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The impact of bleaching using 15% carbamide peroxide on surface properties of CAD-CAM composite structures

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This study aims to evaluate the effects of the home bleaching method on the surface microhardness and surface roughness of both polished and unpolished CAD-CAM resin composite materials. A polymer-infiltrated ceramic network (PICN) block, Enamic (VE), along with four resin composite blocks (RCB) (Grandio [GN], Lava™ Ultimate [LV], BRILLIANT Crios [B], and Cerasmart [CS]), were prepared to dimensions of 14 mm × 12 mm × 2 mm and were categorized into unpolished and polished groups ($n = 4$). Microhardness measurements were conducted using a Vickers microhardness tester (300 gf load for 20 s) at various time points: before home bleaching, after home bleaching with 15% Opalescence for 8 h and for 56 h, 24 h after bleaching, and one month after bleaching. Surface topography was examined using a stylus contact profilometer ($n = 4$) and a scanning electron microscope ($n = 3$) at ×40 k magnification. Control specimens from each group were also measured. Data were analyzed using one-way ANOVA, Tukey's post hoc test, two-way ANOVA and an independent t-test. The polished samples demonstrated a decrease in hardness after 8 h of bleaching, with the most significant reduction observed in VE, followed by GN, LV, CS, and BR. Significant differences were noted between all materials except for CS and LV. After 56 h, VE exhibited the greatest decrease in hardness, followed by GN, LV, BR, and CS, with significant differences between all materials except BR and CS. In the unpolished group, VE showed the highest reduction in hardness after 8 h of bleaching, followed by LV, GN, BR, and CS. After 56 h, the order was VE, LV, GN, CS, and BR, with significant differences observed between all materials except BR and CS. Similar trends in hardness reduction were observed at 24 h and 1 month post-bleaching. Additionally, hardness was significantly reduced after polishing for all materials. Overall, the reduction in hardness was significantly influenced by the type of material, the time, and the interaction between these factors ($p < 0.05$). Home bleaching using 15% carbamide peroxide significantly decreased microhardness. This effect was more pronounced in unpolished groups and with prolonged exposure. Further studies are recommended to determine the suitable concentration and duration of 15% carbamide peroxide application to ensure its use is safe for CAD-CAM materials.

Keywords CAD-CAM composite structures, Polymer-infiltrated ceramic network, Home bleaching, Vickers hardness, 15% carbamide peroxide, Surface roughness

The evolution in the perception of esthetic appearance and advancements in computer-aided design and computer-aided manufacturing (CAD-CAM) technology in dentistry has led to a substantial increase in the development of esthetic materials suitable for CAD-CAM processing[1]. Currently, available CAD-CAM materials,

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ceramics, and resin-based composites are commonly utilized for aesthetic restorations[2,3]. Glass ceramics surpass resin composites in terms of mechanical and optical properties. This superiority is evidenced in clinical practice by their long-term color stability, tissue biocompatibility, and fatigue survival[4,5]. However, resin composites have been devised to mimic the characteristics of glass ceramics through advanced manufacturing processes that utilize various curing modes involving temperature and pressure. These parameters have led to significantly improved restorations with properties comparable to those of ceramics[2].

Resin composites aim to mitigate drawbacks such as polymerization stresses, internal material porosities, and the potential for discoloration, which pose significant challenges in restorative dentistry. Similarly, ceramics face limitations such as brittleness and vulnerability to chipping and cracking, often resulting in catastrophic fractures[2]. To address these disadvantages and harness the beneficial properties of both composite resin and ceramic materials, CAD-CAM resin composite structures materials have been developed[1]. CAD-CAM resin composite structures can be classified into resin composite blocks (RCB) consisting of a filler and a polymer mixed under high pressure and/or temperature and polymer-infiltrated ceramic network (PICN) which features a porous ceramic framework infiltrated by a polymer network[6–8]. However, CAD-CAM composite blocks tend to discolor over time, necessitating bleaching of such restorations following short- or long-term clinical service in the oral cavity[9–11].

Vital bleaching is a commonly utilized routine procedure designed to eliminate stains from natural teeth, using either in-office or at-home bleaching methods[12]. The at-home bleaching approach is a more economical option that patients can undertake with dentist's supervision or on their own, typically using carbamide peroxide (CP) or lower concentrations of hydrogen peroxide (HP)[13].

CAD-CAM resin composite restorations are susceptible to increased surface roughness over time[14], often attributed to factors such as tooth brushing[14–17] or consumption of various foods and beverages[17–19]. This heightened roughness renders the restorations more prone to discoloration, necessitating the use of bleaching agents. Although bleaching is generally considered safe and effective for natural teeth, it can pose risks to certain restorative materials, potentially causing degradation or erosion. This phenomenon may be linked to the absorption of chemical products through the polymeric matrix and the matrix-charge interface, leading to alterations in surface structure and hardness[20].

This study aimed investigate the impact of home bleaching using 15% carbamide on both the microhardness and surface roughness of five commercial CAD-CAM composite blocks. Home whitening with 15% carbamide peroxide is widely utilized due to its accessibility and safety profile for at-home use. It is a clinically relevant concentration that mimics real-life applications, making the study findings directly applicable to common dental practice[21,22]. The originality of this study lies in its focus on the effects of home bleaching on CAD-CAM composite blocks, a topic with limited prior research. This work evaluates both microhardness and surface roughness, providing critical insights into material behavior after home bleaching bleaching. 15% carbamide peroxide is a commonly used home bleaching agent, making the study directly applicable to everyday clinical practice. The increasing use of CAD-CAM restorations and the growing popularity of home bleaching systems necessitate an understanding of their interactions. CAD-CAM materials, such as polymer-infiltrated ceramic networks (PICN) and resin-based composites, differ in composition, structure, and properties. Investigating their response to carbamide peroxide allows for insights into material-specific behaviors, informing clinicians' material selection. The inclusion of various CAD-CAM materials ensures comprehensive findings applicable across different restorative scenarios. While some studies exist on bleaching effects, few have explored the surface microhardness and roughness changes in modern CAD-CAM materials at this carbamide peroxide concentration.

The research focused on examining how bleaching affects both polished and unpolished specimens of the investigated materials. The null hypotheses proposed were as follows: (i) home bleaching using 15% carbamide does not affect the surface hardness of the tested CAD-CAM composite blocks; (ii) the duration of bleaching and the type of the material do not influence the hardness of the tested CAD-CAM composite blocks; (iii) polishing of the samples does not change the hardness after bleaching; (iv) the hardness of the tested CAD-CAM composite blocks does not influenced by the filler weight; and (v) home bleaching using 15% carbamide does not affect the surface roughness of tested CAD-CAM composite blocks.

Materials and methods

Sample preparation

One hundred fifty bar-shaped specimens were sectioned at a targeted dimension of 14 mm × 12 mm × 2 mm from 5 CAD/CAM blocks ($n=30$) (Vita Enamic, Grandio blocs, Lava™ Ultimate, BRILLIANT Crios, and Cerasmart). The specimens were prepared using a MECATCH234 cutting machine (PRESI, France) under constant water (Table 1). While the CAD-CAM blocks used in this study vary in composition, all are indicated by their manufacturers as definitive indirect restorations, including inlays, onlays, and crowns, depending on the clinical scenario. Subsequently, the specimens underwent wet grinding and polishing using silicon carbide papers (P1200, P2500, and P4000 grit) and were further polished with 0.25 µm diamond suspension (Meta Di Supreme, Buehler, IL, USA) using a polishing machine (BETA-VECTOR, Buehler, IL, USA). All specimens were then subjected to an ultrasonic water bath (Ultrasonic Cleaning System; L&R, NJ, USA) for 5 min to ensure thorough cleansing. The dimensions of the specimens were checked and verified using an electronic digital caliper with an accuracy of ± 0.1 mm, and any specimens outside this range were discarded. The sample size for each experiment was calculated initially using mean differences, standard deviations, and a confidence interval of 95% and found to be sufficient with significance level of 0.05.

Materials (Abbreviations)	Composition by weight as provided by manufacturers		Filler composition by weight (%) experimentally measured	Manufacturer
	Polymer matrix	Filler matrix		
Polymer infiltrated ceramic network (PICN)				
Vita™ Enamic (VE)	14% UDMA + TEGDMA	86% Fine structure feldspar ceramic	85.1 (0.1)	Vita Zahnfabrik, Germany
Resin composite CAD-CAM blocks				
Grandio™ Blocs (GN)	Bis-GMA, UDMA, and TEDMA	Glass ceramic filler and silicon dioxide nanoparticles	84.6 (0.01)	VOCO, Germany
Lava™-Ultimate (LV)	20% (bis-GMA, UDMA, bis-EMA, TEGDMA)	80% silica and zirconia nano particles	74.8 (0.1)	3 M ESPE, USA
BRILLIANT™ Crios (BR)	Cross-linked methacrylates (bis-GMA, bis-EMA, TEGDMA)	70% of glass and amorphous silica	70.1 (0.05)	COLTENE, Switzerland
Cerasmart™ (CS)	bis-MEPP, UDMA, DMA	71% silica and barium glass nanoparticles	66.1 (0.2)	GC dental products, Europe
Materials (Abbreviations)	**Type**	**Composition**	**Manufacturer**	
Bleaching agent				
Opalescence™ PF	Chemically activated home bleaching agent	15% Carbamide peroxide, potassium nitrate and fluoride	Ultradent Products, South Jordan, UT, USA	

Table 1. The manufacturers' compositional information and experimentally measured filler weight percentage[23] of the investigated materials and the bleaching agent used.

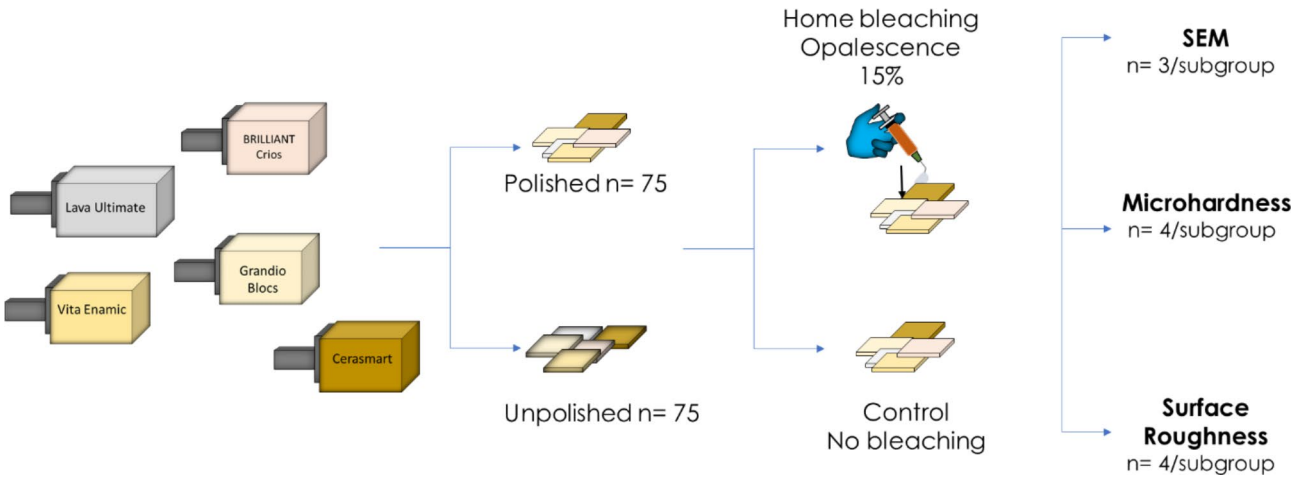

Fig. 1. A schematic diagram of the experimental procedure.

Bleaching

The obtained samples were randomly assigned to either polished or unpolished groups ($n = 15$) (Fig. 1). Randomization was achieved by assigning each specimen a number and using a random number generator to allocate them to different test and control groups.

A single experienced operator performed the bleaching procedure. Specimens were fully immersed in Opalescence™ PF 15% at room temperature for a total of 8 h and 56 h. After bleaching, the specimens were washed with water, air-dried, and then placed in a closed container filled with fresh distilled water. Additional variables such as ambient temperature, humidity, and operator experience were controlled by conducting all experimental procedures in a temperature- and humidity-regulated laboratory environment. A single experienced operator performed all steps to minimize variability.

Microhardness

The experimental and control groups ($n = 4$/group) were assessed for surface microhardness at various time points: before bleaching, after 8 h, 24 h, 56 h, and 1 month post-bleaching. The Vickers hardness number (VHN) was determined using a Vickers microhardness instrument (HXD-1000 TMC, Shanghai Taiming Optical Instrument, Shanghai, China) with a load of 300 gf applied for 20 s. Ten indentations were made randomly on each specimen at 0.5 mm intervals. The corresponding hardness value was calculated by the machine and then provided as the Vickers hardness number (VHN).

The percentage reduction in hardness (HR) following bleaching was calculated using the following equation:

$$HR\% = \frac{VHN\,(before) - VHN\,(after)}{VHN\,(before)} \times 100\%$$

$VHN(_{before})$ and $VHN(_{after})$ represent the Vickers hardness values before and after bleaching, respectively, at each measurement interval.

Surface roughness

A stylus contact profilometer (Mahr Perthometer M1 [L_t = 5.6 mm, λ_c = 0.800 mm]) was used to measure the surface roughness. The arithmetic average of roughness (Ra) was calculated across six lines, 1 mm apart: three vertical and three horizontal on 4 randomly selected specimens from each group. The average of six readings per line was calculated, totaling six readings per specimen.

Scanning electron microscopy imaging

To enhance imaging quality, three random specimens from each group were sputter-coated with gold. These coated specimens were then examined using a scanning electron microscope (SEM) model S-4800 from Hitachi, Tokyo, Japan. Secondary electron images were captured at a magnification of ×40,000 to assess the surface topography.

Statistical analyses

GraphPad Prism, version 9.1.2 (226) was used for were statistical analysis of the quantitative data. The Shapiro-Wilk test evaluated the data normality, and parametric statistical methods were applied accordingly. A two-way ANOVA was performed to assess the impact of material type, bleaching, and their interaction. For multiple comparisons, a one-way ANOVA followed by Tukey's post hoc test was conducted, with statistical significance established at $\alpha = 0.05$.

The relationship between the percentage change in hardness and the filler weight across all groups was explored using Pearson correlation analysis. Furthermore, independent t-tests were performed to compare the percentage change in hardness between polished and unpolished groups. This test was also used to compare bleached and unbleached samples within the same group at various time points.

Results

Surface hardness

The percentage change in hardness was calculated for bleached and unbleached (control) samples at 8 h and 56 h of bleaching, as well as 24 h and 1 month post-bleaching. Significant differences were found between bleached and unbleached samples for each material, with the exception of the CS polished group at 8 h and 56 h of bleaching, as identified by the independent sample t-test (Table 2). Furthermore, the data were presented as line graphs in Figs. 2, 3 and 4.

After 8 h of bleaching of the polished samples, significant differences in the hardness reduction percentage (HR%) were observed between all the materials except CS and LV, with the highest HR% recorded for VE, followed by GN, LV, CS and BR. After 56 h of bleaching, significant differences in HR% were noted between all the materials except BR and CS. For the polished samples, the greatest harness reduction occurred in VE, followed by GN, LV, BR and CS. In the unpolished group, after 8 h of bleaching, the descending order was VE, LV, GN, BR, and CS. After 56 h of bleaching, the order was VE, LV, GN, CS, and BR, with significant differences between all the materials except BR and CS.

	Polished				Unpolished			
Material	8 h	56 h	24 h	1 month	8 h	56 h	24 h	1 month
VE	8.28 (0.6)^{A}	14.99 (0.42)^{A}	19.03 (0.79)^{A}	25.09 (0.06)^{A}	11.37 (0.82)^{A}	19.41 (0.2)^{A}	24.59 (0.9)^{A}	36.3 (0.21)^{A}
VE-cont	0.29 (0.09)	0.71 (0.12)	1.82 (0.31)	16.78 (0.20)	−0.08 (0.31)	2.71 (0.66)	3.56 (1.73)	26.57 (0.63)
GN	5.19 (0.59)^{B}	7.75 (0.17)^{B}	10.75 (0.27)^{B}	15.61 (0.78)^{B}	8.09 (0.03)^{B}	10.13 (0.41)^{B}	14.95 (0.13)^{B}	30.28 (0.63)^{B}
GN-cont	4.06 (0.27)	4.17 (0.35)	5.55 (0.48)	5.12 (0.24)	4.13 (0.04)	4.49 (0.57)	8.17 (1.14)	19.31 (0.28)
LV	1.41 (0.56)^{C}	3 (0.88)^{C}	4 (0.69)^{C}	16.3 (0.16)^{C}	12.53 (0.16)^{C}	15.09 (0.41)^{C}	19.13 (0.91)^{C}	35.05 (0.96)^{C}
LV-cont	1 (0.4)	0.7 (0.55)	0.7 (0.11)	15.6 (0.42)	0.34 (0.29)	1.17 (0.31)	11.66 (0.47)	29.34 (0.63)
BR	−3.69 (0.5)^{D}	1.3 (0.46)^{D}	1.39 (0.5)^{D}	12.33 (0.53)^{D}	1.9 (1.2)^{D}	3.64 (0.43)^{D}	3.6 (0.2)^{D}	14.38 (1.06)^{D}
BR-cont	0.15 (0.12)	−0.47 (0.38)	−0.32 (0.01)	8.72 (0.04)	4.65 (0.3)	4.06 (0.02)	4.52 (0.1)	14.98 (0.34)
CS	1.36 (2.61)^{C,*}	0.76 (2.91)^{D,*}	−0.65 (2.33)^{E}	11.88 (0.39)^{E}	0.26 (0.66)^{E}	3.97 (0.97)^{D}	5.23 (0.86)^{E}	13.97 (0.87)^{D}
CS-cont	0.66 (0.33)	−0.05 (0.0001)	−2.1 (0.46)	10.76 (0.03)	7.02 (0.6)	6.94 (0.73)	7.19 (0.31)	17.27 (0.58)

Table 2. Mean and standard deviation values of HR% after 8 h and 56 h of home bleaching and after 24 h and 1 month post bleaching. Identical superscript letters indicate no significant difference among different materials (Tukey post hoc tests ($\alpha = 0.05$)) at each time point. Identical superscript asterisks indicate no significant difference between bleached and unbleached (control) specimens for both polished and unpolished surfaces for each material at each time point (Independent sample t-test). *VitaEnamic (VE); Grandio Blocs (GN); Lava™- Ultimate (LV); BRILLIANT Crios (BR); Cerasmart (CS); Control (cont).

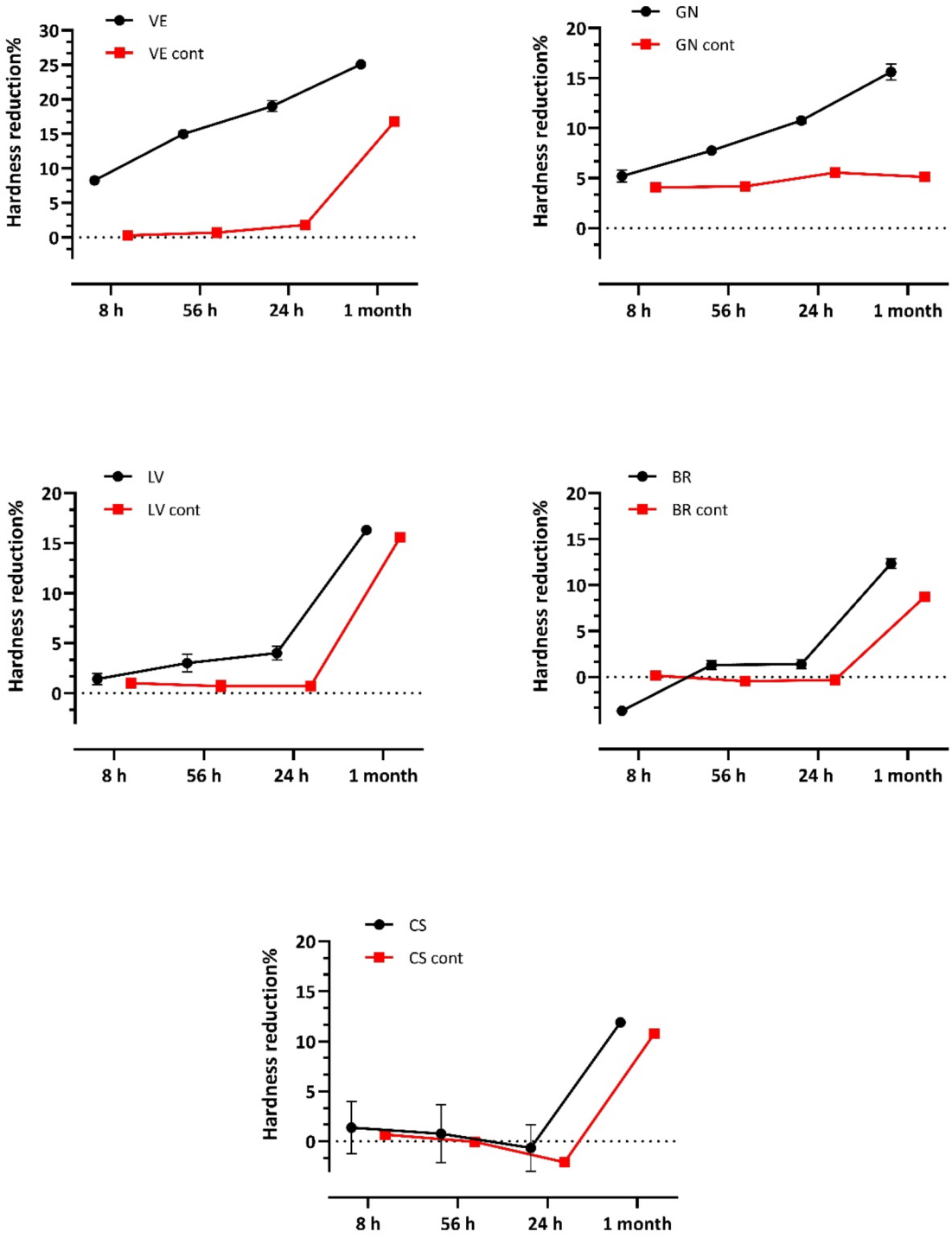

Fig. 2. Mean hardness reduction percentages at different time points with and without home bleaching (cont) for polished surfaces of the investigated materials.

At 24 h post bleaching of the polished samples, the greatest hardness reduction was observed in VE, followed by GN, LV, BR and CS, with significant differences among all the materials. For the unpolished group, the descending order was VE, LV, GN, CS and BR, also with significant differences among all the materials. There was a significant difference in the hardness reduction between the polished and unpolished specimens for all materials. At 1 month post-bleaching of the polished samples, was for VE exhibited the greatest hardness reduction, followed by LV, GN, BR, and CS, with significant differences among all the materials. The unpolished

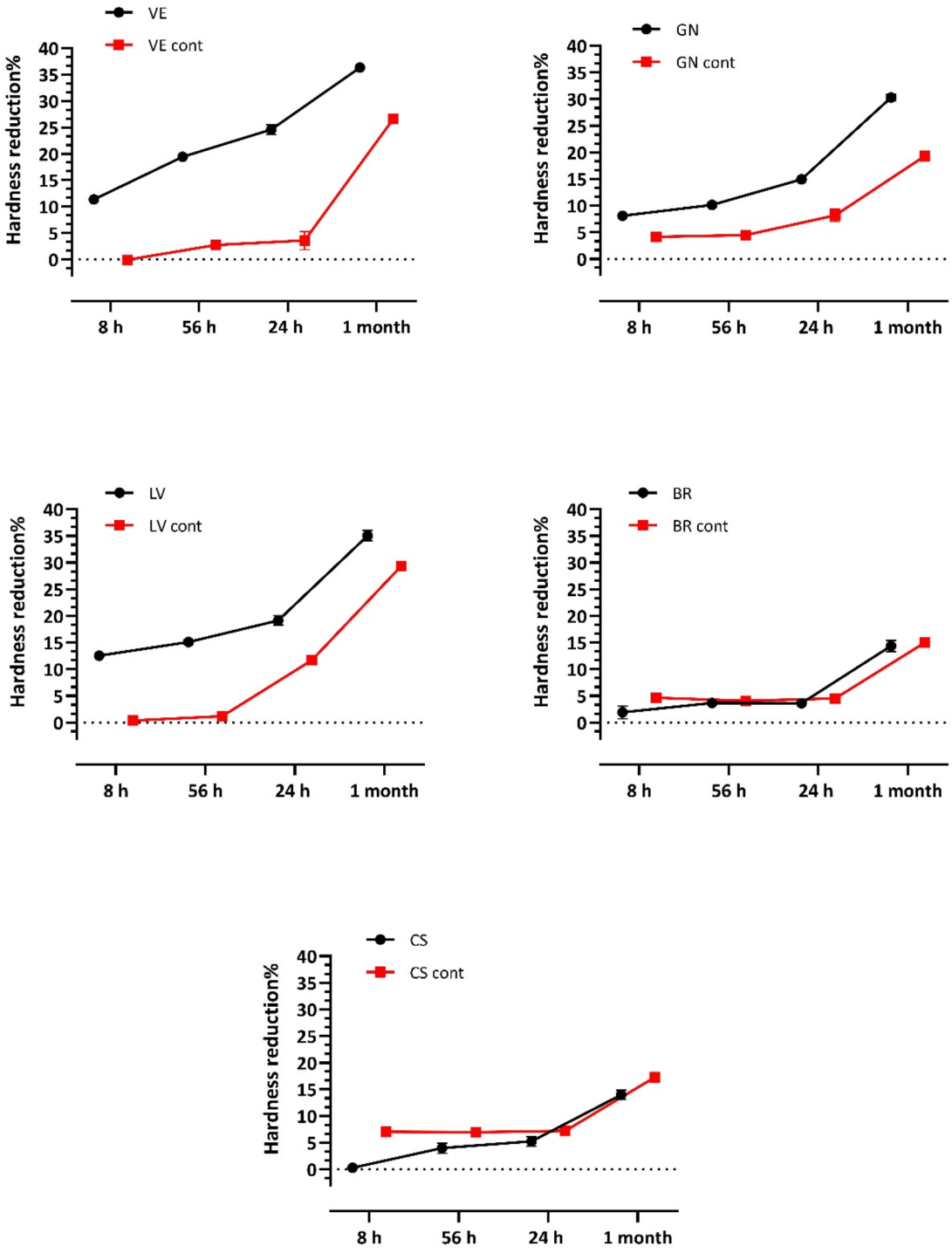

Fig. 3. Mean hardness reduction percentages at different time points with and without home bleaching (cont) for unpolished surfaces of the investigated materials.

materials showed a similar trend, with VE having the highest reduction, followed by LV, GR, BC, and CS, with significant differences between all materials except CS and BR.

The two-way ANOVA revealed a significant impact of material, time and their interaction on the hardness reduction ($p < 0.05$). For the polished surfaces, the material effect and simple main effect (0.78) had a greater influence compared to the time effect (0.088). Similarly, for the unpolished surfaces, the material effect (0.86) was more influence than the time effect (0.09).

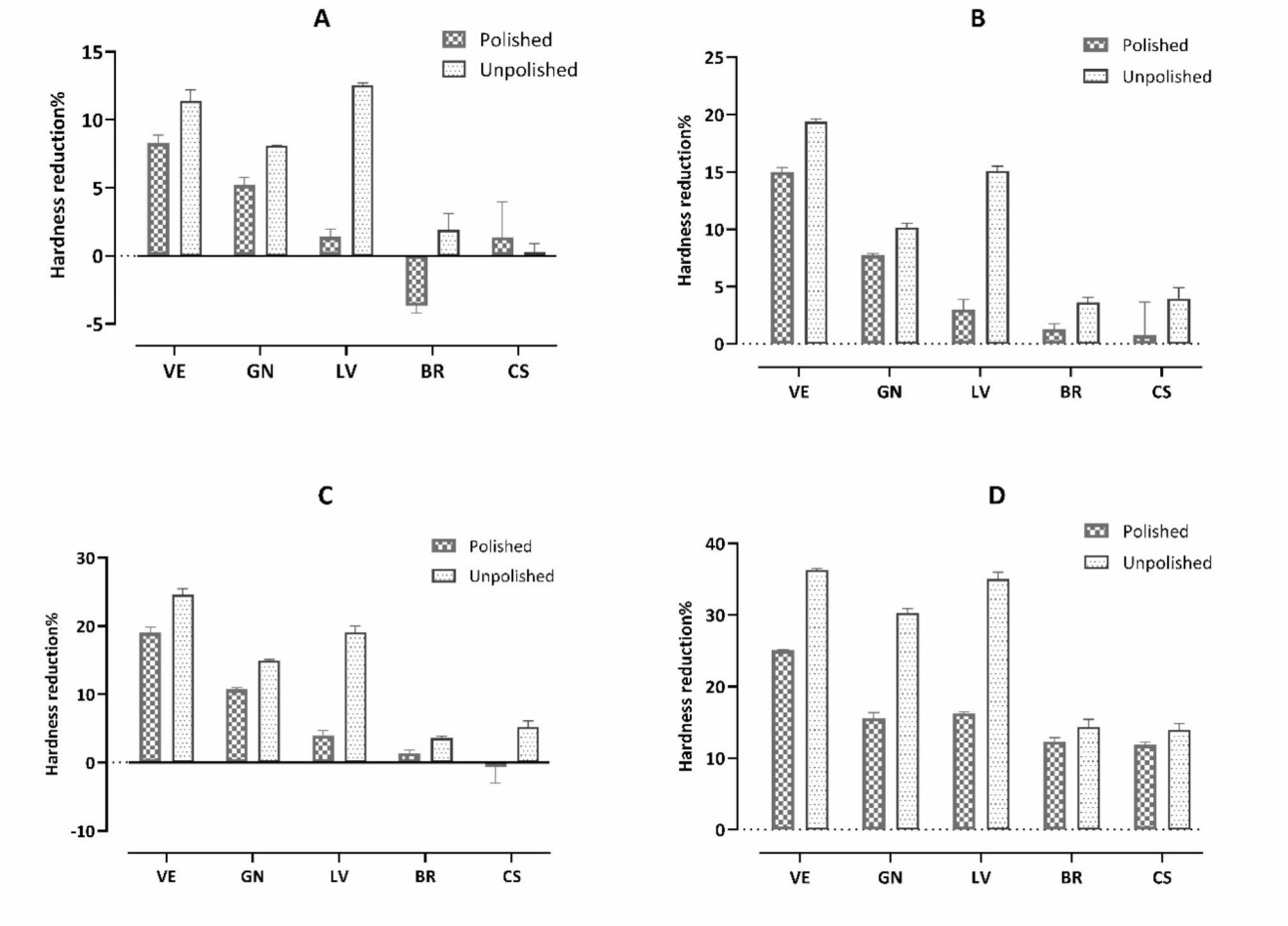

Fig. 4. A bar chart displaying the mean percentage reduction in hardness (HR%) at 8 h (**A**) and 56 h (**B**) during the bleaching process, as well as at 24 h (**C**) and 1 month (**D**) after bleaching. The standard deviation values are presented as error bars.

A significant positive correlation between filler weight (measured in a previous study[24]) and hardness reduction in the polished group ($R^2 = 0.79$, $p = 0.04$) was revealed, according to Pearson correlation analysis (Fig. 5). In the unpolished group, there was a nonsignificant positive correlation between filler weight and hardness reduction ($R^2 = 0.57$, $p = 0.14$). Furthermore, an insignificant positive correlation was observed between the polished and unpolished samples ($R^2 = 0.65$, $p = 0.1$).

According to the independent sample t-test, there was a significant difference between the polished and unpolished surfaces for each material at every time interval (Table 2).

Surface roughness

The Ra was measured before bleaching, 56 h post bleaching, and 1 month post-bleaching (Table 3). Bleaching affected the surface roughness of all tested materials in the polished group; both LV and BR exhibited significantly increased Ra values after 56 h of bleaching, while VE demonstrated significantly increased Ra values 1 month post-bleaching.

15% carbamide treatment affected the surface roughness of all tested materials in the unpolished group; both GN and LV exhibited significantly higher Ra values after 56 h of bleaching, whereas VE demonstrated non-significantly higher Ra values 1 month post-bleaching. Additionally, BR and CS displayed significantly higher Ra values 1 month post-bleaching.

Surface microstructure

SEM images of all materials at ×40k before bleaching, after 56 h of bleaching, and 1 month post-bleaching are displayed in Figs. 6 and 7. In the polished group, the particle margins were less demarcated and more rounded after 56 h of bleaching and 1 month post-bleaching. LV exhibited a prominent clustering of filler particles and more dark spaces, which represented the polymer matrix. GN and CS showed detachment between the filler and polymer matrix; note the dark spaces around the filler particles (red arrows). The unpolished group exhibited more prominent surface deterioration and margin fractures than did the polished group.

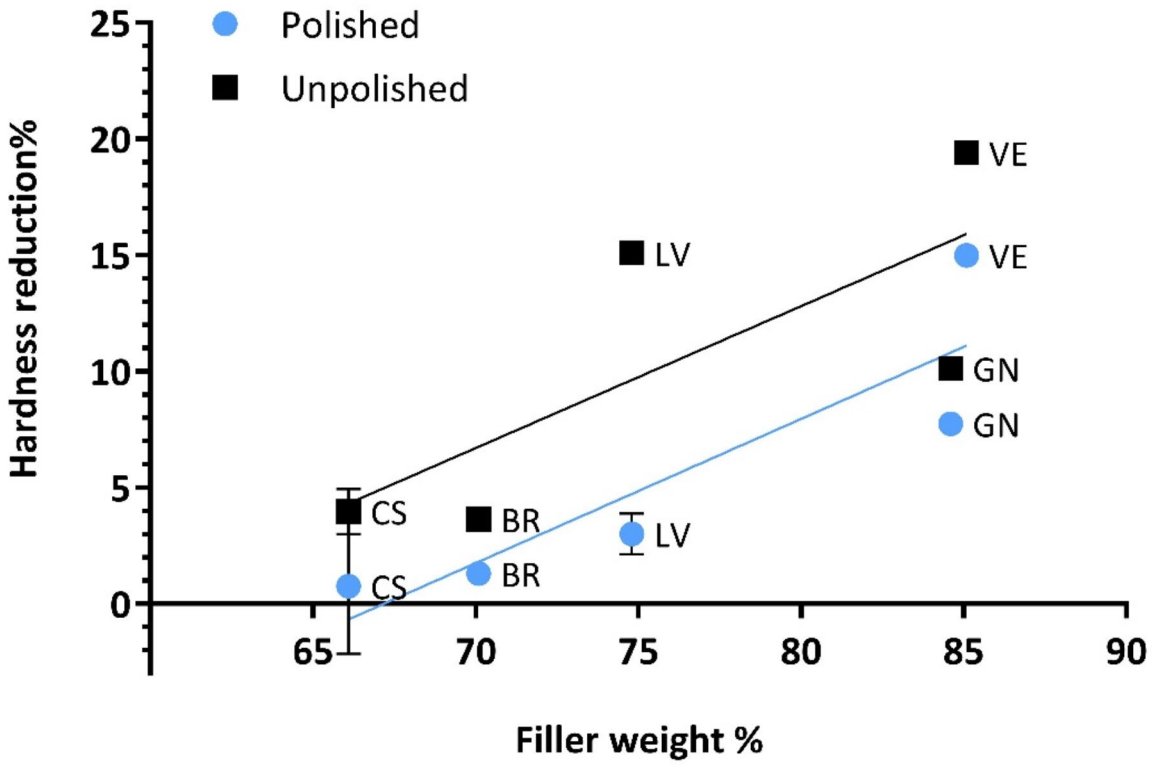

Fig. 5. A scatter plot displaying a significant positive correlation between filler weight (measured in a previous study) and the percentage (%) reduction in hardness in the polished group ($R^2 = 0.79$, $p = 0.04$). In contrast, the unpolished group exhibited an insignificant positive correlation between filler weight and hardness reduction ($R^2 = 0.57$, $p = 0.14$). No significant positive correlation between polished and unpolished samples, ($R^2 = 0.65$, $p = 0.1$).

Polishing	Polished			Unpolished		
Material	Before bleach	56 h post bleach	After 1 month	Before bleach	56 h post bleach	After 1 month
PICN						
VE	0.07 (0.02)	0.06 (0.02)	0.09** (0.01)	0.35 (0.02)	0.33 (0.03)	0.41 (0.09)
Resin composite blocks (RCB)						
GN	0.03 (0.00)	0.03 (0.01)	0.03 (0.00)	0.22** (0.02)	0.26 (0.03)	0.27 (0.05)
LV	0.03** (0.00)	0.05** (0.01)	0.02** (0.01)	0.23** (0.03)	0.24 (0.04)	0.24 (0.05)
BR	0.03 (0.00)	0.06** (0.02)	0.03 (0.00)	0.17 (0.01)	0.15 (0.01)	0.20** (0.05)
CS	0.03** (0.00)	0.02** (0.00)	0.04** (0.01)	0.10 (0.01)	0.09 (0.01)	0.18** (0.06)

Table 3. Mean and standard deviation values of surface roughness (Ra) measured before bleaching and after home bleaching, and 1 month post bleaching. Asterisks indicate significant differences among the values for each material at every time interval, as determined by one-way ANOVA.

Discussion

The comparison of the percentage change in hardness between the bleached and unbleached (control) groups for each material revealed significant differences. Furthermore, both the type of material and duration had a significant impact on hardness reduction ($p < 0.05$), with material type having a more significant effect. As a result, the first and second null hypotheses were rejected.

The comparison of the change in hardness percentage between polished and unpolished specimens for each material revealed significant differences, resulting in the rejection of the third null hypothesis. The filler weight% significantly affected the material softening of the polished samples but had an insignificant effect on the unpolished samples. Therefore, the fourth null hypothesis was partially accepted. Additionally, bleaching

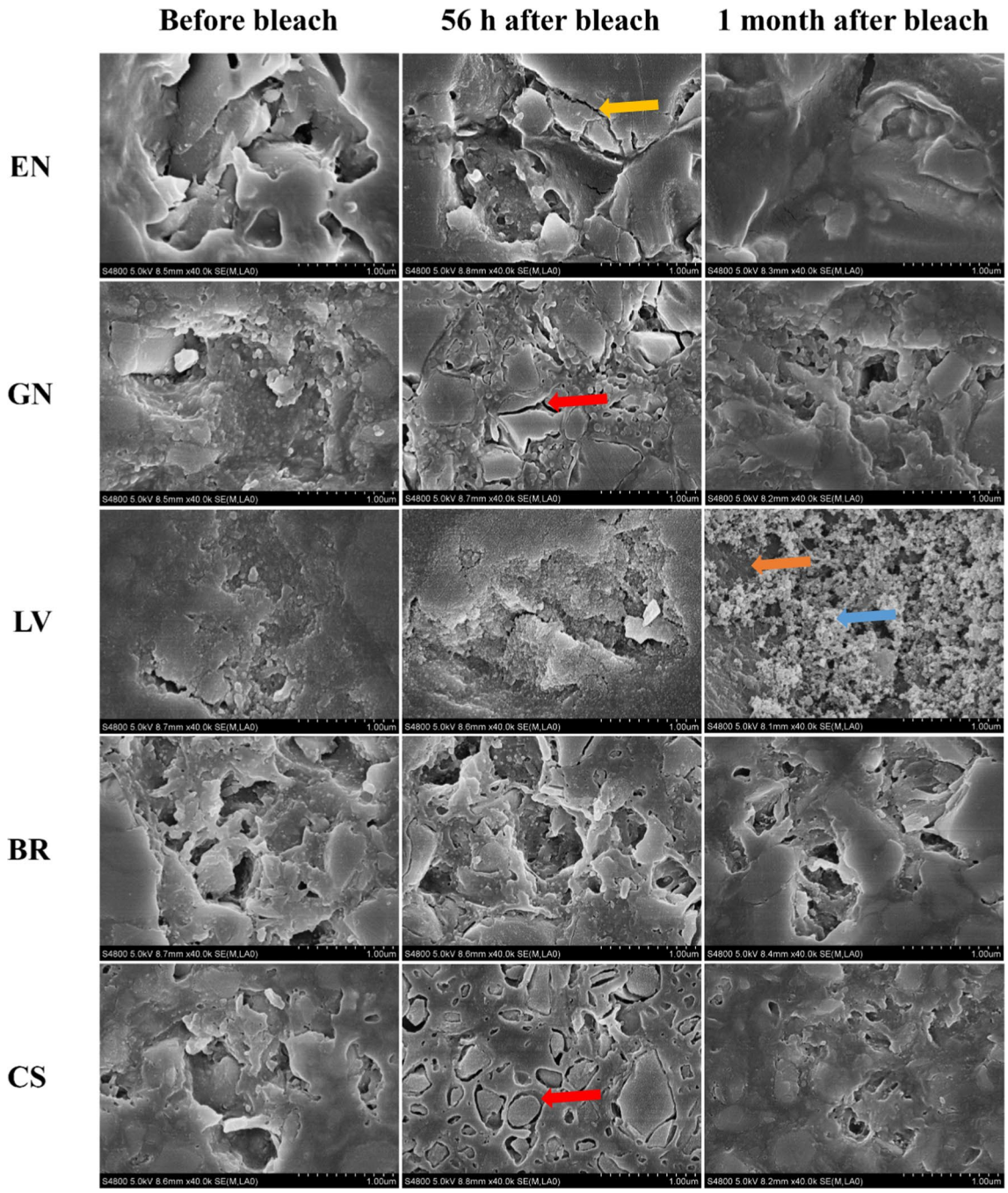

Fig. 6. SEM images at × 40 magnification of the polished surfaces of all materials before bleaching, after 56 h of bleaching, and 1 month after bleaching. Observations reveal that particles appear more rounded and exhibit less prominent margins at 56 h of bleaching and 1 month post bleaching compared to those of the unbleached samples. LV displayed the clustering of filler particles (indicated by blue arrows) and more dark spaces, representing the polymer matrix (indicated by orange arrows). In contrast, GN and CS showed detachment between the filler and polymer matrix; note the dark spaces around the filler particles (indicated by red arrows).

affected the surface roughness of some, but not all, of the examined materials, resulting in the partial acceptance of the fifth null hypothesis.

Vita Enamic, an interpenetrating ceramic-polymer network, is reported to exhibit durability against degradation[25–28] and has shown the highest level of material softening of all tested materials in both the polished and unpolished groups. This contrasts with the findings of previous studies in which VE was shown to be more resistant to softening by various storage media than were other RCBs[28,29] and even to increase the microhardness

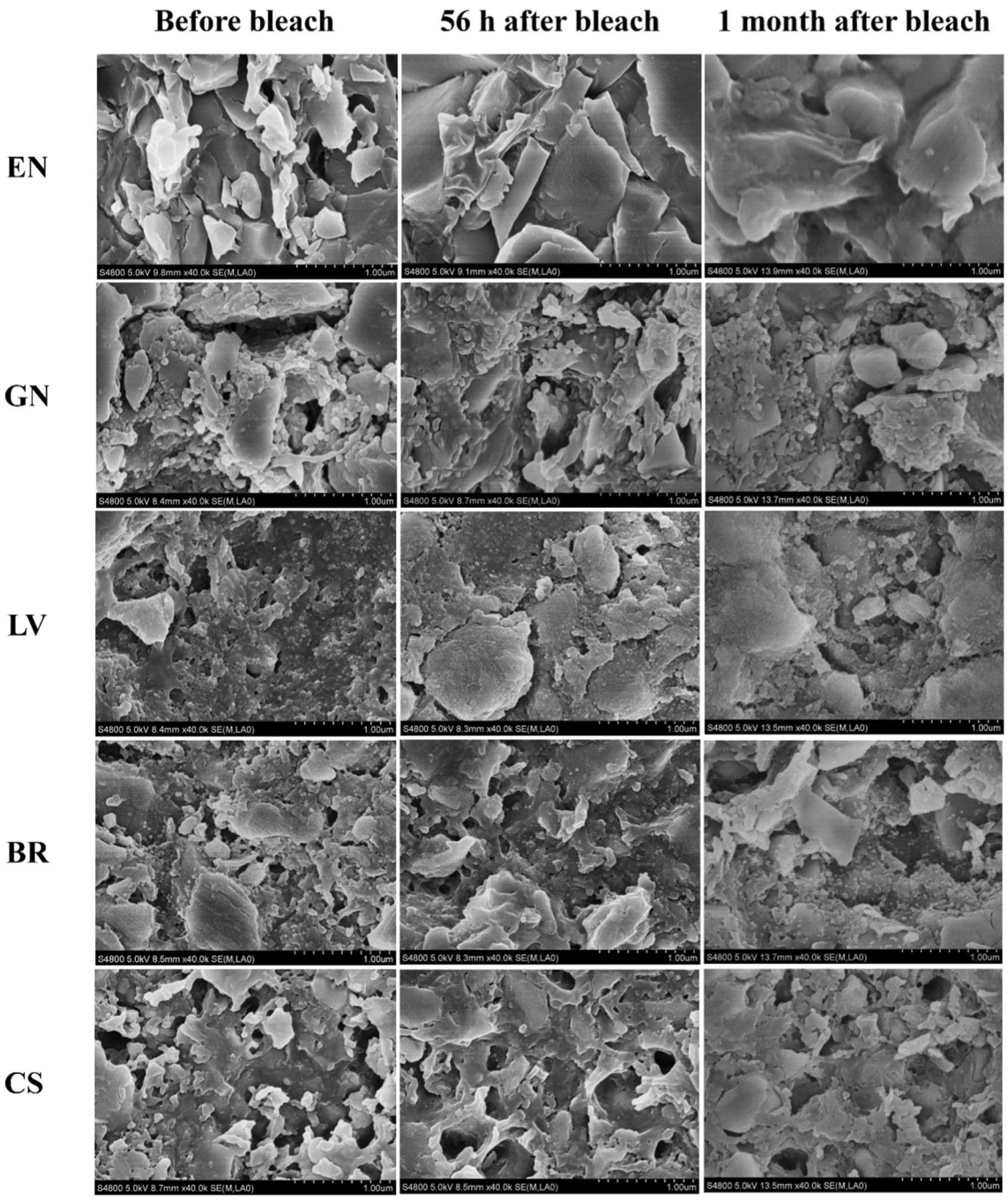

Fig. 7. SEM images of the unpolished surfaces of all tested materials at ×40 magnification, captured before bleaching, after 56 h of bleaching, and 1 m post bleaching. The images indicate that particles appear more rounded with less prominent margins after 56 h of bleaching and 1 month post bleaching, in comparison to the unbleached samples.

after home bleaching[30,31]. VE has a feldspathic ceramic structure that has shown less softening resistance than zirconia-containing materials[23].

RCBs exhibited greater material softening resistance than Vita Enamic. However, higher filler content correlated with increased material softening. For instance, GN with a filler weight of 86 wt% exhibited greater softening than LV, BR, and CS, which have filler weight percentages of 75 wt%, 70 wt%, and 66 wt%, respectively, in the polished group. Additionally, LV showed greater material softening than both BC and CS. This could be explained by the fact that LV is composed of nanoparticles of zirconium silicate that are more likely to undergo hydrolysis by the silane-coupling agent[32]. Furthermore, silanes tend to break down over time in resin composites[33]. On the other hand, for the unpolished group, LV showed greater material softening than GR,

which could be explained by the presence of defects and voids within the nanoclusters of LV; hence, more levels of surface degradation[34] could be expected for rough or unpolished surfaces.

Regarding the effect of polishing the samples on the material softening resistance, all unpolished surfaces exhibited less resistance to softening than the polished surfaces. The unpolished group better represents the clinical conditions of the restorations. In the oral cavity, dental restorations are subjected to moisture, temperature, acidity and mechanical stress, which can create rough surfaces that are more vulnerable to increased penetration by bleaching agents. This could subsequently be an indication to polish dental restorations before bleaching procedures.

The current study found a positive correlation between filler weight and material softening in the polished group, while an insignificant positive correlation was observed in the unpolished group for all tested materials. These findings contrast with previous studies that reported a negative correlation between material softening and filler weight across various storage media[35,36] and bleaching agents[37]. Furthermore, the significant correlation between filler weight and hardness reduction ($R^2 = 0.79$) in polished surfaces was reported in a previous study[31]. This discrepancy may be attributed to factors such as the filler microstructure, the homogeneity of the fillers, and the degree of cross-linking between the fillers and the resin matrix, all of which can influence the interaction between the restorative materials and the bleaching agents[38].

Various techniques can be used to assess surface roughness, such as contact stylus tracing, noncontact laser stylus methods, compressed air measurements, scanning electron microscopy (SEM), profilometry, and AFM[32]. In this study, surface roughness was assessed using profilometry and further analyzed using SEM.

The surface roughness of all of the tested materials was influenced by home bleaching, except for that of GN in the polished group, which is comparable with similar studies showing an increase in surface roughness as well as the appearance of surface pitting under SEM observation[25–28]. This can be attributed to the chemical interactions that occur between the bleaching agent and dental materials[29,38], which may also be influenced by the composition of the bleaching agent, as well as the bleaching time and concentration[20,29]. Nevertheless, a R_a value of 0.2 µm is the cutoff point for preventing biofilm accumulation[39]. This value was exceeded for unpolished samples of VE, LV, and GN. Furthermore, SEM images of the polished group showed that LV had a greater clustering of filler particles, while GN and CS showed detachment between the filler and polymer matrix. Furthermore, in comparison to the unbleached samples, the SEM images of the unpolished group of all the tested materials exhibited fewer distinct particle margins and more rounded particles after 56 h of bleaching and one month after bleaching. Thus, it is advisable to protect the restoration by polishing before bleaching agent application.

The choice to include both polymer-infiltrated ceramic networks (PICN) and resin composite blocks was deliberate to represent the full spectrum of CAD-CAM composite materials. This ensures a broader understanding of how bleaching affects materials with varying polymer and ceramic content.

Though the effect of home bleaching on surface properties of various restoration materials has been investigated, this study has limitations. The effects of home bleaching on the optical properties, stainability of the CAD-CAM material, and biofilm formation were not assessed. Additionally, only one PICN material (Vita Enamic) was used, which may not represent all available hybrid materials. While in vitro studies offer controlled conditions, clinical trials provide a more comprehensive understanding of how home bleaching agents can compromise the surface properties of CAD-CAM restorations. Furthermore, it would be clinically relevant to mechanically test the fatigue resistance and fracture strength of CAD-CAM materials subjected to home bleaching agents.

Conclusion

Home bleaching using 15% carbamide peroxide significantly decreased microhardness, primarily attributed to organic matrix erosion within the material. This effect was more pronounced in unpolished groups and with prolonged exposure. Further studies are recommended to determine the suitable concentration and duration of 15% carbamide peroxide application to ensure its use is safe for CAD-CAM materials.

Data availability

Data is provided within the manuscript.

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Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by RA. The first draft of the manuscript was written by RA and all authors commented on previous versions of the manuscript. JY: Conceptualization, Methodology, Software, Data curation, Writing—Original draft preparation, Visualization, Investigation. AA: Reviewing and editing. JH: Supervision, conceptualization, validation, reviewing and editing. BY: Proofreading, editing and supervision. AE: Supervision, conceptualization, validation, reviewing and editing. All authors read and approved the final manuscript.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

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