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Original Article

Evaluating the masking ability of CAD/CAM hybrid ceramics with different thicknesses

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Abstract

Aim: A discoloration existing under tooth restoration can affect the final restoration color, and various techniques can be used to address this. The aim of this study was to investigate the masking ability of the substructure color of different hybrid CAD/CAM ceramics in various thicknesses.
Methodology: A total of 120 samples were produced from 4 different CAD/CAM hybrid ceramic blocks (Cerec blocs, GC Cerasmart, Vita Enamic, 3M Lava Ultimate) in 1-, 1.5-, and 2-mm thicknesses. The samples were sliced at a pressure of 100 N with a low-speed precision cutting device under water cooling. The specimens were placed over a neutral grey background for initial spectrophotometric measurements. A three-color posterior nanohybrid composite (14x7x1 mm) was preferred to mimic discoloration in the substructure. The cementation procedure of the composite and the CAD/CAM hybrid ceramic complex was standardized under 10 N continuous pressure and was performed using a dual-cured resin cement. All samples were incubated at 37°C for 24 hours after cementation. The second spectrophotometric measurement was done via the L*, a*, and b* color attributes of the complex specimens. Additionally, ΔE* values were calculated to determine the color differences between each group. A Kruskal Wallis test was used for statistical analysis, and a Dunn's test was used for group comparison. Significance was evaluated at $p<0.05$.
Results: It was found that as the thickness of the ceramics increased, the substructure color was better masked, the thickness making a statistically significant difference in the masking ability ($p<0.01$). For 1-mm-thick samples, the highest ΔE* value was found in in Lava Ultimate (11.59) while the lowest value was found in GC Cerasmart (4.27).
Conclusion: Within the limitations of this study, it was concluded that the tested CAD/CAM hybrid ceramics showed better masking ability than Cerec blocs.

Keywords: CAD-CAM, ceramics, tooth discoloration

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Introduction

Computer aided design/computer aided manufacturing (CAD/CAM) technologies based on data collection, data processing, and manufacturing have recently shown a significant developmental acceleration. This technological movement has enabled many new CAD/CAM technologies in the dental market. In addition, the preferences of companies for open systems makes CAD/CAM technology an inseparable part of routine treatment procedures (1).

That the majority of dentists regularly use CAD/CAM systems in their clinical practice, with another significant part of them thinking of making investments in these systems, has made the need for new material for digital technologies inevitable (2). The most important focus of the new materials has been to join the superior aesthetic characteristics of ceramics with the advantageous intraoral repair options of composite-based materials (3). As a result, CAD/CAM hybrid ceramic materials in monolithic structures have been presented dentists' use (4).

Natural tooth color is determined by the optical characteristics of the enamel and dentin, and it has always been a struggle to be able to reproduce this color with restorations in dentistry (5). Clinical success may be unpredictable when metallic core structures that need to be masked, endodontic treatment, or the coloring conditions frequently observed, especially in the cervical area due to the old restorations, are added to the mix (6). Although layering has been suggested as the solution to these clinical conditions in the literature (7), some researchers have drawn attention to the fact that material thickness and cement color may constitute a solution (8, 9). However, the focus of these so-far limited studies has been ceramic materials reinforced with zirconia and lithium disilicate (10). To the current authors' knowledge, there are no studies assessing the masking efficiency of the hybrid ceramic materials that have reached an undeniable popularity today.

The aim of this in vitro study is to assess the masking efficiency of CAD/CAM hybrid ceramics (GC Cerasmart, Lava Ultimate, Vita Enamic) and CAD/CAM feldspathic ceramics (Cerec Blocs) manufactured in different thicknesses (1, 1.5, and 2 mm). The null hypothesis of the study is that the selected material and thickness will not change the masking efficiency of the restoration.

Materials and Methods

In this study, the masking efficiency of three different CAD/CAM hybrid ceramics, with the CAD/CAM feldspathic porcelain as the control group, has been examined. The compositions, brands, and manufacturing company details of the tested materials are shown in Table 1.

Table 1. Composition, brands and manufacturer of the tested materials

Material	Material Type	Composition	Manufacturer
Cerec Blocs	Feldspathic glass ceramic	SiO_2, Al_2O_3, Na_2O, K_2O, CaO, TiO_2	Dentsply Sirona Corporation, Germany
GC Cerasmart	Resin nanoceramic	71% inorganic (SiO_2 and barium glass nanoparticles) %29 organic	GC Europe Corporation, Belgium
Vita Enamic	Hybrid ceramic	86% inorganic (SiO_2, Al_2O_3, Na_2O, K_2O, ZrO_2) 14% organic	VITA Zahnfabrik, Germany
Lava Ultimate	Resin nanoceramic	80% inorganic (SiO_2, ZrO_2) 20% organic	3M ESPE, USA

One-hundred-and-twenty (n = 10) samples in plate shape were attained in 1-, 1.5-, and 2-mm thicknesses with 14-mm length and 7-mm width under water cooling with the help of a low-speed diamond knife (IsoMet 1000, Buehler Ltd., Lake Bluff, IL) from A1 colored CAD/CAM hybrid and feldspathic ceramic blocks. All samples have been sandpapered for 20 seconds with 400-, 600-, and 1000-grid rotational silicon carbide papers at 150 cycles per minute under water cooling before surface finishing procedures were carried out for the standardization of the surfaces. The prepared samples were kept in an ultrasonic cleaner containing distilled water at vibrations of 40 kHz for five minutes and dried with air. The surface-finishing and polishing processes for Vita Enamic and Lava Ultimate samples were conducted according to the instructions of the manufacturer company in three stages (rough, mild, fine) with universal polishing wax at 10,000 rpm with an angle drive with stable speed. The polish material (Optiglaze, GC Corporation, Tokyo, Japan) specific to the GC Cerasmart samples was applied to the surface of the material in a fine layer with a brush and polymerized with an LED device (D-Light Pro, GC Corporation, Tokyo, Japan) for 60 seconds. A fine-glaze layer was applied to the surface of the Cerec Blocs forming the control group with a ceramic brush, and heat treatment was applied, with a heat increase by 80°C/min starting from 500°C and a preliminary heating of four minutes in a porcelain oven. The final temperature was adjusted to 950°C, and the samples were left to gradually cool to room temperature. The thicknesses of the samples were rechecked with a digital caliper (Figure 1). Color measurements of the samples whose surface polishing processes were completed were conducted with a spectrophotometer (Spectroshade, Verona, Italy) against a neutral gray background color according to the CIE L*a*b* color scale, and the measurements were repeated five times for each sample.

Figure 1. Measurement of the material thickness with a digital caliper.

One-hundred-and-twenty plate-shaped samples were produced from A3 colored nanohybrid composite (Clearfil Majesty ES-2, Kuraray America Inc., New York, USA) with a stainless-steel mold with a length of 14 mm, a width of 7 mm, and a thickness of 1 mm for the purpose of imitating the colored tooth tissue. Afterwards, surface preparations of the ceramic samples were started in order to form the composite CAD/CAM hybrid ceramic complexes. Hydrofluoric acid at 4,5% was applied to each ceramic sample surface for 10 seconds. All samples were washed for five seconds after the acidification process and air dried. Bond was applied with an applicator on the nanohybrid composite surface according to the manufacturer’s user instructions, which was thinned with air and polymerized under LED light for 20 seconds. The composite and CAD/CAM hybrid ceramics whose surface processes were finished were then cemented with dual-cure adhesive cement (G-CEM LinkForce, GC Corporation, Tokyo, Japan) under 10 N of pressure, and light was applied for 20 seconds with an LED device. After the cementation process, samples were kept at 37°C in a drying oven for 24 hours. The spectrophotometric measurement of the composite and CAD/CAM hybrid ceramic complexes placed against a neutral gray background color after the waiting period was saved as the second color measurement. The masking efficiency was calculated according to the following formula, taking the difference between the two color measurements as its basis:

$$\Delta E^* = [(\Delta L^*)2 + (\Delta a^*)2 + (\Delta b^*)2] / 2$$

Statistical analysis

The NCSS 2007 (Number Cruncher Statistical System, Kaysville, Utah, USA) program was used for the statistical analyses. While a Kruskal Wallis test was used in the comparison of three or more groups, a Bonferroni Dunn test was used in binary comparisons.

The significance level used was $p<.05$.

Results

The ΔE* descriptive statistical values representing the masking efficiency, according to the used material and preferred thicknesses, are shown in Table 2. The Kruskal Wallis test results have shown that both material composition and thickness have statistically significant effects on the efficiency of the masking ($p < .01$). An increase in masking efficiency was detected in connection to increased thickness for all materials. In addition, the Bonferroni Dunn test has shown that the statistical difference in material thickness stems from the ΔE* difference in the materials with 1- and 2-mm thicknesses ($p<.05$; Table 3). While the highest masking efficiency was detected in the GC Cerasmart group (2.98), with the 2-mm thickness showing the lowest ΔE* value, the highest ΔE* value was observed in the Lava Ultimate group, with the 1-mm thickness having a value of 11.59. One eye-catching pieces of data from the study is that, unlike all other materials, no statistically significant difference in masking efficiency according to material thickness was detected in the Vita Enamic group ($p = .335$).

Table 2. Descriptive statistics and Kruskal Wallis test result based on material thickness

CAD/CAM Ceramics		Masking Ability (ΔE*) Material Thickness 1 mm (n=10)	1.5 mm (n=10)	2 mm (n=10)	p
LAVA ULTIMATE	Min-Max (Median)	9,2-16,8 (9,5)	8,4-16,7 (9,2)	8,4-9,7 (8,9)	0,008**
	Mean±SD	11,59±3,46	10,55±3,11	9,05±0,37	
CEREC BLOCS	Min-Max (Median)	8,6-9,4 (8,9)	7,9-9,0 (8,6)	6,4-17,1 (7,7)	0,008**
	Mean±SD	8,99±0,23	8,58±0,34	9,36±3,87	
VITA ENAMIC	Min-Max (Median)	5,9-7,0 (6,2)	5,8-6,4 (6,0)	5,0-15,7 (5,9)	0,335
	Mean±SD	6,32±0,36	6,04±0,23	8,51±4,71	
GC CERASMART	Min-Max (Median)	3,5-4,7 (4,2)	3,3-5,0 (3,6)	2,4-3,5 (3,0)	0,001**
	Mean±SD	4,27±0,33	3,73±0,48	2,98±0,33	

Table 3. Dunn's test result for masking ability according to binary comparisons of material thicknesses.

CAD/CAM Ceramics	Binary Comparisons 1 mm-1.5 mm	1 mm-2 mm	1.5 mm-2 mm
LAVA ULTIMATE	0,560	0,006**	0,226
CEREC BLOCS	0,612	0,006**	0,214
GC CERASMART	0,017*	0,001**	0,226

Discussion

The current results have shown that the material selected and the material thickness have statistically significant effects on the masking efficiency of the restoration. For this reason, the null hypothesis of the study has been rejected.

When the current CAD/CAM hybrid ceramic blocks are compared to the traditional ceramics, they show higher elastic modulus due to their resin content, and this situation contributes to the clinical processability and flexibility of the material (11). In addition, it is easier for CAD/CAM hybrid ceramic blocks to be milled when compared to traditional CAD/CAM ceramic blocks, which ensures an ease of repair in the event of the failures that may occur during long-term clinical usage (12). Furthermore, the ceramic particles found in their compositions provide the materials with both desirable aesthetics and durability (13). However, studies focus mostly on ceramic and zirconia restorations when masking efficiency is defined as one of the important properties of material (10, 14). For this reason, three different CAD/CAM hybrid ceramics have been included in this study, taking into consideration the dearth of scientific evidence regarding the issue of masking efficiency in hybrid ceramic materials in the literature, and Cerec blocs, being a feldspathic ceramic, were used as a control group. As is known by both researchers and clinicians, the selected restorative material type and its thickness are not the only factors in the determination of the final color of the restoration (15). It is known that the color of the resin cement used in the restoration and the thickness of film layer are also important (16). When these effects are taken into consideration—because the only effect of factors related to the restorative material were assessed in this study—a single-resin cement type and color were preferred, the polymerization process was conducted under stable force, and the cement film thickness was standardized to the extent possible.

Lambert's law holds that a decrease occurring in the material thickness causes a decrease in its absorption; this allows more light transmission from the material, while increases in thickness have inverse effects (17). This rule explains the increase in masking efficiency and the decrease in the calculated ΔE* value that result from the thickness increases. Similarly, in a study conducted by Ongun et al., in which the effects of material thickness in monolithic CAD/CAM blocks produced at thicknesses of 0.5 and 1 mm were assessed in terms of the final restoration color of the cement type and restorative material type, they detected lower ΔE00 values as a result of the increase in thickness. While researchers also claim that the decrease in light permeability, namely translucency occurring as a result of the increase in thickness, constitutes the main reason for this finding, they have, in this way, interpreted that the effects of the underlying structures could be decreased on the final restoration color (18). In a study conducted by Al-Haj Husain et al. on three different ceramic-based CAD/CAM hybrid blocks with 0.1- and 1.2-mm thickness, the researchers concluded that material thickness had a significant effect on the masking efficiency (4). All these findings are in parallel to the results of the present study. Moreover, in a study conducted by Turgut et al. on leucite-based CAD/CAM lamina veneers, although they attained higher ΔE* values with 0.5-mm thicknesses compared to the samples with 1-mm thickness in the present study's findings, they emphasized that this difference does not have any statistical significance in opaque ceramics (6). This difference in results could only be explained by the preference of HT blocks with high translucency properties or the differences in the thickness values preferred in methodology. A decrease in the ΔE* value with an increase in material thickness, as in the current study, was found in a study conducted by Chongkavinit et al. on three different HT CAD/CAM ceramics with high translucency and thickness values of 1, 1.5 and 2 mm. The authors' interpretation that only the ceramics with 2-mm thicknesses and yellow colored zirconia infrastructure could be masked support this claim (19).

It is known today that the crystal content, grain shape, structure, homogeneity, particle dimension distribution, and fracture index are the factors that directly affect the optic properties of a material (20, 21). However, when the currently used monolithic CAD/CAM ceramic materials are examined, different crystal structures are detected in their content, such as lithium disilicate, leucite or fluorapatite, and these crystal ratios show differences in most of them (22). This proportional increase in the crystal structure not only affects the durability of the material but also causes a decrease in the masking efficiency and translucency value of the material (23). It has been reported in a study in which the masking efficiency of materials with different crystal content and translucency values were assessed that the highest masking efficiency was detected in the GC Cerasmart group, and the lowest masking efficiency was detected in the Vita Enamic group (18). It has also been detected in the results of the current study that the material selected has a significant effect on masking efficiency, and GC Cerasmart was the material showing the highest masking efficiency. This situation could be explained by the fact that GC Cerasmart is a flexible resin nanoceramic containing alumina-barium silicate particles embedded in the polymer network (24). In a different study, in which a Lava Ultimate block was included as a resin nanoceramic, Lava Ultimate showed lower masking efficiency when compared to glass ceramics. Researchers have related the low masking efficiency of Lava Ultimate to the higher translucency value it has when compared to glass ceramics with the same thickness (4). The material found to have the lowest masking efficiency in this study was also in the Lava Ultimate group. Vita Enamic, having a double-penetrating polymer-infiltrated ceramic network, has alumina content of 8.31% by weight (25). As specified by Noort et al., the increase in the alumina content of the material causes a decrease in its translucency value (26). This explains the inability to detect a significant difference in the masking efficiency depending on thickness in the Vita Enamic group. However, there is also a study in the literature showing that the masking efficiency of Vita Enamic significantly changes depending on its thickness (18). This difference could be related to the fact that the researchers used an LT block with a low translucency value, in contrast to the current study.

As in every in vivo study, this study has various limitations. Nanohybrid composite was used in the simulation of the tooth tissue colored below, and as known, the optic properties of natural tooth tissue may show differences compared to composite structure. Moreover, the use of a single color and material has been preferred in the current study in order to imitate natural colored tissue. It is possible that results may show differences with the use of different materials and colors. Furthermore, translucency values' effects on masking efficiency have not been calculated. An often-preferred ΔE* formulation has been used instead of the ΔE00 formulation revised in the calculation of the masking efficiency. For these reasons, future studies are needed.

Conclusions

The following conclusions can be drawn, given the limitations of the study:

1. Masking efficiency increases as material thickness increases in CAD/CAM hybrid ceramics.
2. Masking efficiency is affected by the composition of the materials used.
3. All CAD/CAM hybrid ceramics tested for the restorations with 2-mm thickness show better masking efficiency compared to CAD/CAM feldspathic ceramics.

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