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The Effect of Substrate Shades on the Outcome Color of the Chairside CAD/CAM Restorative Material for Veneer Restorations

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Abstract: *The aim of this study was to investigate and compare the translucency and the color differences of several kinds of CAD-CAM materials against different resin backgrounds.A total of 66 specimens measuring (12 × 14 × 0.6 mm ± 0.01 mm) were prepared from eleven CAD/CAM materials (Lava Ultimate HT/LT, Vita SuprinityHT/T, Vita Enamic HT/T,Vita Blocs MarkII, IPS Empress CAD HT/LT, IPS e.max CAD HT/LT). Then composite resin specimens (n=1) were fabricated in 5 shades （A2, A4, B2, C2 and D2）to simulate the normal background dentine shade. A spectrophotometer was used to measure the translucency parameter (TP) and color difference (ΔE00) of the samples. Commission Internationale d'Eclairage (CIE) L*a*b* values of ceramic specimens over the A2 Shade served as the control group for others. Data of the experimentalA4, B2, C2 and D2shades acting as abutment were analyzed and compared to the control shade A2. Color differences values between control and test groups were computed using CIEDE2000 Formula. Among all the materials, VitaEnamic T showed lowest TP values (34.98±0.77), whereas LavaUltimate HT showed highest TP values (51.08±1.35). The color differences of all the materials under the B2 shade background are lower than 2.25, which is clinically acceptable. However, under the A4, B2, C2 and D2 shades background, the color differences of all the materials are far more than 2.25, which indicates the ΔE00 values is affected by the resin background. The results of two-way ANOVA showed that the color differences were influenced by materials, background, as well as the interaction terms of these two variables ($p<0.05$). The substrate color mainly affects the final color of CAD/CAM veneer. Microstructure of CAD/CAM material also affects its translucency property.*

Key words: computer-aided design and computer-aided manufacturing; dental veneer; translucency; color difference.

INTRODUCTION

Over two decades computer-aided design (CAD) and computer-aided manufacturing (CAM) have evolved into very functional technology in cosmetic dentistry[1].As becomes a more common technology seen in dental practices and laboratories the materials used to create restorations via these systems continue to evolve [2].There are diversities of CAD/CAM materials to select which are produced digitally to provide efficient restoration offering to a patient a more accurate fit, while also reducing production time and cost [3]. Because the work flow is computerized and there is no risk of dimension changes as compared with the elastomeric impression which has multiple traditional phases, these ceramic veneers fit suitably when the impression is taken digitally instead of the traditional elastomeric impression[4]. Digital impression has eased communication between technician and the dentist especially on color code and tooth morphology [5]. Coupled with the above also accuracy and precision has been increased, thus reducing the action of recalling the patients back for modification of the restoration [6]. Nonetheless for digital impression accuracy depends on the knowledge and experience of the operator. In other words, if technique is not properly followed it will result into misfit restorations as compared with the conventional impressions [7].

Available CAD/CAM in block form includes glass ceramics, zirconia, resin nano ceramics, ceramic composite, ceramic and resin composite [8].When choosing a block of CAD/CAM we should be very much sure it is indicated for the intended restoration type and placement, this will increase patient satisfaction to receive durable and beautiful restorations [9].Perfect selection of the material will done best if optical and chemical properties of the restoration are known prior to placement [10].

Some of the abutments have discolorations due to different reasons like blood extravasation, outcome of endodontic treatment, root resorption, contamination from old amalgam restorations and trauma. Due to this reason of discoloration causes bad appearance to the patient and the condition dictate the patient to seek treatment, CAD/CAM ceramic material has shown hope for solving this problem [11].Ideal CAD/CAM restorative material for restorations should have ability to mask color of the substrate [12]. Nevertheless, intensive study needs to be conducted to study every ceramic restorative material evolving in market.

Block technology has introduced common large number of CAD/CAM materials for veneer like Vita Suprinity, Vita Blocs MarkII, IPS Empress CAD, IPS e.max CAD, Lava Ultimate, Vita Enamic. Their optical properties need to be thoroughly studied and investigated to aid in clinical guidance [13,14].VitaSuprinity is a new generation of glass ceramic material enriched with approximately 10% zirconia by weight, because of its good optical properties and high strength, only small amount of enamel is reduced to accommodate it, hence minimizing adverse reaction of the pulp [15].Vita BlocsMarkII is a monochromatic, tooth colored feldspar blanks with shades that match those of residual teeth, which is very much used in dental esthetic reconstruction. It is a fine-structured feldspar ceramic blocks provided for different CAD/CAM systems, permitting for all types of single-tooth restorations[16].IPS Empress CAD is a typical Leucite-reinforced glass ceramic block for the CAD/CAM technology, it closely simulates the characteristics of the natural tooth due to its distinct chameleon effects and lifelike fluorescence. This type of product is made up of a total of four to eight main and intermediate layers in order to create an optical illusion for human eyes to avoid the visible transitions between the individual layers[17].IPS e.max CAD is a highly esthetic, reliable and versatile lithium disilicate glass-ceramic for the CAD/CAM technique. These specific characteristics has led to its most use in crowns, veneers, inlay and onlays manufacturing [18]. LavaUltimate is very strong, easily milled, durable and having strong wear resistance, it can be used for veneer, inlays and onlays restorations[19].VitaEnamic is the first dental hybrid ceramic with a dual network structure. It is composed by a methacrylate-based matrix where is dispersed a feldspar-based ceramic. As a result, this is a durable restoration with the capable of absorbing masticatory forces[20].

Deep knowledge on the chemical composition, strength and optical properties of these aforementioned and discussed ceramic veneer need to be known especially when they are required to mask color of the dentine [21]. The perfect CAD/CAM system is the one under minimum thickness can hide the color of the substrate and still provide strongest mechanical properties to withstand masticatory forces. Although CAD-CAM ceramic veneer materials have been proven to be clinically successful in longevity, little is known about optical properties of different types of CAD/CAM veneer when placed on different kinds of substrate. This study aims to shed light on the knowledge of clinician and eventually reduces chair side time with the patient. Main purpose of this experimental study was to research masking ability of each CAD/CAM material at the thickness of 0.6mm, when placed over different substrates.

MATERIALS AND METHOD

Fabrication of ceramic veneers

Sixty-six specimens were produced with the CAD-CAM system from eleven CAD/CAM(Lava Ultimate HT/LT, VitaSuprinityHT/T, VitaEnamic HT/T,Vita BlocsMarkII, IPS Empress CAD HT/LT, IPS e.max CAD HT/LT) blocks under continuous flow of cold water. The cut specimens were polished using sandpaper (600,800,1000,1500,2000)adjusted to thickness 0.6±0.01.The thickness of the specimens was measured using a digital vernier caliper to ensure consistency all over the specimen. After these processes the specimen were ultrasonically cleaned for about 10seconds in distilled water. When the specimens were thoroughly clean, they were dried in oil free air for about 25 minutes. Then every specimen was divided into eleven groups (n=6). The chemical composition of the ceramic veneer is listed in table 1.

Table 1: Chemical composition of ceramic veneer.

Product	Material type	Main composition	Factory
IPS e.max CAD HT/LT	Lithium disilicate-reinforced glass ceramic	SiO_2, Li_2O, K_2O	IvoclarViva dent
IPS Empress CAD HT/LT	Leutice-reinforced ceramic	SiO_2, Al_2O_3, K_2O	IvoclarViva dent
LavaUltimate HT/LT	Composite ceramic	80wt%(65vol%) nanoparticles	3M
Vita SuprinityHT/LT	Zirconia reinforced lithium disilicate glass ceramic	ZrO_2, Al_2O_3	Vita
Vita Enamic HT/T	Composite ceramic	Polymer network, ceramic	Vita
Vita Blocs MarkII	Feldspar-based ceramic	Sio_2, Al_2O_3, Na_2O	Vita

(Fabrication of composite resin background disks

Composite disk specimens (n= 1) shades A2, A4, B2, C2and D2 were fabricated to simulate the normal background dentine shade. A silk rubber mold with 8 mm inner diameter and 1mm in thickness was used, composite was incrementally filled in the mold and covered with a cover glass to ensure a flat and smooth surface through compression and then eventually light cured for 40seconds. The surface of composite resin was polished with sandpaper number 600 until when the thickness of 1mm was achieved.

Color measurement

The Commission Internationaled'Eclairage (CIE) L*a*b* values of the polishedsurfaces of each specimen were measured individually with the spectrophotometer(Crystaleye; Olympus). This device had seven emitting diodes. The capture time was 0.2 seconds, reflectance values ranged from 400 to 700 nm with 1 nm intervals for each pixel. The CIEL*a*b* values of each specimen were measured 3 times, and then eventually mean value was assigned as the color of the specimen. Distilled water was placed between the specimen and substrate as coupling liquid/agent. Ceramic specimens were seated on the composite disks (A2, A4, B2, C2 and D2) as substrate material. Data from spectrophotometer were transferred into the computer. Commission Internationaled'Eclairage (CIE) L*a*b* values of ceramic specimens over the A2 shade served as the control group for others. Data of the experimental A4, B2, C2 and D2 shades acting as abutment were analyzed and compared to the control shade A2. Color differences (ΔE) values between control and test groups were computed using CIEDE2000 Formula. In this scenario the TP is the color difference of a material of a given thickness in optical contact with ideal white and black backgrounds. (The flow chat of this experiment is given in figure 1).

Calculation of color difference and translucent parameter of the materials

The formula used to calculate Translucent Parameter was

$TP = [(L^*_B - L^*_W)^2 + (a^*_B - a^*_W)^2 + (b^*_B - b^*_W)^2]^{1/2}$ where B is for black and W for white.

The formula used to calculate the color difference was CIEDE2000[22].

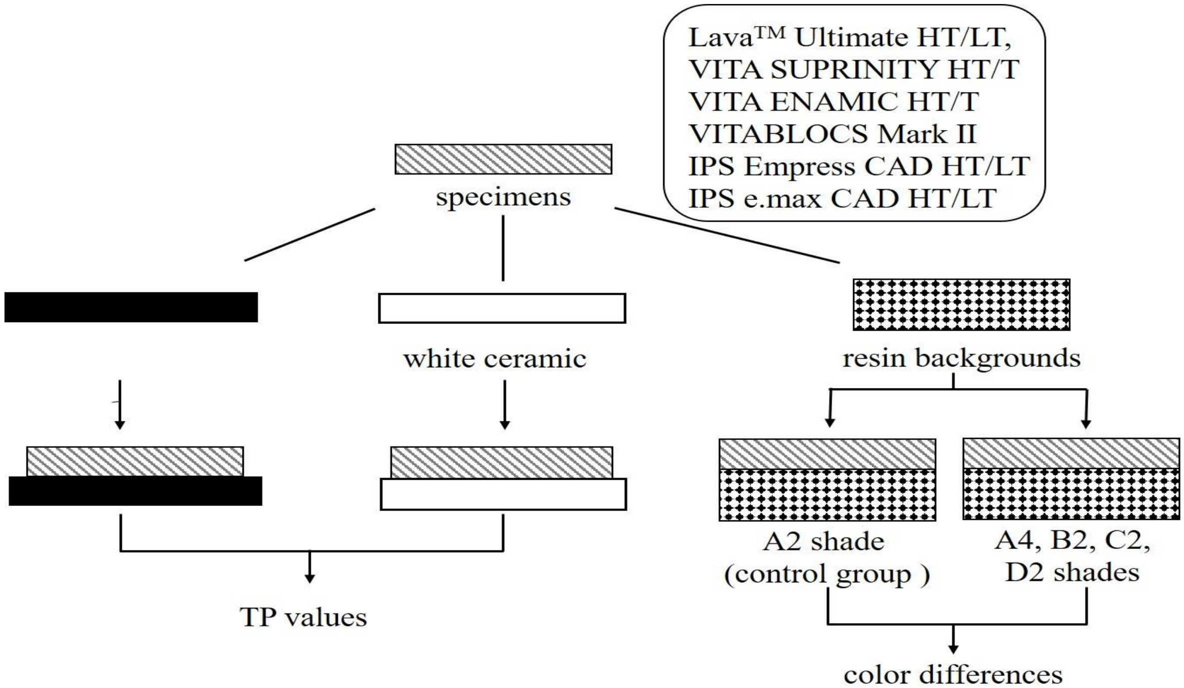
$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta L'}{K_C S_C}\right)^2 + \left(\frac{\Delta L'}{K_H S_H}\right)^2 + R_T \left(\frac{\Delta L'}{K_C S_C}\right)\left(\frac{\Delta L'}{K_H S_H}\right)}$$

The clinical significance of the color differences was determined by comparing them with the perceptibility threshold (ΔE_{00}=1.3) and the acceptability threshold (ΔE_{00}=2.25)[23]

Statistical analysis

Statistical analysis of the data was performed by one-way ANOVA, two-way ANOVA and Tukey HSD multiple tests using SPSS 25.0 software. Mean and Standard deviation of (ΔE_{00}) were computed. All data were calculated with the significance set at 0.05.

Figure 1: Flow chat of the experiments



RESULTS

Among all the materials, Enamic T showed lowest TP values (34.98±0.77), whereas Ultimate HT showed highest TP values (51.08±1.35) (Table 2, Figure 2). And a significant difference in the TP values was observed between the materials (*p* <0.001, Table3).

Table 4-6 presents the mean values and standard deviations of the L*, a*and b* coordinates of all groups. Suprinity HT showed lowest a* and b*values against A4 composite resin background. Ultimate LT showed highest a* and lowest b*values under the B2 shade background. Enamic HT displayed lowest L*and highest a*, b*values against C2 composite resin background. IPS e.max CAD LT exhibited highest L* and lowest a*value, meanwhile Enamic HT showed highest a* and b*values under the D2 shade background.The results of two-way ANOVA showed that the color differences were influenced by materials, background, as well as the interaction terms of these two variables ($p<0.05$,Table 7).

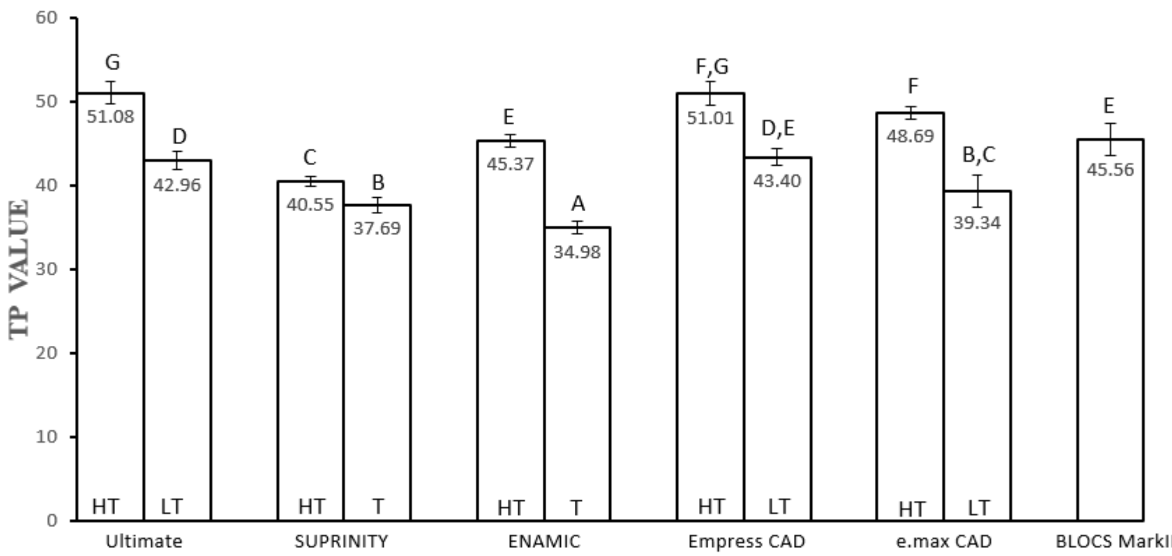
The highest mean ΔE_{00} values was observed for Empress CAD LT under the B2 shade background (0.80±0.18), whereas the Ultimate LT against the A4 shade background exhibited the lowest ΔE_{00} values (7.14±1.60). The results of Tukey's HSD test showed that the mean ΔE_{00} value under B2 shade background was significantly smaller than that under A4 shade background. The color differences of all the materials under the B2 shades background are lower than 2.25, which is clinically acceptable; under the A4, C2, D2 shades background, the color differences of materials are far more than 2.25, which indicates theΔE_{00} values is affected by the different resin background (Table 8).

Table 2. The TP values of specimens

Materials	TP
Lava^{TM}Ultimate HT^{G}	51.08±1.35
Lava^{TM}Ultimate LT^{D}	42.96±1.10
VITA SUPRINITY HT^{C}	40.55±0.61
VITA SUPRINITY T^{B}	37.69±0.92
VITA ENAMIC HT^{E}	45.37±0.79
VITA ENAMIC T^{A}	34.98±0.77
IPS Empress CAD HT^{F,G}	51.01±1.40
IPS Empress CAD LT^{D,E}	43.40±0.96
IPS e.max CAD HT^{F}	48.69±0.74
IPS e.max CAD LT^{B,C}	39.34±1.86
VITA BLOCS MarkII^{E}	45.56±1.89

$^{A-G}$ Similar capital letters corresponds to no statistical difference.

Figure 2: Histogram of the TP values of the specimens



Note: Different uppercases indicate significant differences (*P*<0.05).

Table3. The result of one-way ANOVA for the effect of materials on TP values.

	Sum of Squares	df	Mean Square	F	Sig
Between Groups	1683.993	10	168.399	116.364	.000
Within Groups	79.595	55	1.447		
Total	1763.588	65			

Table4. The L* values of specimens against the different composite resin backgroundshades

	A2	A4	B2	C2	D2
Ultimate HT	69.36±0.99	61.35±1.15	69.82±0.70	65.05±1.31	64.80±1.67
Ultimate LT	70.70±1.62	62.53±0.83	68.94±0.42	65.89±1.23	65.85±1.81
Suprinity HT	69.18±0.61	63.28±0.86	68.38±0.84	65.57±0.63	65.54±0.42
Suprinity T	67.66±0.68	63.01±0.64	68.30±0.91	64.57±1.10	65.42±0.86
Enamic HT	68.84±1.19	61.61±1.39	69.29±1.72	63.54±0.87	64.04±0.68
Enamic T	69.56±0.48	64.13±1.35	69.91±1.05	64.85±0.72	65.45±1.11
BLOCS MarkII	69.25±0.62	62.68±1.14	69.78±1.00	64.53±1.36	63.67±1.07
EmpressCAD HT	69.13±0.38	61.28±0.56	69.26±0.48	64.18±0.18	64.57±0.33
EmpressCAD LT	69.10±0.79	62.53±0.63	69.01±0.58	64.77±1.26	65.20±0.95
e.max CAD HT	68.68±0.64	61.68±0.80	69.61±0.78	63.84±0.54	63.84±0.45
e.max CADLT	70.15±1.11	62.93±0.48	68.71±0.99	66.49±0.99	65.87±1.57

Table 5. The a* values of specimens against the different composite resin background shades

	A2	A4	B2	C2	D2
UltimateHT	3.39±0.27	5.07±0.43	3.02±0.17	2.95±0.31	3.99±0.51
UltimateLT	3.40±0.50	5.07±0.14	3.58±0.17	2.99±0.43	3.84±0.40
Suprinity HT	3.08±0.17	3.83±0.27	3.14±0.19	2.38±0.21	3.07±0.17
Suprinity T	3.60±0.21	3.87±0.13	3.17±0.19	2.63±0.33	3.15±0.24
Enamic HT	3.81±0.30	5.30±0.36	3.18±0.26	3.55±0.21	4.36±0.20
Enamic T	3.69±0.14	4.36±0.35	3.31±0.29	3.17±0.26	3.92±0.23
BLOCS MarkII	2.95±0.12	4.04±0.41	2.30±0.28	2.45±0.32	3.72±0.28
EmpressCAD HT	3.22±0.17	4.92±0.24	2.55±0.09	2.95±0.04	3.83±0.18
EmpressCAD LT	3.31±0.25	4.60±0.23	2.84±0.13	2.99±0.29	3.62±0.27
e.max CADHT	2.82±0.62	4.44±0.48	2.46±0.31	2.44±0.64	3.49±0.64
e.max CADLT	2.47±0.50	4.10±0.26	2.76±0.25	1.80±0.40	2.84±0.55

Table6. The b values of specimens against the different composite resin background shades

	A2	A4	B2	C2	D2
UltimateHT	18.97±0.48	16.90±0.81	19.72±0.46	15.90±0.71	15.84±0.91
UltimateLT	18.57±1.08	16.30±0.51	19.36±0.33	15.31±1.96	15.78±0.64
Suprinity HT	19.29±0.34	15.48±0.43	20.95±0.70	16.13±0.38	16.08±0.31
Suprinity T	21.08±0.46	16.70±0.45	21.21±0.57	17.74±0.45	17.49±0.36
Enamic HT	21.37±0.93	20.31±1.08	21.60±0.97	19.56±0.72	19.33±0.60
Enamic T	21.05±0.43	18.62±0.53	21.48±0.51	18.79±0.48	18.60±0.54
BLOCS MarkII	18.75±0.18	17.56±0.44	19.43±0.55	16.66±0.53	16.88±0.35
EmpressCAD HT	20.57±0.19	20.17±0.36	21.26±0.42	19.05±0.24	18.22±0.18
EmpressCAD LT	21.00±0.57	19.22±0.48	21.71±0.52	19.06±0.51	18.42±0.63
e.max CADHT	20.94±1.25	20.52±1.07	22.00±1.19	19.30±1.09	18.85±1.31
e.max CADLT	20.05±0.47	17.81±0.57	20.88±0.48	17.42±0.55	17.49±0.61

Table 7. The result of two-way ANOVA for the effect of materials and backgrounds on color difference.

Source	Sumof Squares	df	Mean Square	F	Sig.
Corrected Model	854.181[a]	43	19.865	42.233	.000
Intercept	3632.609	1	3632.609	7722.972	.000
Background	778.743	3	259.581	551.872	.000
Materials	44.685	10	4.469	9.500	.000
Background × Materials	30.754	30	1.025	2.179	.001
Error	103.480	220	.470		
Total	4590.271	264			
Corrected Total	957.661	263			

Table 8. The color difference of specimens between the substrates and control group (A2shade background)

Materials	$\triangle E_{00A4-A2}$	$\triangle E_{00B2-A2}$	$\triangle E_{00C2-A2}$	$\triangle E_{00D2-A2}$
Ultimate HT	$7.02\pm1.19^{A,d,e}$	$0.87\pm0.15^{B,a}$	$3.93\pm0.85^{C,a,b}$	$4.26\pm0.47^{C,b}$
Ultimate LT	$7.14\pm1.60^{A,e}$	$1.76\pm1.02^{B,a}$	$4.37\pm0.66^{C,b}$	$4.33\pm1.80^{C,b}$
Suprinity HT	$5.42\pm0.28^{A,a,b,c}$	$1.29\pm0.62^{B,a}$	$3.46\pm0.45^{C,a,b}$	$3.48\pm0.31^{C,a,b}$
Suprinity T	$4.59\pm0.42^{A,a}$	$0.81\pm0.43^{B,a}$	$3.24\pm0.50^{C,a}$	$2.76\pm0.43^{C,a}$
Enamic HT	$6.19\pm0.33^{A,b,c,d,e}$	$1.10\pm0.42^{B,a}$	$4.42\pm0.62^{C,b}$	$4.12\pm0.52^{C,a,b}$
Enamic T	$4.72\pm1.03^{A,a,b}$	$0.83\pm0.35^{B,a}$	$4.00\pm0.44^{A,a,b}$	$3.60\pm0.75^{A,a,b}$
Empress CAD HT	$6.70\pm0.56^{A,c,d,e}$	$1.03\pm0.13^{B,a}$	$4.07\pm0.28^{C,a,b}$	$3.99\pm0.24^{C,a,b}$
Empress CAD LT	$5.66\pm0.40^{A,a,b,c,d,e}$	$0.80\pm0.18^{B,a}$	$3.64\pm0.49^{C,a,b}$	$3.49\pm0.54^{C,a,b}$
e.max CAD HT	$6.03\pm0.60^{A,a,b,c,d,e}$	$1.21\pm0.55^{B,a}$	$4.06\pm0.46^{C,a,b}$	$4.23\pm0.33^{C,b}$
e.max CAD LT	$6.31\pm0.82^{A,c,d,e}$	$1.37\pm1.01^{B,a}$	$3.39\pm0.66^{C,a,b}$	$3.94\pm0.78^{C,a,b}$
BLOCS Mark II	$5.56\pm0.74^{A,a,b,c,d}$	$1.16\pm0.42^{B,a}$	$4.07\pm0.72^{C,a,b}$	$4.77\pm0.66^{A,C,b}$

Different superscript lowercase letters represent significant differences in columns and different superscript capital letters indicate significant differences in rows.

DISCUSSION

In modern era of dentistry lots of materials are available in market selection depends on material properties, however, due to advertisements and techniques involved puts clinician in dilemma. Without proper material knowledge, the selection of material for successful restoration is difficult. The clinical outcome of restorations depends on the type of restorative material. The thickness, color stainability and translucency of the material all need to be seriously considered when evaluating different materials.

TP value is the difference in color between similar thickness of the material measured over white and black background. Tested CAD/CAM veneer materials displayed a wide range of TP values from 51.08±1.35 to 34.98±0.77. Ultimate HT, Empress CAD HT and e.max CAD HT showed higher Translucent Parameters, while e.max CAD LT, SuprinityT, Enamic T showed to have lower Translucent Parameters. These results were consistent with the research reported by Sun Yuan et al which showed high translucency in Lava Ultimate HT and Empress CAD HT also low translucency in SuprinityT, Enamic T[24].

Reasons of the CAD/CAM veneer to have high TP value is thought to be the microstructure of the material, density and grain size of the particles matters a lot. Low density and big particles allow more light to pass through and the vice versa. Meanwhile, presence of impurities and structural defects like pores lead to light absorption and scattering which reduce the translucency of the material. In case the material of low translucency is needed these factors should be maximized. Dopent such as alumina sometimes is added to the veneer materials to increase aging stability of the material, nevertheless, alumina has different refractive index which decrease translucency of the material by scattering.

Materials with lower TP value mask well the color of the abutment tooth consequently will minimize the destruction of sound tooth during preparation of an abutment tooth. Ideal veneer material is the one under minimum thickness can mask the color of the substrate, provided on that thickness it has high flexural strength to withstand masticatory forces.

Colorimetric data analysis from this experiment showed that composite substrate shade affected the final color outcome of CAD-CAM veneer restoration used in this experiment. In this experiment the ΔE_{00} among all the CAD/CAM Materials under the B2 shade background were under 2.25, which is clinically acceptable. Therefore, these materials may better reproduce enamel characteristics and achieve the color match between milled the veneer and natural tooth. However, the color difference of the above aforementioned CAD/CAM materials on A4, C2 and D2 were clinically unacceptable as the color difference level was above 2.25.

Limitations of this experiment were as follows. Composite resins of different shades were used to simulate the color of abutment teeth however the optical properties of resin and natural teeth are also different. This in vitro experimental did not replicate factors found in the oral cavity like gums and saliva which affect the surface optical properties of the CAD/CAM veneer. Future study design should be done in vivo, lastly during all measurements to evaluate color precisely. The spectrophotometer measuring tip was positioned in the middle of each specimen, but for more accuracy in future study design, measurement should be taken in three different positions of the sample for example upper, middle and lower.

CONCLUSION

The substrate color mainly affects the final and translucency property color of CAD/CAM Veneer.

The color differences of all the materials under the B2 shades background are clinically acceptable; however, the color differences of materials were clinically unacceptable under the A4, C2 and D2 shades background.

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