high-volume excavator (HVE) suction was employed in tandem, which is representative of actual clinical settings [20]. While one of the operators performed the application by pressing the pedal for the specified period of time, the other one controlled the suction and the experimental setup.

The main objective of the study was to investigate the differences between independent groups and measurements taken according to time. Similar studies that can be used in sample size calculation were examined and the sample size calculation that gives the highest number according to the statistical methods to be applied in line with the main hypotheses was taken into consideration. In this study, using the "G. Power- 3.1.9.2" program, [21] at 95% confidence level ($\alpha = 0.05$), the standardized effect size was calculated as 0.5022 from a similar study [22] (Table 1, Ra, between groups) and the minimum sample size for each group was obtained as 4 with theoretical power of 0.85. Considering the possible losses during the study, it was decided to use 5 samples per group.

Descriptive statistics of the data (mean, standard deviation, median, minimum, and maximum) are given. The assumption of normal distribution was checked by Shapiro Wilk test, homogeneity of variance by Levene's test, and sphericity assumption by Mauchly's W test. In cases where the assumption of normality was met, the Independent Sample T-test was used to compare two independent groups, and in cases where the assumption was not met, the Mann–Whitney U test was applied. ANOVA test was used to compare three or more independent groups with normal distribution and the Kruskal–Wallis test was used when there was no normal distribution. Repeated Measures ANOVA (Greenhouse–Geisser Statistics) test was used to examine the difference between the averages of three dependent groups where the normality assumption was met with the interaction effect, and the Friedman test was used when there was no normal distribution. Post Hoc Bonferroni and Corrected Bonferroni tests were performed to reveal the group or groups that created the difference. Analyses were performed in the IBM SPSS 25 program.

Results

Table 2 shows the distribution of hardness measurements according to the study groups.

Statistically significant differences were determined in EF45, EM90, SF45, SF90, SM90, and GF90 groups according to the measurement times ($p < 0.05$).

Post-hoc analysis (Bonferroni test) proceeded proved that T1 and T0 measurements were higher than T2 measurements in EF45, SF45 groups ($p < 0.05$). T1 measurements were higher than T2 measurements in the EM90 group ($p < 0.05$). T0 measurements were higher than T2 measurements in SF90, SM90, and GF90 groups ($p < 0.05$). There were no statistically significant differences between the groups in all pairwise comparisons ($p > 0.05$). Statistically significant differences were determined between T2 hardness measurements in M90 groups compared to powders ($p < 0.05$). Bonferroni tests showed statistically significant differences between Erythritol and Sodium bicarbonate and Glycine measurements ($p <$ 0,05). Erythritol measurements were higher than those of sodium bicarbonate and glycine.

The distributions and comparisons of roughness measurements according to the study groups are given in Table 3. Statistically significant differences were determined in all measurements according to the measurement times ($p < 0.05$).

Post-hoc analysis (Bonferroni test) proceeded proved that, T2 measurements are higher than T0 measurements in EF45, EF90, SF45, SM45, SF45, SF90, GF90 and GM45 groups ($p < 0.05$). T2 measurements were higher than T0 and T1 measurements in EM45 and EM90 groups ($p < 0.05$) (Fig. 2). T2 measurements were higher than T0 and T1 measurements; T1 measurements were higher than T0 measurements in SM90 and GM90 groups ($p < 0.05$) (Figs. 2 and 3), T1 measurements were higher than T0 measurements in GF45 group ($p < 0.05$). Pairwise comparisons revealed statistical differences between EM45 and EM90 at T2 time, between GF45 and GM45 at T0 time, and between GF45 and GF90 groups at T1 time ($p < 0.05$) (Fig. 4). EM90 measurements were higher than EM45 measurements. GF45 measurements were higher than GM45 measurements. GF90 measurements were higher than GF45 measurements. Statistically significant differences were determined between T2 roughness measurements in the F45, F90, M45, and M90 groups according to powders ($p < 0.05$).

Post-hoc analysis (Bonferroni test) proceeded proved that, Sodium bicarbonate measurements were higher than Erythritol and Glycine measurements in F45 groups ($p < 0.05$). Sodium bicarbonate measurements were higher than Glycine measurements in F90 and M45 groups ($p < 0.05$). Sodium bicarbonate measurements were higher than the Erythritol and Glycine measurements, and Erythritol measurements were higher than Glycine measurements in M90 groups ($p < 0.05$) (Fig. 5).

Discussion

This in vitro investigation evaluated the effects of air-polishing protocols with different powders, power modes, and angulation for application on the roughness and hardness of gingiva-colored composites. Significant differences were observed among the tested groups. Therefore, the null hypothesis was rejected.

Studies have revealed that bacterial plaque is retained on restored surfaces faster than on tooth surfaces and that this deposition subsequently causes periodontal disease [23]. Air polishing devices for the application of new small-sized powders are currently recognized as the most effective and least abrasive or invasive cleaning method for both tooth surfaces and materials [24]. However,

Table 2 Distribution and comparison of microhardness measurements according to groups

	T0	T1	T2	By Time	
	Mean ± S.D. (Median)	Mean ± S.D. (Median)	Mean ± S.D. (Median)	Test Statistic	*p*
EF45	40.18 ± 10.67 (39.8)	37.85 ± 10.41 (36.86)	31.08 ± 7.88 (30.7)	18.740	0.010*
EF90	38.34 ± 8.22 (40.6)	34.33 ± 10.21 (38.58)	28.3 ± 8.14 (24.9)	5.997	0.063
EM45	37.68 ± 13.74 (30.4)	35.64 ± 14.33 (32.17)	34.7 ± 11.16 (29.8)	2.227	0.170
EM90	38.02 ± 7.43 (39)	36.29 ± 7.25 (38.44)	35.95 ± 7.81 (37.42)	9.779	0.007*
	Test Statistic/p	Test Statistic/p	Test Statistic/p		
EF45-EM45	0.321/0.756	0.280/0.787	− 0.593/0.570		
EF90-EM90	0.065/0.950	− 0.350/0.735	− 1.515/0.168		
EF45-EF90	0.306/0.768	0.540/0.604	0.549/0.598		
EM45-EM90	− 0.049/0.962	− 0.091/0.930	− 0.205/0.843		
	Mean ± S.D. (Median)	Mean ± S.D. (Median)	Mean ± S.D.(Median)	Test Statistic	*p*
SF45	35.08 ± 7.62 (32.4)	28.02 ± 6.83 (23.32)	25.86 ± 5.84 (22.67)	25.893	< 0.001*
SF90	37.3 ± 3.8 (36.7)	25.65 ± 7.1 (22.12)	21.61 ± 3.38 (21.52)	18.255	0.001*
SM45	39.48 ± 13.66 (35.4)	31.52 ± 9.17 (32.05)	27.07 ± 6.09 (27.54)	7.801	0.050
SM90	34.18 ± 5.16 (32.87)	26.6 ± 6.82 (25.76)	23.78 ± 4.44 (21.32)	14.696	0.002*
	Test Statistic/p	Test Statistic/p	Test Statistic/p		
SF45-SM45	− 0.629/0.547	− 0.686/0.512	− 0.320/0.757		
SF90-SM90	1.088/0.308	− 0.216/0.835	− 0.868/0.411		
SF45-SF90	− 0.583/0.576	− 0.538/0.605	1.407/0.197		
SM45-SM90	0.812/0.453	0.964/0.365	0.976/0.358		
	Mean ± S.D. (Median)	Mean ± S.D. (Median)	Mean ± S.D. (Median)	Test Statistic	*p*
GF45	40.01 ± 12.47 (37.3)	33.55 ± 8.76 (32.26)	28.95 ± 4.65 (29.1)	5.812	0.071
GF90	37.61 ± 4.68 (35.1)	31.10 ± 2.00 (30.9)	23.35 ± 6.82 (26.98)	12.163	0.006*
GM45	37.11 ± 5.41 (35)	35.21 ± 6.24 (35.3)	31.77 ± 6.45 (29.2)	5.200**	0.074
GM90	36.43 ± 4.11 (35.89)	32.97 ± 1.33 (33.6)	26.42 ± 7.76 (30.65)	4.934	0.084
	Test Statistic/p	Test Statistic/p	Test Statistic/p		
GF45-GM45	0.477/0.646	− 0.346/0.739	− 0.419†/0.690		
GF90-GM90	0.423/0.683	− 1.740/0.120	− 0.666/0.126		
GF45-GF90	0.404/0.697	0.608/0.560	1.519/0.167		
GM45-GM90	0.224/0.829	0.784/0.456	− 0.104†/1.000		
Between the Powders	Test Statistic/p	Test Statistic/p	Test Statistic/p		
F45	0.385/0.689	1.574/0.247	0.876/0.441		
F90	0.041/0.960	1.821/0.204	1.454/0.272		
M45	0.060/0.942	0.234/0.795	0.967‡/0.617		
M90	0.565/0.583	3.614/0.059	4.357/0.038*		

* $p < 0.05$

**Friedman test

†Mann Whitney U test

‡Kruskal Wallis test

these powders are known to cause surface damage to composite materials in varying amounts depending on the abrasive powder's particle size, hardness, and angularity [12]. This is even more important for gingiva-colored composites because of their specific use close to or in contact with gingival tissues [16].

Studies have shown that the more powder introduced in a given time interval, the more efficient the cleaning becomes; however, depending not only on the amount but also on the properties of the powder, more abrasion on the surface can occur [24]. Therefore, mastering powder consumption has become a focus of materials science and is essential for achieving the best and least invasive prophylactic treatment. In this in vitro study, two different power modes, medium and full, were used, and statistically significant differences between the treatments performed in medium and full power modes were found between EM45 and EM90 at T2 time and between GF45

Table 3 Distribution and comparison of roughness measurements according to groups

	T0	T1	T2	By Time	
	Mean ± S.D. (Median)	Mean ± S.D. (Median)	Mean ± S.D. (Median)	Test Statistic	*p*
EF45	0.07 ± 0.01 (0.08)	0.11 ± 0.06 (0.09)	0.19 ± 0.06 (0.17)	10.000**	0.007*
EF90	0.06 ± 0.02 (0.06)	0.12 ± 0.08 (0.1)	0.28 ± 0.12 (0.29)	8.400**	0.015*
EM45	0.07 ± 0.02 (0.07)	0.11 ± 0.03 (0.12)	0.18 ± 0.02 (0.18)	46.064	< 0.001*
EM90	0.06 ± 0.02 (0.07)	0.12 ± 0.04 (0.12)	0.22 ± 0.02 (0.22)	40.197	< 0.001*
	Test Statistic/p	Test Statistic/p	Test Statistic/p		
EF45-EM45	− 0.940†/0.421	− 0.234/0.821	0.175/0.865		
EF90-EM90	− 0.234/0.821	− 0.731†/0.548	1.119/0.323		
EF45-EF90	− 0.940†/0.421	− 0.522†/0.690	− 1.578/0.153		
EM45-EM90	− 0.429/0.679	− 0.269/0.795	− 3.128/0.014*		
	Mean ± S.D. (Median)	Mean ± S.D. (Median)	Mean ± S.D. (Median)	Test Statistic	*p*
SF45	0.07 ± 0.03 (0.06)	0.15 ± 0.05 (0.19)	0.41 ± 0.15 (0.45)	8.400**	0.015*
SF90	0.07 ± 0.02 (0.07)	0.19 ± 0.1 (0.16)	0.42 ± 0.21 (0.3)	9.804	0.007*
SM45	0.07 ± 0.01 (0.07)	0.14 ± 0.06 (0.12)	0.40 ± 0.23 (0.31)	10.000**	0.007*
SM90	0.08 ± 0.02 (0.07)	0.15 ± 0.01 (0.15)	0.41 ± 0.03 (0.41)	255.299	< 0.001*
	Test Statistic/p	Test Statistic/p	Test Statistic/p		
SF45-SM45	− 0.132/0.901	− 0.104†/1.000	0.095/0.926		
SF90-SM90	− 0.632/0.545	0.996/0.375	0.155/0.881		
SF45-SF90	− 0.200/0.846	− 0.731†/0.548	− 0.65/0.950		
SM45-SM90	− 0.977/0.371	− 1.149†/0.310	− 0.044/0.966		
	Mean ± S.D. (Median)	Mean ± S.D. (Median)	Mean ± S.D. (Median)	Test Statistic	*p*
GF45	0.07 ± 0.01 (0.07)	0.10 ± 0.01 (0.11)	0.17 ± 0.06 (0.17)	9.053	0.035*
GF90	0.07 ± 0.01 (0.07)	0.14 ± 0.02 (0.13)	0.17 ± 0.03 (0.19)	44.391	< 0.001*
GM45	0.06 ± 0.01 (0.06)	0.09 ± 0.04 (0.09)	0.15 ± 0.04 (0.13)	18.980	0.001*
GM90	0.08 ± 0.02 (0.08)	0.13 ± 0.03 (0.13)	0.16 ± 0.03 (0.15)	56.296	< 0.001*
	Test Statistic/p	Test Statistic/p	Test Statistic/p		
GF45-GM45	2.500/0.037*	0.427/0.689	0.430/0.679		
GF90-GM90	− 0.749/0.475	0.486/0.640	0.743/0.479		
GF45-GF90	0.178/0.863	− 3.191/0.013*	− 0.111/0.914		
GM45-GM90	− 2.424/0.042*	− 1.671/0.133	− 0.119/0.908		
Between the Powders	Test Statistic/p	Test Statistic/p	Test Statistic/p		
F45	0.240‡/0.887	1.680‡/0.432	9.184/0.004*		
F90	0.949/0.414	4.020‡/0.134	4.046/0.045*		
M45	1.273/0.315	1.530/0.256	5.036/0.026*		
M90	1.391/0.286	0.939/0.418	107.022/< 0.001*		

* $p < 0.05$

**Friedman test

†Mann Whitney U test

‡Kruskal Wallis test

and GF90 groups at T1 time. No statistically significant differences were observed between the other groups. According to a study conducted by Donnet et.al. [25], which analyzed the surface roughness of micro-hybrid resin composites after applying sodium bicarbonate jet spray, there was a significant increase in the surface roughness of all resin composites compared to the initial values. Similarly, Gomes et al. reported that prophylaxis using a sodium bicarbonate jet significantly increased the roughness of nanoparticle-reinforced resin [26]. According to Babina et al. [27], air polishing with powdered calcium carbonate and sodium bicarbonate increased the surface roughness of composite resins and restorations more than other methods. Similarly, in this in vitro study, it was observed that air flow application with sodium bicarbonate caused a greater increase in the surface

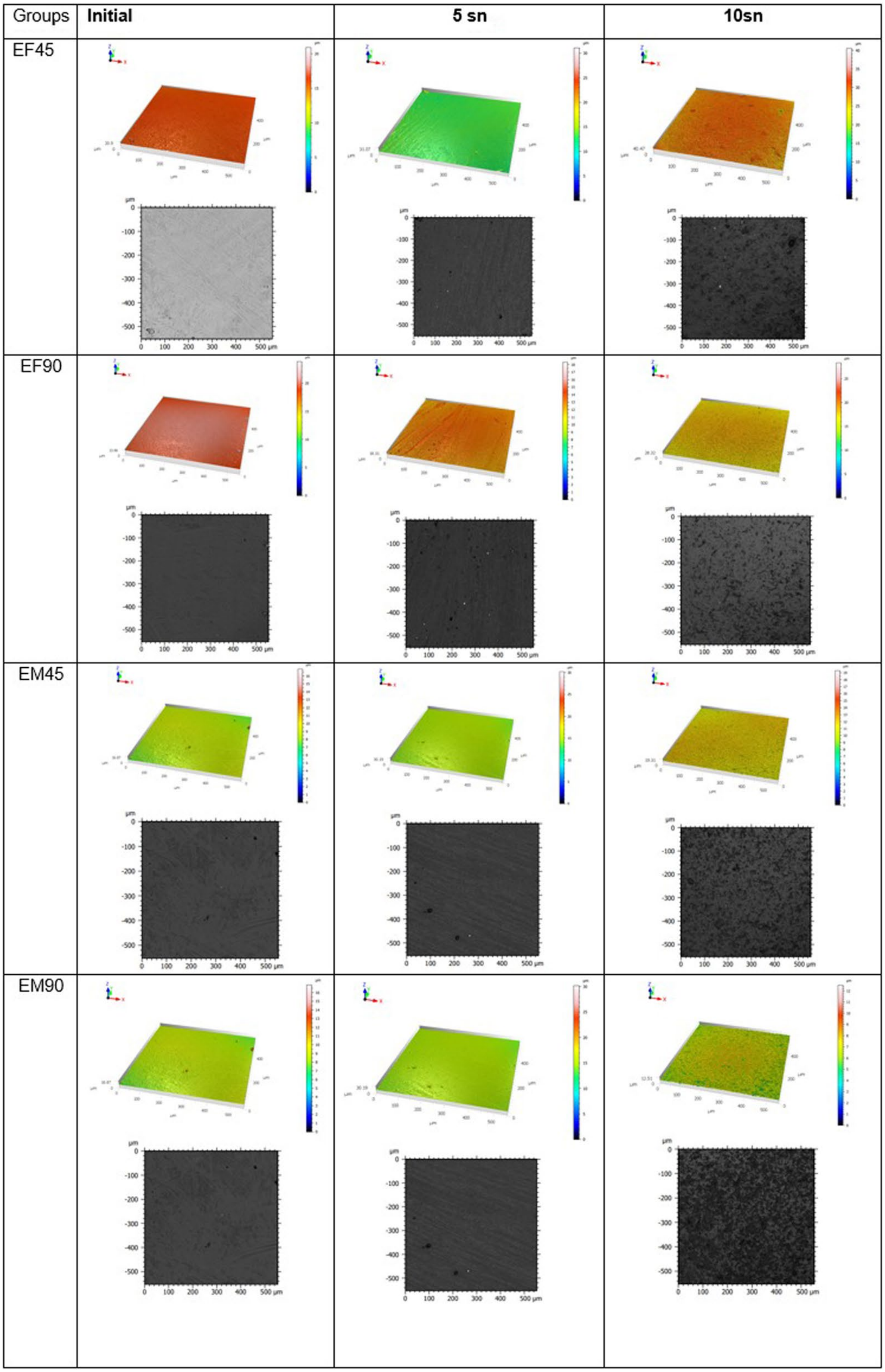

Fig. 2 Surface roughness after Erythritol powder application

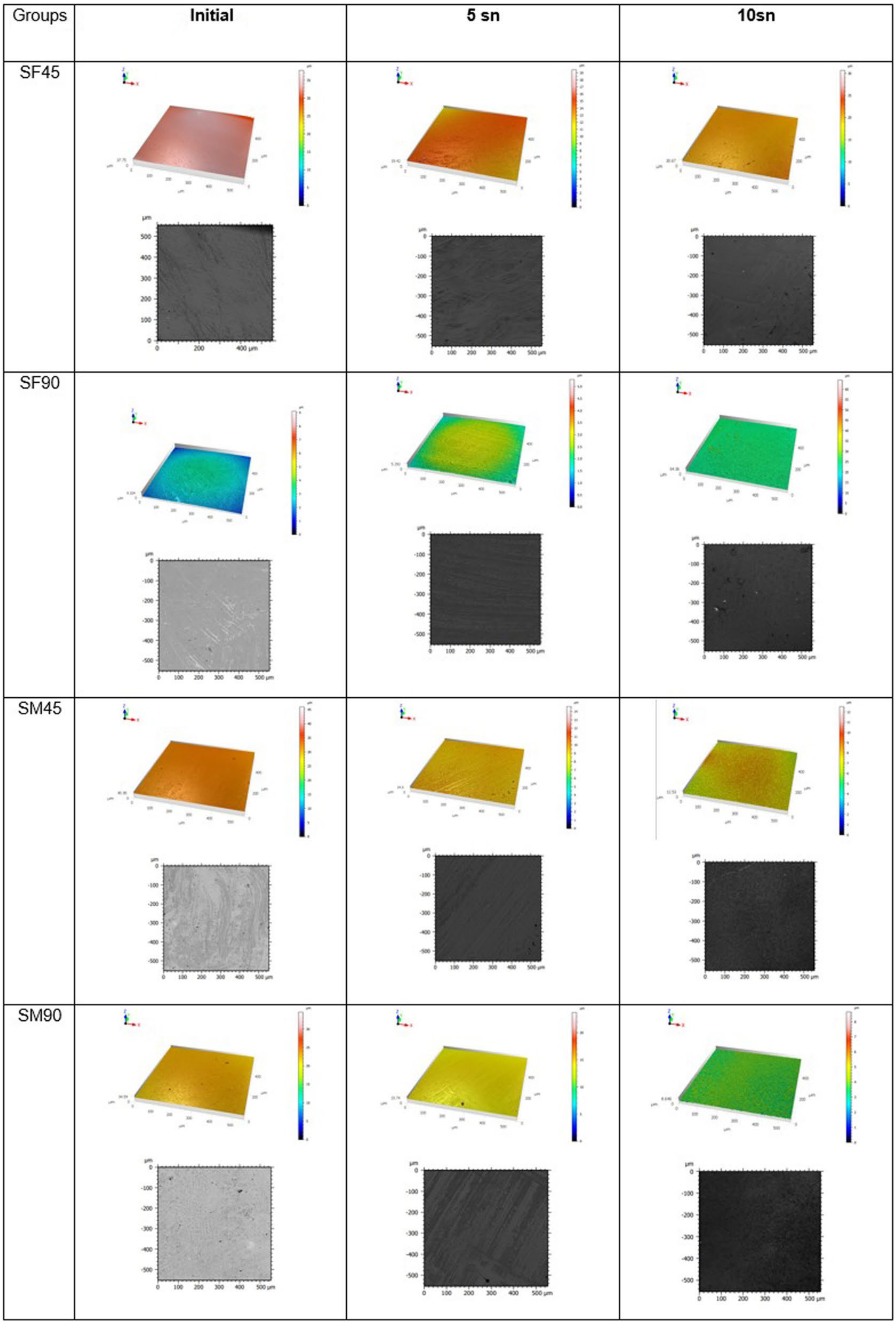

Fig. 3 Surface roughness after Sodium bicarbonate powder application

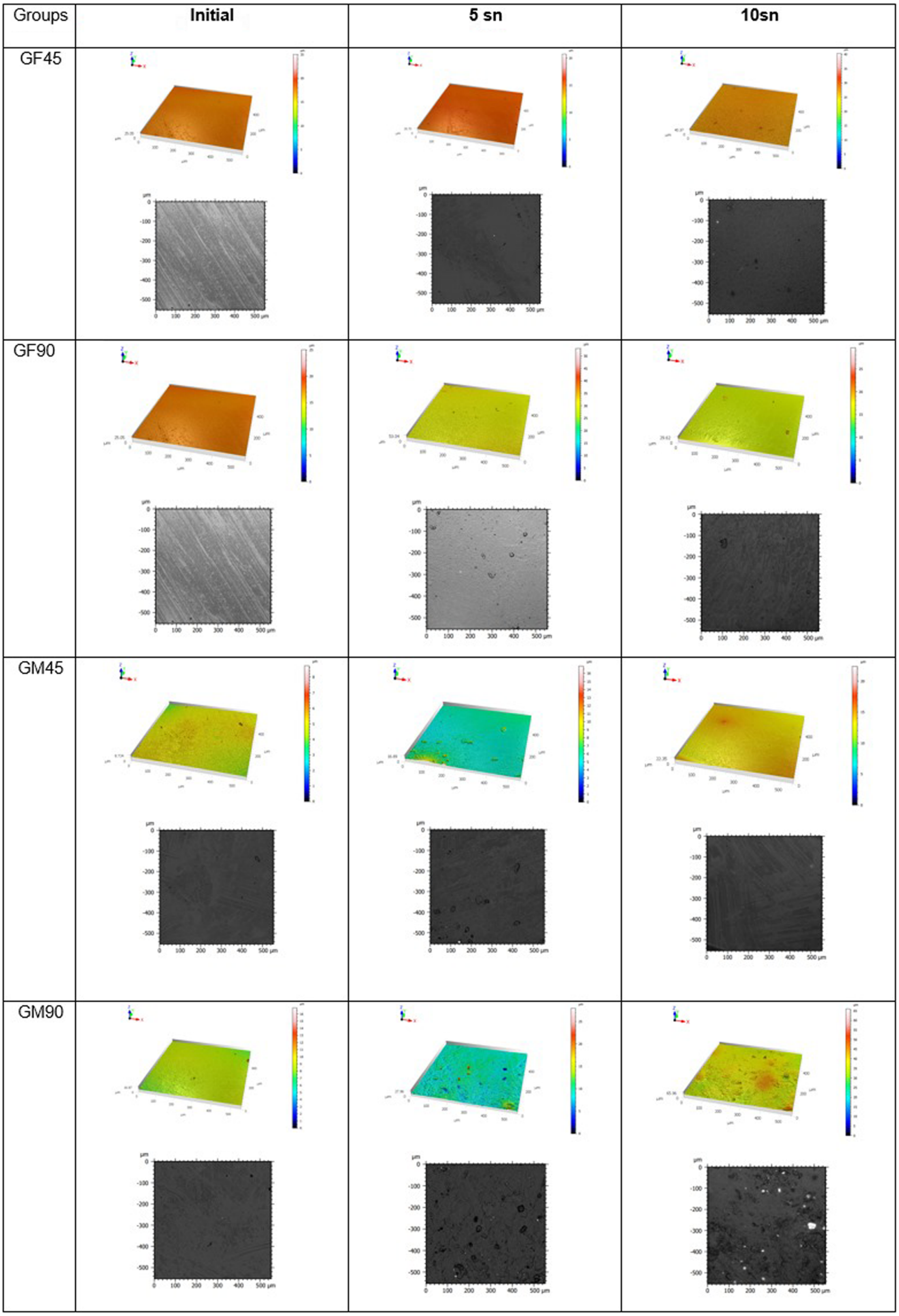

Fig. 4 Surface roughness after Glycine powder application

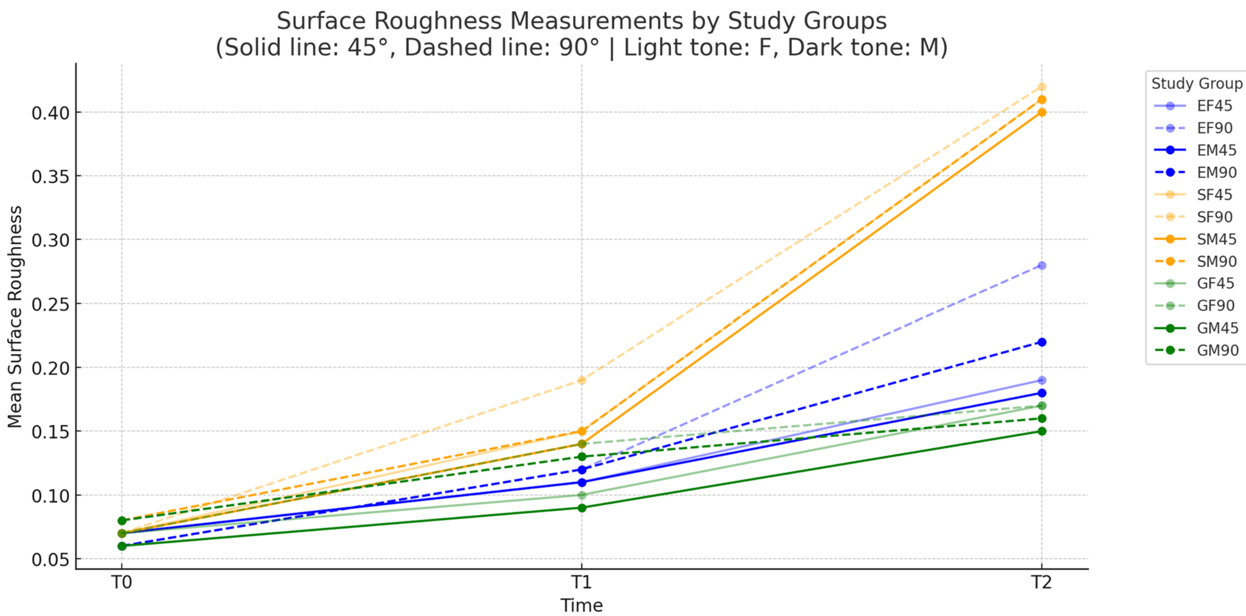

Fig. 5 Comparison of surface roughness measurements according to time and groups

roughness of GCCs compared to glycine and erythritol. This is likely to be due to the higher particle diameter and hardness of sodium bicarbonate than glycine and erythritol.

Hardness, a mechanical attribute that represents a material's resistance to indentation or penetration, is impacted by the resin's chemical composition as well as the filler's size, weight, and volume [28]. Typically, surface hardness measurement techniques such as Vickers and Knoop are used to measure the hardness of resin composites and have the advantage of being relatively simple, reproducible, and non-destructive [29]. In this study, the Vickers test was used to determine how the hardness of the composites investigated in this study was affected. In line with the literature, a force of 100 g was applied for 15 s [30].

Optiglaze is a light polymerized surface sealant agent containing silica dioxide (SiO_2) and titanium dioxide (TiO_2) nanoparticles [31]. These nanoparticles are often incorporated into dental polymer-based materials to strengthen the material, improve mechanical properties, and promote chemical interfacial interaction between phases [32]. It has been demonstrated that adding TiO_2 in particular greatly enhances the performance of resins, leading to notable increases in hardness and elastic modulus [33]. Sun et al. reported that the addition of TiO_2 nanoparticles exhibited a sharp increase of 48% in elastic modulus [34], while the hardness was 2.4 times higher than other materials [35]. Based on this, it can be suggested that the degradation of the Optiglaze layer during the air-polishing procedure in this investigation may have contributed to a reduction in the samples' hardness.

Depending on the area to be studied, there may be differences in the distance or angularity of the jet from the tip, which can affect the effectiveness of the result [36]. Therefore, in this study, airflow handpiece with two different angles of 45 and 90 degrees were used. Although not statistically significant, it was observed that the microhardness decreased more and the surface roughness increased more in most of the samples treated with a 90-degree angle compared to the samples treated with a 45-degree angle. Petersilka et al. reported that there were no major differences between 45° and 90° angulation in their study investigating the damage caused by air-polishing on the root surface [37]. Bühler et al. investigated the effects of air polishing with glycine and sodium bicarbonate on tooth surfaces and reported that a 45° angulation resulted in a greater increase in surface roughness for both powders compared to a 90° angulation [14]. Variations in the study results may be attributed to differences in the devices used, as well as the surface properties and dimensions of the samples.

To get a healthy oral cavity with pleasing aesthetics, surface roughness should be reduced. It is advised to have a minimum plaque-retentive restoration with a surface roughness of less than 0.2 μm [38]. In addition, the absence of re-polishing following dental prophylaxis can result in the surface roughness of restorative materials, which can induce plaque accumulation, gingival irritation, pigmentation susceptibility, higher wear and tear rates, recurrent caries, and a shorter restoration lifespan [36, 39]. In this study, roughness values below 0.2 μm, which were initially observed, increased especially when sodium bicarbonate was applied, and exceeded the threshold value.

The results of the study demonstrated that air polishing applications at T1 (5 s) and T2 (10 s) yielded different impacts on the surface quality of the specimens. For all groups, at T2, a more significant increase in surface roughness and a more significant decrease in microhardness compared to T1 were observed. The changes were most pronounced in the groups using sodium bicarbonate powder but less so in the groups using erythritol. Furthermore, the effects at the end of time T2 were shown to interact with additional parameters such as powder type, power mode, and angulation, leading to more complex results. The results show that the timing of application is an important parameter in preserving the surface properties of GCC. Similarly, Németh et al. [40] reported in their study that the effect of air-polishing with sodium bicarbonate on the surface roughness (Ra) of nanofill and microhybrid resin composites varied depending on the application duration (5 s or 10 s). For the nanofill composite (Filtek Ultimate), they observed that 5 s of air-polishing significantly increased the Ra value, while extending the application duration to 10 s resulted in a slight increase in Ra, which was not statistically significant. For the microhybrid composite (Enamel Plus HRi), they reported a significant increase in Ra following 5 s of air-polishing, whereas a 10-s application led to a further increase in surface roughness and more pronounced surface degradation. They attributed these differences to the variations in filler particle size and matrix composition between the two types of composites.

This study's primary limitation is that it was conducted through in vitro simulation, which makes it impossible to replicate the intricate interactions of variables in vivo. It is scheduled to do additional research to evaluate intraoral simulative characteristics. Another important limitation of this study is that it cannot provide sufficient information about the condition of the optiglaze layer after the applications. Its condition may need to be measured with more advanced methods.

Conclusion

Erythritol and glycine showed less abrasive effects compared to sodium bicarbonate, leading to minimal hardness loss and roughness increase on the GCC surface. Although less significant in terms of power mode and application angles, the use of medium power mode at 45° angulation resulted in smaller increases in surface hardness and roughness.Based on the evaluated parameters, the airflow application protocol can be tailored according to the findings of this study to achieve optimal outcomes for patients with GCC restorations.

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Clinical trial number
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Authors' contributions
Ö.S.A and Ü.T.K. were responsible for conceptualization the idea, conducting the study design and methodology, and did the methods procedures. Ö.S.A. conducted the statistical analysis and was responsible for writing manuscript. Ü.T.K. revised the manuscript into the final version. All authors reviewed and approved the final manuscript.

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Data availability
"The data of the current study are available from the corresponding author on reasonable request."

Declarations

Ethics approval and consent to participate
Not applicable.

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References

1. Westfelt E. Rationale of mechanical plaque control. J Clin Periodontol. 1996;23:263–7.
2. Wenzler JS, Krause F, Böcher S, Falk W, Birkenmaier A, Conrads G, Braun A. Antimicrobial impact of different air-polishing powders in a subgingival biofilm model. Antibiotics (Basel). 2021;10(12):1464.
3. Pelka MA, Altmaier K, Petschelt A, Lohbauer U. The effect of air-polishing abrasives on wear of direct restoration materials and sealants. J Am Dent Assoc. 2010;141(1):63–70.
4. Aykent F, Yondem I, Ozyesil AG, Gunal SK, Avunduk MC, Ozkan S. Effect of different finishing techniques for restorative materials on surface roughness and bacterial adhesion. J Prosthet Dent. 2010;103:221–7.
5. Sawai MA, Bhardwaj A, Jafri Z, Sultan N, Daing A. Tooth polishing: The current status. J Indian Soc Periodontol. 2015;19:375–80.
6. Barnes CM, Covey D, Watanabe H, Simetich B, Schulte JR, Chen H. An in vitro comparison of the effects of various air polishing powders on enamel and selected esthetic restorative materials. J Clin Dent. 2014;25(4):76–87.
7. Abdulbaqi HR, Shaikh MS, Abdulkareem AA, Zafar MS, Gul SS, Sha AM. Efficacy of erythritol powder air-polishing in active and supportive periodontal therapy: A systematic review and meta-analysis. Int J Dent Hyg. 2022;20(1):62–74.
8. Yildirim TT, Oztekin F, Keklik E, Tozum MD. Surface roughness of enamel and root surface after scaling, root planning and polishing procedures: An in-vitro study. J Oral Biol Craniofac Res. 2021;11(2):287–90.
9. Kröger JC, Haribyan M, Nergiz I, Schmage P. Air polishing with erythritol powder - In vitro effects on dentin loss. J Indian Soc Periodontol. 2020;24(5):433–40.

10. Kruse AB, Burkhardt AS, Vach K, Hellwig E, Woelber JP, Schlueter N, Ratka-Krüger P. Impact of air-polishing with erythritol on exposed root dentin: A randomized clinical trial. Int J Dent Hyg. 2025;23(1):63–72.
11. Reinhart D, Singh-Hüsgen P, Zimmer S, Bizhang M. In-vitro influence of the use of an erythritol powder through air polishing on the surface roughness and abrasiveness of various restorative materials. PLoS ONE. 2022;17(7): e0270938.
12. Janiszewska-Olszowska J, Drozdzik A, Tandecka K, Grocholewicz K. Effect of air-polishing on surface roughness of composite dental restorative material-comparison of three different air-polishing powders. BMC Oral Health. 2020;20:30.
13. Eliades GC, Tzoutzas JG, Vougiouklakis GJ. Surface alterations on dental restorative materials subjected to an air-powder abrasive instrument. J Prosthet Dent. 1991;65(1):27–33.
14. Bühler J, Schmidli F, Weiger R, Walter C. Analysis of the effects of air polishing powders containing sodium bicarbonate and glycine on human teeth. Clin Oral Invest. 2015;19:877–85.
15. Zalkind M, Hochman N. Alternative method of conservative esthetic treatment for gingival recession. J Prosthet Dent. 1997;77(6):561–3.
16. Petropoulou A, Dimitriadi M, Zinelis S, Sarafianou A, Eliades G. Surface characteristics and color stability of gingiva-colored resin composites. Materials (Basel). 2020;13(11):2540.
17. An H-S, Park J-M, Park E-J. Evaluation of shear bond strengths of gingiva-colored composite resin to porcelain, metal and zirconia substrates. J Adv Prosthodont. 2011;3:166–71.
18. Kalyoncuoğlu ÜT, Yilmaz B, Sipahi C. Determination of the degree of conversion, the diffuse reflectance, and the color stability after different aging processes of gingiva-colored composite resins. J Prosthodont. 2023;32(8):743–51.
19. Papathanasiou I, Papavasiliou G, Kamposiora P, Zoidis P. Effect of staining solutions on color stability, gloss and surface roughness of removable partial dental prosthetic polymers. J Prosthodont. 2022;31(1):65–71.
20. Turunç Oğuzman R, Yüzbaşıoğlu E. Air-polishing powders' effect on the color of CAD/CAM restorative materials. Appl Sci. 2023;13(20):11573.
21. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using: tests for correlation and regression analyses. Behav Res Methods. 2009;41(4):1149–60.
22. Valian A, Ansari ZJ, Rezaie MM, Askian R. Composite surface roughness and color change following airflow usage. BMC Oral Health. 2021;21(1):398.
23. Quirynen M, Bollen CML. The influence of surface roughness and surface-free energy on supra- and subgingival plaque formation in man: A review of the literature. J Clin Periodontol. 1995;22(1):1–14.
24. Donnet M, Fournier M, Schmidlin PR, Lussi A. A novel method to measure the powder consumption of dental air-polishing devices. Appl Sci. 2021;11(3):1101.
25. Alawjali SS, Lui JL. Effect of one-step polishing system on the color stability of nanocomposites. J Dent. 2013;4:e53–61.
26. Gomes IA, Mendes HG, Filho EMM, et al. Effect of dental prophylaxis techniques on the surface roughness of resin composites. J Contemp Dent Pract. 2018;19(1):37–41.
27. Babina K, Polyakova M, Sokhova I, Doroshina V, Arakelyan M, Zaytsev A, Novozhilova N. The effect of ultrasonic scaling and air-powder polishing on the roughness of the enamel, three different nanocomposites, and composite/enamel and composite/cementum interfaces. Nanomater. 2021;15:3072.
28. Scougall-Vilchis RJ, Hotta Y, Hotta M, Idono T, Yamamoto K. Examination of composite resins with electron microscopy, microhardness tester and energy dispersive X-ray microanalyzer. Dent Mater J. 2009;28:102–12.
29. Comba A, Scotti N, Maravić T, Mazzoni A, Carossa M, Breschi L, Cadenaro M. Vickers hardness and shrinkage stress evaluation of low and high viscosity bulk-fill resin composite. Polymers. 2020;12(7):1477.
30. Roubickova A, Tichy A, Vrbova R, Bradna P. Indentation size effect in Knoop and Vickers hardness measurement of dental resin-based composites. J Mech Behav Biomed Mater. 2025;162: 106823.
31. Choi JJE, Uy CE, Ramani RS, Waddell JN. Evaluation of surface roughness, hardness and elastic modulus of nanoparticle containing light-polymerized denture glaze materials. J Mech Behav Biomed Mater. 2020;103: 103601.
32. Kaizer MR, Almeida JR, Goncalves AP, Zhang Y, Cava SS, Moraes RR. Silica coating of nonsilicate nanoparticles for resin-based composite materials. J Dent Res. 2016;95:1394–400.
33. Yoshida K, Taira Y, Atsuta M. Properties of opaque resin composite containing coated and silanized titanium dioxide. J Dent Res. 2001;80:864–8.
34. Sun J, Foster AM, Johnson PM, Eidelman N, Quinn G, Schumacher G, Zhang X, Wu WL. Improving performance of dental resins by adding titanium dioxide nanoparticles. Dent Mater. 2011;27:972–82.
35. Sun J, Watson SS, Allsopp DA, Stanley D, Skrtic D. Tuning photo-catalytic activities of TiO_2 nanoparticles using dimethacrylate resins. Dent Mater. 2016;32:363–72.
36. Jost-Brinkmann PG. The influence of air polishers on tooth enamel. An in-vitro study J Orofac Orthop. 1998;59(1):1–16.
37. Petersilka GJ, Bell M, Mehl A, Hickel R, Flemmig TF. Root defects following air polishing: An in vitro study on the effects of working parameters. J Clin Periodontol. 2003;30(2):165–70.
38. Bollen CM, Lambrechts P, Quirynen M. Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: A review of the literature. Dent Mater. 1997;13:258–69.
39. Craig RG, O'Brien WJ, Powers JM. Dental materials: properties and manipulation. 7th ed. St Louis (MO): Mosby Year Book; 2000.
40. Németh KD, Haluszka D, Seress L, Lovász BV, Szalma J, Lempel E. Effect of Air-Polishing and Different Post-Polishing Methods on Surface Roughness of Nanofill and Microhybrid Resin Composites. Polymers. 2022;14(9):1643.

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