Original Article

The Effect of Try-in Paste Shade and Framework Design on the Color Characteristics of Dental Zirconia Restorations

Abolghasem Mohammadi¹, DDS, MSc; Alireza Gerami², DDS; Sara Tavakolizadeh¹, DDS, MSc; Rahab Ghoveizi¹, DDS, MSc; Ehsan Rouhollahpour Ahangar³, DDS;

¹ Dept. of Prosthodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

² Graduate Student, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

³ Postgraduate Student Dept. of Prosthodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

KEY WORDS	ABSTRACT
Computer-Aided	Background: Favorable esthetic and mechanical qualities, together with rapid advance-
Design;	ments in CAD/CAM technology, have increased the adoption of zirconia restorations. De-
Crowns;	spite acceptable optical characteristics of zirconia, achieving natural tooth color resemblance
Dental Prosthesis	remains challenging.
Design;	Purpose: This study was conducted to determine how the try-in paste shade, tooth region,
Dental Cements;	and framework design affect the color properties of zirconia restorations.
Zirconia;	Materials and Method: In this in vitro study, a maxillary central incisor was prepared and
Try-in paste;	scanned. Frameworks with four different designs were fabricated. Ten crowns were de-
	signed in each group categorized as simple core (SC), dentin core (DC), trestle design core
	(TC), and monolithic crown (MC). Veneering was performed for all groups except MC.
	Subsequently, all crowns were cemented with try-in paste Bisco CHOICE 2 cement in
Received: 25 November 2023; Revised: 20 April 2024; Accepted: 26 October 2024;	shades A1-A3 and B1. The color data (Lab) were determined using the SpectroShade Micro
	II device. Color difference (ΔE) with the Lab B2 color sample as the target color was calcu-
Convright	lated using the CIE ΔE 2000 formula. Data analysis was performed using the repeated
© Journal of Dentistry, this is an open access article distribut- ed under the terms of the Creative Commons Attribution 4.0 International License, (http://creativecommons. org/licenses/by/4.0/) which permits reusers to copy and	measure ANOVA test.
	Results: Zirconia core design, tooth region and cement shade, significantly impacted the ΔE
	and there were interactions among these factors. The highest ΔE was observed when no
	cement was used, while the lowest ΔE was observed with A2 cement. Among the various
	framework designs, the lowest and highest ΔEs were observed in MC and, SC frames, re-
redistribute the material in any	spectively (p Value < 0.05).
medium or format if the origi-	Constant and the light of the Coding of Communication of the minimum AF and he calify doubt

Conclusion: In the light of the findings of current study, minimum ΔE can be achieved with trestle design framework at the middle portion of the tooth. The try-in paste shade also has a considerable impact on the final ΔE value.

Corresponding Author: Rouhollahpour Ahangar E, Dept. of Prosthodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran. Tel: +98-2122181142 Email: ehsanrhp@gmail.com

Cite this article as: Mohammadi A, Gerami A, Tavakolizadeh S, Ghoveizi R, Rouhollahpour Ahangar E. The Effect of Try-in Paste Shade and Framework Design on the Color Character-istics of Dental Zirconia Restorations. J Dent Shiraz Univ Med Sci. June 2025; 26(2): 151-159.

Introduction

The need for fixed prostheses is increasing due to the growing number of older people in society [1]. Fixed prostheses offer advantages such as better durability and fewer complications [2-3]. The success of fixed prosthetic treatments depends on factors such as esthetics, fracture resistance, and internal fit. Achieving a natural tooth shade in dental restorations is a challenge due to the complexity of the shade characteristics of natural teeth [4]. Several factors influence the color of fixed crowns, including the tooth substrate [5], the cement [6], the zirconia core [7], porcelain veneer [8], and the glaze [9]. The framework design also plays a role in the final shade of the restoration [10]. Although metal-ceramic systems are standard [11], they cannot achieve a natural appearance due to the light-blocking properties of the

nal work is properly cited, and attribution is given to the creator. The license also permits for commercial use.

metal [12-13].

For this reason, various all-ceramic systems have been developed and evaluated over the last 45 years to solve the esthetic problems of metal-ceramic crowns [14]. The main drawbacks of first full-ceramic crowns were inadequate marginal fit and poor physical properties. In recent years, the use of zirconia has significantly improved the physical properties of all-ceramic restorations [15]. In addition, the CAD/CAM systems used for zirconia crowns are so advanced that the marginal fit of these restorations is comparable to that of metal-ceramic crowns [16]. As already mentioned, the choice of cement plays a decisive role in the final color of the restoration. Zirconia is a semi-transparent material, which means that the color of the underlying cement will influence the final color of the restoration. Fazi et al. [17] found that even a 0.5mm thick porcelain veneer on zirconia crowns is not sufficient to cover the cement shade. A temporary cement (for short-term esthetics and performance) or a permanent cement is usually used to cement the restoration [18]. For implant-supported zirconia-based restorations, a temporary cement can be used for a longer period of time [19]. In order to achieve a better esthetic result, it is advisable to carry out a tryin of the restoration before cementing. This allows the dentist and the patient to assess the color changes of the restoration by using try-in pastes that are the same color as the resin cements [20]. Several studies have investigated the compatibility between try-in systems and cements [21-22]. Generally, it is believed that the use of try-in paste can practically predict the final esthetic results of resin cements. However, some studies have not reported the color match between resin cements and tryin paste, indicating that the dentist should not rely on the try-in paste for the final color assessment [20]. Despite the significant influence of cement on the final color of all-ceramic restorations, the effect of cement on the color of zirconia-based restorations has been studied only to a limited extent [23-26], leading to an incomplete understanding of its role [19]. The aim of this study was to investigate the effects of four types of tryin paste resin cements on the color properties of zirconia crowns with four different framework designs (including simple core, dentin core, trestle design core, and monolithic crown) to help clinicians select the optimal try in-paste shade and framework design to achieve

Mohammadi A, et al

optimal esthetics. Our null hypothesis was that the final color of zirconia restorations would not be affected with tooth region, different designs and try-in paste shades.

Materials and Method

The present study was conducted at Shahid Beheshti University of Medical Sciences (Ethical code: IR. SBMU.RIBS.REC.1396.533). In this experimental laboratory study, 40 zirconia cores were divided into four groups (N= 10): simple cores without anatomical contour, dentin core contour, trestle core, and monolithic crowns. A human upper right central tooth that was extracted for periodontal reasons was mounted in a resin model (AcroPars, Marlic Medical Industries Co., Iran) with the resin positioned 3 mm more apically than the cementoenamel junction (CEJ). The tooth silicon index was obtained using Speedex Putty silicone (COLTENE, Germany, Berlin). An intra-oral scanner (LMTmag, Optical 3D Scanner, OpenTechnologies SRL, Italy) was used to scan the unprepared tooth for further design of monolithic crowns. The tooth was prepared anatomically with a turbine and a diamond bur up to 1 mm coronal to the CEJ. Tooth preparation was performed under air and water spray. Based on the guidelines of the Kuraray factory and available instructions to prepare all-ceramic crowns [27], 1.5mm incisal reduction and 1 mm axial wall reduction with a convergence angle of 6 degrees were performed. The finishing line was a heavy chamfer. After initial preparation, all sharp angles were rounded and the spaces were rechecked with the putty index. The IUS3D scanner (Open Technologies Dental, Italy, Brescia) was used to digitally scan the prepared tooth. The frameworks were designed with ExoCAD software (ExoCAD Dental CAD, Darmstadt, Germany). The features of the frameworks were as follows:

- **Simple zirconia core**: Without anatomical contour with a uniform thickness of 0.5 mm (Figure 1)
- Zirconia core with trestle design contour: Similar to the porcelain fused to metal (PFM) core with 3 mm collar in the palatal area and proximal buttress up to half the proximal height (Figure 2).
- Zirconia core with dentin-like contour: Due to the different thicknesses of dentin and enamel in various tooth portions, it was a challenge to design with ExoCAD. Therefore, an acrylic replica of the tooth was created with an unprepared tooth model. The resin



Figure 1: Simple core design, a: Buccal view, b: Palatal view



Figure 2: Trestle design, a: Buccal view, b: Palatal view



Figure 3: Preparations for dentin core design



Figure 4: Monolithic design

replica was then divided vertically into three sections and horizontally into five sections. Depth cuts with enamel thickness were made in the indicated areas, the depth cuts were connected and the prepared sample was digitally scanned as a dentine core (Figure 3). The core was prepared manually and then scanned to achieve the desired result [28].

• Zirconia monolithic crown: A full contour crown was designed according to the contour of the unprepared tooth (Figure 4).

The ARUM milling machine (Doowon ID Co, Korea) was used to mill the designed frameworks on a KATANA HTML PLUS blank (Kuraray Noritake Dental Inc, Japan). The rationale behind selecting the KAT-ANA HTML PLUS blank was its versatility in being suitable for both framework design and monolithic crowns. Samples without defects were included. In the next step, a trained technician veneered three core groups with feldspar based zirconium oxide veneering ceramic (Zr-FS) (GC, Europe A.G., E.U.) according to the unprepared tooth index. The veneering material consisted of two dentin and enamel powders. First, the framework modifier was heated at 450°C preheat, followed by dentin at 600°C preheat and 810°C. Finally, the glaze process was carried out at 480°C preheat and 832° C. During these processes, the samples and their dimensions were continuously monitored with the index.

After crown preparation, the tooth was placed on a white ionolite plate for color evaluation. The ΔE values were determined in the incisal, middle and cervical tooth regions of the buccal surface. The Panasil white silicone paste was applied to ensure a uniform background and to fix the crown. Shade matching was performed with the SpectroShade Micro II (SpectroShade, USA) according to the Vita Classic criteria and settings for the upper teeth. First, the tooth shade was evaluated with the SpectroShade Micro II, which identified the closest match to B2 and served as a reference for comparison. Bisco CHOICE 2 try-in paste in shades A1, A2, A3, and B1 was used. The color of each crown was examined with the SpectroShade Micro II instrument according to the Vita Classic criteria and specific settings for the upper teeth. Each crown was evaluated five times with the SpectroShade Micro II (once without cement and four times with different cements). After each cement evaluation, the crowns were removed and







Figure 5: a: ΔE based on the type of design, b: ΔE based on cement color, c: ΔE based on tooth region

both the tooth and the crown were rinsed with water. The crowns were then ultrasonically cleaned in distilled water for 2-3 minutes and then dried.

Each analysis included four settings (total color, one-third of the crown, and mapping, for a total of five images). The data included color information based on the Lab CIE system for the entire crown and one-third of each crown. Color changes were measured using the CIE Δ E00 method, the latest technique for evaluating color changes in a sample with a color source identical to that of the tooth and is calculated based on the following formula:

 $\Delta E_{00}[L_1^*, a_1^*, b_1^*; L_2^*, a_2^*, b_2^*] = \Delta E_{00}^{12} = \Delta E_{00} \text{ In}$ this formula, (L_1^*, a_1^*, b_1^*) and (L_2^*, a_2^*, b_2^*) are the color values based on the sample Lab and source. This formula can also be adjusted based on the importance of lightness, chroma, and hue.

 ΔE generated by SPSS software version 22 (IBM Co., Chicago, IL, USA) were amplified by repeated measure ANOVA. Statistical significance (*p* Value) was determined to be 0.055.

Results

The three-way ANOVA test confirmed the significant interaction of the framework design, tooth region and try-in paste shade on ΔE (Table 1). Figures 5 and Tables 2-4 illustrate the average ΔE values in study groups.

The mean ΔE values for each framework design we-

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2396.991 ^a	79	30.342	85.659	.000
Intercept	9460.722	1	9460.722	26709.006	.000
Design	12.196	3	4.065	11.477	.000
Location	2163.620	3	721.207	2036.073	.000
Cement	4.165	4	1.041	2.940	.020
Design * Location	168.543	9	18.727	52.869	.000
Design * Cement	9.809	12	.817	2.308	.007
Location * Cement	13.917	12	1.160	3.274	.000
Design * Location * Cement	24.740	36	.687	1.940	.001
Error	255.035	720	.354		
Total	12112.748	800			
Corrected Total	2652.026	799			

Table 1: Three-way ANOVA, interaction of the framework design, tooth region and try-in paste shade on ΔE

a. R Squared = .904 (Adjusted R Squared = .893) b. Computed using alpha = .05

Decian	Mean	Std.	95% Confidence Interval			
Design		Error	Lower Bound	Upper Bound		
Monolithic	3.475	.042	3.393	3.558		
Dentin Core	3.597	.042	3.514	3.680		
Simple Core	3.430	.042	3.348	3.513		
Trestle Design	3.253	.042	3.170	3.336		

Table 2: ΔE based on the framework design

Table 3: ΔE based on try in-paste shade

Comont	Mean	Std.	95% Confidence Interval		
Cement		Error	Lower Bound	Upper Bound	
Without Cement	3.528	.047	3.436	3.621	
A1	3.341	.047	3.248	3.433	
A2	3.367	.047	3.275	3.460	
A3	3.471	.047	3.379	3.564	
B1	3.487	.047	3.394	3.579	

Table 4: ΔE ba	sed on tooth	region
-------------------------------	--------------	--------

Docion	Maan	Std.	95% Confidence Interval			
Region	Mean	Error	Lower Bound	Upper Bound		
Overall	2.158	.042	2.076	2.241		
Incisal	4.050	.042	3.968	4.133		
Middle	1.702	.042	1.620	1.785		
Cervical	5.845	.042	5.762	5.927		

re as follows: monolithic group 2.33 ± 0.300 , dentin core group 2.59 ± 0.174 , simple core group 2.08 ± 0.333 and trestle design group 2.57 ± 0.207 . All framework designs had clinically acceptable ΔE values (< 5.5).

Comparing the tooth regions, cervical third showed the highest ΔE values (p < 0.05). The mean control ΔE values in the incisal region were 2.28±0.321, 5.23± 0.204, 4.04±0.168 and 3.62±1.738, for the monolithic, dentin core, simple core, and trestle design groups, respectively. The results of the ANOVA test showed significant differences between groups (p < 0.001).

The mean control ΔE in the middle third for the groups were 1.95±0.297, 2.135±0.234, 1.48±0.364 and 2.09±0.201, respectively. The ANOVA test showed significant differences between groups (p< 0.001) and within groups (p= 0.001).

In the cervical third, the mean ΔE for the groups were 6.72±0.336, 5.53±0.161, 6.32±0.240 and 5.48± 1.032. The ANOVA test revealed significant differences between the groups (p< 0.001).

Considering the try in-paste shade, the highest ΔE was in shade B1 and the lowest ΔE value was observed in A2 (p< 0.05). For the monolithic design, the highest ΔE was found in shade A1 and the lowest in shade A2. For the dentin core group, the highest ΔE was in shade B1 and the lowest in A3. In the simple core group, the

highest ΔE value was in shade B1 and the lowest in shade A1. For the trestle design, the highest ΔE value was in color B1 and the lowest in A1. Statistical analysis revealed a significant difference in ΔE between the different colors (p < 0.001).

Discussion

In modern dentistry, advances in dental materials and tools have raised society's expectations for a more natural color, shape, and durability of crowns. The introduction of CAD/CAM technology in dentistry has made the fabrication of all-ceramic crowns almost standard practice [29]. This technology allows for precise control of the crown manufacturing process and offers a wide range of treatment options. Attaining the intended color by indirect bonded restoration is a crucial prerequisite for achieving a favorable outcome in esthetic rehabilitation procedures [29]. Based on the findings of our study, the final color of a zirconia restoration is affected by the core design, try in-paste shade, and tooth region. These items also had significant interactions.

All framework designs in this study had a ΔE value within the clinically acceptable range ($\Delta E < 5.5$) [30-32]. When comparing various framework designs, we found that crowns with dentin core framework had the highest ΔE value followed by the monolithic crowns. Simple and trestle core designs had less color change than the monolithic crowns.

In line with our finding, a previous comparison of the color of monolithic and layered zirconia fabricated with cut-back + enamel (bi-layer), cut-back + dentin + enamel (tri-layer) approaches revealed that the monolithic crowns had higher CIE L*, a*, b*, and C* values than the layered crowns indicating the substantial impact of the veneering ceramics on the color of the zirconia restorations [33]. The study conducted by Bacchi et al. [34] found that bi-layer crowns demonstrated superior masking efficiency on discolored substrates compared to monolithic crowns. Rayyan et al. [33] compared the amount of color difference in 5 different coping designs for an upper right maxillary first molar, which were defined as full-veneer coping covering to finish line (control), 1mm cervical-shoulder (CS), monolithic zirconia with window cut-back on the buccal surface (BW), monolithic zirconia with window cutback on buccal, lingual and mesial surfaces (3W) and

circular projections of 1 mm on palatal cusps and midpalatal surface (MM). They stated that, while there was no significant difference between the given designs, veneering aids in the reduction of color differences in monolithic zirconia. [33]. In addition to the veneering effect, it has been stated that monolithic zirconia has been found to possess greater translucency compared to framework zirconia with the same thickness [35]. According to Tuncel et al. [35], at the thickness of 1 mm, the average translucency parameter (TP) value was recorded as 16.4 for monolithic zirconia and 7.0 for framework zirconia. Therefore, higher values of monolithic zirconia can be attributed to the increased translucency of these crowns. Fabricating the monolithic crowns with less translucent materials can increase the masking ability of these restorations [33].

Due to the translucency of zirconia, light can pass through all zirconia crowns and interact with the underlying materials (i.e., luting cement or try in-paste). Therefore, the shade of try in-paste and cement plays a role in determining the final color of the restoration [36]. In 2009, Chang et al. [37] indicated that the shade of leucite glass-ceramic and zirconia crowns could cause noticeable color changes in the cervical and middle portions when particular combinations of abutment tooth material, cement, and ceramic crowns are used. In this study, the highest ΔE values were observed when the B1 shade was used and the lowest ΔE value was for the A1 shade. Regardless of the try in-paste shade, the dentin core design had the highest color difference in the incisal and middle sections, whereas the monolithic crowns showed the largest ΔE value in the cervical area. On average, the cervical area had the largest ΔE value. It appears that the effect of cement shade and tooth portion on color change is determined by the restoration thickness. Prior research has established that the thickness of the monolithic zircon directly influences its ultimate color [38-39]. Malkondu et al. [38] conducted a study to assess the alterations in color of monolithic zirconia using two different thicknesses (0.6 and 1mm) and three different types of resin luting agents. According to their findings, the average ΔE values for zirconia that is 0.6mm thick were greater than the values for zirconia that is 1mm thick. According to Tabatabian et al. [39], achieving a satisfactory final color requires a crown thickness of at least 0.9mm. On the other hand, Sancaktar et al. [40] discovered that there was no significant difference in the ΔE values of IPS emax CAD (LT C14) and Celtra Duo (LT C14) when utilized as full ceramic materials with thicknesses of 0.4 and 0.6mm when they were cemented with various backgrounds and resin cements. Dai et al. [36] sintered a layer of opaque porcelain onto the Co-Cr alloy substrate. They found that zirconia crowns with a thickness ranging from 1.2 to 1.5mm achieved clinically acceptable color differences ($\Delta E < 5.5$) when used with any try-in paste shade, while restorations with a thickness of 0.7-1.0 mm in most shades achieved clinically acceptable color differences when appropriate shades of try-in paste were selected. Fachinetto et al. [41] conducted an in vitro investigation to assess the impact of try-in paste shade, ceramic type, and thickness on the color differences observed when cementing CAD/CAM monolithic ceramics onto discolored tooth substrates. Six different types of ceramics (high-translucent lithium disilicate (LD-HT), medium-translucent lithium disilicate (LD-MT), low-translucent lithium disilicate (LD-LT), lowtranslucent leucite (LC-LT), feldspathic ceramic (FC), and BL1 low-translucent lithium disilicate stained to A1 shade (LD-BL1-LT) at thicknesses of 0.5 mm, 1.0 mm, and 1.5 mm were used in this study. Their research disclosed that the color differences were influenced by all investigated factors. LD-LT and LC-LT ceramics, along with Opaque White try-in paste, generally resulted in lower $\Delta E00$ values. The optimal ceramic thickness changed depending on the discoloration of the substrate. By using a ceramic thickness of 1.0 mm, it was feasible to achieve a $\Delta E00$ value below the threshold of perceptibility for substrates C2 and A3, as well as a $\Delta E00$ value below the threshold of acceptability for C3 and B3. The $\Delta E00$ values obtained for B2, A3, and C2 were below the acceptable criterion when using a ceramic thickness of 0.5mm. The cement's masking effect can serve as an alternative for increasing the thickness of the restoration [36].

Try-in pastes can serve as guidance in resin luting agent selection [42]. Research suggests that try-in pastes may not match the color of resin luting agents used for all-ceramic restorations, despite their thickness [42-43]. A Δ E value of less than 2.0 (0.5, 0.8, or 1.0mm) indicates no perceptible color difference between resin luting agents and their try-in pastes [20]. ALGhazali *et al.*

[44] found that the color difference between try-in pastes and cured resin luting agents ranged from ΔE values of 1.05 to 3.34, which is in the clinically acceptable range. However, color agreement may not always be attained, particularly with darker and opaque luting materials [42]. Try-in pastes with matching cement agent colors enable dentists, patients, and technicians to assess tooth/crown color, ensuring aesthetic expectations are met [20, 29, 44]. While various manufacturers may assign different names to specific shades of try-in paste, the shades we examined would likely encompass most of them. These shades are suitable for a wide range of patients. Hence, the findings of this study have the potential to offer useful guidance for selecting proper cement shades in clinical practice. However, it should be noted that color matching between the try-in paste and the accompanying resin cement is not consistently accomplished especially on the incisal and cervical tooth regions [21].

Conclusion

The current investigation demonstrated that the monolithic and dentin core designs had the highest ΔE , while the simple core group had the lowest ΔE . The A2 try-in paste yielded the smallest ΔE value. These findings can provide dental laboratories with guidance on using designs that have the lowest ΔE content, such as simple core and trestle core. Similarly, dentists can choose tryin paste with the lowest ΔE content, such as A2, B1, A1, and A3, respectively.

Conflict of Interest

All of the authors declare that there is no conflict of interest.

References

- Loch C, Brunton PA, Rahim ZA, Liew L, Lynch CD, Wilson N, et al. The teaching of removable partial dentures in dental schools in Oceania. J Dent. 2020; 95: 103309.
- [2] Vasileva R. Techniques for fixed dental restorations removal-classification, decision on the correct approach, advantages and disadvantages. J IMAB–Annual Proceeding Scientific Papers. 2021; 27: 3510-3517.
- [3] Brânzan R. Essential factors for the success of fixed prosthetic works. Impression, temporary prosthesis, fixation.

Int J Med Dent. 2020; 24: 298.

- [4] Ahmad I. An introduction to aesthetic dentistry. BDJ Team. 2021; 8: 26-32.
- [5] Yousef HM, Abd El Aziz SA, El Sharkawy ZR. The Effect of substrate and resin cement shades on the optical properties of two ceramic laminate veneer materials. Al-Azhar Dentl J Girls. 2021; 8: 223-230.
- [6] Hoorizad M, Valizadeh S, Heshmat H, Tabatabaei SF, Shakeri T. Influence of resin cement on color stability of ceramic veneers: in vitro study. Biomater Investig Dent. 2021; 8: 11-17.
- [7] Suarez MJ, Perez C, Pelaez J, Lopez-Suarez C, Gonzalo E. A Randomized Clinical Trial Comparing Zirconia and Metal-Ceramic Three-Unit Posterior Fixed Partial Dentures: A 5-Year Follow-Up. J Prosthodont. 2019; 28: 750-756.
- [8] Ge C, Green CC, Sederstrom DA, McLaren EA, Chalfant JA, White SN. Effect of tooth substrate and porcelain thickness on porcelain veneer failure loads in vitro. J Prosthet Dent. 2018; 120: 85-91.
- [9] Manziuc MM, Gasparik C, Burde AV, Colosi HA, Negucioiu M, Dudea D. Effect of glazing on translucency, color, and surface roughness of monolithic zirconia materials. J Esthet Restor Dent. 2019; 31: 478-485.
- [10] Yilmaz B, Alp G, Johnston WM. Effect of framework material on the color of implant-supported complete-arch fixed dental prostheses. J Prosth Den. 2019; 122: 69-75.
- [11] Kaleli N, Ural Ç, Uçar Y. Computer-aided dental manufacturing technologies used in fabrication of metal frameworks. J Exper Clin Med. 2021; 38: 119-122.
- [12] Jeong ID, Bae SY, Kim DY, Kim JH, Kim WC. Translucency of zirconia-based pressable ceramics with different core and veneer thicknesses. J Prosth Dent. 2016; 115: 768-772.
- [13] Harada K, Raigrodski AJ, Chung K-H, Flinn BD, Dogan S, Mancl LA. A comparative evaluation of the translucency of zirconias and lithium disilicate for monolithic restorations. J Prosth Dent. 2016; 116: 257-263.
- [14] Ayash G, Osman E, Segaan L, Rayyan M, Joukhadar C. Influence of resin cement shade on the color and translucency of zirconia crowns. J Clin Expe Dent.2020;12: e257.
- [15] Li SL, Zhang Q, Wu FF, Hu JY, Wang Q. Research progress on all ceramic zirconia core/veneer interface: a review. Sci Advanc Materials. 2020; 12: 5-14.
- [16] Lehmann KM, Weyhrauch M, Bjelopavlovic M, Scheller

H, Staedt H, Ottl P, et al. Marginal and Internal Precision of Zirconia Four-Unit Fixed Partial Denture Frameworks Produced Using Four Milling Systems. Materials. 2021; 14: 2663.

- [17] Fazi G, Vichi A, Ferrari M. Influence of four different cements on the color of zirconia structures of varying ceramic thickness. Int Dent SA. 2006; 9: 54-61.
- [18] Tabatabaian F, Khodaei MH, Namdari M, Mahshid M. Effect of cement type on the color attributes of a zirconia ceramic. J Advanced Prosthot. 2016; 8: 449-456.
- [19] Le M, Papia E, Larsson C. The clinical success of tooth-and implant-supported zirconia-based fixed dental prostheses. A systematic review. J Oral Rehabil. 2015; 42: 467-480.
- [20] Xing W, Jiang T, Ma X, Liang S, Wang Z, Sa Y, et al. Evaluation of the esthetic effect of resin cements and tryin pastes on ceromer veneers. J Dent. 2010; 38: e87-e94.
- [21] Daneshpooy M, Azar FP, Oskoee PA, Bahari M, Asdagh S, Khosravani SR. Color agreement between try-in paste and resin cement: Effect of thickness and regions of ultratranslucent multilayered zirconia veneers. J Dent Res Dent Clin Dent Prospects. 2019; 13: 61.
- [22] Miura S, Tsukada S, Fujita T, Isogai T, Teshigawara D, Saito-Murakami K, et al. Effects of abutment tooth and luting agent colors on final color of high-translucent zirconia crowns. J Prosth Res. 2022; 66: 243-249.
- [23] Turgut S, Bagis B. Effect of resin cement and ceramic thickness on final color of laminate veneers: an in vitro study. J Prosth Dent. 2013; 109: 179-186.
- [24] de Azevedo Cubas GB, Camacho GB, Demarco FF, Pereira-Cenci T. The effect of luting agents and ceramic thickness on the color variation of different ceramics against a chromatic background. European J Dent. 2011; 5: 245-252.
- [25] 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 Prosth Dent. 2011; 105: 83-90.
- [26] Luo MR, Cui G, Rigg B. The development of the CIE 2000 colour-difference formula: CIEDE2000. Color research & application: endorsed by inter-society color council, the colour group (great Britain), Canadian society for color, color science association of Japan, Dutch society for the study of color. The Swedish colour centre foundation, colour society of Australia, centre Fra-

nçais de la couleur. 2001; 26: 340-350.

- [27] Marchack BW, Futatsuki Y, Marchack CB, White SN. Customization of milled zirconia copings for all-ceramic crowns: a clinical report. J Prosth Dent. 2008; 99: 169-173.
- [28] Tavakolizadeh S, Yazdani N, Ghoveizi R, Mohammadi A, Beyabanaki E, Koulivand S. Fracture resistance of zirconia restorations with four different framework designs. Front Dent. 2023; 20: 2.
- [29] Vaz EC, Vaz MM, de Torres ÉM, de Souza JB, Barata TdJE, Lopes LG. Resin cement: correspondence with try-in paste and influence on the immediate final color of veneers. J Prosth. 2019; 28: e74-e81.
- [30] Ragain Jr JC, Johnston WM. Color acceptance of direct dental restorative materials by human observers. Color research & application: Endorsed by inter-society color council, the colour group (great Britain), Canadian society for color, color science association of Japan, Dutch society for the study of color. The Swedish colour centre foundation, colour society of Australia, centre Français de la couleur. 2000; 25: 278-285.
- [31] Douglas RD, Steinhauer TJ, Wee AG. Intraoral determination of the tolerance of dentists for perceptibility and acceptability of shade mismatch. J Prosth Dent. 2007; 97: 200-208.
- [32] Ruyter I, Nilner K, Möller B. Color stability of dental composite resin materials for crown and bridge veneers. Dent Mater. 1987; 3: 246-251.
- [33] Gasparik C, Manziuc MM, Burde AV, Ruiz-López J, Buduru S, Dudea D. Masking ability of monolithic and layered zirconia crowns on discolored substrates. Materials (Basel). 2022; 15: 2233.
- [34] Bacchi A, Boccardi S, Alessandretti R, Pereira GKR. Substrate masking ability of bilayer and monolithic ceramics used for complete crowns and the effect of association with an opaque resin-based luting agent. J Prosth Res. 2019; 63: 321-326.
- [35] Tuncel İ, Turp I, Üşümez A. Evaluation of translucency of monolithic zirconia and framework zirconia materials. J Advanced Prosthodontics. 2016; 8: 181-186.
- [36] Dai S, Chen C, Tang M, Chen Y, Yang L, He F, et al. Choice of resin cement shades for a high-translucency zirconia product to mask dark, discolored or metal substrates. J Advanc Prosth. 2019; 11: 286-296.
- [37] 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: 937-943.

- [38] Malkondu O, Tinastepe N, Kazazoglu E. Influence of type of cement on the color and translucency of monolithic zirconia. J Prosth Dent. 2016; 116: 902-908.
- [39] Tabatabaian F. Color in zirconia-based restorations and related factors: a literature review. J Prosth. 2018; 27: 201-211.
- [40] Sancaktar Ö, Bayındır F. Investigation of Color Change of Different Restoration Thickness, Background Color and Resin Cement Shade on CAD/CAM Glass Ceramic Materials. Open J Stomatol. 2023; 13: 143-155.
- [41] Fachinetto E, Chiapinotto GF, Barreto VSM, Pecho O, Pereira GKR, Bacchi A. Masking ability of CAD/CAM monolithic ceramics: effect of ceramic type and thickness and try-in paste shade. Quintessence Int. 2023; 54: 442-

450.

- [42] Xu B, Chen X, Li R, Wang Y, Li Q. Agreement of try-in pastes and the corresponding luting composites on the final color of ceramic veneers. J Prosth. 2014; 23: 308-312.
- [43] Mourouzis P, Koulaouzidou E, Palaghias G, Helvatjoglu-Antoniades M. Color match of luting composites and tryin pastes: the impact on the final color of CAD/CAM lithium disilicate restorations. Int J Esthet Dent. 2018; 13: 98-109.
- [44] ALGhazali N, Laukner J, Burnside G, Jarad F, Smith P, Preston A. An investigation into the effect of try-in pastes, uncured and cured resin cements on the overall color of ceramic veneer restorations: an in vitro study. J Dent. 2010; 38: e78-e86.