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Masking ability of computer-aided design and manufacturing bleach shade ceramics with different thicknesses on titanium abutments

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ABSTRACT

Background: Titanium abutments are the gold standard of implant treatments. However, they may not create sufficient color matching to the natural teeth due to the gray color showing through under the ceramic crown. The present study aimed to determine the masking ability of computer-aided design and manufacturing () bleach shade ceramics in different thicknesses on titanium abutments.

Materials and Methods: In this laboratory study, a total of 90 specimens of bleach shade ceramics Celtra Duo (CD), Vita Suprinity (VS), and zirconia Luxen were prepared in thicknesses of 1, 1.5, and 2 mm (n = 10). Background specimens of G-aenial composite in A3 color and titanium were used. The ceramic specimens were placed on titanium and composite backgrounds and L*a*b* color parameters and color difference (ΔE) were measured with the VITA Easyshade spectrophotometer. Data were analyzed using three-way and one-way analysis of variance tests. Pairwise comparisons of groups were also performed with Tukey's test. P <0.05 was considered statistically significant and ΔE <2.7 was considered clinically acceptable criteria.

Results: The effects of thickness, ceramic type, and their interaction effects on the ΔE were statistically significant (all three: P <0.001). The difference in ΔE values of bleach shade ceramics on titanium and composite backgrounds was estimated to be statistically significant in the thicknesses of 1 mm (P = 0.01), 1.5 mm (P < 0.001), and 2 mm (P = 0.001). Zirconia had a better performance for masking ability in thicknesses of 1.5 mm (P < 0.001) and 1 mm (P = 0.01), while VS ceramic showed the best masking ability in thicknesses of 2 mm (P = 0.001). The masking ability of ceramics was improved by increasing the thickness.

Conclusion: Except for VS ceramic in thickness of 1 mm, the rest of the bleach shade ceramics in all three thicknesses of 1, 1.5, and 2 mm have adequate ability to mask the titanium background and their use in line with the masking ability of titanium background has brought acceptable esthetic results.

Key Words: Ceramic, color, computer-aided design, titanium

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INTRODUCTION

Nowadays, there are different ceramic materials with various mechanical and physical properties. Color and translucency are essential factors in selecting a restorative material and creating a beautiful restoration.[1] Ceramic systems with high strength core

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have better physical properties, although they are more opaque due to higher crystalline content. In addition, ceramic systems with more translucent cores are more esthetical due to more light transmission and less light reflection, although the color of these materials is affected by the tooth or abutment, restoration, and cement.[2,3] Ceramic materials are produced by various techniques, including condensation and sintering, casting and ceraming, pressing, slip casting, and computer-aided design and manufacturing systems (CAD/CAM). In this regard, the CAD/CAM system has wide applications due to the use of new materials, reduction of laboratory time and cost, and the possibility of quality control.[4]

Nowadays, many advances have been made in CAD/CAM techniques, and the use of this technology by companies is expanding. Dentists also use this technique more. Thus, the need to study the results of this technique is felt more than before.[3] The CAD/CAM system has continuously evolved since the early 1990s, and its greater application along with the progress in materials science has led to the emergence of new restorative materials.[4] Feldspathic ceramics, lithium disilicate, reinforced lithium silicate, zirconia, resin-impregnated ceramics, and resin nanoceramics are different types of CAD/CAM materials that have different chemical structures.[5]

These ceramics are used in making inlays, onlays, and anterior and posterior masking.

Dental implants are the right choice for complete or partial edentulous cases, which improve esthetics and function, and increase the patient's self-confidence, although there are problems with implant placement in cosmetic areas. The position, slope, shape, and color of the restoration are the basic factors in the beauty of implants. Titanium abutments are the gold standard for implants due to both their biological and mechanical properties, although they may not provide an adequate appearance adaptation to natural teeth due to gray discoloration. Furthermore, ceramic restoration with a more translucent core may not mask discoloration or the metal structure of the titanium abutment due to the light passage.[2] The CIEL* a*b* color system is extensively used to quantify color and measure the color difference between two different materials due to its simplicity, easy implementation protocol, and high reliability. A spectrophotometer instrument is used to measure CIEL* a*b* values. In this system, L is the lightness level, a is the value of the red-green vector, and b is the value of the yellow-blue vector. Color differences are also calculated as ΔE and ΔE is compared with the clinically acceptable threshold (ΔE = 2.7).

Several studies have reported the minimum thickness of zirconia at 0.9 mm to achieve an acceptable color adaptation.[5,6] A study revealed that the color of ceramics is affected by the type of ceramics, the different levels of translucency, and the type of background. In another study, lithium disilicate had a better appearance than zirconia and more opaque materials were more suitable for dark backgrounds.[7] There are currently various ceramic systems available in the market for masking implants. However, the effects of implant abutment on the final color of bleach shade ceramics have not yet been definitively clarified.[2] Furthermore, there is a contradiction in the results of the studies. Thus, the present study aimed to investigate the masking ability of CAD/CAM bleach shade ceramics in different thicknesses of 1, 1.5, and 2 mm on titanium implant abutments.

MATERIALS AND METHODS

In this *in vitro* study, three CAD CAM bleach shade ceramics were used. Table 1 shows the characteristics of materials used in the research.

Preparation of ceramic specimens

Square specimens of 7 × 7 dimensions with thicknesses of 1, 1.5, and 2 mm were cut from each Vita Suprinity (VS) and Celtra Duo (CD) ceramic block using a slow-speed saw (Delta Precision Sectioning Machine, Mashhad, Iran) with plenty of water. Based on the thickness and type of ceramic (10 mm × 3 mm × 3 mm), a total of 90 ceramic specimens were prepared.[2,8] Zirconia discs were cut from zirconia blank and the sintering of specimens was done in a Kousha Fan Pars (KFP) dental auto-sinter furnace (1650 KFP, Iran) for 2 h at 1500°C. Given the shrinkage of zirconia during sintering, its shrinkage coefficient was included in the design process of the software. Ceramic specimens were

Table 1: List of the bleach shades of ceramic blocks

Ceramic type	Color	Type	Manufacturing company
CD	BL2	ZLS	Dentsply Sirona, Germany
VS	OM1	ZLS	VITA Zahnfabrik, Germany
Zr	White, HT	Zirconia	Dental Max, Korea

CD: Celtra duo; VS: Vita Suprinity; Zr: Zirconia Luxen; ZLS: Zirconia-reinforced lithium silicate polished with 400-, 600-, 800-, and 1200-grit silicon carbide paper. Furthermore, the thickness of each specimen was confirmed using a digital caliper (Shinwa Digital Caliper, Niigata, Japan).

Zirconia Luxen (Zr) ceramics were glazed with Ceramill Glaze (Amann Girrbach, Austria) for 10 min at a temperature of 850°C. VS ceramics were glazed with VITA AKZENT Plus (VITA Zahnfabrik, Bad Sackingen, Germany) at a temperature of 820°C for 12 min, and CD ceramics were glazed with Celtra universal Glaze (Dentsply Sirona Restorative, Germany) at a temperature of 820°C for 8 min. Finally, the ceramic specimens were cleaned of any fat and dust contamination using ultrasonic (BioSonic UC50D, Coltene, Whaledent, USA) for 5 min in 99% ethanol.

Preparation of backgrounds

A titanium block with dimensions of 1 cm × 1 cm and a thickness of 2 mm was prepared for the background in the laboratory. A3 composite (G-aenial Anterior, GC, Japan) was used to prepare the composite background. A composite specimen with dimensions of 1 cm × 1 cm and a thickness of 2 mm was prepared in a silicone mold, and then, a celluloid strip was placed on it and was light cured using a VALO light cure device (Ultradent, USA) and an intensity of 1000 Mw/cm^2 for 20 s.

Color measurement

Each of the ceramic specimens was placed on the titanium and composite backgrounds, and a drop of water was used to prevent light refraction between the ceramic and the background. Color measurement was done using a VITA Easyshade Advance 4.0 spectrophotometer (VITA Zahnfabric, Bad Sackingen, Germany). For this purpose, the device was set to the restoration mode. The device was placed on the middle part of each ceramic specimen and the values of L a*b * parameters were recorded. In this criterion, L represents the lightness, a* represents the value of the red-green vector, and b* represents the value of the yellow-blue vector.

A silicon mold was built around the easy shade unit head and the ceramic specimen to eliminate the effects of ambient light and reproducibility of the procedure. The color measurement was repeated 3 times for each specimen and the device was calibrated based on the manufacturer's guidelines before measuring the color of each specimen. The difference of L* a*b* ceramic on titanium and composite background was calculated using the formula ΔE.

$$\Delta E=\sqrt{\left[\Delta L^2+\Delta a^2+\Delta b^2\right]}$$

Finally, the minimum thickness required for the background masking was determined by comparing ΔE values and clinically acceptable threshold (2.7). A decrease in ΔE indicates a greater ceramic capability for masking.

Statistical analysis method

Data were analyzed using SPSS-26 statistical software ((SPSS Inc., IL, USA). The mean and standard deviation, minimum, and maximum changes of L, a, b, and ΔE parameters in different groups of ceramics and according to their thicknesses on the background of titanium and composite were measured and reported. Three-way analysis of variance (ANOVA) was used to determine the effects of ceramic type parameters, ceramic thickness, and their interaction effects on color parameters. Furthermore, the values of changes in color parameters in ceramic groups according to the thickness and in different thicknesses based on the ceramic type were examined using a one-way ANOVA test. Pairwise comparisons of ceramic groups and in different thickness groups according to ceramic type were also performed with Tukey's test. The acceptable first-type error rate was considered to be 0.05.

RESULTS

Tables 2-5 present the statistical indices of color parameters L, a, b, and ΔE in Zr, CD, and VS ceramics on titanium and A3 composite backgrounds in thicknesses of 1 mm, 1.5 mm, and 2 mm.

The results of the three-way ANOVA showed that the effects of ceramic thickness ($P < 0.001$), the type of ceramic ($P = 0.001$), and the interaction effects of ceramic and thickness ($P < 0.001$) on the overall color changes of the specimens (ΔE) were statistically significant. Based on the results of one-way ANOVA and in the thickness of 1 mm, statistically significant differences were observed regarding ΔL ($P = 0.02$), Δa ($P < 0.001$), and ΔE ($P = 0.01$) parameters of ceramics, but statistically significant differences were not observed regarding the Δb parameter ($P = 0.18$).

In the thickness of 1.5 mm, statistically significant differences were observed regarding ΔL ($P = 0.001$), Δa ($P < 0.001$), and ΔE ($P < 0.001$) parameters of ceramics. However, statistically significant differences were not observed regarding the Δb

Table 2: Mean and standard deviation of ΔL parameter of zirconia Luxen, Celtra Duo, and Vita Suprinity ceramics in different thicknesses on titanium and composite background

Ceramic	Thickness (mm)			*P*
	1.0	1.5	2.0	
Zr	1.98±0.39^{a,A}	1.30±0.48^{a,B}	1.17±0.53^{a,B}	0.001
CD	2.42±0.71^{a,b,A}	2.2±0.49^{b,A}	−0.39±0.68^{b,B}	<0.001
VS	2.83±0.69^{b,A}	1.47±0.53^{a,B}	0.44±0.16^{c,C}	<0.001
P	0.02	0.001	<0.001	

Different lowercase letters indicate statistically significant differences between ceramics for each thickness (Tukey's test), Different capital letters indicate statistically significant differences between thicknesses for each ceramic (Tukey's test), *P* values in last column and row indicate the results of the ANOVA analysis. CD: Celtra Duo; VS: Vita Suprinity; Zr: Zirconia Luxen; ANOVA: Analysis of variance

Table 3: Mean and standard deviation of Δa parameter of zirconia Luxen, Celtra Duo, and Vita Suprinity ceramics in different thicknesses on titanium and composite background

Ceramic	Thickness (mm)			*P*
	1.0	1.5	2.0	
Zr	0.12±0.14^{a,A}	0.06±0.09^{a,A}	0.05±0.05^{a,A}	0.27
CD	−0.39±0.19^{b,A}	−0.09±0.20^{b,B}	−0.15±0.14^{b,B}	0.003
VS	−0.32±0.19^{c,A}	−0.04±0.08^{a,B}	−0.07±0.19^{a,b,B}	0.001
P	<0.001	<0.001	0.01	

Different lowercase letters indicate statistically significant differences between ceramics for each thickness (Tukey's test), Different capital letters indicate statistically significant differences between thicknesses for each ceramic (Tukey's test), *P* values in last column and row indicate the results of the ANOVA analysis. CD: Celtra Duo; VS: Vita Suprinity; Zr: Zirconia Luxen; ANOVA: Analysis of variance

Table 4: Mean and standard deviation of Δb parameter of zirconia Luxen, Celtra Duo, and Vita Suprinity ceramics in different thicknesses on titanium and composite background

Ceramic	Thickness (mm)			*P*
	1.0	1.5	2.0	
Zr	−0.07±0.14^{a,A}	0.10±0.16^{a,A}	0.07±0.21^{a,A}	0.08
CD	−0.49±0.73^{a,A}	0.36±0.53^{a,B}	0.88±0.40^{b,B}	<0.001
VS	−0.35±0.45^{a,A}	0.51±0.35^{a,B}	0.18±0.26^{a,B}	<0.001
P	0.18	0.07	<0.001	

Different lowercase letters indicate statistically significant differences between ceramics for each thickness (Tukey's test), Different capital letters indicate statistically significant differences between thicknesses for each ceramic (Tukey's test), *P* values in last column and row indicate the results of the ANOVA analysis. CD: Celtra Duo; VS: Vita Suprinity; Zr: Zirconia Luxen; ANOVA: Analysis of variance

Table 5: Mean and standard deviation of ΔE values of zirconia Luxen, Celtra Duo, and Vita Suprinity ceramics in different thicknesses on titanium and composite background

Ceramic	Thickness (mm)			*P*
	1.0	1.5	2.0	
Zr	1.99±0.39^{a,A}	1.32±0.49^{a,B}	0.49±1.21^{a,B}	0.001
CD	2.59±0.76^{a,b,A}	2.29±0.47^{b,A}	1.18±0.37^{a,B}	<0.001
VS	2.90±0.71^{b,A}	1.63±0.36^{a,B}	0.56±0.19^{b,C}	<0.001
P	0.01	<0.001	0.001	

Different lowercase letters indicate statistically significant differences between ceramics for each thickness (Tukey's test), Different capital letters indicate statistically significant differences between thicknesses for each ceramic (Tukey's test), *P* values in last column and row indicate the results of the ANOVA analysis. CD: Celtra Duo; VS: Vita Suprinity; Zr: Zirconia Luxen; ANOVA: Analysis of variance

parameter (P = 0.07). In the thickness of 2 mm, statistically significant differences were observed regarding the ΔL (P < 0.001), Δa (P = 0.01), Δb (P < 0.001), and ΔE (P = 0.001) parameters.

According to the results of the one-way ANOVA, there were statistically significant differences regarding the ΔL (P = 0.001) and ΔE (P = 0.001) parameters in zirconia specimens and their different thicknesses. However, statistically significant differences were not observed in the different thicknesses of these specimens regarding Δa (0.274) (P = 0.08) and Δb (P = 0.08) parameters. Furthermore, there are statistically significant differences regarding the ΔL (P < 0.001), Δa (P = 0.003), Δb (P < 0.001), and ΔE (P < 0.001) parameters in CD ceramic specimens and in its different thicknesses. Furthermore, statistically significant differences were observed regarding the ΔL (P < 0.001), Δa (P = 0.001), Δb (P < 0.001), and ΔE (P < 0.001) parameters in VS ceramic specimens and in its different thicknesses.

DISCUSSION

According to the results of this study, the effects of three factors of ceramic thickness, ceramic type, and their interaction on ΔE were statistically significant. These results can be explained by the different relative translucency values of ceramics, especially zirconia, and the color characteristics of the titanium background.[9] The background color may show its color properties under the ceramic and present its effects on the final color. The final color will be the result of both the ceramic and background color.

In the present study, as ceramic thickness increased, the efficiency of masking increased, and ΔE was reduced. Similarly, in a study conducted by Değirmenci and Rasool, the masking ability of CAD/CAM hybrid ceramics with different thicknesses was investigated. They reported that by increasing the ceramic thickness, masking efficiency improved.[3] The study by Ellakany *et al*. showed that the thickness of 0.5 mm of lithium disilicate ceramics (IPS E-max CAD) and leucite-reinforced ceramics (IPS empress CAD) had the highest ΔE values. They also showed that by increasing thickness, the masking ability of ceramics increases.[5] Similar results were also reported in other studies.[10,11]

Based on the reports, the ceramic thickness should be at least 2 mm to mask the color changes of teeth or abutments in final restorations.[11] However, based on the results of the present study, Zr and CD ceramics in the thickness of 1 mm and all three groups of ceramics in the thicknesses of 1.5 mm and 2 mm could mask the dark color of titanium abutments. These results are clinically significant since it may not be possible to prepare ceramic restorations with a thickness of 2 mm in some cases. By reducing the material thickness, its absorption capability will decrease, and thus, more light will pass through it. Furthermore, by increasing the material thickness, the reverse results will occur. This rule explains the increase in the efficiency of the masking and the decrease in ΔE values simultaneously with the increase in the thickness of the ceramics in the present study. Researchers have also argued that the reduction of light penetration or opacity that occurs due to the increase in the ceramic thickness is the primary reason for these findings. According to this argument and with the increase in the ceramic thickness, the effects of the underlying structures of the restorations in their final color should be reduced.[12]

In the present study, the effect of ceramic type on titanium abutment masking was also statistically significant. Zr had a better performance for masking the color of the titanium substrate in thicknesses of 1.5 mm and 1 mm. In the thickness of 2 mm, VS ceramic showed the best masking capability. In general, Zr showed a capability to mask the color of the substrate in lower thicknesses than other ceramics. In this regard, Vohra *et al*. examined the masking of lithium disilicate ceramics on titanium abutments. They showed that zirconia copings in smaller thicknesses (0.5 mm) compared to lithium disilicate crowns (1.5 mm) could mask the titanium abutments. These results are similar to the present study.[13] This result was also reported in other studies.[14-16]

Al Hamad *et al*. examined the color effects of metal and ceramic copings in restoring color with translucent zirconia and low translucent lithium disilicate ceramics. They showed that lithium disilicate ceramics had better results than zirconia in creating a color adaptation, which was the opposite of the present study. It may be due to the use of a different background or a different type of zirconia.[7] The visual characteristics of dental ceramics are affected by the chemical composition, shape, average particle size, crystal phase distribution, production process, porosity, and microstructure.[17] Different ceramics have different microstructures. Furthermore, the color characteristics of the substrate can affect the final color results of restorations and the masking ability of ceramics.[18,19] However, different types of zirconia have structural differences that lead to significant differences in light absorption and emission in them.[20] This issue should be considered in the interpretation of the results of different studies.

In the interaction effect of ceramic type and thickness based on the research results, statistically significant differences were observed regarding ΔE. In other words, different thicknesses of ceramics have a specific role in the masking efficiency of the titanium substrate. Similarly, in all three studied groups, the difference in ΔE between the thicknesses of 1 mm and 2 mm was statistically significant. However, the differences between the thicknesses of 1 mm and 1.5 mm and between the thicknesses of 1.5 mm and 2 mm were not statistically significant in some cases. In the study by Tabatabaian *et al*., the minimum thickness of zirconia to achieve acceptable color adaptability was reported to be 0.9 mm, and the acceptable threshold ΔE was 3.3.[6] In another study, Tabatabaian *et al*. showed that as the thickness of zirconia ceramic increased, its masking ability increased and its ideal masking was observed at a minimum thickness of 1.6 mm. The acceptable threshold was 2.6. The difference between the two studies regarding the minimum acceptable thickness of zirconia for masking was due to the use of different types of zirconia, backgrounds, and acceptable thresholds.[2] Therefore, zirconia can mask in small thicknesses compared to other ceramics. It is necessary to achieve maximum color matching in the conservative preparation of dental structures.[21] In the present study, the value of ΔE = 2.7 was considered a criterion of clinical acceptability.[22] Based on the results of the present study, except for VS ceramics in the thickness of 1 mm (ΔE = 2.9), the rest of the ceramics in all three thicknesses of 1 mm, 1.5 mm, and 2 mm could mask the titanium abutment. Titanium abutments are the first choice in dental treatments due to their good mechanical properties. Due to the many applications of titanium abutments in implant treatments, based on the results of this study, it is possible to use CD and VS bleach shade ceramics and Zr to mask the color of titanium abutments.

In this study, the masking ability of three types of ceramic in different thicknesses on titanium and A3 composite backgrounds was investigated. Since the color of the background may affect the final color of the restoration, it is necessary to examine other colors and the composition of the background in this regard. Thus, other studies are needed on different types and colors of ceramics to determine the minimum thickness required for masking ability.

CONCLUSION

The results of investigating the masking ability of CAD/CAM bleach shade ceramics in different thicknesses on implant abutments showed:

1. The effects of thickness, type of ceramic, and their interaction on the masking ability of the ceramics were statistically significant
2. Zirconia has a better performance for masking the color of titanium background in thicknesses of 1.5 mm and 1 mm, and in the thickness of 2 mm, VS ceramic showed the best masking ability. Zirconia showed that it can mask the color of the titanium in lower thicknesses than other ceramics
3. The masking ability of ceramics improved as the thickness increased. Except for the VS ceramic in the thickness of 1 mm, all ceramics in all three thicknesses showed adequate masking of the color of the titanium background.

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Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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