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Research Article

Effect of Bleaching Agents on the Microhardness of Different Resin Matrix Ceramics

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Abstract

Aim: The objective of this study is to assess the effect of different bleaching protocols and concentrations on the microhardness of CAD/CAM materials in vitro.

Material and Method: Five contemporary CAD/CAM blocks—resin nanoceramic, flexible nano-hybrid ceramic, hybrid ceramic, resin-infiltrated ceramic, and reinforced composite—were used. One hundred samples were prepared for each block and bleaching procedure (n = 10) with a thickness of 1.5 mm. Finishing and polishing were applied in accordance with the manufacturers' recommendations. Opalescence PF bleaching gel with a 16% carbamide peroxide content was applied to the at-home bleaching group for 14 days, 6 hours per day, whereas Opalescence Boost bleaching gel with a 40% hydrogen peroxide content was applied to the in-office bleaching group for 20 minutes, two times per session on days 1 and 7. The microhardness of the samples was measured with a Vickers hardness device before and after processing. The data were statistically evaluated using repeated-measures analysis of variance and the Bonferroni correction.

Results: After bleaching, the highest microhardness values were observed in the resin-infiltrated ceramic group ($p < 0.05$). The microhardness values of the hybrid ceramic decreased significantly ($p < 0.05$). No significant difference was detected between in-office and at-home bleaching protocols in blocks other than the hybrid ceramic.

Conclusion: Bleaching protocols, both in-office and at-home, do not decrease the microhardness of resin-infiltrated ceramic restorations, and they may better preserve esthetics during bleaching. Therefore, this type of CAD/CAM block may be preferred in cases involving bleaching treatments.

Keywords: Hybrid blocks, Bleaching, Microhardness

INTRODUCTION

In recent years, interest in digital dentistry applications has increased with the development of computer-aided design/computer-aided manufacturing (CAD/CAM) technology and the growing diversity of materials [1–3]. Dental materials currently used in digital dentistry include resin matrix ceramics, which have subgroups such as resin nanoceramics, polymer-infiltrated hybrid ceramics, and flexible hybrid ceramics according to their composition [1–3]. Resin matrix ceramics can be easily milled [1]. They have become popular due to their advantages, such as easy milling, better clinical adaptability than glass and polycrystalline ceramics, an elastic modulus similar to dentin tissue compared to traditional ceramics, and ease of repair [1].

A number of applications are used in vital tooth bleaching, e.g., bleaching performed in the clinic by the dentist (in-office), at home under the dentist's supervision (at-home), and combined bleaching, in which at-home and in-office bleaching are carried out together [4]. Hydrogen peroxide is applied in high concentrations (25–40%) in in-office bleaching [5]. In at-home bleaching, gels with a 5–35% carbamide peroxide content or a 2–10% hydrogen peroxide content are utilized as bleaching agents [5].

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The conditions leading to tooth discoloration differ and can impact dental tissues and restorations at varying intensities. This is an essential factor when deciding on the use of a bleaching agent. Although bleaching is considered relatively safe, the close contact of hydrogen peroxide or carbamide peroxide with teeth and restorations raises concerns about possible unwanted changes that bleaching may cause in both teeth and restorative materials. In this respect, clinicians seek information about the impact of tooth bleaching procedures on restorative materials in dental practice.

Numerous studies have demonstrated that bleaching agents can adversely affect dental restorative materials in terms of their optical, physical, and mechanical properties [6–13]. It is still uncertain whether alterations in the surface texture and hardness of dental materials after bleaching are clinically relevant or whether they merely represent surface phenomena that can be eliminated by simple polishing of the restoration. Bleaching agents cause chemical softening of restorative materials, which may influence their microhardness and surface roughness and, thus, the clinical longevity of tooth-colored restorations [12–14]. Decreased [15–16] and increased [17–18] microhardness values have been reported for various bleaching methods. Nevertheless, some studies have indicated no considerable changes [19,20].

Resin block materials are hybrid, nano-hybrid, and nano-filler containing composites that are produced at high temperature and pressure with standardized parameters [21]. Frequently used resin matrix ceramics include polymer-infiltrated ceramic (25% resin, 75% nanoceramic by volume), resin nanoceramic, and hybrid nanoceramic structured composite resin filled with nanoparticles [21]. These resin blocks are softer than ceramics, which makes their production and repair easier. Their physical and optical properties are better than those of indirect resin composites [22].

Previous research on CAD/CAM frameworks has assessed microhardness, flexural properties, fatigue behavior, bond strength, and chipping resistance [3,6–8,21,22]. However, there are few studies in the literature evaluating the microhardness of CAD/CAM materials after exposure to at-home and in-office bleaching [6–9]. Hence, the objective of the current study was to assess the impacts of different bleaching agents on microhardness values after applying different bleaching agents to contemporary esthetic CAD/CAM materials used in prosthetic treatment.

The null hypothesis of our research is as follows: Bleaching agents will not impact the microhardness of current CAD/CAM materials. When bleaching treatments are needed, it is clinically important to use ceramic materials in restorations that will not be affected by these procedures.

MATERIAL AND METHOD

This study did not involve human or animal participants, personal data collection, or clinical interventions. Therefore, ethical committee approval was not required. Our research investigated the effects of various bleaching processes on the microhardness of five CAD/CAM ceramic block materials. The list of the materials utilized in our research is presented in Table 1.

Table 1. Materials used in the study

Material	Composition	Manufacturer
Lava Ultimate (Resin nanoceramic)	80 wt% nanoceramic, 20 wt% resin (Bis-GMA, UDMA,TEGDMA)	3M ESPE St Paul, MN, USA
GC Cerasmart (Flexible nano-hybrid ceramic)	Nanoparticle-filled resin (UDMA, DMA) containing 71 wt% silica and barium glass filler	GC Corporation, Tokyo, Japan
Shofu Block HC (Hybrid ceramic)	61 wt% Zirconium silicate, Silica flour, UDMA, TEGDMA	Shofu Dental Corportaion, Kyoto, Japan
Vita Enamic (Resin-infiltrated ceramic)	86 wt% feldspathic ceramic enriched with Al_2O_3, 14 wt% polymer (UDMA, TEGDMA)	Vita Zahnfabrik, Bad Saeckingen, Germany
Brilliant Crios (Reinforced composite)	70 wt% barium glass and silica, Bis-GMA, TEGDMA	Coltene, Altstätten, Switzerland

GC Cerasmart (flexible nano-hybrid ceramic) (GC Dental Products Europe, Leuven, Belgium), Lava Ultimate (resin nanoceramic) (3M ESPE, Seefeld, Germany), Shofu Block HC (hybrid ceramic) (Shofu, Kyoto, Japan), Brilliant Crios (reinforced composite) (Coltene, Altstätten, Switzerland), and Vita Enamic (resin-infiltrated ceramic) (VITA Zahnfabrik, Bad Säckingen, Germany) blocks in A2-HT color were used.

The samples were cut at low speed (Microtome, Mecatome T180; Presi SA, Eybens, France) under water cooling at 2.0 mm intervals, taking into account the thickness (0.5 mm) of the diamond cutting disc used (Dimos, Metkon, Bursa, Turkey), resulting in a final thickness of 1.5 mm for each sample. Twenty samples were obtained for each material, and a total of 100 CAD/CAM block samples were prepared in this way. The sample size was 10 for each block and bleaching procedure group (n = 10). The thickness of the samples was checked with a digital caliper (Hogetex Digital Caliper, Netherlands) and confirmed to be 1.5 mm.

The surface of the samples to be treated was ground for 60 seconds under water using 600-, 800-, and 1000-grit silicon carbide (SiC) sandpapers. An ultrasonic cleaner (Skymen Heatable Ultrasonic Cleaner JP-4820, China) was used to clean the prepared samples for 5 minutes, and they were then dried with sterile sponges.

The samples' surfaces were polished using appropriate polishing systems in accordance with the manufacturers' recommendations. Lava Ultimate and GC Cerasmart samples were polished with Sof-Lex Spiral Wheel; Shofu Block HC samples with the CeraMaster Finishing & Polishing Kit CA0125 and CA0125C; Vita Enamic samples with the Vita Enamic Polishing Clinical Set; and Brilliant Crios samples with the Coltene Diatech Shape Guard polishing system. Afterwards, all polished samples were treated with GC DiaPolisher diamond-filled paste to complete the polishing process.

The samples were divided into five main groups based on block type and into two subgroups based on the bleaching procedures applied (in-office and at-home bleaching) (n = 10). The study groups are shown in Table 2.

Table 2. Study groups

CAD/CAM Blocks	Lava Ultimate (n=20)+3 SEM	GC Cerasmart (n=20)+3 SEM	Shofu Blok HC (n=20)+3 SEM	Vita Enamic (n=20)+3 SEM	Brilliant Crios (n=20)+3 SEM
Office bleaching (O) (40% Hydrogen peroxide)	Opalescence BOOST (LU-O) (n=10)	Opalescence BOOST (CE-O) (n=10)	Opalescence BOOST (SH-O) (n=10)	Opalescence BOOST (EN-O) (n=10)	Opalescence BOOST (BR-O) (n=10)
Home bleaching (H) (16% Carbamide peroxide)	Opalescence PF (LU-H) (n=10)	Opalescence PF (CE-H) (n=10)	Opalescence PF (SH-H) (n=10)	Opalescence PF (EN-H) (n=10)	Opalescence PF (BR-H) (n=10)

The finished and polished CAD/CAM block samples were stored in distilled water for 24 hours at 37 °C in an incubator (Incubator IN75 Memmert, Schwabach, Germany) [6, 12, 23]. Then, the initial microhardness values of the samples were measured using a Vickers microhardness tester (HMV Microhardness Tester, Shimadzu, Japan), by applying a 1 kg load and a 15-second dwell time according to the standard test method for Vickers indentation hardness of advanced ceramics as described in previous studies [24–26]. Measurements were taken from three regions of each sample, and the average microhardness values were recorded.

After the initial measurements, Opalescence BOOST (Ultradent Products Inc., South Jordan, UT, USA) and Opalescence PF (Ultradent Products Inc., South Jordan, UT, USA) bleaching agents were applied to the samples according to the manufacturers' instructions. In-office bleaching (Opalescence BOOST) was performed on days 1 and 8 by applying the agent twice per session, each application lasting 20 minutes, for a total of 80 minutes. At-home bleaching (Opalescence PF) was applied for 6 hours per day for 14 days, with a total application time of 84 hours.

Bleaching gels from syringes were applied evenly using a cotton applicator, and the thickness of the gel layer was adjusted to approximately 0.5 mm. During the bleaching process, samples were stored in sterile, enclosed containers. After each daily application, samples were rinsed with distilled water for 1 minute and kept in renewed distilled water until the next session. At the end of day 14, the samples were prepared for final microhardness measurements. To ensure measurement from the same area, the samples were placed on the same stage, the previous indentations were located under the microscope, and the new measurements were made as close as possible to the original marks.

Three samples of each material were prepared for SEM analysis. Gold coating was applied to the sample surfaces to improve image quality before examination. The samples were grouped and mounted on a metal tray. Surface changes before and after bleaching were evaluated under ×2000 magnification.

Statistical Analysis

The data were analyzed statistically using the SPSS 20 (SPSS Inc., Chicago, USA) program. The Shapiro–Wilk test was conducted to evaluate the conformity of the data to the normal distribution. Since the data were normally distributed, the difference between the groups was determined using repeated-measures analysis of variance (Repeated-Measures ANOVA). The difference between the groups revealed as a result of the repeated-measures analysis of variance was evaluated with the post hoc Tukey multiple comparison test and Bonferroni correction. The results were considered significant at a significance level of $p < 0.05$.

RESULTS

Table 3 shows the mean and standard deviation values for the microhardness of the CAD/CAM materials used in our research before and after bleaching. The highest mean microhardness values were measured in Vita Enamic samples before and after bleaching, followed by Lava Ultimate, Shofu Block HC, GC Cerasmart, and Brilliant Crios samples, respectively. In the at-home bleaching groups before bleaching, Vita Enamic samples had the highest microhardness value (214.80 ± 27.19), which was statistically significant ($p < 0.05$). While no significant difference was found between Shofu Block (106.45 ± 16.20) and Lava Ultimate (104.61 ± 7.77) samples, these two materials had significantly higher microhardness values than GC Cerasmart (80.38 ± 6.24) and Brilliant Crios (71.02 ± 5.64) samples. The microhardness values of GC Cerasmart and Brilliant Crios did not differ significantly ($p > 0.05$).

Before in-office bleaching, GC Cerasmart (78.27 ± 11.73) and Shofu Block (83.73 ± 7.79) samples did not differ significantly. Similarly, there was no significant difference between GC Cerasmart (78.27 ± 11.73) and Brilliant Crios (72.46 ± 1.97) samples. Lava Ultimate showed significantly higher values than these three groups, with the highest values observed in Vita Enamic (226.60 ± 33.97) samples.

After at-home bleaching, there was no significant difference between GC Cerasmart (84.19 ± 11.75) and Shofu Block (92.98 ± 6.77) samples. The lowest microhardness values were found in Brilliant Crios (72.36 ± 3.37) samples. The highest statistically significant values were observed in Vita Enamic (255.10 ± 29.05) samples, followed by Lava Ultimate (105.71 ± 6.01) samples.

In the in-office bleaching groups after bleaching, the lowest values were found in GC Cerasmart (75.69 ± 6.27), Shofu Block (73.35 ± 2.95), and Brilliant Crios (73.08 ± 2.78) samples ($p < 0.05$); however, these three groups did not differ significantly from each other ($p > 0.05$). The highest statistically significant values were observed in Vita Enamic (258.40 ± 31.74) samples, followed by Lava Ultimate (104.34 ± 3.96) samples.

When the CAD/CAM materials were evaluated within themselves, no statistically significant change was found in the microhardness values of Lava Ultimate, GC Cerasmart, and Brilliant Crios samples before and after bleaching ($p > 0.05$). Likewise, there was no significant difference between at-home and in-office bleaching for each of these materials ($p > 0.05$). However, a statistically significant increase in microhardness was observed in Vita Enamic samples after both at-home and in-office bleaching ($p < 0.05$), with no significant difference between the bleaching methods ($p > 0.05$). The microhardness values of Shofu Block samples decreased significantly after both bleaching treatments ($p < 0.05$), and a significant difference was found between at-home and in-office bleaching, with lower microhardness values resulting from in-office bleaching ($p < 0.05$).

Table 3. Mean and standard deviation values for microhardness before/after bleaching procedures and the results of Tukey multiple comparison test

Bleaching procedure	Before bleaching		After bleaching	
Groups	Home bleaching (H)	Office bleaching (O)	Home bleaching (H)	Office bleaching (O)
Vita Enamic (EN)	214,80(±27,19)^{Aa}	226,60(±33,97)^{Aa}	255,10(±29,05)^{Ab}	258,40(±31,74)^{Ab}
GC Cerasmart (CE)	80,38(±6,24)^{Ba}	78,27(±11,73)^{BDa}	84,19(±11,75)^{BDa}	75,69(±6,27)^{Ba}
Shofu Block HC (SH)	106,45(±16,20)^{Ca}	83,73(±7,79)^{Bb}	92,98(±6,77)^{Bc}	73,35(±2,95)^{Bd}
Lava Ultimate (LU)	104,61(±7,77)^{Ca}	101,07(±6,56)^{Ca}	105,71(±6,01)^{Ca}	104,34(±3,96)^{Ca}
Brilliant Crios (BR)	71,02(±5,64)^{Ba}	72,46(±1,97)^{Da}	72,36(±3,37)^{Da}	73,08(±2,78)^{Ba}

Different capital letters in the same column and different lowercase letters in the same row indicate statistical significance (p<0,05).

Scanning Electron Microscope (SEM) Analysis

Representative SEM images of the untreated and treated samples are shown in Figure 1. In the SEM images taken from the Lava Ultimate material, streaking and pitting areas were observed on the surface compared to the pre-treatment surface image after both at-home and in-office bleaching. However, no changes were observed in the GC Cerasmart material compared to the pre-treatment surface image after at-home and in-office bleaching.The SEM images of the Shofu Block HC material showed deepening and an increase in the number of pit-like areas after both bleaching procedures, similar to the Lava Ultimate material. In the SEM images of the Vita Enamic material, no changes were observed compared to the pre-treatment surface image after at-home and in-office bleaching treatments, similar to the GC Cerasmart material. In the Brilliant Crios material, streak-like formations appeared on the surface after at-home bleaching, while both streaking and pit-like areas were observed after in-office bleaching, compared to the pre-treatment surface image.

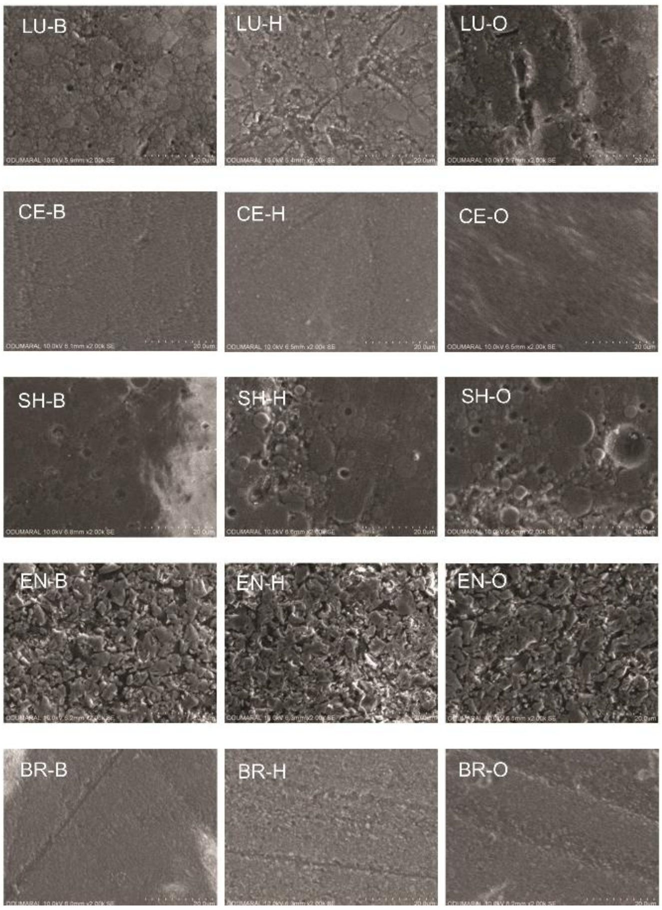

Figure 1. SEM images of all tested groups at 2000x magnification. LU-B: Lava Ultimate Before bleaching, LU-H: Lava Ultimate Home bleaching, LU-O: Lava Ultimate Office bleaching. CE-B: GC Cerasmart Before bleaching, CE-H: GC Cerasmart Home bleaching, CE-O: GC Cerasmart Office bleaching. SH-B: Shofu Block HC Before bleaching, SH-H: Shofu Block HC Home bleaching, SH-O: Shofu Block HC Office bleaching. EN-B: Vita Enamic Before bleaching, EN-H: Vita Enamic Home bleaching, EN-O: Vita Enamic Office bleaching. BR-B: Brilliant Crios Before bleaching, BR-H: Brilliant Crios Home bleaching, BR-O: Brilliant Crios Office bleaching.

DISCUSSION

In our study, we used different CAD/CAM blocks, such as Lava Ultimate (resin nanoceramic), GC Cerasmart (flexible nano-hybrid ceramic), Shofu Block HC (hybrid ceramic), Vita Enamic (resin-infiltrated ceramic), and Brilliant Crios (reinforced composite). The effects of in-office bleaching with 40% hydrogen peroxide and at-home bleaching with 16% carbamide peroxide on the materials' microhardness values were investigated.

According to the study findings, no statistically significant change was detected in Lava Ultimate, GC Cerasmart, and Brilliant Crios CAD/CAM blocks after applying in-office and at-home bleaching; no difference was observed between in-office and at-home bleaching for these three materials ($p>0.05$). The microhardness values of the Shofu Block HC material decreased statistically significantly, and it was observed that in-office bleaching caused lower microhardness values in this material ($p<0.05$). Microhardness values increased statistically significantly in Vita Enamic samples after bleaching ($p<0.05$). No difference was determined for this material between in-office and at-home bleaching ($p>0.05$). According to these findings, the null hypothesis of the research stating that 'bleaching agents will not impact the microhardness of current CAD/CAM materials' was rejected.

With developments in the field of dental CAD/CAM, resin-based ceramics have been produced by combining the positive properties of composite resin and ceramic materials [27]. The studies have suggested that these materials with a ceramic and polymer double network structure are less brittle, easier to process and have better marginal adaptation [28]. Nowadays, hybrid ceramics with different structures, including polymer-infiltrated ceramic network and resin nanoceramic materials, are available in the market [29]. Researchers indicated that current esthetic CAD/CAM materials could be used as an alternative to glass-ceramics [29-32].

Because of their strong oxidizing features, bleaching agents may lead to various physical, mechanical, and optical alterations in restorative materials in the mouth [12]. Compounds that are released due to oxidation influence the carbon bonds in the resin matrix content. They also change the structural and surface characteristics of the materials by acting on the silane binding the resin matrix and filler components [33].

The literature contains few studies on the impacts of bleaching agents on esthetic hybrid materials combining the properties of ceramic and composite materials produced with CAD/CAM [34-36]. Although hydrogen peroxide is the most commonly used agent in bleaching process, carbamide peroxide has increased the demand for its use in home whitening treatment due to its advantages such as ease of accessibility and use, being economical and safe, and showing successful results [yeni 37-39]. While 35-40% hydrogen peroxide-containing agents were mostly preferred for in-office bleaching in studies [35,40], agents containing 10-16% carbamide peroxide were preferred as at-home bleaching agent [11,13,36,41,42]. Application sessions and durations vary according to the type of the bleaching agent used. In our study, Opalescence BoostTM PF (Ultradent Products Inc., South Jordan, UT, USA) gel with a 40% hydrogen peroxide content, which is frequently preferred in the literature, was used as an in-office bleaching agent in 2 sessions of 20x2 minutes for a total of 80 minutes in accordance with the manufacturer's recommendations. For at-home bleaching treatment, Opalescence PF (Ultradent Products Inc., South Jordan, UT, USA) gel containing 16% carbamide peroxide was applied 6 hours a day for a total of 14 days.

The hardness value of a material indicates the material's resistance to wear during its function [43]. There are different studies in the literature on the impacts of bleaching agents on the microhardness features of restorative materials, such as composites and ceramics [12,20,23,24,34-36,44-46].

In a study researchers examined the impact of the bleaching technique applied with a LED light device on the surface nanohardness of different CAD/CAM ceramic materials [8]. Samples made of resin nanoceramic (Lava Ultimate), resin-infiltrated ceramic (Vita Enamic), lithium disilicate glass-ceramic, and zirconia ceramic blocks were bleached with 35% hydrogen peroxide using or not using the LED light device. As a result of the research, zirconia ceramics displayed a slight surface alteration following bleaching. The said materials primarily consist of strong oxide ceramics and are capable of resisting surface change caused by the bleaching agent. The authors observed significantly reduced surface hardness following bleaching in Lava Ultimate and Vita Enamic samples and attributed this to the highly cross-linked polymer matrix and fine nano inorganic filler particle content of both materials. The amount and type of inorganic fillers impact the surface hardness and strength of the resin nanoceramic and hybrid ceramic. Hence, the cleavage impact of hydrogen peroxide on the resin matrix of the mentioned resin polymers causes decreased surface hardness [8]. These results were inconsistent with our study because we observed an increase in Vita Enamic samples and no alteration in Lava Ultimate samples. It is possible to explain the different results by the various application methods of bleaching agents.

Serin-Kalay et al. [36] evaluated the impact of an at-home bleaching agent with a 16% carbamide peroxide content on the microhardness of the four different types of CAD/CAM materials (Brilliant Crios, Lava Ultimate, Vita Enamic, Vita Suprinity). The microhardness values of CAD/CAM materials decreased after the bleaching procedure. However, this decrease in the microhardness values of the materials was not statistically significant. Similar to this study, there was no significant difference after at-home and in-office bleaching in Brilliant Crios, Lava Ultimate, and Cera Smart samples in our study, whereas there was a significant increase in Vita Enamic samples. Rangel et al. [35] also found the improved surface microhardness for the resin-infiltrated ceramic (Vita Enamic) in accordance with our study. The increased microhardness of resin materials after bleaching is rarely reported in the literature [47]. The resin-infiltrated ceramic Vita Enamic is a dual network material, in which the dominant ceramic network is reinforced by a polymer network with every network penetrating the other for the purpose of creating a hybrid material with the positive features of a ceramic and a composite [48]. The polymeric chain is dissociated by the free radicals that are released from the hydrogen peroxide, breaking the double bonds from the cross-linked chains, causing chemical and physical degradation. The interface between the inorganic and polymeric matrix may be disintegrated by the oxidative free radicals released from bleaching gels [16]. This leads to the decomposition of the polymeric matrix [16] and monomer release from resin, and the high amount of the inorganic matrix on the materials' surface can improve surface microhardness [49].

There are debates about the impact of carbamide peroxide gels in low concentrations such as 10–16% on the surface microhardness of restorative composite materials. Cooley and Burger [17] revealed that the hardness of composite resins significantly increased after their being exposed to 10% carbamide peroxide gels. Lima et al. [50] demonstrated that 16% carbamide peroxide decreased the microhardness of the hybrid composite surface. According to the results of other studies, the hardness of composite materials was not significantly influenced by in-office tooth bleaching agents (35% carbamide peroxide or 35% hydrogen peroxide) [19,51]. The increased concentration of the bleaching gel increases the release of hydrogen peroxide, which can cause increased degradation in the structure of restorative materials [20]. Nevertheless, a number of studies showed that bleaching products in high concentrations did not influence the microhardness of composite resins, [52] hybrid ionomers, and glass ionomers [19].

Polydorou et al. [12] revealed that bleaching with 15% carbamide peroxide did not statistically significantly affect the microhardness of resin-based composite materials and ceramic samples tested. These results are in agreement with our study, except for Shofu (hybrid ceramic) and Vita Enamic (resin-infiltrated ceramic) samples. The microhardness values of the Shofu samples tested in our study decreased significantly. Shofu is a hybrid ceramic material, and bleaching agents may reduce microhardness due to organic matrix erosion that may affect the surface properties of materials and influence the durability of restorations [36]. The amount of material's inorganic and organic fillers, the grain size of finishing and polishing materials, the type of abrasives, and the particle size are the factors that affect surface properties [53]. According to the information provided by the manufacturer, the inorganic content of Shofu block materials is lower than the other materials tested in this study.

When measuring the surface hardness of hybrid materials, the device's tip may coincide with the soft or hard region. Therefore, in our study, three measurements were made from each surface with the Vickers hardness measurement method. In our study, the highest microhardness values were determined in Vita Enamic samples before and after in-office and at-home bleaching applications (226-258 kg/mm2 before-after in-office bleaching values; 214-255 kg/mm2 before-after at-home bleaching values), while the lowest values were found in Brilliant Crios samples (72-73 kg/mm2 before-after in-office bleaching values; 71-72 kg/mm2 before-after at-home bleaching values). These low microhardness values of Brilliant Crios are caused by a reinforced composite material and its high resin content. There are also polymeric molecules (UDMA and TEGDMA) in the resin-infiltrated ceramic (Vita Enamic). Its inorganic filler content (86 wt% feldspathic ceramic enriched with Al_2O_3) is higher than the other hybrid ceramic and composite materials utilized in the current research (Table 1). Thus, the microhardness values of Vita Enamic were affected by the action of peroxides in the organic matrix. The increased microhardness of Vita Enamic could be due to both the organic matrix deterioration or making most of the measurements on the samples' inorganic site.

The impacts of at-home bleaching with 16% carbamide peroxide and in-office bleaching with 40% hydrogen peroxide on the microhardness of the materials tested did not differ statistically significantly, except for Shofu blocks due to the greater organic matrix. The above-mentioned findings are consistent with the study by Costa et al. [44]. However, other studies reported significant differences between the effects of bleaching procedures. They found that at-home bleaching agents did not reduce microhardness significantly [23,34,53]. Although we did not reveal the said finding in the current research, we anticipated a more considerable decrease in microhardness in resin-based ceramics due to their higher organic matrix content, which represents the possible site of the oxidation reaction, as stated by numerous authors [12,16].

There is an association between the bleaching agent's impact and how deep it penetrates restorative materials [45]. With an increase in the strength of restorative materials, the resistance to bleaching penetration will also increase. If materials are strong, the diffusion of bleaching agents beyond the surface and through the inner structure is challenging [45]. Hence, the bleaching impact is displayed only superficially, which can explain different degrees of surface change in the various ceramic materials tested. Scanning electron micrographs showing different surface irregularities of the various ceramic materials tested can also confirm this. To evaluate the surface changes of the blocks used in our study, imaging was performed with SEM under x2000 magnification. No change in surface morphology was observed in the SEM images of Vita Enamic samples after in-office and at-home bleaching. The SEM images of Lava Ultimate, Shofu Block HC, and Brilliant Crios block samples treated with at-home bleaching showed slight streaking and crack-like changes on the surface. In addition to the surface changes, pit-like appearances were obtained in the samples treated with in-office bleaching. As a result of evaluation with scanning electron microscopy, researchers observed more surface changes in groups to which hydrogen peroxide was applied than in groups to which carbamide peroxide was applied [54]. The above-mentioned finding is similar to previous research [18,42,55,56] stating that hydrogen peroxide can accelerate the composite's hydrolytic degradation. The free radical per-hydroxyl generated as a result of the breakdown of HP has a great oxidizing potential that can influence both the pigment macromolecules and the resin matrix. It has been asserted that peroxides cause the oxidative decomposition of polymer chains, which leads to bonding problems between inorganic fillers and the resin matrix [55]. This can be associated with the decreased hardness of resin-based materials.

In vitro studies that better reflect the oral environment with an aging process like thermal cycle application may be more useful in finding results close to the clinic in the evaluation of microhardness. Likewise, the decreased microhardness after bleaching can be caused by the usage of artificial saliva storage media in the course of and following bleaching. However, in the study by Alqahtani et al. [57], the usage of artificial saliva did not inhibit the microhardness reduction in various resin-based composite materials following bleaching. A limitation of our study is that the results could be affected by the usage of artificial saliva and aging process.

CONCLUSION

Concerning the experimental limitations of the current in vitro research, it is possible to conclude that at-home and in-office bleaching with 16% carbamide peroxide and 40% hydrogen peroxide, respectively, did not alter the microhardness of hybrid CAD/CAM blocks, except for one ceramic-based material (Shofu Block HC). It can be concluded that restorations made of resin-infiltrated ceramic material (Vita Enamic) are safer in terms of hardness in cases when bleaching is applied to patients.

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Ethical approval: This study did not involve human or animal participants, personal data collection, or clinical interventions. Therefore, ethical committee approval was not required.

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