Original Article

Assessment of Relative Translucency and Resultant Color of Contemporary Resin-Matrix Ceramics Indicated for Laminate Veneers and Full Crowns

S Uğur, B Günal

Department of Prosthetic Dentistry, Faculty of Dentistry, Near East University, Nicosia, Mersin-10 Turkey

ABSTRACT

Background and Aims: Evaluation of the optical properties of restorative materials is an important parameter for identifying clinical success. The aim of this study was to compare the translucency of contemporary resin-matrix ceramics (RMCs) and to evaluate the effect of cement shade on the final color of RMCs indicated for laminate veneers and full crowns. **Materials and Methods:** A hundred A2 shade RMC specimens were fabricated by using Mazic Duro (MD), CAMouflage NOW (CN), KZR-CAD HR2 (KZR), Grandio Block (GB), and Brilliant Crios (BC) at 0.7-mm and 1.5-mm thicknesses (n = 10). A2 shade composite resin was used for the foundation structure. Twenty resin-cement specimens were prepared from A2 and translucent shades at 0.1-mm thickness. Interchangeably, the foundation-cement-resin matrix ceramic assemblies were created with optical gel. The color coordinates were recorded using a spectrophotometer. After calculating translucency parameter (TP_{00}) and color difference (ΔE_{00}) values, data were analyzed statistically (P = 0.05). **Results:** TP_{00} values were influenced by RMC type and thickness. TP_{00} values of RMCs can be listed in descending order as MD>GB = CN>BC=KZR. ΔE_{00} values were significantly influenced by all parameters and their interactions. MD exhibited higher ΔE_{00} values among tested RMCs. The effect of A2 cement was not perceived visually while TR cement demonstrated visually perceptible but clinically acceptable values for both laminate veneers and full crowns. As the material thickness decreased, the TP_{00} and ΔE_{00} values increased in all RMCs. **Conclusions:** Clinicians should carefully prefer cement shade and RMC material by contemplating their impact on the optical properties particularly when the restoration is thin.

Keywords: *Color difference, esthetic, relative translucency, resin cement, resin-matrix ceramic*

Received: 04-Mar-2022; **Revision:** 13-May-2022; **Accepted:** 02-Jun-2022; **Published:** 16-Aug-2022

Introduction

Mechanical and esthetic characteristics have been considered as pivotal factors for the long-term viability of a dental restoration. The replication of optical properties of natural teeth by using dental ceramic restorations poses a great challenge.[1] In particular, metal-ceramic restorations prevent light transmission due to the metallic coping and thereby create undesirable negative chromatic results.[2]

To circumvent this unesthetic appearance, ceramics free from metals have been launched. Remarkably swift progression in Computer-Aided Design and Computer-Aided Manufacturing (CAD-CAM) technology has led to the diversification of preprocessed blocks/discs used in the fabrication of these restorations.[3] Due to the controlled industrial manufacturing process, lesser defects and porosities are encountered in these

Access this article online

Quick Response Code:

Website: www.njcponline.com

DOI: 10.4103/njcp.njcp_172_22

Address for correspondence: Dr. S Uğur, Department of Prosthetic Dentistry, Faculty of Dentistry, Near East University, Near East Boulevard - 99138, Nicosia, Mersin-10 Turkey. E-mail: suzan.ugur@neu.edu.tr

How to cite this article: Uğur S, Günal B. Assessment of relative translucency and resultant color of contemporary resin-matrix ceramics indicated for laminate veneers and full crowns. Niger J Clin Pract 2022;25:1324-31.

blocks/disks.[4,5] Latterly, high-performance multiphasic materials, namely, resin-matrix ceramics (RMCs), in which a dominant ceramic mesh is strengthened with a polymeric matrix have been marketed.[3,6,7]

RMCs amalgamate the advantageous properties of dental ceramic and composite materials, thereby presenting superior characteristics including high fatigue and wear resistance, gentleness to the opposite dentition, high fracture resistance especially during occlusal adjustments, enhanced machinability, and edge stability.[7–10] Moreover, the intraoral repair is feasible and there is no need for sintering or crystallization firing.[8,11,12] Microstructure, content, volume and size of filler particles, resin-matrix content, and manufacturing technique (high pressure-high temperature) were previously stated as the paramount factors influencing the characteristic properties of RMC materials.[13] Consistently with the advancements in industrial technologies, RMCs with new chemical formulations continue to be developed.

The translucency property of dental material can be described as the relative light transmission and can be stated as a cumber stone in controlling esthetics.[1,14,15] As the human eye is more effective at detecting changes in value (brightness) compared to chroma or hue, brightness errors among natural teeth are considered as the most prominent esthetic errors.[14] Moreover, its translucency is closely related to the polymerization performance of the underlying resin luting cement.[16] The relative translucency parameter (TP) is frequently preferred to determine the translucency of dental materials.[1,15,17,18] Filler particle size, content, and amount,[19–21] material thickness,[12,21–23] surface texture,[12,17] metal oxides,[8,20] and underlying foundation,[12,24] can become influential on the TP value.

Resin cement is preferred in the cementation of RMC restorations due to their advantages such as low solubility in oral fluids, improved mechanical properties, strong bonding between tooth tissue and restorative material, and superior esthetic properties.[5,25] Resin cements in different shades are in use to mask the undesirable foundation shade, to better achieve the targeted color, and thereby to provide a life-like appearance for the restoration.[26–28] Since the type and thickness of the restoration material,[5,11,27,28] the color and thickness of the cement,[26,28–31] and the color of the substructure[8,30,31] affect the final color of the translucent dental restoration; especially when the restoration thickness is less than 1.5 mm, all above-stated factors can become influential in achieving optimal esthetic success.[26,31,32]

The CIE (Commission Internationale de l'Eclairage) has been liable for acquainting the main color systems, color difference (ΔE_{00}) concepts, and illumination patterns. For color difference evaluation, the CIELab formula has been previously preferred.[33] However, this formula suffers from perceptual uniformity. To overcome this drawback, a more complex but more accurate formula, namely, CIEDE 2000 formula, has been developed.[33]

Although there is a variety of information in the literature about the translucency and final color of predecessor RMCs; data regarding newly introduced RMCs are sparse to the authors' knowledge. Therefore, it was aimed to compare the translucency properties of recently introduced RMCs and evaluate the influence of material type and resin-cement shade on the final color of RMCs. The first null hypothesis was that (1) the translucency properties of tested RMCs with two different thicknesses representative of a laminate veneer and a full crown would not differ from each other. The second null hypothesis was that (2) the RMC type, RMC thickness, and resin cement shade would not significantly affect the resultant color of the restorations.

Materials and Methods

The materials used in this study and the schematic setup are demonstrated in Table 1 and Figure 1, respectively. A total of 100 rectangular RMC specimens (12 × 14 mm, High Translucency, A2 shade) were obtained from five different RMC blocks (Grandio Block [GB], Brilliant Crios [BC], KZR-CAD HR2 [KZR], Mazic Duro [MD], and CAMouflage NOW [CN]) at two different thicknesses (0.7 and 1.5 mm) by slicing in a low-speed precision cutting device (Isomet 1000, Buehler, Lake Bluff, Illinois, USA) under water irrigation with the help of a 0.3 mm thick diamond separator (n = 10). One surface of the specimens was polished for 15 seconds with finger pressure by using #800, #1000, #1200, and #2000 silicon carbide abrasive grinding papers (Eagle Abrasives, Japan) on a sanding machine (Gripo 2 V, Metkon Instruments Ltd., Bursa, Turkey) at 100 rpm/min for 15 seconds under water irrigation. Subsequently, all specimens were polished (Diacomp Plus Twist, EVE Ernst Vetter Gmbh, Germany; Diacomp Paste Twist, EVE Ernst Vetter Gmbh, Germany) with an electric handpiece at 10,000 rpm for 15 seconds. The final thickness was controlled from four different points by using a digital caliper (Digimatic Caliper, Mitutoyo Corp., Japan) presenting an accuracy of ± 0.01 mm. All specimens were ultrasonically cleaned (Biosonic Ultrasonic Cleaner UC1–110, Coltene Whaledent, Cuyahoga Falls, Ohio) and air-dried.

For the preparation of the foundation structure, composite resin material (Clearfil Majesty Esthetic, Kuraray Medical, Tokyo, Japan) in A2 shade was incrementally placed into the mold (12 × 14 × 4.0 mm) and grounded with #600 grit silicon carbide paper.

For the fabrication of the resin-cement specimens with two different shades (A2 and translucent [TR]), 20 rectangular gaps (12 x 14 mm) were created on the 0.1 mm hard plastic plate. To standardize the dimensions of resin cement specimens, a metal punch made of stainless steel was used. The glass plates were covered with a stretch nylon film to prevent the resin cement from sticking to the glass plates. An appropriate amount of cement was injected into the negative spaces on the hard plastic plate placed between the two glass plates. After injection, the upper glass plate was closed at an angle of 45° and a stainless-steel standard weight (0.75 kgf) was placed onto the glass plates. The cement was waited to be chemically cured for 10 minutes, then the light-curing process was completed by using a halogen light source (Hilux Dental Curing Unit, Ultra Plus, Ankara, Turkey) for 20 seconds on the upper and lower surfaces of each specimen. The specimens were carefully removed from the plate with gentle finger pressure. The foundation structure and resin cement specimens were kept at 37 ± 1°C for 24 hours in an incubator which was placed in a light-proof box to achieve complete polymerization. The specimens were then air-dried.

In a viewing booth, all color-coordinate measurements were accomplished by using a spectrophotometer (VITA Easyshade Compact, VITA Zahnfabrik, Bad Säckingen, Germany) according to CIE 2° standard observer and CIE D65 illuminant.[21] The spectrophotometer device was calibrated before the color measurement of each specimen and the probe was placed in the center of the specimen surface with full contact by the same operator (S.U.). Each measurement was repeated three times and the average value was recorded.

For the evaluation of TP_{00}, the color coordinates of each RMC specimen were measured on a black (L^* = 1.15, a^* = -0.12, and b^* = 1.2) and then white background (L^* = 99.0, a^* = -0.1, and b^* = 2.2) and obtained data were inserted to the following formula:

$$TP_{00} : \sqrt{\left(\frac{L'_w - L'_b}{kLSL}\right)^2 + \left(\frac{C'_w - C'_b}{kCSC}\right)^2 + \left(\frac{H'_w - H'_b}{kHSH}\right)^2 + RT\left(\frac{C'_w - C'_b}{kCSC}\right)^2\left(\frac{H'_w - H'_b}{kHSH}\right)^2}$$

where the "*w*" and "*b*" for *L'*, *C'*, and *H'* present to lightness, chroma, and hue of each specimen over the black and the white backgrounds, respectively.

For the evaluation of color differences (ΔE_{00}), each RMC specimen was placed on an A2 shade composite resin foundation structure (L^* = 80.5, a^* = 0.60, and b^* = 22.4) using optical fluid without resin cement specimens and first color measurements were performed on a neutral grey background (L^* = 56.79, a^* = -2.25, and b^* = 3.02). A refractive index solution of 1.52 (Cargille Optical Gel) was used to provide optical coupling. The first GB specimen and the first A2 cement were placed over the composite resin foundation structure with the help of optical gel and a second color measurement was performed on a neutral grey background. A single drop of optical fluid was dripped onto the composite resin foundation and A2 cement specimen was positioned on the foundation. Subsequently, a single drop of optical fluid was dripped onto the cement specimen and RMC specimen was positioned on it. Accordingly, optical coupling of specimens was done.[8,11,31,34,35] This process was repeated for the other 9 GB specimens assembled with the A2 and TR cement groups. Then, the second color measurements of the other RMC specimens were performed in the same order. Color differences were calculated by using the CIEDE2000 color difference formula. $\Delta E_{00} \leq 0.8$ and $0.8 < \Delta E_{00} \leq 1.8$ are perceptibility and acceptability thresholds, respectively.[36]

$$\Delta E^*_{00} = \sqrt{\left(\frac{\Delta L\prime}{kLSL}\right)^2 + \left(\frac{\Delta C\prime}{kCSC}\right)^2 + \left(\frac{\Delta H\prime}{kHSH}\right)^2 + RT\left(\frac{\Delta C\prime}{kCSC}\right)^2\left(\frac{\Delta H\prime}{kHSH}\right)^{2.}}$$

The expressions ΔC', ΔH', and ΔL', in the formula indicate the differences in chroma, hue, and brightness between two different measurements, respectively. In both formulae, S_L, S_C, and S_H are weighting functions used for luminance, chroma, and hue, adjusting the total color difference for variations in the location of the color difference in the measurements of L', a', and b' coordinates. R_T, defined as the rotation function, gives the interaction between chroma and hue in the blue region. $K_{H,}$ K_L, and K_C, are parametric factors for hue, brightness, and chroma, respectively. In this study, the parametric factors were set to 1.

The conformity of the data to the normal distribution was checked with the Shapiro Wilk test. The data were found to be in accordance with the normal distribution ($P > 0.05$) and thereby, the 2-way ANOVA was used to evaluate the TP_{00} values. In the analysis of ΔE_{00} values, the 3-way ANOVA test was conducted to compare the main factors (material type, thickness, and cement shade). The 1-way ANOVA coupled with Tukey test was conducted for multiple comparisons. A *P* value less than 0.05 shows statistical significance.

Results

Two-way ANOVA results showed that TP_{00} values were affected by RMC type and thickness ($P < 0.001$), but their interaction terms did not affect TP_{00} values [Table 2]. In Table 3, the means and standard deviations of TP_{00}

Table 1: Materials used in this study

Materials	Compositions	Shade	Manufacturers
Mazic Duro	Organic part: Bis-GMA, TEGDMA Inorganic part: 80 wt% silica (10 nm), barium glass (500 nm), and zirconia (1 μm)	HT A2	Vericom, Chuncheon, Korea
CAMouflageNow	Organic part: No data İnorganic part: 80 wt% nanohybrid fillers	HT A2	Glidewell Dental Laboratories, Newport Beach, USA
KZR CAD HR 2	Organic part: UDMA, TEGDMA İnorganic part: ~74 wt% SiO_2 (20 nm), aggregated SiO_2-Al_2O_3-ZrO_2 (200-600 nm), ceramic cluster (1-20 μm), fluoride filler (700 nm)	HT A2	Yamakin Co., Ltd, Kochi, Japan
Grandio Block	Organic part: UDMA, DMA İnorganic part: 86 wt% nanohybrid fillers	HT A2	Voco GmbH, Cuxhaven, Germany
Brilliant Crios	Organic part: Bis-GMA, Bis-EMA, TEGDMA İnorganic part: 70.7 wt% barium glass (<1.0 μm), amorphous silica SiO_2 (<20 nm), inorganic pigments (ferrous oxide or titanium dioxide)	HT A2	Coltène Whaledent AG, Altstatten, Switzerland
Bifix QM	Bis-GMA, 1,6-hex-anediylbismethacrylate, benzoyl peroxide, amines	A2 Translucent	VOCO GmbH, Cuxhaven, Germany
Cargille optical gel	Phthalate esters and gelling agents	Colorless	Cargille Lab, Cedar Grove, NJ, USA

Abbreviations: Al_2O_3 - alumina; Bis-EMA – ethoxylated bisphenol A glycol dimethacrylate; Bis-GMA - bisphenol A diglycidyl ether dimethacrylate; DMA - dimethacrylate, SiO_2-Al_2O_3-ZrO_2 - zirconia aluminosilicate; SiO_2 - silica; UDMA - urethane dimethacrylate; TEGDMA - triethylene glycol dimethacrylate; wt - weight

Table 2: Two-way ANOVA results of TP_{00} values

Source	Type III Sum of Squares	Df	Mean Square	*F*	Sig.
Corrected Model	1328,261[a]	9	147,585	418,232	,000
Intercept	23877,667	1	23877,667	67665,543	,000
Resin-Matrix Ceramic Type (A)	110,012	4	27,503	77,939	,000
Thickness (B)	1215,498	1	1215,498	3444,531	,000
A * B	2,751	4	,688	1,949	,109
Error	31,759	90	,353		
Total	25237,687	100			
Corrected Total	1360,020	99			

Df, degree of freedom; F, variance analysis test statistics. $P<0.05$ indicates a significant difference

Table 3: Relative translucency parameter (TP_{00}) values (mean±standard deviation) of CAD-CAM resin-matrix ceramic materials and multiple comparisons

Resin-Matrix Ceramic Type	Thickness		Total
	0.7 mm	1.5 mm	
Mazic Duro	20.57±0.95	13.21±0.26	16.89±3.83[A]
CamouflageNOW	19.31±0.63	12.45±0.62	15.88±3.57[B]
KZR CAD HR2	17.73±0.60	10.46±0.22	14.10±3.75[C]
Grandio Block	19.21±0.76	12.79±0.46	16.00±3.35[B]
Brilliant Crios	17.88±0.52	10.92±0.55	14.40±3.61[C]
Total	18.94±1.25[a]	11.97±1.17[b]	15.45±3.71

The difference of uppercase superscript letters in the same colomn indicates statistical difference ($P<0.05$). The difference of lowercase superscript letters in the same row indicates statistical difference ($P<0.05$)

values and Tukey multiple comparison test results are presented. TP_{00} values of RMCs revealed that MD was significantly more translucent among the tested materials. The lowest TP_{00} values were observed in KZR and BC, and the difference between them was insignificant. Also, the difference between the TP_{00} values of GB and CN was detected as insignificant. According to the RMC types evaluated in this study, TP_{00} values can be listed in descending order as MD > GB = CN > BC = KZR. The decrease in material thickness significantly increased the translucency of RMCs ($P < 0.001$).

Three-way ANOVA proved that ΔE_{00} values were significantly affected by all variables and their interaction terms ($P \leq 0.05$) [Table 4]. The mean ΔE_{00} values and standard deviations with Tukey post hoc comparisons are given in Table 5. ΔE_{00} values in all groups were smaller than the acceptability threshold ($\Delta E_{00} < 1.8$). The lowest color difference was occurred in BC coupled with A2 cement at full crown thickness, while the highest color

Table 4: Three-way ANOVA results of color difference (ΔE_{00}) values

Source	Type III Sum of Squares	Df	Mean Square	*F*	Sig.
Corrected Model	31,660[a]	19	1,666	49,559	,000
Intercept	135,285	1	135,285	4023,572	,000
Resin-Matrix Ceramic Type (A)	2,805	4	,701	20,860	,000
Resin-Matrix Ceramic Thickness (B)	4,196	1	4,196	124,804	,000
Cement Shade (C)	22,171	1	22,171	659,403	,000
A* B	,470	4	,118	3,497	,009
A * C	,584	4	,146	4,342	,002
B * C	,995	1	,995	29,606	,000
A * B * C	,437	4	,109	3,252	,013
Error	6,052	180	,034		
Total	172,997	200			
Corrected Total	37,712	199			

Df, degree of freedom; F, variance analysis test statistics. *P*<0.05 indicates a significant difference

Table 5: Color difference (ΔE_{00}) values (mean±standard deviation) of CAD-CAM resin-matrix ceramic materials and multiple comparisons

Cement Shade	Thickness	Resin-Matrix Ceramic Type				
		Mazic Duro	Camouflage NOW	KZR CAD HR 2	Grandio Block	Brilliant Crios
A2	0.7	0.66±0.11$^{A, a}$	0.56±0.13$^{A, a}$	0.54±0.11$^{A, a}$	0.58±0.10$^{A, a}$	0.48±0.17$^{A, a}$
	1.5	0.58±0.13$^{A, a}$	0.34±0.18$^{A, a}$	0.43±0.11$^{A, a}$	0.40±0.10$^{A, a}$	0.33±0.10$^{A, a}$
TR	0.7	1.79±0.23$^{A, a}$	1.37±0.17$^{B, C, a}$	1.07±0.17$^{C, a}$	1.46±0.27$^{A, B, a}$	1.17±0.22$^{B, C, a}$
	1.5	1.15±0.38$^{A, b}$	0.85±0.19$^{A, b}$	0.94±0.11$^{A, a}$	0.91±0.24$^{A, b}$	0.85±0.17$^{A, a}$

The difference of uppercase superscript letters in the same line indicates statistical difference (*P*<0.05). The difference in lowercase superscript letters in the same column indicates statistical difference (*P*<0.05)

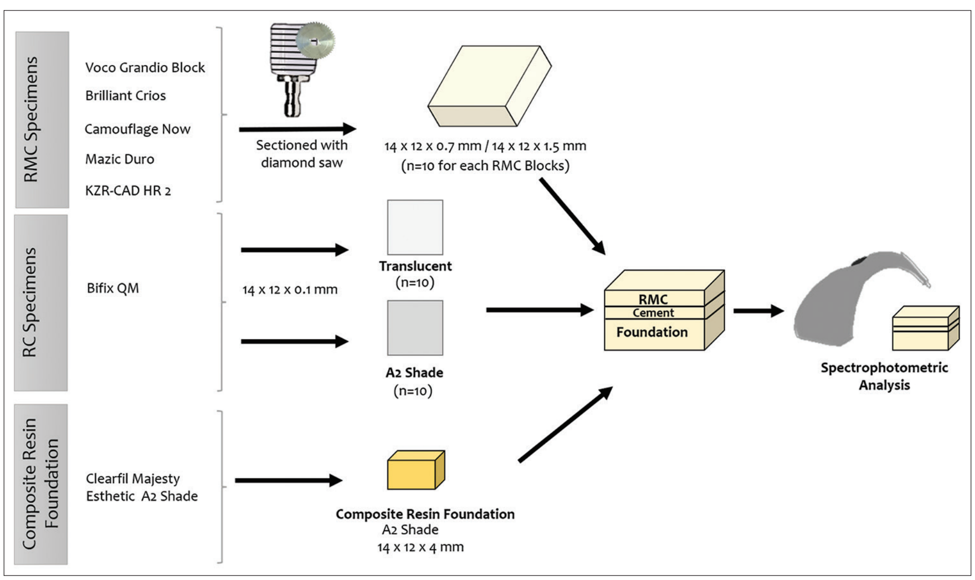

Figure 1: Workflow of study

difference was observed in MD coupled with TR cement at laminate veneer thickness.

The color differences resulting from the use of A2 cement were below the perceptibility threshold value (ΔE_{00} < 0.8) in all RMCs in both thicknesses. In specimens where the TR cement was used, all color differences were above the perceptibility threshold value, but within the clinically acceptable range (0.8 < ΔE_{00} ≤ 1.8) in both thicknesses.

The increase in RMC thickness provided a decrease in ΔE_{00} values in all tested groups. Among TR cement used specimens, the increase in RMC thickness did not affect ΔE_{00} values of BC and KZR, while GB, MD, and CN were significantly affected (*P* < 0.05).

The differences in ΔE_{00} values between full crown and laminate veneer thicknesses of RMCs were insignificant for A2 cement groups.

When the cement color changed for each RMC material, the differences were significant for both thicknesses ($P < 0.05$). When A2 cement was applied to RMC specimens, the differences among the RMC materials were insignificant for both thicknesses. In TR cement, the differences between ΔE_{00} values of some RMCs at laminate veneer thickness were significant ($P < 0.05$), while the differences between RMC materials at full crown thickness were insignificant.

Discussion

All variables significantly influenced the TP_{00} and ΔE_{00} values of tested RMCs. Moreover, significant interactions were detected on the data of ΔE_{00} values. Therefore, tested null hypotheses were rejected.

In this study, standardized composite resin foundation structure, resin-matrix ceramic, and resin cement specimens were used to compose all test groups to minimize the variations related to the tested materials and make reliable comparisons with previous studies[8,26,31] that have the same experimental setup. Thus, it was aimed to prevent or minimize potential changes in the optical properties of the specimens during the fabrication process.

Refractive index solutions can be used as an optical coupling tool in dental color studies,[8,11,26,31,34,35] because they increase light transmission by reducing internal reflection. It has been stated that the refractive index of most dental ceramic materials is very close to the tooth tissues, the refractive index value of enamel tissue varies between 1.52 and 1.63, and the refractive index of dentin tissue varies between 1.43 and 1.57.[37,38] The refractive index value (n = 1.52) of the optic fluid used in this study is similar to the refractive index value of dental tissues. Similar to previous studies using the same methodology,[8,11,31,34,35] in this study, the optical gel was used to create an optical coupling effect between the RMC specimen – resin cement – composite foundation, to provide a better light transmission and eliminate light scattering from the interface. However, Ceylan *et al.*[39] stated that refractive index solutions affect the color of the luting cement and that the contact time should be kept as short as possible in dental studies that preferred refractive index solution. In this study, accordingly, the contact of the specimens with the optical gel was kept as short as possible.

It has been reported that the differences in light-transmission characteristics among dental restorative materials stem from the diffraction index of the polymeric matrix, monomer type, filler type and content, size, and amount of fillers.[1,12,21,27,40,41] The researchers[12,20,41] underlined that the light diffusion through the resin composite is due to the multiple refraction and reflection of light at the interface of the resin matrix and the filler particle, while the light scattering on the surface is affected by the refractive index difference between the particle and the matrix phase. The total refractive index and thickness of a material are directly related to each other.[21] In previous studies,[1,12,21,42] it has been underlined that increasing the material thickness results in a significant decrease in translucency of RMCs. This provides consistency with the current study.

Ceramics are optically heterogeneous due to the different components they contain and consist of small particles with different refractive indices,[43] There can be a difference even in the light transmittance of ceramic materials of the same category and thickness. Among the RMC materials used, MD exhibited the highest TP_{00} value. This can be attributed to different reasons: (1) MD, unlike other RMCs, consists of nanoceramics in its resin matrix composition, and as it is known, particles smaller than the wavelength of visible light cause less light scattering. This explains the high light transmittance of the nanometer-sized fillers found in MD compared to other materials.[44] (2) MD contains Bis-GMA, which is widely used as a base monomer in polymeric matrices.[40,44] Bis-GMA has been reported to be more translucent than other monomers like UDMA and TEGDMA.[40] With this translucency level of MD, it was feasible to obtain higher ΔE_{00} values as it tends to transmit the light more and thereby to be influenced more from the underlying color.

Luting agents can have different effects on the color of the restoration in ceramic systems that are prepared relatively thinner, such as laminate veneer restorations.[5,8,27] In the cementation of translucent dental restorations, if there is no discoloration in the underlying structure, translucent or universal shades of the resin cement are generally preferred.[26] In accordance with the results of this study, in all RMCs, A2 cement shade provided the ΔE_{00} values below the perceptibility threshold. However, TR cement shade caused the ΔE_{00} values to be above the perceptibility threshold, but within the clinically acceptable range. In the anterior region, where esthetics is of concern, TR cement shade should not be the first choice if laminate veneer or full crown restoration fabricated from tested high translucent RMCs would be performed on the A2 underlying structure. Using TR shade resin cement with MD material may pose a great risk in terms of esthetics, especially in laminate veneer indication.

Among tested RMCs, KZR indicated the lowest TP_{00} value, followed by BC. This behavior of KZR can be correlated with TEGDMA, Al_2O_3, and SiO_2 content in its microstructure which all act as opacifying agents and decrease its TP_{00} value. The opaque behavior of BC can be correlated with a number of factors: (1) It contains cross-linked methacrylate and inorganic pigments, namely, zirconium oxide (ZrO_2) and titanium dioxide (TiO_2). These oxides act as scattering centers in its matrix and thereby, negatively affect light transmission by increasing the level of opacity,[12,20] Large refractive-index inconsistencies between the reinforcing filler and the polymeric matrix can lead to increased opacity values due to multiple reflection and refraction at the matrix-phase interface.[20,41] The refractive indices of UDMA (1.48), Bis-GMA (1.55), Bis-EMA (1.53), TEGDMA (1.46), TiO_2 (2.49), Al_2O_3 (1.77), and ZrO_2 (2.22) have been reported previously.[20,40] Radiopaque fillers such as strontium, barium, and zirconium offer refractive indices of about 1.55.[40] TiO_2 exhibits the greatest incompatibility with the resin matrix as it has the highest refractive index of all, which explains why BC exhibited higher opacity. This opacity provides a superior ability to mask the underlying color which explains the reason for the low ΔE_{00} value.

There is still no consensus in the literature on acceptable and perceptible threshold values. While Ghinea *et al*.[45] stated the perceptibility and acceptability threshold values for the ΔE_{00} color difference formulation as 1.25 and 2.23, respectively; Paravina *et al*.[36] stated them as 0.8 and 1.8, respectively. The decrease in the threshold values may be related with the enhancement in the human's color perception over time. In this study, the 0.8 and 1.8 threshold values were used to analyze the mean ΔE_{00} values.

This study has a number of limitations. The structure of the composite resin used to stimulate the underlying tooth structure differs from the optical properties of natural teeth.[46] Spectroradiometer was not used. Spectrophotometer is less reliable due to the edge-loss phenomenon.[47] Different results can be achieved with different cement and background shades. Therefore, further studies are needed.

Conclusion

Within the limitations of this study, the following conclusions can be drawn:

(1) Different resin-matrix ceramics can present different optical properties due to differing chemical compositions. Among tested resin-matrix ceramics, Mazic Duro exhibited the highest relative translucency value and thereby, the highest color differences.

(2) Thickness can also become influential on the optical properties of resin-matrix ceramics as with decreasing thickness, the relative translucency and color difference values increased.

(3) In comparison to A2 cement shade, TR cement shade exhibited higher color difference values. Even so, the influence of TR cement shade on the resultant color of RMCs was within the range of clinical acceptability.

Financial support and sponsorship

We are very grateful to Voco GmbH Company and Vericom for material support.

Conflicts of interest

There are no conflicts of interest.

References

1. Gunal B, Ulusoy MM. Optical properties of contemporary monolithic CAD-CAM restorative materials at different thicknesses. J Esthet Restor Dent 2018;30:434–41.
2. Carrabba M, Vichi A, Tozzi G, Louca C, Ferrari M. Cement opacity and color as influencing factors on the final shade of metal-free ceramic restorations. J Esthet Restor Dent 2022;34:423-9.
3. Blatz MB, Conejo J. The current state of chairside digital dentistry and materials. Dent Clin North Am 2019;63:175–97.
4. Beuer F, Schweiger J, Edelhoff D. Digital dentistry: An overview of recent developments for CAD/CAM generated restorations. Br Dent J 2008;204:505–11.
5. Günal-Abduljalil B, Ulusoy MM. The effect of resin cement shade and restorative material type and thickness on the final color of resin-matrix ceramics. J Prosthodont Res 2022;66:75–82.
6. Gracis S, Thompson VP, Ferencz JL, Silva NRFA, Bonfante EA. A new classification system for all-ceramic and ceramic-like restorative materials. Int J Prosthodont 2015;28:227–35.
7. Bajraktarova-Valjakova E, Korunoska-Stevkovska V, Kapusevska B, Gigovski N, Bajraktarova-Misevska C, Grozdanov A. Contemporary dental ceramic materials, a review: Chemical composition, physical and mechanical properties, indications for use. Open Access Maced J Med Sci 2018;6:1742–55.
8. Önöral Ö, Günal-Abduljalil B, Ongun S. Effect of color of the cement and the composite resin foundation on the resultant color of resin-matrix ceramics. J Prosthet Dent 2021;125:351.e1–7.
9. Jovanović M, Živić M, Milosavljević M. A potential application of materials based on a polymer and CAD/CAM composite resins in prosthetic dentistry. J Prosthodont Res 2021;65:137–47.
10. Hampe R, Theelke B, Lümkemann N, Eichberger M, Stawarczyk B. Fracture toughness analysis of ceramic and resin composite CAD/CAM material. Oper Dent 2019;44:E190–201.
11. Ongun S, Önöral Ö, Günal-Abduljalil B. Evaluation of shade correspondence between current monolithic CAD/CAM blocks and target shade tab by considering the influence of cement shade and restorative material thickness. Odontology 2021;109:393–402.
12. Günal-Abduljalil B, Ongun S, Önöral Ö. How will surface conditioning methods influence the translucency and color properties of CAD-CAM resin-matrix ceramics with different

thicknesses? J Esthet Restor Dent 2021;33:925–34.

13. Mainjot AK, Dupont NM, Oudkerk JC, Dewael TY, Sadoun MJ. From Artisanal to CAD-CAM Blocks: State of the Art of Indirect Composites. J Dent Res 2016;95:487–95.
14. Al Amri MD, Labban N, Cert MP, Alhijji S, Alamri H, Iskandar M, *et al*. *In vitro* evaluation of translucency and color stability of CAD/CAM polymer-infiltrated ceramic materials after accelerated aging. J Prosthodont 2021;30:318–28.
15. Della Bona A, Nogueira AD, Pecho OE. Optical properties of CAD-CAM ceramic systems. J Dent 2014;42:1202–9.
16. Caprak YO, Turkoglu P, Akgungor G. Does the translucency of novel monolithic CAD/CAM materials affect resin cement polymerization with different curing modes?. J Prosthodont 2019;28:e572–9.
17. Turgut S, Bağiş B, Korkmaz FM, Tamam E. Do surface treatments affect the optical properties of ceramic veneers? J Prosthet Dent 2014;112:618–24.
18. Barizon KTL, Bergeron C, Vargas MA, Qian F, Cobb DS, Gratton DG, *et al*. Ceramic materials for porcelain veneers. Part I: Correlation between translucency parameters and contrast ratio. J Prosthet Dent 2013;110:397–401.
19. Arikawa H, Kanie T, Fujii K, Takahashi H, Ban S. Effect of filler properties in composite resins on light transmittance characteristics and color. Dent Mater J 2007;26:38–44.
20. Haas K, Azhar G, Wood DJ, Moharamzadeh K, van Noort R. The effects of different opacifiers on the translucency of experimental dental composite resins. Dent Mater 2017;33:e310–6.
21. Awad D, Stawarczyk B, Liebermann A, Ilie N. Translucency of esthetic dental restorative CAD/CAM materials and composite resins with respect to thickness and surface roughness. J Prosthet Dent 2015;113:534–40.
22. Turgut S, Bağiş B, Korkmaz FM, Tamam E. Do surface treatments affect the optical properties of ceramic veneers? J Prosthet Dent 2014;112:618–24.
23. Turgut S, Bagis B, Ayaz EA, Korkmaz FM, Ulusoy KU, Bagis YH. How will surface treatments affect the translucency of porcelain laminate veneers? J Adv Prosthodont 2014;6:8–13.
24. Basso G, Kodama A, Pimentel A, Kaizer M, Bona A Della, Moraes R, *et al*. Masking colored substrates using monolithic and bilayer CAD-CAM ceramic structures. Oper Dent 2017;42:387–95.
25. Küçükekenci A, Kurt M, Dede DO. Resin cements effect on the final color of novel monolithic CAD/CAM restorations. Minerva Stomatol 2018;67:202–9.
26. Dede DO, Ceylan G, Yilmaz B. Effect of brand and shade of resin cements on the final color of lithium disilicate ceramic. J Prosthet Dent 2017;117:539–44.
27. Kürklü D, Azer SS, Yilmaz B, Johnston WM. Porcelain thickness and cement shade effects on the colour and translucency of porcelain veneering materials. J Dent 2013;4:1043–50.
28. Hernandes DKL, Arrais CAG, Lima E De, Cesar PF, Rodrigues JA. Influence of resin cement shade on the color and translucency of ceramic veneers. J Appl Oral Sci 2016;24:391–6.
29. Seyidaliyeva A, Rues Dipl-Ing S, Evagorou Z, Hassel AJ, Rammelsberg P, Zenthöfer A. Color stability of polymer-infiltrated-ceramics compared with lithium disilicate ceramics and composite. J Esthet Restor Dent 2020;32:43–50.
30. Czigola A, Abram E, Kovacs ZI, Marton K, Hermann P, Borbely J. Effects of substrate, ceramic thickness, translucency, and cement shade on the color of CAD/CAM lithium-disilicate crowns. J Esthet Restor Dent 2019;31:457–64.
31. Dede DÖ, Sahin O, Özdemir OS, Yilmaz B, Celik E, Köroğlu AS. Influence of the color of composite resin foundation and luting cement on the final color of lithium disilicate ceramic systems. J Prosthet Dent 2017;117:138–43.
32. Chaiyabutr Y, Kois JC, LeBeau D, Nunokawa G. Effect of abutment tooth color, cement color, and ceramic thickness on the resulting optical color of a CAD/CAM glass-ceramic lithium disilicate-reinforced crown. J Prosthet Dent 2011;105:83–90.
33. International Commission on Illumination. CIE technical report: Colorimetry. CIE publication no. 15.3. Vienna, Austria: CIE Central Bureau; 2004.
34. Chang J, Da Silva JD, Sakai M, Kristiansen J, Ishikawa-Nagai S. The optical effect of composite luting cement on all ceramic crowns. J Dent 2009;37:937-43.
35. Dede DO, Armaganci A, Ceylan G, Cankaya S, Celik E. Influence of abutment material and luting cements color on the final color of all ceramics. Acta Odontol Scand 2013;71:1570-8.
36. Paravina RD, Ghinea R, Herrera LJ, Bona AD, Igiel C, Linninger M, *et al*. Color difference thresholds in dentistry. J Esthet Restor Dent 2015;27:S1–9.
37. Ota M, Ando S, Endo H, Ogura Y, Miyazaki M, Hosoya Y. Influence of refractive index on optical parameters of experimental resin composites. Acta Odontol Scand 2012;70:362-7.
38. Hariri I, Sadr A, Nakashima S, Shimada Y, Tagami J, Sumi Y. Estimation of the enamel and dentin mineral content from the refractive index. Caries Res 2013;47:18-26.
39. Ceylan G, Dede DÖ, Külünk S, Ongöz Dede F. Effects of refractive index solutions on the color of different luting cements. Acta Odontol Scand 2013;71:88-91.
40. Azzopardi N, Moharamzadeh K, Wood DJ, Martin N, van Noort R. Effect of resin matrix composition on the translucency of experimental dental composite resins. Dent Mater 2009;25:1564–8.
41. Güth J, Zuch T, Zwinge S, Engels J, Stimmelmayr M, Edelhoff D. Optical properties of manually and CAD/CAM-fabricated polymers. Dent Mater J 2013;32:865–71.
42. Arif R, Yilmaz B, Johnston WM. *In vitro* color stainability and relative translucency of CAD-CAM restorative materials used for laminate veneers and complete crowns. J Prosthet Dent 2019;122:160–6.
43. Azer SS, Rosenstiel SF, Seghi RR, Johnston WM. Effect of substrate shades on the color of ceramic laminate veneers. J Prosthet Dent 2011;106:179–83.
44. Kang YA, Lee HA, Chang J, Moon W, Chung SH, Lim BS. Color stability of dental reinforced CAD/CAM hybrid composite blocks compared to regular blocks. Materials (Basel) 2020;13:4772.
45. Ghinea R, Perez MM, Herrera LJ, Rivas MJ, Yebra A, Paravina RD. Color difference thresholds in dental ceramics. J Dent 2010;38:57–64.
46. Su Y, Xin M, Chen X, Xing W. Effect of CAD-CAM ceramic materials on the color match of veneer restorations. J Prosthet Dent 2021;126:255.e1-7.
47. Bolt RA, Bosch JJ, Coops JC. Influence of window size in small-window colour measurement, particularly of teeth. Phys Med Biol 1994;39:1133–42.