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Evaluation of color and translucency of colored and pre-colored monolithic zirconia ceramics

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Aim: The present *in vitro* study evaluated the Color and Translucency of Colored and Pre-colored Monolithic Zirconia ceramics.

Materials and methods: Twenty disks of Monolithic Zirconia with a diameter of 10 mm and a thickness of 1.5 mm were milled from White and Pre-colored Blanks. The disks milled from the White blanks were subjected to immersion in Coloring liquid. The disks were divided into Group I Colored Zirconia and Group II Pre-colored Zirconia. Twenty Co-Cr disks of diameter of 10°mm and thickness of 2.5°mm with a superficial hollow spacer of 8°mm diameter and 0.1°mm thickness were used in this study to serve as metallic substrates for the Zirconia disks. Using a Color Spectrophotometer, Color coordinates were observed. Color difference (AE) was measured over a white backdrop, metal substrate before, and metal substrate after cementation. The Translucency Parameter (TP) was measured over a white and black backdrop. Independent '*t*-test and Mann Whitney *U* test were used to analyze the Color difference and Translucency Parameter data, respectively.

Results: The Mean Color difference between Colored Zirconia and Pre-colored Zirconia against a white backdrop and metal substrate before cementation was 12.32 and 10.37, respectively. The Mean Color difference between Colored Zirconia and Pre-colored Zirconia against a white- backdrop and metal substrate after cementation was 2.48 and 3.41, respectively. The mean color difference between Colored and Pre-colored Zirconia against metal substrate before and after cementation was 8.37 and 9.13, respectively. Pre-colored Zirconia showed a statistically significantly higher color difference than Colored Zirconia ($P° < °0.05$). The mean Translucency parameter for Colored Zirconia and Pre-colored Zirconia was 7.73 and 8.83, respectively. The mean Translucency parameter for Colored Zirconia and Pre-colored Zirconia over metal substrate was 0.52 and 0.57, respectively.

Conclusion: On comparison of Colored and Pre-colored Zirconia from a white background to the metal substrate before and after cementation, the Colored Zirconia showed lower color difference than the Pre-colored Zirconia, which suggests that Colored Zirconia has better masking ability than Pre-colored Zirconia. However, comparing these two materials for Translucency, the Pre-colored Zirconia material demonstrated higher translucency than the Colored Zirconia material before and after cementation over the metal substrate.

Keywords: zirconium, zirconium oxide, cobalt chromium alloys, spectrophotometry, computer-aided design, ultrasonics

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Introduction

Shade matching in modern-day dentistry is extremely challenging to mirror adjacent natural tooth optics, especially in restoring anterior esthetics. Progressive research and innovations in material science have given more knowledge on the optical characteristics of natural teeth and the dental resources that help achieve the desired outcome (1–3).

Metal-ceramic restorations have good mechanical properties, clinically acceptable esthetics, and biological properties needed for the maintenance of periodontal health. The anterior esthetics of porcelain fused to metal crowns are restricted by the metal coping and the opaque porcelain layer required for masking the underlying shade of metal (2, 3).

Metal-free ceramic restorations are an alternative to porcelain fused to metal crowns to address the cosmetic constraints. All ceramic materials for example Zirconia, Lithium disilicate, Leucite-reinforced glass, and Glass-infiltrated Alumina are available for use as restorative material (3).

Leucite and Lithium disilicate reinforced glass ceramics are esthetic options in the anterior zone. However, as fixed dental prostheses are unable to endure the occlusal load of more than one pontic in the anterior zone, and as a result of their inadequate flexural strength, they are contraindicated in the load-bearing posterior regions. Zirconia was first discovered as a result of a necessity for a material that has mechanical capabilities comparable to those of Porcelain fused to metal (PFM), enhanced biocompatibility, and esthetics comparable to those of glass ceramics (4). Zirconia, being a white material, preserves the natural color of oral tissue than PFM.

Zirconia restorations are fabricated by the CAD-CAM process of Pre-sintered or completely sintered blanks. Completely sintered Zirconia has a lower volume of pores and greater strength due to its high density, resulting in longer milling times and rapid wearing of machining tools. Whereas partially sintered blanks are easy to mill but require further sintering to achieve improved strength and optical properties (5).

Zirconia is a whitish, opaque polycrystalline material that is layered with porcelain to obtain the natural appearance of restorations, but chipping of porcelain was a big clinical concern. Hence, Monolithic Zirconia was introduced. It has been considered the material for zones with minimal inter-arch space because it exhibits good mechanical properties even at minimal thickness (5, 6).

Zirconia is a semi-translucent material. However, its white and opaque nature makes it critical to replicate translucency and shade so that there is color compatibility between a Monolithic Zirconia restoration and natural dentition. Hence, Zirconia is colored in a pre-sintered manner for an enhanced natural-looking color match (7). Zirconia color shading could be conducted through various approaches, for example by adding metallic pigments to the nanopowder of Zirconia during fabrication of the blank, producing Pre-colored Blanks, or by immersion of White Zirconia in coloring liquid or by coating their surfaces with coloring liquid (5, 8, 9).

The Dental ceramic restoration esthetic value depends on the color, fluorescence, translucency, surface structure, and shape (7). In terms of esthetics, color, and translucent quality of dental ceramics are of utmost importance.(10) The more translucent ceramic systems create a more lifelike appearance while also allowing for great light transmission through the material. The translucency of a Monolithic Zirconia increases the difficulty in color matching, and the final color might be impacted by factors such as the thickness of the ceramic, substrate type, and the luting agent of a Monolithic Zirconia restoration (11). The use of a dark or high-opacity substrate, when compared with that achieved with a light or low-opacity substrate, results in a detectable color change after cementation. The thickness regulating its translucency and luting cement also influences the restoration's final color (12).

Zirconia high translucency has a requirement of a minimum thickness of 4.0mm to conceal the metallic abutment, although increasing ceramic-layer thickness is constrained by tooth preparation. Hence, various shades of luting agents and the ideal restoration thickness mask metal abutments. Resin cement is the luting agent of choice for Zirconia restorations due to its durable adhesion, good sealing properties, color, and solubilization. Previous research showed that a White opaque shade of resin cement of 100°μm to 300°μm could enhance the masking capability of Monolithic Zirconia restorations, yielding acceptable color matches over metallic and discolored backgrounds (11, 13, 14).

The kind of zirconia ceramic employed has an impact on the translucency of monolithic zirconia restorations. Zirconia ceramics have been created by manufacturers with varied visible light transmittance percentages ranging from 20 to 50 percent. Typically, core treatment is done with low-translucency zirconia, while full-contour zirconia restorations are done with high-translucency zirconia (15). Since Color and Translucency play an essential role in achieving acceptable esthetics in a restoration, these properties of Colored and Pre-colored Monolithic Zirconia materials need to be evaluated before and after cementation over a metal substrate.

Studies on evaluating color and translucency using a Color Spectrophotometer have been published. In a three-dimensional space called Lab, where L represents the value (lightness or darkness) coordinate, a represents the red-green chromaticity coordinate, and b represents the yellow-blue chromaticity coordinate, they assess spectral reflectance (4, 6). The difference in color between two different objects, denoted by the symbol ΔE, can be calculated by comparing the color coordinate values of every one of the objects. For dental professionals, $\Delta E > 1.0$ and $\Delta E < 3.7$ are accepted as the threshold values for perceptible and acceptable color

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changes, respectively. The TP is frequently utilized in the process of evaluating the degree to which dental materials are translucent. TP is the color variations among the values against a background of black-and-white, corresponding to common visual translucency assessments (7, 16, 17).

In literature there are several studies regarding the restoration thickness impact and shade of the resin cement on the translucency and color of High translucent Monolithic Zirconia restorations. Limited research has been published evaluating the parameters of the color and translucency of recently introduced High translucency Monolithic Zirconia fabricated with different coloring procedures. Hence, in light of this, the present *in vitro* research has been done to comparatively analyze the Translucency and Color of highly translucent Colored Zirconia disks, colored by immersion in coloring liquid of shade A2 and Pre-colored Zirconia disks of shade A2 over a metal substrate before and after cementation using Opaque Resin cement. The assumption that there will not be a substantial difference in color and translucency between Colored Zirconia and Pre-colored Zirconia serves as the basis for the current study's null hypothesis.

Materials and methods

A native file format for the stereolithography CAD software developed by 3D systems is called STL (Standard Tessellation Language).

It does not include any representation of color, texture, or other typical CAD model features; it merely depicts the surface geometry of a three-dimensional object. Using TINKERCAD (AutoDesk, Mac, 2017) Ceramic Disks of 10 Diameter and 1.5 mm thickness were drawn. STL, the file is imported CAD/CA software (DGSHAPE, Roland DG, Japan), and the design was done.

A blank of Translucent Zirconia Disks (Dental Direkt BIO ZX^2, A2, Germany) was mounted in the 5-axis milling machine (DWX-52D, DG SHAPE, Roland DG, Japan), and ten disk specimens of 1.5°mm thickness were milled in dry mode by utilizing the diamond coated burs for Zirconia. After completion of the milling process, specimens were separated from blank and finally finished.

Another blank of High Translucent Zirconia Disks (Dental Direkt BIO ZX^2, WHITE, Germany) was placed in the 5-axis milling machine (DWX-52D, DG SHAPE, Roland DG, Japan), and ten disk specimens of 1.5 mm thickness were milled in dry mode utilizing the diamond coated burs for Zirconia. After completion of the milling process, the specimens were separated from the blank and finally finished. Then, the specimens were immersed in A2 shade coloring liquid (DD Basic shade, A2) for 10°s and left to dry. Sintering was carried out at 1,530°C for 12 h in a sintering furnace (5F, Sinosteel Luoyan Research, China). After the sintering process, the specimens were finished with burs. At the end of the process, the specimens' thickness was evaluated by the use of Electronic Digital Vernier Caliper, and specimens with the dimensions of 10°mm°x°1.5 mm were thus obtained and assigned for Spectrophotometric Analysis.

A silicone index of the metal prototype was made with polyvinyl addition silicone putty consistency material (3M ESPE, USA) to fabricate twenty resin patterns made with Clear Auto-polymerizing acrylic resin (DPI Cold Cure RR, India). The resin patterns were trimmed with acrylic burs and finished with emery paper of grit sizes 3, 20, 220, and 180.

This whole assembly of 20 distributed patterns of plastic participated in the casting ring (Siliring, Delta Labs, Chennai, India) using phosphate-bonded investment material (Bellasun, Bego, Germany). The investment was utilized as per the recommendations of the manufacturer and had a powder-to-liquid ratio of 160°grams powder to 37 ml liquid. Before pouring the investment, mixing was completed using a vacuum mixer (The Continental, Whip Mix, Kentucky, USA) for 60°s. The silicone ring was taken from the bench after 20 min. The set investment was positioned in a burnout furnace (Technico, Ind Products, Chennai) such that melted resin could escape by having the crucible end hit the floor. The pre-heating approach was applied to the designs in the burnout furnace for 30 min at a temperature of 450°C. The investment mold was then continuously heated in the burnout furnace to 900°C at a rate of 8°C/min. The investment mold was stored in the machine of centrifugal casting (Delta Labs, Chennai, India) and aligned so the sprue hole approximated the ceramic crucible. Four Co-Cr casting alloy pellets were placed in the crucible. The reducing cone of the gas-oxygen torch flame was adjusted to 40mm, and the tip of the cone is used to make a rapid and clean melt. After the metal had melted, the lever has been released to let the machine spin and cast the metal into the mold. This happened once the mold had been prepared. Twenty different metal substructures were obtained using this approach. After Casting, the machine is still braked, and the investment is left to bench cool. The castings were denied, and the leftover surface investments were eliminated using a sandblaster (Delta labs, Chennai, India) with 110°µm of aluminum oxide media (Delta labs, Chennai, India). Sprues were severed using carborundum disks (Dentorium, New York, U.S.A), and nodules were eliminated through the tungsten carbide bur (Edenta, Switzerland). A steam cleaner was used to remove any surface pollutants from the surface of the metal that was going to be luted with the luting cement. This was done by cleaning the surface of the metal with pressurized steam. The metal average thickness was adjusted to 2.5°mm. The surface was air-abraded having 50°µm aluminum oxide at 75 psi pressure. Twenty Co-Cr metal substrates were obtained. Ten metal disks were assigned randomly to every group of High translucent Zirconia ceramics (n = 20). The Fabricated Test samples were grouped as

1. Group I – High translucent Zirconia 1 (Unshaded) disks stained in coloring liquid- A2 Shade (n = 10), (**Figure 1**).

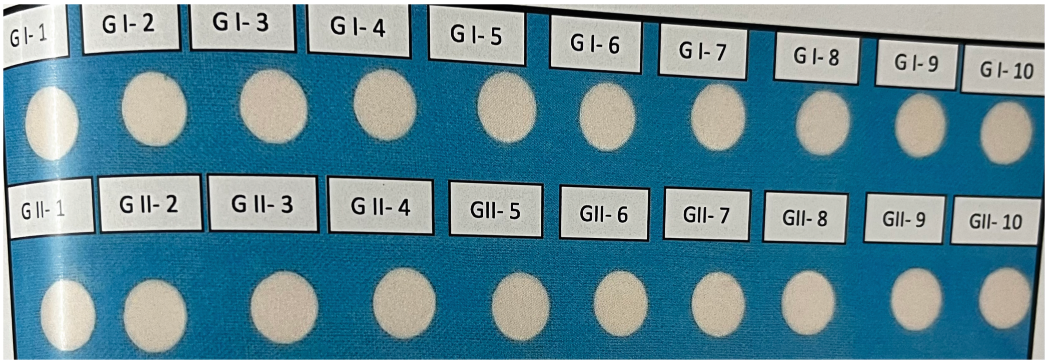

FIGURE 1 | Grouping of test samples, Group1: colored zirconia disks 10; Group 11:precolored zirconia disks.

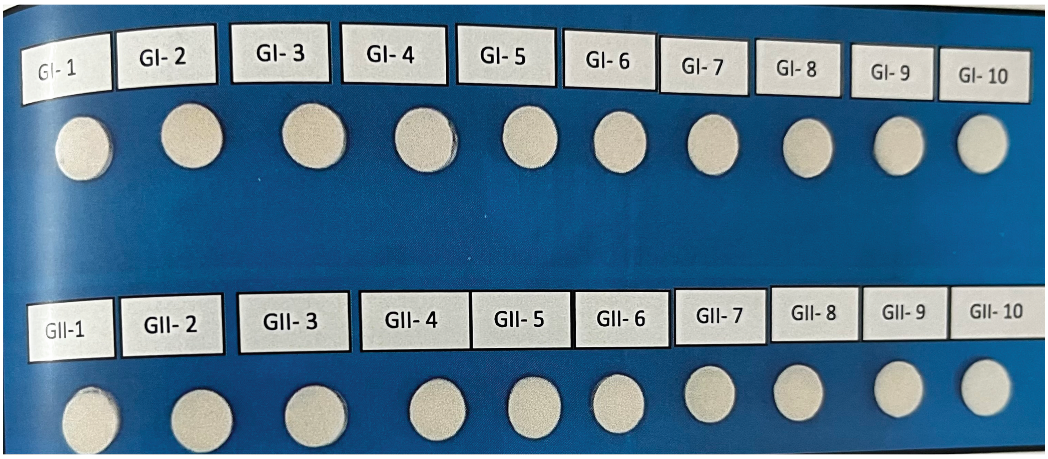

FIGURE 2 | Grouping of test samples after cementation.

2. Group II – High Translucent Zirconia Pre-shaded Disks- A2 Shade (n = 10), (**Figure 1**).

Prior to the Spectrophotometric Analysis test, samples of both Group I and Group II were ultrasonically cleaned (Beijing Ultrasonic Co., China) for 10 min and etched by using 10% hydrofluoric acid (Porcelain conditioner, Angelus, Brazil) for 30°s. Then, the disks were rinsed by using a spray of water for 1 min, followed by air-drying. Silane coupling agent (Silano, Angelus, Brazil) was painted on the etched surface with a microtip applicator brush (Denmax microtip applicator, India). Thus, 20 Zirconia disk samples were surface treated before luting.

The specimens' color parameters (L*a*b) were determined with a Color Spectrophotometer at a 360—740°nm wavelength by placing against the standard white background and black background. The L*, a*, and b* parameters were calculated as per the CIE (Commission Internationale de l'Eclairage). The specimens were placed on a metal substrate with distilled water between the Zirconia disk and metal substrate against a standard white and black background, and the color parameters (L*a*b) of the specimens were calculated by using the Color Spectrophotometer in 360—740°nm wavelength. The L*, a*, and b* parameters were calculated as per the CIE. The automated Resin cement (Calibra universal, Opaque shade, Dentsply Sirona, Germany) was delivered onto the sandblasted Co-Cr substrate of the metal disc. The Zirconia disk was placed over this, and the force of 20N was added to the sample for 4 min and 30°s; excessive was removed at the gel stage after 45°s of seating over the metal substrate (**Figure 2**). The specimens cemented on a metal substrate were placed against a standard white and black background, and the parameters of color (L*a*b) of the specimens were calculated by using a Color Spectrophotometer at a 360—740°nm wavelength (**Figures 3**, **4**). According to the CIE, the L*, a*, and b* parameters were measured.

Each specimen of color was calculated by using the Color Spectrophotometer according to the CIELAB, CIE system, operating in the length range of light spectrum λ = 360—740 nm. According to the commission system, every experimental group's color was determined in 3 coordinate dimensions of L* a* b.

L*- Lightness ranges from 0 [black] to 100 [white]
a*- red/green value (—a* = green; +a* = red)
b*- yellow/blue value (—b* = blue; +b* = yellow).
ΔE value was calculated according to the formula,

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

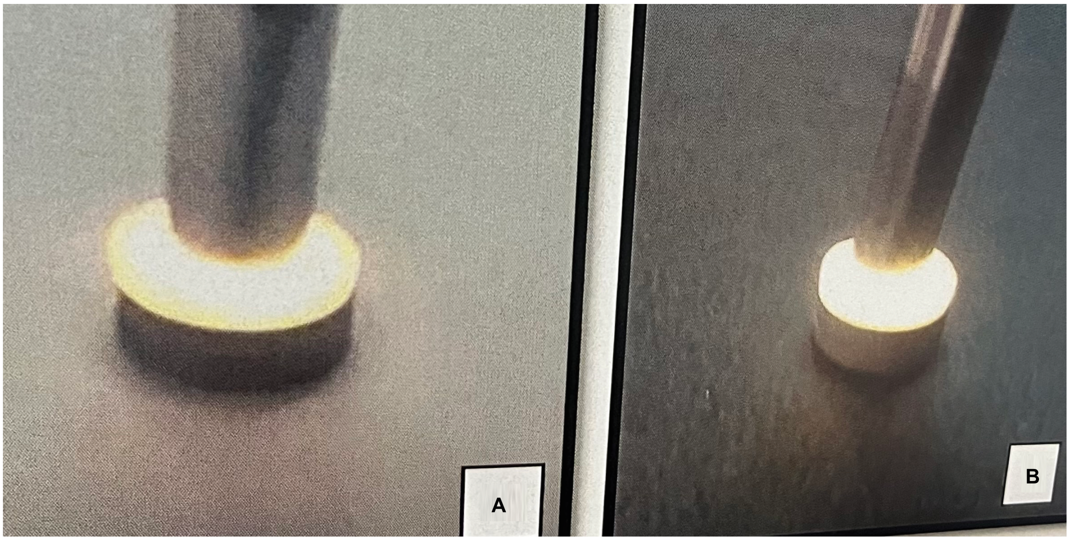

FIGURE 3 | Spectrophotometric analysis of Group1 colored zirconia disks cemented over metal substrate against (A)- white background, (B)-black background.

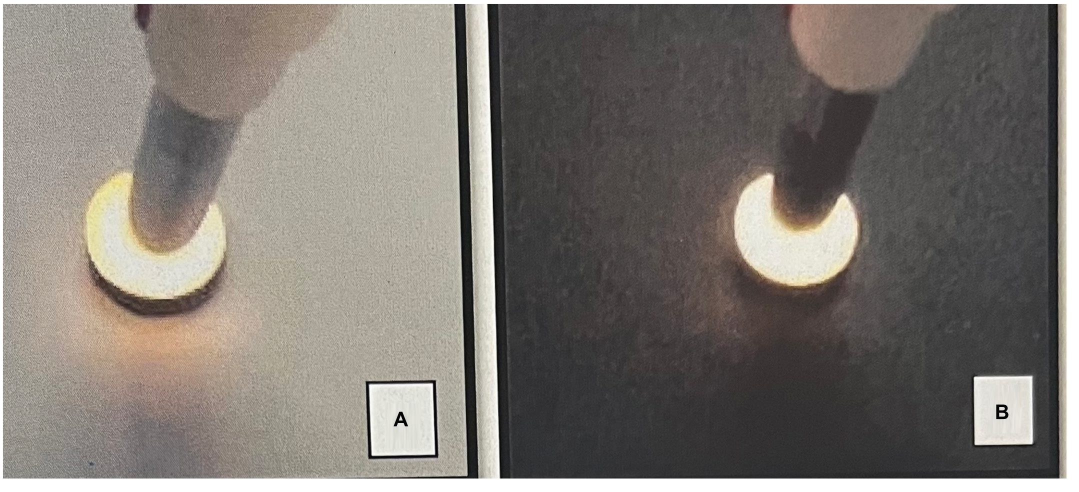

FIGURE 4 | Spectrophotometric analysis of Group 11 colored zirconia disks cemented over metal substrate against (A)- white background, (B)-black background.

ΔL- the difference in lightness
Δa -difference in a coordinates
Δb -the difference in b coordinates
ΔE –TOTAL COLOUR DIFFERENCE

These differences of the color are expressed as ΔL* Δa* Δb* (Δ represents "delta," which denotes a difference. Translucency Parameter (TP), which directly relates to everyday visual evaluations, has been explained as the material's color difference of a certain "thickness over black and white backgrounds." By calculating the difference in color between measurements over black & white backgrounds, TP was determined.

The Translucency Parameter (TP) was measured as per :

$$TP = [(L^*B - L^*W)^2 + (a^*B - a^*W)^2 + (b^*B - b^*W)^2]^{1/2}$$

Δ L*B- L value of Black Background
Δ L*W- L value of White Background
Δ a*B- a value of Black Background
Δ a*W- a value of White Background
Δ b*B- b value of Black Background
Δ b*W- b value of White Background"

that subscripts as B and W are the measurements on backgrounds of black and white.

Translucency Parameter (TP) value 0 corresponds to entirely opaque and 100- Corresponds to completely translucent, (Greater Translucency Parameter Value means Higher Actual Translucency), Translucency measurements were performed with a Color spectrophotometer.

The results were tabulated, and the data were statistically evaluated by utilizing the SPSS-16 software.

Results

The mean ΔE value of Group I Colored and Group II Pre-colored Zirconia disks against white background was 5.07, showing a significant color difference between Colored and Pre-colored Zirconia. The mean ΔE of Group I Colored as well as Group II Pre-colored Zirconia disks over metal substrate before cementation was 3.28, which is above the perceptibility threshold value but below the acceptability threshold value of ΔE 3.7, which implies that there is an acceptable color difference between Colored and Pre-colored Zirconia over a metal substrate before cementation.

The mean ΔE of Group I Colored & Group II Pre-colored Zirconia disks metal substrate after cementation was 4.00, showing a significant color difference between Colored and Pre-colored Zirconia over the metal substrate after cementation. The mean value of ΔE was 10.37 for Group I Colored Zirconia, and the mean value of ΔE was 12.32 for Group II Pre-colored Zirconia against a White Background and metal substrate before cementation. The color difference values for both groups were above the perceptibility and acceptability thresholds (ΔE > 3.7) before cementation over a metal substrate, which suggested that both Colored and Pre-colored Zirconia did not mask the underlying metal substrate. The color difference (ΔE) rise in Group I and Group II Zirconia disks, under the impact of metal disks made of Co-Cr, is because of the reduction in values of L*a*b*. Between Colored and Pre-colored Zirconia, the mean ΔE increased in Pre-colored Zirconia, which showed that Colored Zirconia had better masking ability than Pre-colored Zirconia in the presence of a metal substrate. However, ideal masking ability was not achieved (ΔE > 3.7). The mean ΔE value was 2.58 for Group I Colored Zirconia, and the mean ΔE value was 3.41 for Group II Pre-colored Zirconia against White Background and metal substrate after cementation (**Tables 1–7**).

The mean ΔE value was 8.37 for the Group I Colored Zirconia and 9.13 for Group II Pre-colored Zirconia against metal substrate before and after cementation. The mean Color difference value of Colored Zirconia is lower than Pre-colored Zirconia, which implies that Colored Zirconia has better masking ability than Pre-colored Zirconia. However, ideal masking ability was not achieved (ΔE > 3.7), (**Tables 8–15**).

TABLE 1 | Basic data of L*a*b* values for Group I Colored Zirconia disks against White Background and Black Background.

Sample no	Group I					
	White background			Black background		
	L	a	b	L	a	b
1	86.4	2.2	26.2	80.5	0.9	22.0
2	86.7	2.3	26.9	80.5	1.1	22.7
3	86.9	2.1	26.1	80.9	0.8	21.7
4	87.2	1.9	26.7	81.6	0.5	22.3
5	87.0	1.9	26.5	80.9	0.7	22.3
6	87.9	2.1	26.2	81.5	0.9	22.0
7	86.4	2.3	25.9	80.5	0.8	21.9
8	86.2	2.4	27.5	80.0	1.1	23.6
9	86.7	2.0	26.3	81.0	0.8	22.0
10	86.2	2.3	26.6	80.3	1.0	22.3
Mean	86.76	2.15	26.49	80.77	0.86	22.28

Inference: 1. The mean "L" value was 86.76 against a White Background and 80.77 against a Black Background. 2. The mean "a" value was
2. 15 against White Background and 0.86 against Black Background
3. The maximum mean "b" value was 26.49 against a White Background and 22.28 against a Black Background.

TABLE 2 | Basic data of L*a*b* values for Group II Pre-colored Zirconia disks against White Background and Black Background.

Sample no	Group II					
	White background			Black background		
	L	a	b	L	a	b
1	90.9	1.2	29.7	83.7	−0.2	24.4
2	91.8	1.0	28.7	84.8	−0.2	23.7
3	91.7	1.0	29.4	84.6	−0.3	24.0
4	90.3	0.9	27.9	83.7	−0.3	22.0
5	91.0	1.1	28.9	83.5	−0.1	23.7
6	91.2	1.1	28.8	83.7	−0.2	23.6
7	90.0	0.9	29.1	84.1	−0.4	23.5
8	90.5	0.8	28.6	84.5	−0.1	23.2
9	91.2	0.9	28.8	84.0	−0.3	23.7
10	91.4	1.0	29.2	84.1	−0.3	24.0
Mean	91.00	0.99	28.91	84.07	−0.24	23.58

Inference: 1. The mean "L" value was 91.00 against a White Background and 84.07 against a Black Background
2. The mean "a" value was 0.99 against White Background and −0.24 against Black Background
3. The mean "b" value was 28.91 against a White Background and 23.58 against Black Background.

Discussion

Shade compatibility with adjacent natural teeth, especially when rehabilitating the maxillary anterior aesthetic zone, is challenging (7, 18–20).

It is claimed that Lithium Disilicate Glass-ceramics are more translucent than Zirconia restorations as they are predominantly glass ceramics, while Zirconia is a polycrystalline material with high opacity (8). However, the translucency of Lithium when these restorations are luted over tanned dentin or metal foundation restorations, the presence of dilicates impairs the perceived color (4, 11, 18). So, with low translucency, Zirconia was preferred to mask dark substrate (1, 12, 19, 21).

Zirconia frameworks were conventionally veneered with porcelain to obtain a shade match of adjacent natural

TABLE 3 | Basic data of L*a*b* values for Group I Colored Zirconia disks placed over the metal substrate before cementation against White Background and Black Background.

Sample no	Group I					
	White background			Black background		
	L	a	b	L	a	b
1	78.1	0.5	20.5	78.1	0.5	20.4
2	78.3	0.6	20.8	78.1	0.7	21.1
3	78.3	0.5	20.3	78.6	0.4	20.1
4	78.7	0.2	20.9	79.6	0.1	20.4
5	78.5	0.3	20.5	78.4	0.3	20.5
6	78.5	0.4	21.5	78.9	0.3	20.6
7	78.4	0.3	20.3	79.2	0.5	20.1
8	77.6	0.7	21.9	77.4	0.7	21.9
9	78.0	0.4	20.8	78.7	0.4	20.6
10	77.9	0.7	21.0	77.9	0.7	20.8
Mean	78.23	0.46	20.85	78.49	0.46	20.65

Inference: 1. The mean "L" value was 78.23 against a White Background and 78.49 against a Black Background
2. The mean "a" value was 0.46 against White Background and 0.46 against Black Background
3. The mean "b" value was 20.85 against White Background and 20.65 against Black Background.

TABLE 4 | Basic data of L*a*b* values for Group II Pre-colored Zirconia disks placed over the metal substrate before cementation against White Background and Black Background.

Sample no	Group II					
	White background			Black background		
	L	a	b	L	a	b
1	81.2	−0.6	22.2	81.6	−0.6	22.1
2	81.9	−0.6	21.9	82.2	−0.6	21.7
3	81.3	−0.6	21.7	82.2	−0.7	21.0
4	81.5	−0.5	21.3	81.9	−0.5	21.2
5	80.8	−0.5	21.0	80.6	−0.5	21.3
6	81.0	−0.5	21.5	81.5	−0.6	21.3
7	81.1	−0.7	21.5	81.2	−0.7	21.6
8	80.1	−0.6	23.4	80.6	−0.6	21.9
9	80.9	−0.6	21.6	80.9	−0.6	21.8
10	81.1	−0.6	22.1	81.6	−0.5	21.8
Mean	81.09	−0.58	21.82	81.43	−0.59	21.57

Inference: 1. The mean "L" value was 81.09 against a White Background and 81.43 against a Black Background
2. The mean "a" value was -0.58 against White Background and −0.59 against Black Background
3. The mean "b" value was 21.82 against a White Background and 21.57 against a Black Background.

TABLE 5 | Basic data of L*a*b* values for Group I Colored Zirconia disks placed over metal substrate after cementation against White Background and Black Background.

Sample no	Group I					
	White background			Black background		
	L	a	b	L	a	b
1	83.4	1.3	25.3	82.9	1.4	25.6
2	84.5	2.1	26.3	84.8	2.1	26.6
3	84.9	1.7	26.1	84.6	1.6	25.8
4	85.1	1.7	26.7	84.9	1.6	26.8
5	84.7	1.6	26.5	84.9	1.6	25.8
6	84.9	1.6	26.5	84.8	1.6	26.5
7	84.8	1.6	26.7	84.2	1.6	26.7
8	84.0	2.0	27.2	83.9	2.0	27.3
9	84.9	1.9	26.3	84.8	1.9	26.2
10	82.7	1.3	24.9	82.8	1.4	25.0
Mean	85.39	1.68	26.25	84.26	1.68	26.13

Inference: 1. The mean "L" value was 85.39 against a White Background and 84.26 against a Black Background
2. The mean "a" value was 1.68 against White Background and 1.68 against Black Background
3. The mean "b" value was 26.25 against a White Background and 26.13 against Black Background.

TABLE 6 | Basic data of L*a*b* values for Group II Pre-colored Zirconia disks placed over metal substrate after cementation White Background and Black Background.

Sample no	Group II					
	White background			Black background		
	L	a	b	L	a	b
1	88.0	0.7	28.1	87.9	0.6	27.8
2	88.4	0.7	27.7	88.3	0.7	26.8
3	88.9	1.1	28.3	89.1	0.9	27.8
4	88.7	1.8	25.9	88.1	1.2	26.5
5	87.4	0.3	26.8	87.5	0.3	26.5
6	87.6	0.7	27.5	88.0	0.8	27.8
7	88.0	1.9	28.1	87.7	2.0	28.4
8	88.6	1.4	27.0	86.7	1.4	26.5
9	87.9	2.0	26.5	88.1	2.0	25.8
10	86.9	1.3	27.5	86.6	1.3	27.8
Mean	89.04	1.19	27.34	87.8	1.12	27.17

Inference: 1. The mean "L" value was 89.04 against a White Background and 87.8 against Black Background
2. The mean "a" value was 1.19 against White Background and 1.12 against Black Background
3. The mean "b" value was 27.34 against White Background and 27.17 against Black Background.

teeth. However, the major drawback of such restorations is the chipping of the veneering porcelain. Hence, new High translucent Monolithic Zirconia restorations were developed by doping more yttria ions (4—8%) and developing cubic phase crystal lattice that has a higher visible light transmittance of 40% to 50%, It improves esthetics by allowing light to flow through with less dispersion (8, 14, 22, 23).

TABLE 7 | Evaluation of Color difference (ΔE) of Group I Colored Zirconia disks and Group II Pre-colored Zirconia disks against White Background.

Sample no	ΔE
1	5.78
2	5.56
3	5.92
4	3.47
5	4.73
6	4.31
7	5.01
8	4.71
9	5.26
10	5.95
Mean	5.07

Inference: The mean ΔE of Group I Colored and Group II Pre-colored Zirconia disks against a white background is 5.07, which is above the perceptibility and acceptability threshold of ΔE 1.0 and ΔE 3.7, respectively, which implies that there is a significant color difference between Colored and Pre-colored Zirconia.

TABLE 8 | Evaluation of Color difference (ΔE) of Group I Colored Zirconia disks and Group II Pre-colored Zirconia disks against metal substrate before cementation.

Sample no	ΔE
1	4.32
2	3.95
3	3.48
4	2.91
5	2.48
6	2.65
7	3.11
8	3.19
9	3.17
10	3.62
Mean	3.28

Inference: The mean ΔE of Group I Colored and Group II Pre-colored Zirconia disks metal substrate before cementation is 3.28, which is above the perceptibility threshold value of ΔE 1.0 but below the acceptability threshold value of ΔE 3.7, which implies that there is an acceptable color difference between Group I Colored and Group II Pre-colored Zirconia over a metal substrate before cementation.

Translucent copings may negatively affect esthetic results and interfere with the final color of the restoration in specific clinical situations, including discoloration, metal posts and cores, and shaded dental core materials. Optical properties of High Translucency Zirconia-based restoration are affected by a colored background restoration, especially when restoring anterior esthetics (6).

Zirconia blanks usually have a white, opaque color, and to achieve a more natural-looking color match, they were colored to different shades of Vita Classical Shade guide system by immersing in coloring liquid or by adding metallic pigments to the Zirconia nanopowder to fabricate Pre-colored Zirconia Blanks. While the coloring liquid's concentration heavily influences coloring, using coloring liquids is the final shade. Coloration can be achieved with concentrations as low as 0.01 mol percent (24). Few studies that analyzed the impact of color-shading procedures on the structure of Zirconia-based restorations have shown

TABLE 9 | Evaluation of Color difference (ΔE) of Group I Colored Zirconia disks and Group II Pre-colored Zirconia disks against metal substrate after cementation.

Sample no	ΔE
1	5.41
2	4.37
3	4.60
4	3.68
5	3.01
6	3.01
7	3.50
8	4.64
9	3.00
10	4.85
Mean	4.00

Inference: The mean ΔE of Group I Colored and Group II Pre-colored Zirconia disks metal substrate after cementation is 4.00, which is above the perceptibility and acceptability threshold of ΔE 1.0 and ΔE 3.7, respectively, which implies that there is a significant color difference between Group I Colored and Group II Pre-colored Zirconia over a metal substrate after cementation.

TABLE 10 | Comparison of Color difference (ΔE) of Group I Colored Zirconia disks and Group II Pre-colored Zirconia disks against White Background and metal substrate before cementation.

Sample no	Group 1	Group 2
1	10.21	12.39
2	10.51	12.70
3	10.50	13.03
4	10.43	11.08
5	10.52	13.00
6	10.64	12.64
7	9.96	11.81
8	10.40	11.30
9	10.41	12.65
10	10.13	12.61
Mean	10.37	12.32

Group	Mean ΔE	SD	*p*-value
I	**10.37**	0.20	0.000*
II	**12.321**	0.68	

*P value <0.05 indicates significance.
Inference: The mean Color difference ΔE values of both the groups are higher than the perceptibility and acceptability threshold values of 0.1 and 3.7, respectively, implying an acceptable color difference. However, the Group II Pre-colored Zirconia exhibited statistically significantly higher mean ΔE values than Group I Colored Zirconia.

TABLE 11 | Comparison of Color difference between Group I Colored Zirconia disks and Group II Pre-colored Zirconia disks against a white background and metal substrate after cementation.

Sample no	Group 1	Group 2	
1	3.25	3.34	
2	2.28	3.55	
3	2.03	3.01	
4	2.10	2.71	
5	2.12	4.24	
6	3.25	3.84	
7	2.80	2.44	
8	2.25	2.08	
9	1.80	4.17	
10	4.00	4.81	
Mean	**2.58**	**3.41**	
Group	**Mean ΔE**	**SD**	***p*-value**
I	**2.58**	0.70	0.031*
II	**3.41**	0.86	

Inference: The mean Color difference ΔE value of Group I Colored Zirconia and Group II Pre-colored Zirconia is above the perceptibility threshold value of 1.0 but below the acceptability threshold value of 3.7, which implies it has an acceptable color difference value. On comparison of these groups, Group II exhibited statistically significantly higher ΔE values than Group I Colored Zirconia.
**P* value $<$ 0.05 indicates significance.

TABLE 12 | Comparison of Color difference (ΔE) of Group I Colored Zirconia disks and Group II Pre-colored Zirconia disks against metal substrate before cementation and after cementation.

Sample no	Group 1	Group 2	
1	7.19	9.09	
2	8.42	8.80	
3	8.86	10.20	
4	9.01	9.01	
5	8.86	8.82	
6	8.65	9.00	
7	9.14	9.89	
8	8.41	9.44	
9	8.95	8.93	
10	6.21	8.14	
Mean	8.37	9.13	
Group	**Mean ΔE**	**SD**	***p*-value**
I	**8.37**	0.94	0.043*
II	**9.13**	0.58	

Inference: Both groups' mean Color difference ΔE values are higher than the perceptibility and acceptability threshold values of 0.1 and 3.7, respectively. However, the Group II Pre-colored Zirconia exhibited statistically significantly higher mean ΔE values than Group I Colored Zirconia.
**P* value $<$ 0.05 indicates significance.

that color-shading procedures impact the structure of the Zirconia framework in various investigations (24, 25).

The overall behavior of the optical All-ceramic restoration depends on 3 factors: (a) the primary abutment substrate, (b) the resin luting agent, and (c) the ceramic material structure (8, 25). Color matching is critical for masking substrates which are discolored in the anterior esthetic region, particularly when the substrates are metallic cast post

TABLE 13 | Comparison of Translucency Parameter (TP) of Group I Colored Zirconia disks and Group II Pre-colored Zirconia disks against White and Black backgrounds.

Sample no	Group 1	Group 2	
1	7.35	9.04	
2	7.58	8.68	
3	7.55	9.01	
4	7.25	8.93	
5	7.5	9.20	
6	7.74	9.21	
7	7.28	8.23	
8	7.43	8.12	
9	7.24	8.90	
10	7.41	9.05	
Mean	**7.43**	**8.83**	
Group	**Mean TP**	**SD**	***p*-value**
I	**7.43**	0.16	0.000*
II	**8.83**	0.38	

Inference: On comparison of mean Translucency Parameter (TP) values between Group I Colored Zirconia disks and Group II Pre-colored Zirconia disks against White Background and Black Background, the mean TP values of Group II Pre-colored Zirconia disks are statistically significantly higher than those of Group I Colored Zirconia disks.
**P* value $<$ 0.05 indicates significance.

TABLE 14 | Comparison of Translucency Parameter (TP) of Group I Colored Zirconia disks and Group II Pre-colored Zirconia disks over the metal substrate before cementation against White and Black Background.

Sample no	Group 1	Group 2	
1	0.40	0.41	
2	0.37	0.36	
3	0.37	1.14	
4	1.03	0.41	
5	0.10	0.36	
6	0.98	0.54	
7	0.84	0.14	
8	0.20	1.58	
9	0.72	0.20	
10	0.20	0.59	
Mean	0.52	0.57	
Group	**Mean TP**	**SD**	***p*-value**
I	**0.52**	0.16	0.000*
II	**0.57**	0.38	

Inference: On comparison of mean Translucency Parameter (TP) values between Group I Colored Zirconia disks and Group II Pre-colored Zirconia disks against White Background and Black Background, the mean TP values of Group II Pre-colored Zirconia disks are higher than those of Group I Colored Zirconia disks and it was statistically insignificant.
**P* value $<$ 0.05 indicates significance.

TABLE 15 | Comparison of Translucency Parameter (TP) of Group I Colored Zirconia disks and Group II Pre-colored Zirconia disks over metal substrate after cementation against White and Black Background.

Sample no	Group 1	Group 2
1	0.59	0.33
2	0.42	0.90
3	0.43	0.57
4	0.24	1.03
5	0.10	0.31
6	0.72	0.50
7	0.60	0.43
8	0.14	1.96
9	0.14	0.72
10	0.17	0.42
Mean	**0.35**	**0.71**

Inference: On comparison of mean Translucency Parameter (TP) values between Group I Colored Zirconia disks and Group II Pre-colored Zirconia disks against White Background and Black Background, the mean TP values of Group II Pre-colored Zirconia disks are statistically significantly higher than those of Group I Colored Zirconia disks.

and abutment of the titanium implant (21, 26, 27). To resolve this issue, Zirconia restorations of thickness ranging from 0.5 to2.0 are recommended (21, 22, 28). Tabatabaian et al. (9) showed that the Monolithic Zirconia minimum thickness must be 1°mm for masking discolored backgrounds. Two recommendations may be made in clinical situations having a dark shade or present foundation of metal: employing an opaque cement and thickening the repair. An opaque cement might mask the background, and a rise in the thickness of Zirconia enhances its masking capability having a resultant reduction in the translucency of the final restoration (11, 29, 30). According to Niu et al. (11) while testing at 50°μm and 100°μm as the thickness of the film on a metal substrate, the White opaque cement produced an acceptable match of shade and showed higher masking performance than the cement of other shades. Additionally, according to Bacchi et al. (30) opaque cements enhanced the capacity of monolithic Zirconia restorations to cover up metallic and discolored backgrounds.

In the current study, the resin luting cement thickness was standardized at 100°μm, which is in the maximum tolerable marginal adaptation of 120°μm, which is advocated for luting cement.

The mismatch of the shade of the finished restoration frequently leads to remaking of the restoration because the dentist or patient considers it to be unaesthetic. During the process of shade selection, the use of conventional shade tabs is a common mode of operation; however, the utilization of a spectrophotometer has been subjected to extensive research and is now regarded as a standard method. A popular spectrophotometric approach to assess the color coordinates of the translucency characteristic is the CIE Lab system. It has been extensively used in several *in vitro* experiments to assess the potential of all-ceramic systems to mask against various substrates (16–19).

A Dental Color Spectrophotometer was used to measure the L*a*b* values of the Zirconia disks against a white background, against a substrate of the metal before cementation, and after cementation with an Opaque resin cement was observed for calculating Color difference (ΔE) using the CIELAB formula.

According to the findings of many investigations, the acceptable threshold for ΔE can range anywhere from 1.7 to 6.8 while the detectable threshold for ΔE can be anywhere from 1.0 to 2.6. According to the findings of this study, an ΔE value of 1 was deemed to be the perceptibility barrier, while an ΔE value of 3.7 was deemed to be the acceptability level (29).

Dai et al. (21) studied the masking ability of high-translucency Monolithic Zirconia over the metal substrate. They concluded that the opaque shade of luting agents used for cementing Monolithic Zirconia of thickness greater than 1.5°mm ideally masked the Co-Cr metal substrate. This was confirmed in the current study while evaluating the color difference of Monolithic Zirconia of 1.5°mm thickness, the mean ΔE between Colored Zirconia disks and Pre-colored Zirconia disks against metal substrate after cementation with the White opaque resin cement, which showed a marked reduction in color difference values than before cementation, showed that Color difference values of both Colored and Pre-colored Zirconia is acceptable ($\Delta E < 3.7$) against metal substrate after cementation. However, Colored Zirconia had better masking ability than Pre-colored Zirconia over a metal substrate, which is indicated by the lower color difference value of Colored Zirconia than Pre-colored Zirconia. A drop in ΔE was noticed in both groups, which was owing to the increased L*a*b* values, and this is what the study carried out by Niu et al. (11) found when they analyzed the white opaque cement impact on the color difference of zirconia against a Co-Cr metal substrate.

Translucency Parameter (TP) values were obtained for the test samples using the CIELAB formula by substituting the L*a*b* values of the white background with the black background obtained. TP explained as the material color difference of a provided thickness over the black and white backgrounds and corresponds directly to regular visual evaluations. A TP value of zero agrees to the material that is completely opaque, and a more excellent TP value means a higher actual material translucency. This study utilized the standard white A4 chart as a white background as well as a black A4 chart to simulate the black background.

The mean "TP" value was 7.43 for Group I, 8.83 for Group II against White and Black Backgrounds. The mean "TP" value was 0.52 for Group I and 0.57 for Group II before cementation over metal substrate against a White and Black Background. It was 0.35 for Group I and 0.67 for Group II after cementation over metal substrate against a White and Black Background.

This study revealed that Pre-colored Zirconia samples have higher mean TP values than Colored Zirconia, indicating higher translucency observed in Zirconia restorations fabricated using Pre-colored Zirconia blanks. The effect of a metal substrate displayed no major variations and reduced the translucency of both the test sample groups before cementation. However, after cementation, the opaque resin cement induced an increased TP value for Group II Pre-colored Zirconia compared to Group I Colored Zirconia, indicating a cement-induced increased translucency with statistical significance.

In a previous study, Colored Zirconia specimens were sintered according to one of three different final sintering temperatures. The researchers came to the conclusion that increased sintering temperatures resulted in the rise in the translucency by increment in the size of the grain, sintered density, and reduced porosity, which ultimately provided a more compact crystalline structure to Zirconia having a minimal effect on the biaxial flexural strength (31, 32). Their evaluation showed that Pre-colored Zirconia had a higher mean translucency than Colored Zirconia. Kim et al. and Yilmaz et al. have also reported a higher mean translucency for Pre-colored Zirconia cores than that of Zirconia cores immersed in coloring liquid (22, 29). This was confirmed in the present study that Pre-colored Zirconia had a higher Translucency than Colored Zirconia even after cementation with Opaque resin cement. However, comparing Pre-colored and Colored Zirconia over a metal substrate, these materials showed similar translucency.

In their study, Malkondu et al. (33), Wang et al. (34), and Kurtulmus et al. (22) came to the conclusion that the Zirconia translucency values dropped as the outcome of a rise in the overall thickness of the specimens as well as an increase in chromaticity and opacity brought about by the application of cement. This was confirmed in the present study that the mean translucency values have reduced in the presence of a metal substrate before and after cementation, which implies that the presence of a metal substrate had decreased the translucency of these two Zirconia materials. However, comparing Mean TP values before and after cementation, the translucency effect had increased in the presence of Opaque resin cement.

The study's findings indicate that the null hypothesis is not correct. The current investigation had a few shortcomings; the contrast ratio was evaluated to better understand the optical properties, Zirconia materials of varying thicknesses, the resin cement shade influence on the optical color of various ceramics, and variants of Zirconia Ceramics. This would have produced more predictable results. To determine whether or not they are suitable for masking, more recent metal-free core materials like NanoZirconia and PEEK, each of which has varying degrees of opacity, should be tested.

The current study offered extra scientific support to help solve the clinical difficulty of visually masking dark substrates utilizing monolithic Zirconia restorations. These dark substrates include metal foundations. However, further research is required to determine whether or not aggregate the framework thickness, along with the utilization of opaque cement and opaque pigments, can produce color contrasts that are acceptable in comparison to metal substrates.

Conclusion

On comparison of Color, from a white background to a metal substrate before and after cementation, Colored Zirconia showed lower color difference than the Pre-colored Zirconia, which suggests that Colored Zirconia has better masking ability than Pre-colored Zirconia. But on comparison of these two materials for Translucency, Pre-colored Zirconia material demonstrated higher translucency than the Colored Zirconia material before and after cementation over the metal substrate.

Author contributions

PG: collection of literature, concept and design, data collection, manuscript preparation and editing. VM: sample preparation, collection of articles, manuscript preparation. JS, HR, and AS: manuscript review. All authors contributed to the article and approved the submitted version.

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