Original Article

pISSN, eISSN 0125-5614
M Dent J 2023; 43 (Suppl) : S133-S138

Effect of lithium disilicate ceramic thickness on the color outcome of titanium implant abutment

Rujirada Siwachakeeyawate[1], Siriporn Arunpraditkul[2], **Wacharasak Tumrasvin**[2]

[1] *Master of Science Program in Prosthodontics, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand*
[2] *Department of Prosthodontics, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand*

Objective: This study aimed to compare the effects of lithium disilicate thickness on the final color outcome between ceramic restorations on titanium discs and natural die color discs.

Materials and Methods: To represent the color of crown on implant, 10-mm diameter IPS e.max (Emax) LT A2 discs with different thicknesses (1, 1.5, and 2 mm) were matched on the titanium disc. To represent the color of veneer on natural teeth (control groups), a 10-mm diameter Emax LT A2 discs with 0.5-mm thickness were placed on either ND2 (light color) or ND5 (medium-light color) natural die-colored composite discs. The specimens were measured at 4 points by the VITA Easyshade V. The data were captured by the CIELab color system. Mean values of L*, a*, and b* were calculated, and then the ΔE values were used to compare the color difference between the control and experimental groups. Data were analyzed by one-way ANOVA followed by Tukey's post-hoc (P<0.05).

Result: The color difference (ΔE) values for Emax with a thickness of 0.5 mm on the ND2 composite disc compared with Emax with a thickness of 1.5 mm (ΔE = 1.05 ± 0.45) and 2 mm (ΔE = 2.10 ± 0.67) on titanium discs, were found to be lower than perceptibility threshold (ΔE<2.6). When comparing Emax with a thickness of 0.5 mm on ND5 composite discs, the Emax with a thickness of 1.5 mm (ΔE = 2.40 ± 0.35) and 2 mm (ΔE = 1.19 ± 0.38) on titanium discs, were also found to be lower than perceptibility threshold (ΔE<2.6). The thickness of ceramic had a significant effect on the color of restoration (P<0.05).

Conclusion: Titanium discs covered with Emax thicker than or equal to 1.5 mm could achieve color matching with 0.5-mm thickness of Emax on both ND2 and ND5 composite discs.

Keywords: abutment color, crown on implant, lithium disilicate, veneer

How to cite: Siwachakeeyawate R, Arunpraditkul S, **Tumrasvin W.** Effect of lithium disilicate ceramic thickness on the color outcome of titanium implant abutment. M Dent J 2023;43(Suppl):S133-S138.

Introduction

The demand of treatment for esthetic anterior teeth is increasing. The ceramic veneers are an effective treatment option for improving the esthetic appearance of anterior teeth [1]. These ceramic veneers offer several advantages such as esthetic qualities, satisfactory mechanical properties, and the ability to replicate the appearance of natural teeth. Among these ceramics, lithium disilicate stands out as a widely preferred choice owing to its esthetic characteristics and biocompatibility [2, 3]. In situations that patients have lost some of their anterior teeth and desire to create a better overall anterior esthetics, a combination of dental implants tooth substitution, and ceramic veneering can be a treatment of choice.

Zirconia implant abutment can achieve esthetic results when used in the anterior region. However, they have a drawback such as weak point at the internal connection and less precision at the connection [4]. Stimmelmayr M, *et al.* reported titanium connection wore when used with zirconia abutment [5]. Due to this adverse effect of

Corresponding author: Wacharasak Tumrasvin
Department of Prosthodontics, Faculty of Dentistry, Chulalongkorn University
34 Henri-Dunant Road, Wongmai, Patumwan, Bangkok 10330, Thailand
Tel.: +66 8625 0888
Email: wacharasak.t@chula.ac.th
Received: 13 September 2023 **Revised:** 28 September 2023 **Accepted:** 1 October 2023

zirconia abutment, the hybrid abutment was suggested. This hybrid abutment is convenient for use, but it also has a drawback and limitations such as ceramic fracture at the assembly path and insufficient retention from its insufficient retentive post height [6]. In some limited clinical situations, the CAD/CAM titanium abutment may be a treatment of choice. It can be used, for example, to contour interdental papilla in a flat marginal gingiva area, to elevate the margin of crown restoration in a cement-retained crown situation to facilitate excess cement removal, or to strengthen the abutment wall in improper implant position placement [7].

Color matching between a CAD/CAM titanium implant abutment and veneer on natural teeth is always difficult. Jirajariyavej, *et al.* concluded that a 2.5-mm thickness of glass ceramic was clinically unacceptable to mask the metal color of titanium abutment [8]. However, Young-Eun Cho, et al. reported a masking ability of 1.5-mm restoration thickness (both zirconia and lithium disilicate restorations) on titanium abutment [9]. Shade matching can be measured by calculating the color difference (ΔE). Previous studies reported varieties of perceptibility and acceptability thresholds based on ΔE value. This study used a perceptibility threshold at ΔE value of 2.6 and an acceptability threshold ΔE value of 5.5 as reported by Douglas, *et al.* [10]. Despite numerous studies exploring the masking ability of restorations, there is a lack of research study on the color-matching ability of ceramic restoration thickness on titanium implant abutment when used in combination with adjacent ceramic veneering natural teeth. This study aims to evaluate the effect of different ceramic thicknesses covered on titanium implant abutments when compared to tooth-colored stump material covered with ceramic veneering. We designated ND2 to represent light-colored stump material, while ND5 to represent medium-light colored stump material.

Materials and Methods

Fabrication ceramic specimens

Lithium disilicate specimens were prepared from Emax LT ingot (A2 shade, Ivoclar Vivadent, Liechtenstein) by lost wax technique according to the manufacturer's instruction to form 10-mm diameter cylindrical discs with 0.5, 1, 1.5, and 2 mm (3 pieces per thickness, total 12 specimens) (Figure 1). The lost wax ceramic casting technique was conducted by pressing the molten ceramic ingot into an investment ring mold fabricated from preshaped waxing discs.

Fabrication tooth-color and titanium abutment specimens

The Natural Die Materials (ND2 and ND5 colors, Ivoclar Vivadent, Liechtenstein) represented the natural tooth color were built in a putty mold to form a 10-mm diameter cylindrical disc shape with 5-mm thickness. Titanium disc with 10-mm diameter and 5-mm thickness was fabricated from titanium type V alloy (Zirkonzahn, Italy) using the CAD/CAM milling technique with Zirkonzahn software and the M4 Wet Heavy Metal Milling Unit (Figure1).

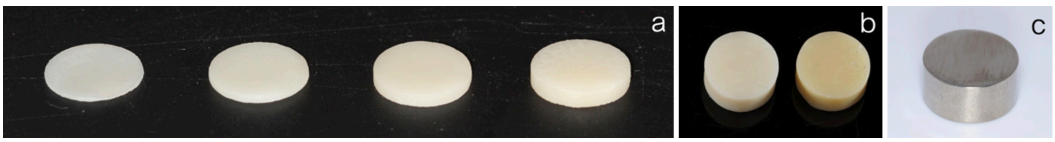

Figure 1 Disc specimens (a) Emax LT specimens with 0.5, 1, 1.5, and 2 mm; (b) Natural Die Materials color ND2 and ND5 specimens; (c) titanium disc specimen.

Color measurement

To represent the crown restoration on titanium implant abutment (experimental groups), Emax LT A2 thicknesses of 1, 1.5, and 2 mm were randomly matched over the titanium disc. To represent the veneer on natural tooth (control groups) Emax LT A2 0.5-mm thickness was placed over either ND2 or ND5 disc specimens (Figure 2).

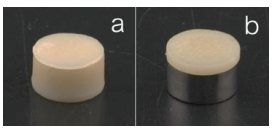

Figure 2 The examples of specimens used for color measurement. (a) Emax LT A2 0.5-mm thickness placed over composite disc; (b) Emax LT A2 2-mm thickness placed over titanium disc

The color outcome of each specimen on different substrates of experimental and control groups was measured using VITA Easyshade V (VITA Zahnfabrik, Germany). This evaluation was conducted at 4 points under the dark box within a temperature-controlled room set at 25 degrees Celsius. The measuring tip was placed in contact with the surface of the specimens at a precise right angle using a measuring jig (Figure 3). Prior to each measurement, the VITA Easyshade V was re-calibrated. The data were obtained from the CIELab system. Subsequently, the mean values of L*, a*, and b* (L*: brightness, a*: redness to greenness, b*: yellowness to blueness) were calculated from three pieces of each group. The ΔE value was calculated to compare the differences in color between the control and experimental group by the formula $\Delta E = [(L^*_1-L^*_2)^2+(a^*_1-a^*_2)^2+(b^*_1-b^*_2)^2]^{1/2}$

Figure 3 Specimen was measured using VITA Easyshade V at 4 points perpendicularly via measuring jig.

Statistical analysis

The examination data exhibited a normal distribution, and the variances were found to be equal. One-way ANOVA followed by Tukey's as a post-hoc test was performed to compare differences between groups. Data were analyzed using SPSS statistics for Mac, Version 29 (IBM, Armonk, NY). A *P*-value less than 0.05 was considered statistically significant.

Results

The means and standard deviations of measured L*, a*, and b* data are shown in Table 1. When the lithium disilicate disc was placed over the ND5 composite disc, a mean of L* and b* showed lower values but a mean of a* showed higher value when compared to that placed over the ND2 composite disc. When the thickness of Emax on the titanium disc increased (1, 1.5, and 2 mm), certain color values were affected. The L* value decreased while the a* and b* values increased.

When comparing the ΔE values between Emax with a 0.5-mm thickness on an ND2 composite disc and Emax discs with thicknesses of 1, 1.5, and 2 mm on a titanium disc, the mean and standard deviation of ΔE values are presented in Table 2. The mean ΔE values for both the 1.5-mm and 2-mm thicknesses of Emax LT A2 on the titanium abutment were found to be lower than the perceptibility threshold ($\Delta E<2.6$). The lowest mean ΔE value was found in the group of Emax with 1.5-mm thickness ($\Delta E = 1.05 \pm 0.45$). The mean ΔE value of Emax LT with 1.5-mm thickness was significantly lower than that of Emax LT with 1-mm thickness but was not significantly different from that of Emax LT with 2-mm thickness.

Table 1 The mean and SD of L*, a*, b* of Emax disc placed over natural die-colored and titanium disc.

Groups	L* (Mean ± SD)	a* (Mean ± SD)	b* (Mean ± SD)
Emax LT A2 0.5 mm on ND2 composite disc	82.43 ± 0.60	0.23 ± 0.17	19.03 ± 0.42
Emax LT A2 0.5 mm on ND5 composite disc	79.26 ± 0.39	0.93 ± 0.89	18.91 ± 0.23
Emax LT A2 1 mm on Ti abutment	84.98 ± 0.09	-0.22 ± 0.94	17.61 ± 0.22
Emax LT A2 1.5 mm on Ti abutment	81.61 ± 0.16	0.57 ± 0.89	18.68 ± 0.23
Emax LT A2 2 mm on Ti abutment	80.42 ± 0.14	0.73 ± 0.05	19.08 ± 0.17

L*: brightness; a*: redness to greenness; b*: yellowness to blueness

Table 2 The mean and SD of ΔE value between different Emax thickness on titanium implant abutment when compared to Emax 0.5-mm thickness on ND2 composite disc

Groups	ΔE (Mean ± SD)
Emax LT A2 1 mm on Ti abutment	2.96 ± 0.75[a]
Emax LT A2 1.5 mm on Ti abutment	1.05 ± 0.45[b]
Emax LT A2 2 mm on Ti abutment	2.10 ± 0.67[a, b]

Means with the same superscript letter are not significantly different from each other based on a statistically significant difference ($P<0.05$)

When the darker tooth-color shade material (ND5 composite disc) covered with 0.5-mm Emax disc was compared to Emax disc with 1, 1.5, and 2 mm-thickness on titanium disc, the mean and standard deviation of ΔE values are shown in the Table 3. The mean ΔE values for both the 1.5-mm and 2-mm thicknesses of Emax LT A2 on the titanium abutment were found to be lower than the perceptibility threshold (ΔE<2.6). The lowest mean ΔE value was found in the group of Emax LT with 2-mm thickness (ΔE = 1.19 ± 0.38). The mean ΔE values between all groups of Emax LT thickness were found to be significantly different.

Discussion

There are previous researches that study about masking ability of ceramic restoration on various types of implant abutments. Dede, *et al.* studied color matching of various types of 1.5-mm thickness all ceramic crowns on different types of implant abutments with natural tooth color composite resin material (Shade A2). The minimum ΔE value was found in zirconia abutment restored with monolithic zirconia crown. While masking ability of lithium disilicate on titanium implant abutment was clinically unacceptable [3]. From the study of

Table 3 The mean and SD of ΔE value between different Emax thickness on titanium implant abutment when compared to Emax 0.5-mm thickness on ND5 composite disc

Groups	ΔE (Mean ± SD)
Emax LT A2 1 mm on Ti abutment	5.98 ± 0.43[a]
Emax LT A2 1.5 mm on Ti abutment	2.40 ± 0.35[b]
Emax LT A2 2 mm on Ti abutment	1.19 ± 0.38[c]

Means with the same superscript letter are not significantly different from each other based on a statistically significant difference ($P<0.05$)

Jirajariyavej, *et al.,* when the control was 4-mm thickness of the same ceramic, 2.5-mm thickness of ceramic could clinically acceptably mask the color of yellow zirconia implant abutment. While the 2.5-mm thickness of ceramic could not clinically acceptably mask the titanium metal color [8]. Young-Eun Cho, *et al.* studied the masking ability of ceramic material by comparing the same thickness of ceramic with different substrates. They concluded that 1.5-mm thickness both zirconia and lithium disilicate restorations on titanium abutments showed an acceptable masking ability. The control of this study was the same thickness of ceramic restoration on composite resin material shade A2 [9]. Our study found that Emax LT A2 with 1.5-mm thickness could clinically match color outcome when compared with ND2 and ND5 natural die shade composite resin materials covered with Emax LT A2 0.5-mm thickness. We designated ND2 to represent light color abutment natural teeth, while ND5 to represent medium-light color abutment natural teeth. The low translucency Emax was selected because it offered better masking capabilities compared to the high translucency Emax [11].

This study used the perceptibility ΔE value at 2.6 and acceptability ΔE value at 5.5 as reported by Douglas, *et al.* [10]. The null hypothesis was rejected because we found that the thickness of ceramic influences the CIELab value. In Tables 2 and 3, it could be observed that both the 1.5-mm and 2-mm thicknesses of Emax LT A2 compared with the 0.5-mm thickness of Emax LT A2 on both ND2 and ND5 composite discs exhibited ΔE values lower than the perceptibility threshold ($\Delta E<2.6$). Thus, the minimum Emax thickness on the titanium implant abutment to match the color of an adjacent veneered natural tooth is 1.5 mm.

In this study, the certain color values were affected by the increasing thickness of Emax LT A2 on the titanium disc (1, 1.5, and 2mm). We used a 0.5-mm thickness of Emax LT A2 to represent the veneer on a natural tooth, as this dimension was an average depth capable of masking the color while the preparation remained within the enamel layer. To minimize confounding factors, color measurements were conducted without the application of luting cement. When the stump shade was darker from ND2 to ND5, a mean of L* and b* decreased but a mean of a* increased (redder and bluer). As the thickness of Emax LT A2 on the titanium disc increased (1, 1.5, and 2mm), certain color values were affected. The L value decreased but the a and b values increased (redder and yellower). The characteristics of certain color values were similar to previous studies [12-15]. When dealing with an esthetic anterior veneering case that is necessary to combine with an implant-supported crown using titanium abutment, clinicians should consider the titanium abutment preparation space based on the color of an adjacent natural tooth after preparation. This was crucial as it could significantly impact both the thickness of the veneer and the final crown applied to the titanium implant abutment.

The study's limitations were related to the shade and translucency of the ceramic material used, especially the specific use of Emax LT A2 shade. Thus, the result might be different when using other shades and translucent ceramics. Moreover, the shades for represent natural teeth that used ND2 and ND5 shades. When dealing with darker natural teeth shades, achieving a shade match could be more challenging. In such cases, additional methods might be necessary to modify the color and achieve optimal esthetic results. As this study is an *in vitro* study, when applied in a real clinical situation, there are many challenges in achieving color matched that need to be concerned such as light conditions, luting cement color, patient perception, and surrounding environment [16, 17].

Conclusion

Within the limitations of this study. It could be concluded as follows:

1) The thickness of ceramic had an influence on the color outcome. The L* value decreased but

the a* and b* values increased when increasing the ceramic thickness covered on the titanium disc.

2) The 1.5-mm thickness of Emax LT A2 on the titanium implant abutment was the minimum thickness to match with 0.5 mm of Emax LT A2 on both ND2 and ND5 shade teeth.

Acknowledgments

We would like to acknowledge the Faculty of Dentistry, Chulalongkorn University for grant support; and Assistant Professor Dr.Soranun Chantarangsu for her guidance in statistical analysis.

References

1. Monaraks R, Leevailoj C. The longevity of ceramic veneers: clinical evaluation of mechanical, biologic and aesthetic performances of ceramic veneers, a 7-year retrospective study. ***J Dent Assoc Thai***. 2018 Jul-Sep;68(3):288–301. doi: 10.14456/jdat.2018.35.
2. Wang F, Takahashi H, Iwasaki N. Translucency of dental ceramics with different thicknesses. ***J Prosthet Dent***. 2013 Jul;110(1):14-20. doi: 10.1016/S0022-3913(13)60333-9.
3. Dede DÖ, Armağanci A, Ceylan G, Celik E, Cankaya S, Yilmaz B. Influence of implant abutment material on the color of different ceramic crown system. ***J Prosthet Dent***. 2016 Nov;116(5):764-769. doi: 10.1016/j.prosdent.2016.04.004.
4. Elsayed A, Wille S, Al-Akhali M, Kern M. Comparison of fracture strength and failure mode of different ceramic implant abutments. ***J Prosthet Dent***. 2017 Apr;117(4):499-506. doi: 10.1016/j.prosdent.2016.06.018.
5. Stimmelmayr M, Edelhoff D, Güth JF, Erdelt K, Happe A, Beuer F. Wear at the titanium-titanium and the titanium-zirconia implant-abutment interface: a comparative in vitro study. ***Dent Mater***. 2012 Dec;28(12):1215-1220. doi: 10.1016/j.dental.2012.08.008.
6. Mostafavi AS, Mojtahedi H, Javanmard A. Hybrid implant abutments: A Literature Review. ***Eur J Gen Dent***. 2021 Sep;10(2):106–115. doi: 10.1055/s-0041-1735766.
7. Rutkowski JL. Fundamentals of Implant Dentistry: Prosthodontic Principles. Beumer J III, Faulkner RF, Shah KC, Moy PK. Hanover Park, Ill: Quintessence Publishing, 2015. J Oral Implantol. 2015 Jun;41(3):343. doi: 10.1563/AAID-JOI-D-15-Review.4103.
8. Jirajariyavej B, Wanapirom P, Anunmana C. Influence of implant abutment material and ceramic thickness on optical properties. ***J Prosthet Dent***. 2018 May;119(5):819-825. doi: 10.1016/j.prosdent.2017.05.015.
9. Cho YE, Lim YJ, Han JS, Yeo IL, Yoon HI. Effect of yttria content on the translucency and masking ability of yttria-stabilized tetragonal zirconia polycrystal. ***Materials (Basel)***. 2020 Oct;13(21):4726. doi: 10.3390/ma13214726.
10. Douglas RD, Steinhauer TJ, Wee AG. Intraoral determination of the tolerance of dentists for perceptibility and acceptability of shade mismatch. ***J Prosthet Dent***. 2007 Apr;97(4):200-208. doi: 10.1016/j.prosdent.2007.02.012.
11. Basso GR, Kodama AB, Pimentel AH, Kaizer MR, Bona AD, Moraes RR, *et al*. Masking colored substrates using monolithic and bilayer CAD-CAM ceramic structures. ***Oper Dent***. 2017 Jul/Aug;42(4):387-395. doi: 10.2341/16-247-L.
12. Dozic′ A, Kleverlaan CJ, Meegdes M, van der Zel J, Feilzer AJ. The influence of porcelain layer thickness on the final shade of ceramic restorations. ***J Prosthet Dent***. 2003 Dec;90(6):563-570. doi: 10.1016/s0022-3913(03)00517-1.
13. Shokry TE, Shen C, Elhosary MM, Elkhodary AM. Effect of core and veneer thicknesses on the color parameters of two all-ceramic systems. ***J Prosthet Dent***. 2006 Feb;95(2):124-129. doi: 10.1016/j.prosdent.2005.12.001.
14. Ozturk O, Uludag B, Usumez A, Sahin V, Celik G. The effect of ceramic thickness and number of firings on the color of two all-ceramic systems. ***J Prosthet Dent***. 2008 Aug;100(2):99-106. doi: 10.1016/S0022-3913(08)60156-0.
15. Ajlouni K, Elshahawy W, Ajlouni R, Sadakah A. Color masking measurement for ceramic coating of titanium used for dental implants. ***J Prosthet Dent***. 2018 Mar;119(3):426-431. doi: 10.1016/j.prosdent.2017.04.008.
16. Falahchai SM, Zeighami S, Hemmati YB. Main factors affecting the final color of ceramic restorations. ***Adv Dent Oral Heal***. 2017 Jul 21;5(3):555661. doi: 10.19080/ADOH.2017.05.555661.
17. Sikri VK. Color: Implications in dentistry. ***J Conserv Dent***. 2010 Oct;13(4): 249–255. doi: 10.4103/0972-0707.73381.