Advances in Dentistry & Oral Health
ISSN: 2472-6389

Research Article
Volume 17 Issue 2 - February 2024
DOI: 10.19080/ADOH.2024.17.555960

Adv Dent & Oral Health

Effect of Luting Cement and Thickness of CAD/CAM Restorations on Final Shade and Translucency

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Submission: February 15, 2024; **Published:** February 27, 2024

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Abstract

Purpose: The purpose of the study is to assess the influence of all-ceramic CAD/CAM restorations' thickness and color of cement used on the restorations' final translucency and color.

Methods: The study utilized five types of ceramic materials - Lithium-Disilicate CAD (LDS), Lithium-Disilicate Press (LS2), Zirconia-Reinforced Lithium-Silicate CAD (ZLS), Zirconia-Reinforced Lithium-Disilicate Press (AMB), and Monolithic Zirconia (ZRC) - resulting in a total of 150 samples prepared. For each cement color, 10 samples were prepared at a thickness of 0.2 mm. Color measurements were conducted with CIE D65 standards.

Results: The most significant ΔE (~9) color change was observed in 0.5 mm specimens in yellow and transparent cements for AMB. For the translucency, the most significant sign was observed in the 0.5 mm LDS, 1 and 1.5 mm ZLS specimens in transparent cement.

Conclusion: It was concluded that final shade and translucency were influenced by the thickness of the ceramic and the color of the resin cement.

Keywords: Zirconia; Monolithic Restoration; Translucency; Color; All Ceramic

Abbreviations: LDS: Lithium-Disilicate CAD; LS2: Lithium-Disilicate Press; ZLS: Zirconia-Reinforced Lithium-Silicate CAD; AMB: Zirconia-Reinforced Lithium-Disilicate Press; ZRC: Monolithic Zirconia; HT: high translucency; T: Transparent; Y: Yellow; TP: Translucency parameter; TP: Translucency parameter

Introduction

Porcelain fused to metal restorations has been widely used in modern dentistry practices, but achieving natural-looking light reflections in these restorations is often a challenge [1]. Furthermore, failures in the metal-porcelain connection can result in fractures and chippings, which are common issues faced in the clinical setting [2]. Higher mechanical and optical properties benefit both physicians and patients. All-ceramic materials that imitate natural teeth, exhibit elevated resistance to abrasion, chemical stability and biocompatibility, have been created [3]. All-ceramic materials can be manufactured using both CAD/CAM (Computer Aided Design and Computer Aided Production) and press methods. These methods can yield ceramics that are either veneered or monolithic. Until recently, attempts have been made to eliminate the insufficiency of monolithic manufacturing in fully ceramic materials to meet aesthetic expectations [4,5]. Since aesthetics play a crucial role in prosthetic treatment and several studies have examined color. These studies have identified various factors related to teeth that impact the final shade, including the color and thickness of underlying teeth, as well as factors related to the ceramic used, such as its chemical content, thickness, color, light transmittance, number of firings, and applied surface treatments [6]. In addition, the shade and viscosity of the bonding agent utilized in the cementation of all-ceramic restorations also affect the final color.

The materials in the construction of the restorations are superior to each other with their content, however; their properties can be increased with various modifications. It provides the superior mechanical properties and masking ability of zirconia ceramics with its low translucency values [7]. LDS provide light transmissions thanks to their high translucency values [8,9]. According to some authors, zirconia added to the material reveals a higher translucency feature [10,11]. LDS has high aesthetic properties, reflects the color of the infrastructure, and is easily affected by the color of the cement, which can make clinical color matching difficult. Conventional and adhesive resin cements are used for bonding all-ceramic restorations to the tooth surface. When resin cements are used with ceramics with high translucency values, they influence the final color [12]. The thickness of the ceramic material and the degree of translucency of the ceramic also affect the polymerization type of the resin cement to be selected [13]. As it can be understood, aesthetic success can be affected by many different parameters, and newly produced materials are also included in clinical applications. CAD/CAM technology and monolithic applications can offer clinicians different options in the selection of restorative materials. The hypothesis of this study is: the type and thickness of the all-ceramic material and the color of the resin cement will not have an effect on the final color and translucency.

Methods

In this research, five different all-ceramic materials have been manufactured monolithically, each with high translucency (HT) and A1 color which were IPS e.max CAD block (LDS), Celtra Duo CAD block (ZLS), Preshade zolid zirconia disc (ZRC), IPS e.max press ingot (LS2), Vita Ambria press ingot (AMB). Samples were prepared as 12x14 mm final thicknesses of 0.5 (±0.1) mm, 1 (±0.1) mm and 1.5 (±0.1) mm, 10 from each thickness group (Figure 1). ZLS, LDS and ZRC samples were cut with precision sectioning device; LS2 and AMB samples were prepared using the press method. In line with the recommendation of the firm, each brand's glaze powder and liquid were mixed and applied on the ceramic samples' one surface with a brush as a single layer. Glaze process has been performed for each company in their own temperature parameters in the Programat EP5000 (Ivoclar Vivadent AG, Schaan, Liechtenstein) oven. The samples were first kept in an ultrasonic cleaner for 10 minutes with distilled water for cleaning process before helding measurement with a spectrophotometer and then they were dried.

Figure 1: Prepared specimens in different thicknesses.

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To examine the effect of cement color; different colors of dual cure resin cement (Multilink Automix, Ivoclar Vivadent AG, Schaan, Liechtenstein) were used, namely Transparent (T) and Yellow (Y). The cement was placed to the gaps created between two glasses with dimensions of 12x14 mm and a thickness of 0.2 mm in a 1:1 ratio (Figure 2). After waiting for a period for chemical curing, a polymerization device (LED.C, Guilin Woodpecker Medical Instrument, Guangxi, CN) producing light at intensity of $1000mW/cm^2$ -$1200mW/cm^2$ and a wavelength of 420-480 nm Polymerization was carried out by applying light to the lower and upper surfaces for 40 seconds (Figure 3). Vita Easyshade Advance 4.0 (Vita Zahnfabrik, Bad Säckingen, Germany) spectrophotometer device was used for color measurement. To ensure standardization for all color measurements and to eliminate light fluctuations in the environment, a box setup with an open single side was prepared. Master TL-D Super 80 18W/865 1SL (Philips, Eindhoven, The Netherlands) lamp with a color temperature of 6500 K that mimics daylight is placed on the ceiling of this box.

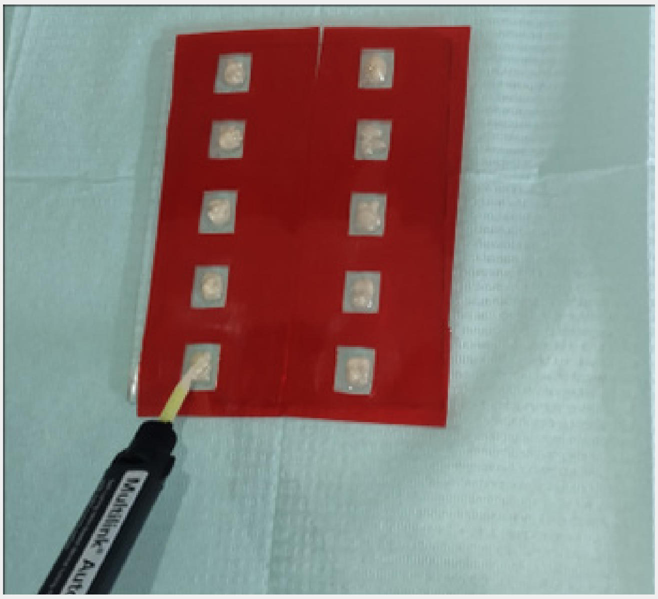

Figure 2: Placement of resin cement onto specimens using custom made uniform thickness aligner device.

Gray background paper was applied to all inner surfaces of the box to observe the color change (ΔE). The same researcher performed all measurements at the same time in a dark environment, in the prepared box. Color measurements were performed three times, from the center of the all-ceramic samples, which were placed in the middle of the box in order, and the average values were taken (Figure 4). Using the CIE Lab color system, these values were recorded as L_g, a_g, b_g before cement was applied. In addition, for the Translucency parameter (TP) measurements, the inner surfaces of the box were first covered with white background paper, and all ceramic samples were taken sequentially, and color measurement was performed three times, from the center (Figure 5). The mean values were represented as L_b, a_b, b_b. Afterwards, the inner surface of the box was covered with black background paper and the same operations were performed and the values were represented as L s, a s, b s. To provide optical coupling of the resin cement and ceramic samples, a refractive index solution (Merck 104699 Immersion Oil Merck KGaA, Darmstadt, Germany) with a refractive index of 1.515- 1.517 was applied to the surface of the resin cement samples in a thin layer with the help of a brush. Color measurement was performed three times, from the center of the prepared all-ceramic-resin cement samples. The mean values obtained were recorded as L g-y, a_{g-y}, b_{g-y} for yellow cement and L_{g-t}, a_{g-t}, b_{g-t} for transparent cement. For the measurement of ΔE and TP, the following formula was used for yellow and transparent cement, respectively.

$$(\Delta E_y)^2 = (L_g - L_{g-y})^2 + (a_g - a_{g-y})^2 + (b_g - b_{g-y})^2 \quad (\Delta E_t)^2 = (L_g - L_{g-t})^2 + (a_g - a_{g-t})^2 + (b_g - b_{g-t})^2$$

$$(TP_y)^2 = (L_{b-y} - L_{s-y})^2 + (a_{b-y} - a_{s-y})^2 + (b_{b-y} - b_{s-y})^2 \quad (TP_t)^2 = (L_{b-t} - L_{s-t})^2 + (a_{b-t} - a_{s-t})^2 + (b_{b-t} - b_{s-t})^2$$

This study examined the effect of material thickness and resin cement color on the final color and translucency of all-ceramic restorations. IBM SPSS Statistics v 25 package program is used to analyze the statistics of our research. Before starting the analyzes, Kolmogorov-Smirnov test (p>0.05) is used to check normality tests and whether variables came from a normal distribution. Anova test was performed for analysis of variance on data from normal distribution. The Kruskal-Wallis H test, one of the non-parametric tests, was used for the data that did not come from the normal distribution. Before the analysis of variance tests, Levene's test was performed to determine whether the variances were homogeneous (p>0.05). Tukey's HSD test, which is one of the Post Hoc tests, was used in paired comparisons in cases where

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the variances were homogeneous, and Tamhane's T2 test, one of the Post Hoc tests, when the variances were not homogeneous. Unless otherwise stated, results for $p<0.05$ were considered to be statistically significant. In this study, statistical power and sample size calculations were made to determine the number of samples. The GPower (Version 3.1.9.4) program was used to determine the number of samples. Significance level (Type 1 error, $\alpha=0.05$) was determined as 0.05 and the power of the test ($1-\beta=0.90$) was determined as 0.90.

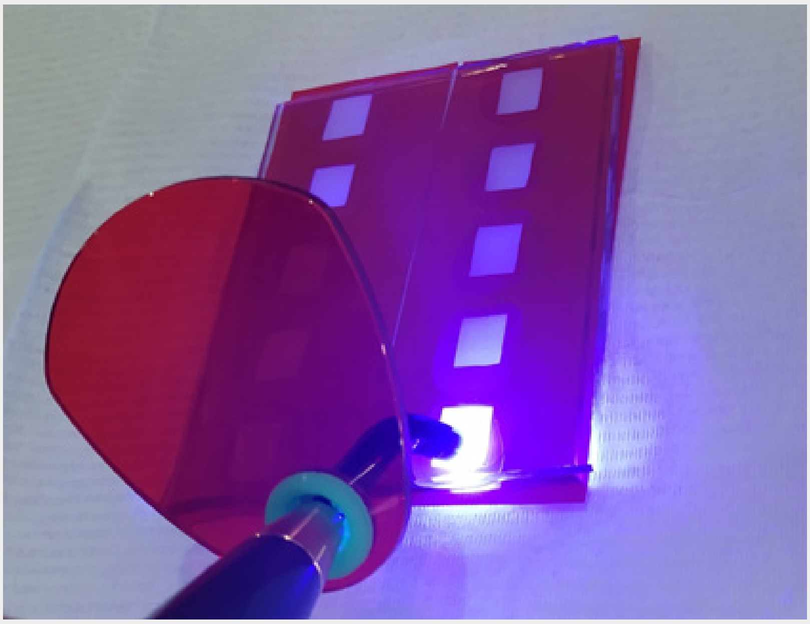

Figure 3: Application of LED curing light over the clear glass for 40 seconds.

Figure 4: Color measurement using a spectrophotometer device in the special box unit.

Results

The maximum ΔE value; was observed in 0.5 mm LDS samples (ΔE=~9.48), the highest ΔEt value was observed in 0.5 mm AMB samples (ΔE=~9). In 0.5 mm thick samples, the lowest value was observed in ZRC group, regardless of the cement color. While the highest ΔE values were observed in ZLS in 1 mm thick

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samples, regardless of the cement color; the lowest ΔE values were observed in ZRC. While ΔEy with a thickness of 1.5 mm is observed in the highest LDS; ΔEt was observed at the highest ZLS. LS2 material showed the lowest value in both ΔEy and ΔEt in samples with 1.5 mm thickness. It was observed that ΔE values decreased as the thickness increased in all ceramic materials, independent of the cement color. While no significant difference was observed between ΔEy and ΔEt values in 1.5 mm thick ZRC, ZLS and LDS materials; Cement color caused different ΔE values in 1.5 mm thick LS2 and AMB materials. Except for AMB, the color change (ΔEy) when using yellow cement was observed more than the color change (ΔEt) when using transparent cement.

Figure 5: Translucency measurement using a spectrophotometer device in the special box unit.

Only 0.5 mm ZRC specimens were treated with yellow cement observed as 'incompatible'. Cement color is important in the selection of 0.5 mm thick ZRC material. ZLS and LDS materials were most affected by yellow cement at all thicknesses. Cement color is very important for LDS and ZLS when the thickness is 1.5 mm or less. In addition, AMB, ZRC and LS2 samples with 1.5 mm thickness, which were applied yellow cement, showed similar ΔE values, these values are in the 'clinically acceptable' range. Although there is no significant difference between thickness variables in ZRC specimens with transparent cement, the ΔE values they show are in the 'clinically acceptable' range. A clear color difference was observed when transparent cement was applied to 0.5 mm thick AMB samples. A clinically acceptable value was observed when transparent cement was applied to 1 and 1.5 mm thick ZRC and LS2 specimens. Even with transparent cement, ZLS and LDS showed more than 3.5 ΔE values even at 1.5 mm thickness (Table 1).

Table 1: General comparison table evaluating the color difference of all-ceramic materials in different thicknesses and using different color cements.

Ceramic Materials	Cement Color	0,5 mm		1 mm		1,5 mm	
		Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
ZRC	ΔEy	3,77	0,56	3,08	0,61	1,99	0,62
	ΔEt	2,54	0,70	2,39	0,49	2,05	0,34
ZLS	ΔEy	8,70	1,17	6,91	1,19	3,59	0,59
	ΔEt	6,38	1,16	5,63	1,04	3,55	0,31
LS2	ΔEy	6,90	0,81	4,44	0,53	1,95	0,49
	ΔEt	4,99	0,40	2,91	0,61	0,85	0,38
LDS	ΔEy	9,48	0,84	5,88	0,67	3,77	0,49
	ΔEt	6,43	0,82	3,98	0,37	3,46	0,30
AMB	ΔEy	7,63	0,98	3,79	0,69	2,10	0,83
	ΔEt	9,19	1,27	4,76	0,86	3,07	0,85

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When the translucency parameters are obtained, the samples with the highest TPt values are; 0.5 mm LDS and 1 and 1.5 mm ZLS. The samples with the highest TPy values are 0.5 and 1 mm AMB, and 1.5 mm LDS. Considering both TPy and TPt values in all groups, ZRC material showed the lowest TP value. In all materials with 1.5 mm thickness, TPy and TPt resulted similar values. As the thickness increases, the effect of the applied cement color decreases. In ZLS samples, TPy and TPt values are very close to each other in all thicknesses, but the TPt value is higher. In ZRC, AMB, TPy values were found to be higher in all thicknesses. In ZLS samples, on the other hand, TPt values were found to be higher in all thicknesses. The TPy and TPt values of 0.5 mm thick ZLS, LDS and AMB materials showed close values (TP=~ 23). The TPy value of 0.5 mm thick ZRC samples and the TPy value of 1 mm thick AMB samples were similar (TP=~ 19) The TPy value of .1 mm thick ZLS samples and the TPy value of 1 mm thick LS2 samples and the TPy value of 1 mm thick LDS samples are similar (TP=~ 18). The TPy value of 0.5 mm thick ZRC samples and the TPy value of 1 mm thick ZLS samples and The TPt value of 1 mm thick LDS samples is similar (TP=~ 17). The TPt and TPt values of 1.5 mm thick ZLS samples, and the TPy value of 1.5 mm thick LDS samples and the TPy value of 1 mm thick ZRC samples are similar (TP=~ 14) (Table 2).

Table 2: General comparison table in which the translucency parameter of all-ceramic materials is evaluated in different thicknesses and different color cements.

Variables	Tp	0,5 mm		1 mm		1,5 mm	
		Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
ZRC	TP_t	17,17	1,77	11,87	1,29	8,74	1,22
	TP_y	19,58	0,98	14,09	1,20	8,95	0,46
ZLS	TP_t	23,48	0,55	18,16	0,80	14,46	0,76
	TP_y	23,14	1,22	17,43	1,12	14,12	0,63
LS2	TP_t	22,57	2,29	15,42	0,38	10,80	1,50
	TP_y	21,54	1,80	18,78	1,63	10,25	0,80
LDS	TP_t	23,76	1,38	17,39	0,68	13,55	0,49
	TP_y	23,39	1,25	18,50	0,84	14,25	0,52
AMB	TP_t	22,95	1,31	16,55	1,43	12,45	1,13
	TP_y	23,93	1,49	19,89	1,13	12,81	1,42

Discussion

The results implied that the content, thickness, and color of the resin cement of all ceramics affect the ΔE and TP values, which hypothesis was rejected. All ceramics are very successful in imitating natural teeth thanks to their chemical and physical properties. Ceramics are being developed to obtain the light transmission and reflections of natural teeth [14]. The homogeneous and dense structure of monolithic materials pioneers' mechanical strength. As a result of the latest developments in monolithic manufacture, it stands out as a great alternative to provide maximum aesthetics to reveal the colors in different parts of the tooth with different color transitions on the same block [15,16]. It has been stated that the ceramic thickness should be 1.6 mm or less than 2 mm for the influence of the infrastructure color on the final shade [17,18]. With the common use of CAD/CAM device today, it is possible to prepare thin restorations that can reflect aesthetic properties by removing a tissue from the sound tooth [19].

According to the study of Yıldırım et al. [20] Celtra Duo and IPS e.max CAD ceramics and resin cement samples of two different colors were used, 0.8 mm thick ceramics are affected by both the infrastructure shade and the cement color. When the TP were examined, it was revealed that IPS e.max CAD samples showed a higher value than Celtra Duo, but no significant difference was observed. When opaque cement used, final color changed and ΔE did not reveal a significant difference when translucent cement color was used. Begum et al. [21] investigated the color change of two different press ceramic materials (E-max Press and Cergo) with 0.5-1- and 1.5 mm thickness depending on the substrate and cement color. When opaque cement is used, the ΔE value differs significantly in 0.5 mm and 1 mm thick ceramic samples compared to translucent cement. No difference was observed at 1.5 mm. In our study, a significant difference was observed in ΔE value between 0.5 and 1 mm thick yellow and transparent cements. At 1.5 mm thickness, it was similar.

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Abdullah [22] used 0.5-1-1.5 mm thick samples with opaque and translucent cements in to examine the effect of thickness on color in AMB material. According to the study, highest ΔE value was obtained 0.5 mm sample and translucent cement (ΔE=5.2±0.29). The lowest ΔE was obtained 1.5 mm and opaque cement was used (ΔE=1.93±0.38). In our study, significant differences were observed between 0.5-1 and 1.5 mm thick AMB samples. When examined together with yellow and transparent cement samples, significant differences were observed between the effects on the final color. ΔE remained above the clinically acceptable limit when the thickness of the samples was less than 1.5 mm (ΔE>3.5). According to Abdullah's study, there is no significant difference in ΔE value between 1 and 1.5 mm samples, and these values are below the clinically acceptable value. Although the thickness of the cement samples was less (0.1 mm), higher values were obtained in our study, contrary to our expectations in terms of ΔE values. The reason for this difference may be that the background color was not used in our study and a dark background color was used in the mentioned study, and the cement samples were not cemented in our study and optical connection was provided with the refractive index solution and ceramic samples.

Among the materials used in our study, ZRC and LS2 materials were found to show less color change in terms of ceramic thickness and cement color compared to ZLS, LDS and AMB. While color changes in 0.5 and 1 mm thicknesses can be observed clinically in ZRC and LS2 ceramics; On the other hand, color change of ZLS and LDS materials was clinically inconsistent even at 1.5 mm thickness (ΔE>3.5). ZLS and LDS materials were more affected by ceramic thickness and cement color than other materials and showed similar values [11,20]. At ZLS samples, more color change at 1 mm samples compared to other materials. At LDS group, more color change revealed at 1 mm compared to AMB and LS2 materials. At 1.5 mm thickness, it was concluded that the LDS material was within the clinical acceptance limit (~3.5). It was concluded that LS2 material showed significantly less color difference than AMB containing zirconia among the thinly manufactured press systems. In our study, LDS and LS2 materials, which were prepared using different manufacturing methods with the same content, showed more color changes than LS2 in all thickness and cement color groups. In addition, LDS showed higher ΔE value as the material thickness decreased. According to Bagis et al. [23], 0.5 mm LS2 manufactured by pressing method showed higher ΔE values than LDS. Our study differed in terms of these values.

ZRC samples of all thicknesses have the lowest ΔE values in every group. The ΔE value of ZRC samples at 0.5 mm is similar with 1 mm for AMB also it obtained similar results for LDS at 1.5 mm thickness [12]. These values are also within the clinical acceptability limit. In this regard, material decision can be made according to tooth preparation and restoration thickness. TP is an important parameter in expressing the material transparency and color match success of the restoration. TP, which is in the visible light spectrum, is affected by the chemical content of the ceramic, the material microstructure and the particle diameter [24]. According to some authors, some factors that determine the translucency effects of zirconia ceramics are density, particle size, sintering pressure and temperature [25-27]. Considering the material contents, the translucency of ZLS was increased by adding smaller silicate crystals included in its content compared to LDS material [10]. Smaller crystals shift the light transmittance of the material. In some of the studies, the influence of ceramics on translucency are evaluated alone and the possible effects of cement or infrastructure are ignored [28,29]. In the clinic, cement and underlying tooth color cannot be ignored but it is possible to increase or decrease the degree of translucency of the material by changing the ceramic thickness [14]. Abdelbary et al. [30] evaluated the effect on translucency of monolithic zirconia samples with 0.5 mm, 0.8 mm, 1 mm and 1.2 mm thickness. It was found that increasing thickness had an effect on TP.

According to the study of Mosharraf et al. [31] measuring the translucency parameters of 1mm IPS e.max CAD, Vita Suprinity, Celtra Duo, Vita Enamic and ZR, the lowest light transmission was obtained with zirconia, highest translucency were respectively Vita Suprinity, Celtra Duo and IPS e.max CAD. In a study comparing LDS material with monolithic zirconias in terms of translucency parameter, the TP value of LDS was found to be significantly higher [32]. When the translucency values between ZLS and LDS are compared, it has been stated in many studies that they show similar values compared to each other and exhibit superior translucency. According to the study of Arif et al. [11], the TP value of ZLS was found to be higher than LDS. On the contrary, LDS showed higher TP value compared to Yıldırım et al. [20]. In our study, although LDS was found to be higher in terms of translucency values, no significant difference was found between ZLS and LDS.

Skyllouriotis et al. [33] investigated the translucency and masking properties of 0.5 mm thick Vitablocks Mark II, IPS e.max CAD, IPS Empress CAD, IPS e.max Press and Kuraray zirconia samples. According to the results, IPS e.max CAD showed the highest translucency value in line with our study. In our study, it was concluded that the translucency value decreased with the increase in thickness, as in the results obtained in similar studies [34,35]. In addition, the TP value varied depending on the material type [31,35]. Considering the translucency values of the samples in our study according to the cement color; The highest TP value was observed in LDS samples from the 0.5 mm thick transparent cement applied ceramic samples, and the highest TP value was observed in AMB samples from the yellow cement applied ceramic samples. The highest TP value at 1 mm thickness was observed in ZLS samples among the transparent cement applied ceramic samples, and the highest TP value was observed in AMB samples among the yellow cement applied ceramic samples. The highest TP value was observed in ZLS samples from the 1.5 mm thick transparent cement applied ceramic samples, and the highest

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TP value was observed in LDS samples from the yellow cement applied ceramic samples. In addition, the material showing the least TP value in all thicknesses and in both cement colors was found to be ZRC. While ZLS and LDS show similar TP values in all thicknesses and in both cement colors; AMB showed the highest TP value in 0.5 and 1 mm thick yellow cement. This result of the AMB material showed a higher TP value, contrary to some studies using opaque or dark resin cement [36,37]. While interpreting these results, no study on AMB material was observed other than that of Abdullah [22].

Conclusion

Material type and thickness affected the final color and translucency. It was observed that the most important effect on translucency was material thickness. The effect of the resin cement color on the final color was evident when thin ceramic restorations were used. Yellow cement color showed more color change than transparent cement except AMB. On the other hand, ZRC showed the lowest TP and color change values compared to other materials.

Acknowledgement

This research was sponsored by Gazi University with grant number 03-2020-24.

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How to cite this article: Emine G-T, Emre T, Serdar P, Kursat E. Effect of Luting Cement and Thickness of CAD/CAM Restorations on Final Shade and Translucency. Adv Dent & Oral Health. 2024; 17(2): 555960. DOI:10.19080/ADOH.2024.17.555960

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DOI: 10.19080/ADOH.2024.17.555960