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Influenceof Opaque with Dentine Layer Thickness to Color Matching on Metal-Ceramic Crown

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Abstract
Background/Purpose: *Color matching on metal-ceramic crown towards the natural teeth is a key for aesthetics success in prosthodontics. Dark shadow which was reflected by the metal coping often happened on the metal-ceramic crown and it causing the color that is resulted in laboratory process didn't match with the shade guide which has been determined in the clinic, so aesthetically is less satisfying. The porcelain layer thickness is one of factors that takes a role to produce the color matching. The aim of this in vitro study was to know the effect of opaque layer thickness with dentine layer thickness to the shade guide color matching on metal-ceramic crown.*
Material and methods:*Twenty seven of metal-ceramic samples were consisted of 0.2 and 0.3 mm opaque with 0.5, 0.7 and 1.0 mmdentine layerthickness. Shade guideVita 3D Master color 3M2 were used as a control group. The measurement of L*, a*, b* value on the sample group and shade guide was held using UV spectrophotometer. The effect of 0.2 and 0.3 mm opaque with 0.5, 0.7 and 1.0 mmdentine layerlayer thickness to the color matching was analyzed by using One-way ANOVA and LSD test. The color matching of metal-ceramic sample groups were obtained by calculating the difference of total color value (ΔE) on each sample, using the following formula:* $\Delta E^* = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2}$.
Results:*The lowest ΔE* value has the most compatible color value with shade guide color. Statistically ΔE* value was the most significant on the 0.2 mm opaque with 1.0 mm dentinelayer thickness (p=0.03).*
Conclusion: *The 0.2 mm opaque with 1.0 mm dentine layer thickness were recommended as a guide in making the metal-ceramic crown to obtain the color matching using shade guide, so as it produce the matching color with natural teeth in oral cavity.*
Key words : *the opaque layer thickness, dentine layer thickness, color matching,shade guide, metal-ceramic crown.*

I. Introduction

Metal-Ceramic crown is a type of denturewhich is the most used by dentists as it has several advantages,including: moreaesthetically compared to all-metal and acrylic crown, greater strength to provide support for mastication load as it is supported by metal coping, it has good adaptation to the tooth tissue, more resistant to fracture, has almost similar thermal coefficient to the tooth, and lower cost compared to all-ceramic crown. However metal-ceramic crown has its own disadvantages, including the appearance of dark shadow which is caused by metal coping reflection, which distinguishes it from the natural tooth structure, in such way so the color produced by the laboratory often doesn't match the shade guide color which has been determined in the clinical practice, resulting in unsatisfying aesthetics. The result of study done by Milleding P, et al(cited from Wee AG, et al 2002) in a clinical study for two years stated that from 40 metal-ceramic crowns which werecemented into the mouth, there were 61% of the color of porcelain didn't match the adjacent natural teeth.

The accuracy of determining and matching color on metal-ceramic crown is a problem for dentists and technicians in thelaboratory.[5-6]Achieving the right color in the process of making metal-ceramic crown is influenced by three factors, such as: factors of color determination in the clinic, good communication between the dentist and technician in laboratory, and factors of color matching in a laboratory.[1-3] Factors of color determining in the clinic, including color matching technic, light resource, metamerism, environmental condition, operator, and patient's position.[7-9] The other factor in the clinic which should also be considered for achieving correct color on the metal-ceramic crown among them is the thickness of abutment tooth preparation by a dentist which should be around 1.2 to 2.0 mm.[1-3] The factors of color matching in laboratory, including porcelain condensation technic, porcelain firing cycle, porcelain glazing cycle, porcelain type, the ratio between porcelain powder and liquid while mixing, type of metal and porcelain layer thickness.[11-16]

Theporcelain layerthicknessto reach the suitable color on the metal-ceramic crown variesaccording to several studyes, however we have to consider the strength to prevent the risk of fracture while the denture is being used. Various studies about the effect of porcelain layer thickness to the color matching in the making of a metal-ceramic crown, with its various thickness, it's in opaque layer, dentine layer or enamel layer. Jacob SH, et al(1987) evaluated the change of hue, value and chroma visually and instrumentally using spectrophotometer device againts dentine porcelain layer with 0.5 and 1.5 mmthickness, in Gold-Platinum-Palladium (Au-Pt-Pd) specimens, high Palladium (Pd), Nickel-Chromium (Ni-Cr) with metal thickness 0.5 mm, and opaque layer with thickness between 0.09 to 0.12 mm. Studies result stated that the dentine porcelain layer with 1.0 mm thickness produced better color on the three metal types. Barghi N et al, Terrada Y et al (cited fromKourtis, et al 2004) stated that the 0.2 to 0.3 mm opaque layerthicknesscould cover metal oxide, and 0.3 mm opaque layer thickness didn't affect the change in porcelain color.[12] Corciolani G et al(2010) evaluated the effect of porcelain thickness towards theresulting color, by varying the thickness of dentine and enamel base layers, metal thickness was 0.3 mm, and opaque layer thickness was 0.15 mm. The thicker dentine layer base produced higher chromatic color. On the contrary, by increasing the transparant dentineand enamel thicknesswould reduce the chroma value. The increase of enamel thickness would reduce lightness (value).[13] Ozcelik TB et al (2008) stated that the 0.1 mm opaque layer thickness which was applied on Ni-Cr and Cobalt-Chromium (Co-Cr) metalscouldn't provide color change in metal-ceramic crown, however there was a significant color change if the 0.1 mm opaque layer was applied on Au-Pd metal which functioned as the control group.[14]

From several studies about the different porcelain thickness to produce the color matching on metal-ceramic crown, therefore the studyer wanted to studythe influence of 0.2 mm and 0.3 mm of opaque layer thicknesses with 0.5,0.7, and 1.0 mm dentine layers to the color matching of metal-ceramic crown.

II. Material And Methods

Twenty-seven samples were used in this study which included cylindrical Ni-Cr metal with the diameter of 15 $\pm$ 1 mm and thickness of0.3 $\pm$ 0.1 mm based on the International Organization for Standarization (ISO 1988), were divided into six groups, and the opaque, dentine and enamel layers of the porcelain were put on the metal.

The materials which were used were type V gypsum (Fuji Rock, GC), vaseline, wax, powder and liquid of self curing acrylic (Hillon, Japan), spru wax (Inlay wax soft, Violet, Tokyo Japan), investment gyps (Deyuan, China), metal Ni-Cr (KeraN: Ni 61,27%, Cr 26,44 %, Mo 10,46 %, Mn,0,001 %, C 0,02 %), sandblasting material (sand particles of 50 micron), powder and liquid of porcelain (Vita VMK Master) which containedopaque layer (OP3), dentine layer (3M2), enamel layer (EN1), and glazing material (Vita VMK Master).

The procedure of making the main model from metal were: providing the main model from metal, cylindrical, with the diameter of 15 mm and thickness of 0.3 mm, apply vaselin on the main model, cast the main model using type V gypsuminto the cuvette as many 30 pieces, then pressed it, and left it until it hardened. Open the cuvette which has already hardened. Applied vaselin on maincast and appliedcold mold seal above the gips inthe cuvette, then fill up the available space with self curing acrylic, polished the cylindrical self curing acrylic. Cast the spru with self curing acrylic, then casted into moffel, mixing the investment gyps with the ratio of powder and liquid according to the manifacturing instruction, then put it on the vibrator. The burn out procedure in the temperature of 1000^0 C, then continued with the casting procedure, the polishing of metal Ni-Cr plate, then sandblastingprocedure with sand particles of 50 micron, oxidation procedure in furnace vacuum with temperature of920^0 C.

The procedure of porcelain layer application, which consisted of the opaque, dentine, and enamel layers, they were: application of the first opaque layer on metal Ni-Cr plate, condensation with vibrationandfiring with the temperature of 950^0 C. Then application of the second opaque layer on the first opaque layer, condensation with vibration, firing with the temperature of945^0 C. Application of first dentine on the second opaque layer, condensating with vibration, firing with temperature 930^0 C. Application of second enamel layer on the first dentine, condensation with vibration and firing with the temperature of925^0 C. Application of the first enamel layer on the second dentine layer, condensation with vibration, firing with the temperature of 930^0 C. Application of second enamel layer on the first enamel layer, condensation with vibration, firing with the temperature of 925^0 C.The first glazing process with the temperature of 920^0C, and then the second glazing with the second temperature of 900^0C

Ceramic-metal samplesconsisted of six groups, among them: group A, representing the opaque layer thickness of 0.2 mm with 0.5 mm dentine layer; group B, representing the opaque layer thickness of 0.2 mm with 0.7 mm dentine layer; group C, representing the opaque layer thickness of 0.2 mm with 1.0 mm dentine layer; group D, representing the opaque layer thickness of 0.3 mm with 0.5 mm dentine layer; group E, representing the opaque layer thickness of 0.3 mm with 0.7 mm dentine layer; Group F, representing the opaque layer thickness of 0.3 mm with 1.0 mm of dentinelayer.Each group had five samples. The shade guide group functioned as the control group.

The measurement of the L*, a*, b* valuein the sample and shade guide groupswere done using UV spectrophotometer device (Spectrophotometer UltraScan XE, Hunter Lab, Germany). Spectrophotometer calibration device and software in the computers using CIELAB system (L*, a*, b*). Then the reading of L*, a*, and b* value were done onthecomputerscreen.

Influence of 0.2 and 0.3 mm of opaque layer thicknesswith the 0.5, 0.7, and 1.0 mm of dentinelayers of towards the color matching were analyzed by using One-way ANOVAand LSD test.

III. Results

The L* value was the brightness value (lightness), which started from 0 (black) to 100 (white). The a* valuewas chromatic color of red-green axis, divided into +a* which represented the red region, and -a* which represented green region. The b* valuewas chromatic of yellow-blue axis, divided into +b* which represented the yellow area, and -b* represented the blue color.[1-3]

From the results of the study showed that the increaseof the dentine layers thickness (0.5, 0.7, and 1.0 mm) would produce lowerL* value, and the results of the One-way ANOVA stated that there was significant increase influencing the dentine layer thickness to the decreaseof the L* value (p = 0.04), that as the dentine layer got thicker, the lower the L* value. The increase of the dentine layer thickness would producehigher a* and b* value, namelyas the dentine layer thicker,a* and b* value would be produced. But the results of a statistical analysis showedthat there was no influence in the dentine layer towardsthe increase of the a* value (p=0.49) and the b* value (p=0.59). The mean ofL*, a*, b* value on the ceramic and metal samples were seen higher when compared to themean of L*, a*, b* valueon shade guide groups. (Table 1).

Table 1. Themeanof L*, a*, b* valueandthe StandardDeviation (SD) and One-wayANOVA tested onthe 0.2 mm opaque with the 0.5, 0.7 and 1.0 mm dentine layers thickness and shade guidegroups.

Group	Color Value						
	n	Mean of L*±SD	One-way ANOVA test (p)	Mean of a*±SD	One-way ANOVA test (p)	Mean of b*±SD	One-way ANOVA test (p)
Opaque 0.2-dentine 0.5	5	72.28±0.61**		3.39±0.38*		17.83±0.81	
Opaque 0.2-dentine 0.7	5	71.13±0.51	0.04	3.65±0.65	0.49	17.70±0.74*	0.58
Opaque 0.2-dentine 1.0	4	70.72±1.32*		3.80±0.40**		18.33±1.21**	
Shade guide	5	64.23±0.23		2.97±0.42		17.56±1.70	

Note: * Lowest value
** Highest value
Significant difference if p<0,05

Based on the result of the study showed that the increasing of dentinelayer thickness (0.5, 0.7and 1.0 mm**)**on the 0.3 mm opaque layer thickness, higherL* value would be producedhigher,however the One-way ANOVA analysis stated that there was no influence of the increasingdentinelayer thicknesstowards the increasing of L* value (p=0,36).The increasing of dentinelayer thicknesson the 0.3 mm opaque layer thickness produced a* value which was getting higher, but the result of One-way ANOVA test analyzed that there was noinfluence of the dentinelayer thicknesson the 0.3 mm opaque layer thicknessto the increasing of a* value(p=0,20). The increasing of dentine layer thickness on the 0.3 mm opaque layer thickness produced b* value which was getting decrease, but the analysis result with one way Anova test stated that there was no increasing effect of the dentine layer thickness on the 0.3 mm opaque layer thickness to the decrease of b* value (p=0,82). Mean of L*, a*, b*value metal ceramic sample on the 0.3 mm opaque layer thickness also seemed higher when compared to mean of L*, a*, b*value on shade guide group which functioned as control group (Table 2).

Table 2.The mean of L*, a*, b*valueand the StandardDeviation (SD) and*One-way*ANOVA test on 0.3 mm opaque with 0.5, 0.7, 1.0 mm dentine layer thickness and shade guide groups.

Group	Color Value						
	n	Mean of L*±SD	One-way ANOVA test (p)	Mean of a*±SD	One-way ANOVA test (p)	Mean of b*±SD	One-way ANOVA test (p)
Opaque 0.3-dentine 0.5	5	71.37±1.08*		3.87±1.08*		18.73±0.94**	
Opaque 0.3-dentine 0.7	4	72.22±0.61**	0.36	4.28±0.61**	0.20	18.57±1.09	0.82
Opaque 0.3-dentine 1.0	4	71.67±0.67		4.11±0.43		18.28±1.15*	
Shade guide	5	64.23±0.23		2.97±0.42		17.56±1.70	

Note: * Lowest value
** Highest value
Significant difference if p<0,0

The ratio of effect between 0.2, 0.3 mm opaque layer thickness and 0.5, 0.7,1,0 mmdentine layer to the shade guide color matching were done using LSD test, which was used to see the opaque layer thicknesswith dentine layer for how much among all the metal-ceramic samples that produced appropriate color that suits with shade guide significantly. Color matching on the respective metal-ceramic sample groups were obtained by calculating the difference of the ΔE value on every sample. The ΔE value among the sample groups were obtained by using this formula:

$$\Delta E^* = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2}$$

ΔL*, Δa*, andΔb*value were obtained by calculating the difference among the mean of ΔL*, Δa*, andΔb*value on the metal-framework sample group with mean of ΔL*, Δa*, andΔb*value on the shade guide group. ΔL* value was the value of lightness (brightness) color difference, Δa* value was the value of red-green chromatic color difference (+Δa*= red color difference and-Δa*= green color difference). Δb* value was the value of yellow-blue chromatic color difference (+Δb*= yellow color difference, -Δb*= blue color difference) (Table 3).

Table3. The mean of ΔL*, Δa*, Δb*valueand theStandardDeviation (SD) of the 0.2and 0.3 mm opaqueof 0.5, 0.7 and 1.0 mmdentinelayers thickness.

Group	n	Mean of ΔL*±SD	Mean of a*±SD	Mean of b*±SD
Opaque 0.2-dentine 0.5	5	8.05±0.27**	0.42±0.38*	0.72±0.32
Opaque 0.2-dentine 0.7	5	6.90±0.23	0.68±0.65	0.66±0.17*
Opaque 0.2-dentine 1.0	4	6.49±0.66*	0.83±0.40	1.18±0.64**
Opaque 0.3-dentine 0.5	5	7.15±0.48	0.90±0.30	1.17±0.94
Opaque 0.3-dentine 0.7	4	7.99±0.30	1.30±0.16**	1.01±1.09
Opaque 0.3-dentine 1.0	4	7.44±0.33	1.14±0.43	0.72±1.15

Note: * Lowest value
** Highest value

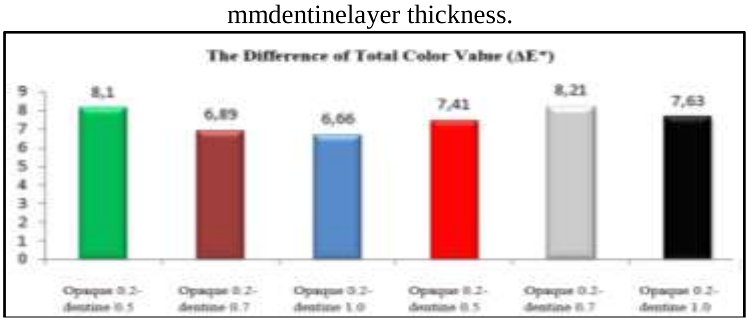
The ΔE value was the total of color difference value on each samples. Before the LSD test were done, ANOVA test was carried out first to see the difference of ΔE value among all the metal-ceramic sample groups. Analysis result statistically stated that there was significant difference among the effect of 0.2, 0.3 mm opaque layer thickness effect with 0.5, 0.7, 1.0 mmdentine layer to the change of the ΔE* value ($p=0,04$) (Table 4 & Graphic 1).

Table 4. The mean of ΔE* value, Standard Deviation, andANOVA test on the 0.2, 0.3 mm opaque with 0.5, 0.7 and 1.0 mmdentinelayer thickness.

Group	n	Mean of ΔE*±SD	One-Way ANOVA test (p)
Opaque 0.2-dentine 0.5	5	8.11±0.61	0.04
Opaque 0.2-dentine 0.7	5	6.99±0.54	
Opaque 0.2-dentine 1.0	4	6.66±1.42*	
Opaque 0.3-dentine 0.5	5	7.41±1.22	
Opaque 0.3-dentine 0.7	4	8.21±0.73**	
Opaque 0.3-dentine 1.0	4	7.64±0.58	

Note: * Lowest value
** Highest value
Significance difference if $p<0,05$

Graphic 1. The mean of ΔE* value of the thickness of0,.2 and 0.3 mm opaque with 0.5, 0.7, and 1.0 mmdentinelayer thickness.



From the LSD test result, it showed that the comparison of the 0.2 mm opaque layer thickness with 0.5 mm dentine layer and 0.2 mm opaque layer thicknesswith 1.0 mm dentine layer; and the difference between 0.2 mm opaque layer thickness with 1.0 mm dentine layer and 0.3 mm opaque layer thickness with 0.7 mm dentine layer had p=0,03 value; which mean that the most appropriate color with the shade guide on the 0.2 mm opaque layer thickness with 1.0 mm dentine layer (p<0,05) (Table 5).

Table5. The mean difference of ΔE* value between the metal-ceramic sample groupsof0.2 and 0.3 mm opaque s with 0.5, 0.7, and 1.0 mmdentinelayers thickness with LSD test.

Group	Group	LSD Test (p) ΔE*
Opaque 0.2-dentine 0.5	Opaque 0.2-dentine 0.7	0.06
	Opaque 0.2-dentine 1.0	0.03*
	Opaque 0.3-dentine 0.5	0.24
	Opaque 0.3-dentine 0.7	0.87
	Opaque 0.3-dentine 1.0	0.45
Opaque 0.2-dentine 0.7	Opaque 0.2-dentine 1.0	0.60
	Opaque 0.3-dentine 0.5	0.47
	Opaque 0.3-dentine 0.7	0.06
	Opaque 0.3-dentine 1.0	0.30
Opaque 0.2-dentine 1.0	Opaque 0.3-dentine 0.5	0.23
	Opaque 0.3-dentine 0.7	**0.03***
	Opaque 0.3-dentine 1.0	0.15
Opaque 0.2-dentine 0.5	Opaque 0.3-dentine 0.7	0.20
	Opaque 0.3-dentine 1.0	0.72
Opaque 0.2-dentine 0.7	Opaque 0.3-dentine 1.0	0.38

IV. Discussion

The increaseof the dentinelayer thickness(0.5, 0.7and 1.0 mm**)**on 0.2 mm opaque layer produced the decreaseL* value, which means that the thicker the dentine layer, darker metal-ceramic crown would be produced. The increase of dentinelayer thicknesswould produce the increasing of a* value, which means that the thicker the dentine layer, higher red chromatic color would be produced. The increasing of dentinelayer thickness(0.5 mm, 0.7 mm, 1.0 mm**)**would produce increasing b* value, which meansthat the thicker the dentine layer, higher yellow chromatic color would be produced. The silica and pigment in a great number, as well as metal oxide which were in thedentine layer (in a small amount), providing translucency and was the determination of the main color of metal-ceramic crown, and providing darker metal-ceramic crown with more reddish and yellowish chromatic color.[1-3]Corciolaniet al (2010) stated that thicker dentine base layer produced higher chromatic color, on the contrary with increasing transparant dentine and enamel thicknesslayer, the chromavalue would decline.[13]The result of the analysis with One-way ANOVA test also showed that there was a significant influence between increasing of dentinelayer thicknessand the decrease of L* value (p=0,04),which meansas the thickerdentine layer, the dark metal-ceramic crown color would be produced, but there was no effect in the increasing of dentinelayer thicknessto the increasing of a* value (p=0,49) and b* value (p=0,58),which means that statistically there was no effect in the increasing of dentinelayer thicknesson 0.2 mm opaque layer to the increasing of red and yellow chromatic color.

The mean of L*, a*, b* value on metal-ceramic sample were seen higher when compared to the mean of L*, a*, b*value on shade guide group. The study result matched the study which was done by Reddy *et al* (2012)which stated that L* value (brightness) and chromatic value (red-green and yellow-blue) on the Vita and Ivoclar metal-ceramic denture was higher (each L* 89.2 and 86.9, a* 5.5 value and 2.8; and b* value 31.3 and 28.9) if compared with L*, a*, and b*valueon shade guide (78; 1,4; and 25,8).[15]This matter was caused because shade guide didn't contain metal coping, but overall was covered by porcelain layer with the thickness of 4.0 mm. Ni-Cr metal oxide on coping had the role to increaseL*, a*, and b*value. Study result which was done by Kourtis et al (2014) stated that Ni-Cr and Pd metal produced higher a* value when compared to Au and Co-Cr metal which was applied on the Vita and Ceramo porcelain layer. The color which was produced on metal-ceramic specimen was affected by metal and porcelain type, while b* value was higher on metal Au and Pd when compared to metal Ni-Cr and Co-Cr.[12]The increasing of dentinelayer thicknesson 0.3 mm opaque thickness produced the increasing of L* and a* value, but the decrease of b* value, which means the increasing of dentine layer thickness on the 0.3 mm opaque layer thickness produced a brighter metal-ceramic crown, with higher red chromatic and lower yellow chromatic. However the analysis result statistically stated that there was no effect of the increasingdentinelayer thicknessto the color change of metal-ceramic crown on the 0.3 mm opaque layer thickness (p>0.05).

The mean of L*, a*, b* value of metal-ceramic samples on the 0.3 mm opaque layer thicknessalso seemed higher than the mean of L*, a*, b*value on the shade guide group. This study result matched with the study that was held by Reddy et al (2012).[15] From Table 1 and 2, there were seen increasing of L* value and the decrease of b* value along with the increasing of opaque thicknesslayer from 0.2 to 0.3 mm, which means the increasing of opaque layer thickness from 0.2 to 0.3 mm, brighter color of the metal-ceramic crown would be produced, with lower yellow chromatic color. This matter was caused by 15% metal oxide on the opaque layer which took role increasing the L* value and decrease the b* value, so it produced brighter metal-ceramic crown with low yellow chromatic color.[17-18] If the opaque layer was too thick, it would increase the L* value (brighter) so it would produce metal-ceramic crown color which didn't match with the shade guide. The opaque layer thickness took an important role to produce the appropriatecolor on the metal-ceramic crown as it had metal oxide in high consentration (reaching 15%) and silica as well aspigment on the opaque layer in small amount.[1-3]

As the metal-ceramic color got brighter, it got more unappropriate with the shade guide color. The brighter metal-ceramic crown color would be affected by metal oxide content in the opaque layer which increased the L* value so if opaque layer was too thick (in this study> 0.2 mm) would produce unsuitable metal-ceramic crown with the shade guide. Opaque thicknesslayer took an important role in producing the suitable color for the metal-ceramic crown, this matter was supported by the study that was carried out by Ozcelik et al (2008).

The color matching of the respective metal-ceramic sample groups was obtained by calculating the difference of ΔE value in each samples. The threshold of color matching value (ΔE*)varied according to several literatures. Ozcelik et al.(2008) stated that the ΔE* value= 2 to 3.5 was the threshold limit value of the matching color which wasstill acceptable clinically.[14] Johnston & Kao (1989); Douglas et al (2007) in their study used the threshold limit valueof ΔE*= 3.7.Sachdevaet al (2007) stated that the threshold limit valueΔE*= 3 to 8.[24]The lowest ΔE* value in this study was the most suitable color value with the shade guide color. In this study, it wasobtained that the most suitable ΔE* value with shade guide was the 0.2 mm opaque layer with 1.0 mm dentine layer which produced ΔE* value=6.66±1.42. This matter matched the study that was carried out by Jacob et al(1987), who stated that the dentine porcelain layer with 1 mm thickness produced better color on the three metal types, namelyGold-Platinum-Palladium, High Palladium, Nickel-Chromium.[11] The cause of ΔE* value = 6.6 in this study was caused by the difference of the highest lightness color valur (ΔL*), following between 6.49-8.05 (Table 3). The metal oxide reflection of the coping increased the L* value (brightness) on the metal-ceramic crown, which means that metal oxide was the causes of a brighter metal ceramic crown.[1-3] The opaque layer took a very important role in covering the metal oxide color, in this study in the 0.2 mm opaque layer thicknesswith 1.0 mm dentine layer could cover the reflection of metal on coping and produce suitable color with the shade guide color.

Based on this study result, it was obtained that the difference of opaque layer thicknesswith dentine layer was very influential towards the shade guide color matching on the metal-ceramic crown.

V. Conclusion

The most suitable color matching (ΔE) with shade guide color was on the0.2 mm opaque with 1.0 mm dentinelayer thickness. The thickness of 0.2 mm opaque layer with 1.0 mm dentine layer was the most significant in producing the color with shade guide on the metal-ceramic crown (p=0,03).

For the clinical implication, the 0.2 mm opaque layer thicknesswith 1.0 mm dentine layer was recommended as the guide to the making of metal-ceramic crown to produce the suitable shade guide color, and this thickness could be reach if tooth preparation which was done by dentist in the clinic had minimal thickness of 1.8 mm (0.3 mm metal coping thickness, 0.2 mm opaque layer, 1.0 mm dentin layer, 0.3 mm enamel layer), so that it producedsuitable color with the natural tooth in the oral cavity with satisfying aesthetics value for the dentist and the patient.

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