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Effects of porcelain layer thickness and luting resin cement on the opalescence properties of porcelain veneers

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Abstract

Background When discolored teeth are repaired with porcelain veneers, the thickness of the restorations should be increased appropriately using opaque porcelain and bonded by applying opaque luting resin cement to cover discolored substrates. However, its impact on the opalescent performance has not been reported yet.

Purpose To analyze the effects of opacity, body porcelain layer thickness, and luting resin cement on the opalescence properties of porcelain veneer restorations for discolored teeth.

Methods Ninety IPS d. SIGN A3 porcelain veneer specimens were prepared via powder–paste coating and sintering. Specimens were divided into three groups according to ceramic type and cement used or not: body porcelain group as control, body/opaque porcelain group and body/opaque porcelain–resin cement composite group. Each group was subdivided into three subgroups based on the thickness, 0.50, 0.75, and 1.00 mm ($n=10$). Variolink N Bleach XL luting resin cement with thickness of 0.1 mm was applied to the bottoms of body/opaque porcelain specimens to produce body/opaque porcelain–resin cement composites. The opalescence (OP) values were calculated and the micromorphological characteristics were analyzed by scanning electron microscope (SEM). Statistical analysis was performed by using ANOVA test ($P<0.05$).

Results The opalescence values determined for the body porcelain groups with thicknesses of 0.50, 0.75, and 1.00 mm and body/opaque porcelain specimens with thicknesses of 0.45/0.05, 0.70/0.05, and 0.95/0.05 mm were 3.35 ± 0.15, 3.83 ± 0.10, 6.73 ± 0.25, 7.95 ± 0.34, 15.16 ± 0.60, and 16.49 ± 0.89, respectively. The specimens in the body and body/opaque porcelain groups exhibited significant increases in their opalescence values with increasing thickness ($P=0.00$). The opalescence values of the specimens increased significantly with the addition of a 0.05 mm opaque porcelain layer ($P=0.00$). The opalescence values of the composites containing body/opaque porcelain layers with thicknesses of 0.45/0.05, 0.70/0.05, and 0.95/0.05 mm and luting resin cement were 9.46 ± 0.17, 16.47 ± 0.15, and 18.38 ± 0.47, respectively. The opalescence values of the composite specimens increased significantly with an increase in the thickness of the porcelain layer($P=0.00$).

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Conclusions The opaque porcelain layer and opaque resin cement can significantly improve the opalescence properties of porcelain laminate veneers for discolored teeth, but the opalescence performance is still poor than natural teeth. The body porcelain only contributes to opalescence within a certain thickness range.

Keywords Porcelain veneer, Opalescence, Power-paste coating and sintering, Luting resin cement, Discolored teeth

Background

The colour and translucency of teeth can change owing to enamel hypoplasia, fluorosis, tetracycline staining, and pulp necrosis, which severely affect the aesthetic appearance of teeth [1]. Porcelain veneers are widely used for the aesthetic restoration of anterior teeth because of their excellent aesthetic properties, minimal tooth preparation, clinical reliability, and durability [2–4]. Powder–paste-coated and sintered porcelain veneers can be employed for the aesthetic restoration of discolored teeth. Opaque porcelain is used to cover the discolored substrate, while the body porcelain of a certain thickness imparts colour and translucency to the restoration, which is bonded to the tooth surface using luting resin cement, thus providing good aesthetics [5].

The optical reflection, scattering, absorption, and transmission phenomena occur when light is projected onto natural teeth, resulting in translucency, opalescence, and fluorescence. These effects, along with brightness, colour, and hue, determine the appearance of natural teeth. As a minimally invasive restoration, fabricating a porcelain veneer with aesthetic appearance that mimics natural teeth is a challenging clinical problem. To make restorations appear more natural, the porcelain material must possess optical properties similar to those of natural teeth. Translucency, opalescence, and fluorescence are important factors that influence aesthetic properties [6]. Opalescence (OP), also known as an "opal effect", is the scattering of light from translucent materials at short wavelengths of the visible-light spectrum that makes opalescent objects look blue-colored in the reflected light and orange/brown-colored in the transmitted light. The opalescence of natural teeth is primarily due to the presence of hydroxyapatite crystals, which significantly scatter short blue waves in the visible light spectrum (380–780 nm) and produce a clear blue-grey opalescent halo tangential to the enamel [7]. The opalescence of the natural tooth enamel lies in the range of 19.8–27.6 [8]. Opalescence is a major secondary optical property of natural teeth, and is closely associated with aesthetic effects of porcelain veneers [9].

Currently, all-ceramic restorations match the colour and translucency of natural teeth. However, their opalescence is not comparable with that of natural teeth. Further optimization of the opalescence properties of porcelain veneer restorations can make them appear more realistic [10, 11]. By observing the microstructures of natural teeth, cat's eye chrysoberyl, and opalescent enamel porcelain, researchers have found that opalescence depends on several key factors such as the presence of one or more dispersed phases, including a considerably small dispersed phase (380–500 nm), a large difference between the refraction coefficients of the substrate and dispersed phase, and high dispersion in the dispersed phase [12]. Different ceramic materials have different crystal structures, and light scattering occurs at the grain boundaries of different crystalline phases. Therefore, their optical properties also differ [13]. In addition, after a porcelain material is processed using different fabrication techniques, the crystal composition changes owing to the interactions among tiny crystals in the porcelain material, thereby imparting different opalescence properties to porcelain veneers [9, 14].

By studying the opalescence properties of all-ceramic materials (such as VITA Mark II, IPS e.max computer-aided design (CAD), and IPS Empress CAD) with a thickness of 1.0 mm fabricated via CAD/computer-aided manufacturing (CAM), Della et al. [15] found that the composition, colour, and translucency of materials strongly affected their opalescence with the IPS Empress LT A3–colored ceramic exhibiting the highest opalescence value. Gunal et al. [16] studied the opalescence properties of VITA Suprinity T, VITA Enamic T, VITA Mark II, GC Cerasmart LT, Lava Ultimate LT, IPS e.max CAD LT, and Prettau Anterior blocks fabricated via CAD/CAM and confirmed that the type and thickness of a ceramic exert significant effects on its opalescence properties. Shiraishi et al. [9] investigated the opalescence properties of zirconia/alumina nanocomposites with different thicknesses and found that the highest opalescence values were achieved at a material thickness of 0.3 mm, which was strongly correlated with the crystal microstructure and difference between the refractive indices of the different dispersed phases.

For the discolored abutments caused by hyperpigmentation, trauma, or tetracycline staining, the thickness of porcelain veneers should be at least 2 mm to ensure masking [17]. However, to provide an adequate surface area for enamel bonding and aesthetic reasons, the thickness of porcelain veneers usually ranges from 0.5 to 1 mm. Li et al. [18] found that porcelain veneers with thicknesses less than 1 mm had low opacity, and the effect of luting resin cement on the final restoration colour was more pronounced. They suggested that luting resin cement with high opacity should be applied. Turgut et al. [19] studied IPS Empress porcelain layers combined with luting resin cement at different thicknesses and colours of both components and found that the luting resin cement significantly affected the optical properties of the final restorations. Therefore, luting resin cement with some opacity should be selected for the aesthetic restoration of discolored teeth with porcelain veneers.

Although the opalescence properties of porcelain materials fabricated via CAD/CAM have been reported previously, the opalescence of porcelain veneers and porcelain veneer–luting resin cement composites prepared via the powder–paste coating process has not been examined. Therefore, the purpose of the present study was to analyze the effects of opacity, body porcelain layer thickness, and luting resin cement on the opalescence properties of porcelain veneer restorations for discolored teeth. The null hypothesis was that the porcelain layer thickness and luting resin cement did not affect the opalescence properties of porcelain laminate veneer restorations for discolored teeth fabricated via the powder–paste coating and sintering techniques.

Methods

The materials and equipment information used in this study have been detailed in Table 1.

Specimens were divided into three groups according to ceramic type and cement used or not: body porcelain group as control, body/opaque porcelain group and body/opaque porcelain–resin cement composite as experimental groups. Each group was subdivided into three subgroups based on the thickness ($n=10$). The thicknesses of the body porcelain groups were 0.50, 0.75, and 1.00 mm. The thicknesses of the body/opaque porcelain groups were 0.45/0.05, 0.70/0.05, and 0.95/0.05 mm. The composite groups were 0.1 mm thick luting resin cement added on the surfaces of body/opaque porcelain specimens with different thicknesses.

Table 1 The materials and equipments

Material and equipment	Manufacturer and model	Country
Refractory material	Shofu	Japan
IPS d. SIGN low-temperature ceramic powder Opaque A3	Ivoclar AG	Liechtenstein
Dentine Body A3 and specialized liquid	Ivoclar AG	Liechtenstein
Variolink N bonding kit	Ivoclar AG	Liechtenstein
4.5% hydrofluoric acid	Ivoclar AG	Liechtenstein
95% ethanol	Lircon	China
Bluephase NMC curing light	Ivoclar AG	Liechtenstein
Radiometer	Kerr	USA
Ceramic furnace	Ivoclar AG	Liechtenstein
Digital Vernier calipers	Yue di	China
1-kg weight	Yue di	China
Dual-beam spectrophotometer	Datacolor 850	USA
Field-emission scanning electron microscope	Nova Nano, FEI	USA

Preparation of porcelain veneer specimens

The refractory investment material was poured into a cylindrical custom-mold impression to obtain a cylindrical refractory investment with a diameter of 22 mm. The cylindrical refractory investment surface was sanded in layers using 180#–1200# Sic abrasive paper until it became sufficiently smooth. Vernier calipers were used to measure the refractory investment thickness and the numbers were marked on one side of the investment. On the other investment side, an opaque porcelain layer was added via powder–paste sintering. After sanding, Vernier calipers were utilized to measure the total thickness at six random positions. If the difference among the thicknesses at the six positions exceeded 0.02 mm, the specimen was excluded from the experiment. The thickness of the opaque porcelain layer was the total thickness minus the refractory investment thickness. After the opaque porcelain layer was prepared, the sintered body porcelain layer was stacked on the surface and polished, and its thickness (the total thickness minus the thickness of the opaque porcelain layer and refractory investment) was determined. To avoid the effect of the number of sintering cycles on specimen properties, the opaque porcelain layer was sintered once, body porcelain layers in the ceramic body/opaque porcelain groups were sintered twice, and body porcelain layers in the body porcelain groups were sintered three times. The above procedures are showing in the Fig. 1.

Preparation of body/opaque porcelain–resin cement composite specimens

The opaque porcelain sides of the porcelain laminate veneer specimens were etched with 4.5% hydrofluoric acid for 60 s, rinsed, ultrasonicated in a 95% ethanol solution for 2 min, blow-dried, and uniformly coated with a silane coupling agent. After 60 s, a water-free and contaminant-free air gun was used for drying, and the specimens were coated with Heliobond #3 bonding agent and blown with air to form uniformly thin layers. Next, after applying Variolink N Bleach XL luting resin cement, a 1-kg weight was placed on the specimen for 30 s to control the thickness of the luting resin cement. A curing light beam (diameter: 8 mm, high-intensity mode, light intensity: 1100 mW/cm^2) was used to pre-cure the specimen for 2 s. Excess adhesive was removed, and the vertical specimen surface was cured for 20 s. The luting resin cement thickness of approximately 0.1 mm was measured using Vernier calipers. The intensity of the curing light was measured and verified after every five irradiations.

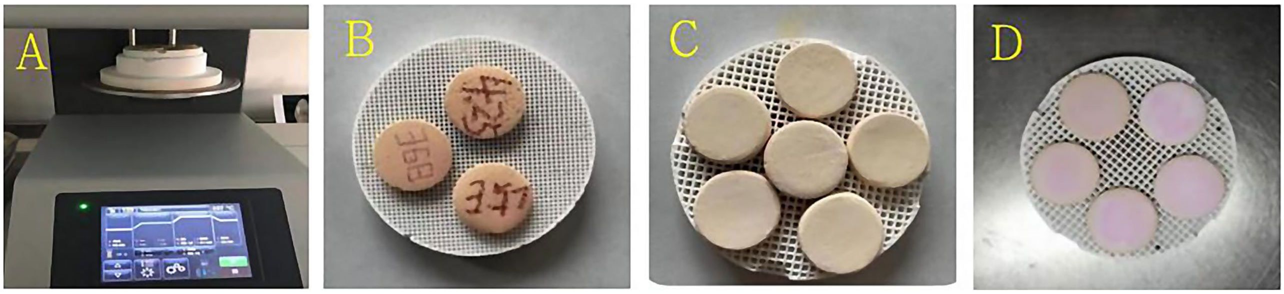

Fig. 1 **A**, Sintering of refractory material. **B**, Measurement of refractory samples. **C**, Sintering of opaque porcelain. **D**, Sintering of body porcelain

Table 2 Chromatic values of the porcelain veneers and porcelain veneer–luting resin composites obtained in the reflectance mode

	Thickness (mm)	Reflectance mode		
		L*	a*	b*
Body porcelain group	0.50	70.66 ± 0.47	0.09 ± 0.06	14.48 ± 0.76
	0.75	71.80 ± 0.57	0.46 ± 0.21	17.60 ± 0.93
	1.00	72.03 ± 0.36	0.23 ± 0.09	11.30 ± 0.94
Body/opaque porcelain group	0.45/0.05	70.90 ± 2.69	0.53 ± 0.30	14.18 ± 1.58
	0.70/0.05	72.57 ± 1.00	2.20 ± 1.12	17.49 ± 3.91
	0.95/0.05	77.42 ± 1.27	1.84 ± 0.42	15.16 ± 0.49
Body/opaque porcelain–resin cement composites	0.45/0.05–0.1	72.35 ± 2.15	0.47 ± 0.25	17.42 ± 0.91
	0.70/0.05–0.1	73.35 ± 0.44	0.67 ± 0.38	17.06 ± 0.35
	0.95/0.05–0.1	76.56 ± 1.18	1.23 ± 0.21	14.25 ± 1.16

Table 3 Chromatic values of the porcelain veneers and porcelain veneer–luting resin composites obtained in the transmittance mode

	Thickness (mm)	Transmission mode		
		L*	a*	b*
Body porcelain group	0.50	72.52 ± 0.63	1.19 ± 0.49	18.25 ± 1.03
	0.75	68.75 ± 0.79	1.39 ± 0.44	23.31 ± 1.31
	1.00	65.22 ± 0.53	0.86 ± 0.23	15.18 ± 0.87
Body/opaque porcelain group	0.45/0.05	64.19 ± 2.21	1.87 ± 0.22	20.33 ± 2.68
	0.70/0.05	56.78 ± 1.57	5.58 ± 1.36	32.21 ± 3.52
	0.95/0.05	53.30 ± 0.89	5.11 ± 0.60	30.07 ± 1.41
Body/opaque porcelain–resin cement composites	0.45/0.05–0.1	60.65 ± 1.53	4.14 ± 0.64	27.54 ± 0.96
	0.70/0.05–0.1	59.66 ± 1.20	2.80 ± 0.68	25.06 ± 0.96
	0.95/0.05–0.1	53.41 ± 1.05	4.89 ± 0.51	31.58 ± 1.20

Opalescence measurements

A spectrophotometer was used to obtain the reflectance and transmission spectral curves of the porcelain veneer and porcelain veneer–resin cement composite specimens and calculate the International Commission on Illumination standard L* a* b* values. A standard D65 light source was used for this purpose, and spectral wavelengths were recorded in the range of 360–700 nm. The observation angle in the reflectance mode was 8°, and measurement aperture diameter was 11 mm. In the transmission mode, the measurement aperture diameter was 20 mm.

Calculation of opalescence values

The colour difference between the reflectance and transmission modes was calculated using the following formula: $OP = [(a^*_T - a^*_R)^2 + (b^*_T - b^*_R)^2]^{1/2}$, where the subscripts T and R denote the colour parameters in the transmission and reflectance modes, respectively.

Scanning electron microscopy (SEM) observations

The fabricated porcelain veneer–resin cement composite specimens were fractured, and the formed rectangular fracture surfaces were fixed onto metal pins and gold-plated using a vacuum sputter coater. The coated samples were observed using the scanning electron microscope.

Statistical analysis

SPSS 25.0 software was used to perform the analysis of variance (ANOVA) and compare the opalescence parameters of the porcelain veneer specimens and porcelain veneer–resin cement composites at a two-sided significance level of $\alpha = 0.05$.

Results

L* a* b* values

The L* a* b* values of all specimens calculated in the reflectance and transmittance modes are listed in Tables 2 and 3, respectively. In the reflectance mode, the L* values of all groups were increased with increasing thickness ($P < 0.05$). When the thickness of the porcelain veneers in the body group and body/opaque porcelain group exceeded 0.75 mm, the a* and b* values were decreased significantly ($P < 0.05$). In the transmittance mode, the L* values of all groups were decreased with increasing thicknesses ($P < 0.05$).

Opalescence values

The opalescence values and ANOVA results obtained for the porcelain veneer and porcelain laminate veneer–resin cement composite specimens with different thicknesses are presented in Table 4.

In the body porcelain group, the opalescence value increases with increasing porcelain layer thickness,

Table 4 Opalescence values and ANOVA results of each group

	Thickness (mm))	Mean ± SD	F	P
Body porcelain group	0.50	3.35 ± 0.15	311.75	0.000
	0.75	3.83 ± 0.10		
	1.00	6.73 ± 0.25		
Body/opaque porcelain group	0.45/0.05	7.95 ± 0.34	151.283	0.000
	0.70/0.05	15.16 ± 0.60		
	0.95/0.05	16.49 ± 0.89		
Body/opaque porcelain–resin cement composites	0.45/0.05–0.1	9.46 ± 0.17	706.50	0.000
	0.70/0.05–0.1	16.47 ± 0.15		
	0.95/0.05–0.1	18.38 ± 0.47		

Note: The differences with $P<0.05$ are considered statistically significant

Table 5 ANOVA results obtained for the opalescence values of the porcelain veneer specimens with different thicknesses

	F	P
Total thickness	34.577	0.001
Presence of the opaque porcelain layer	182.847	0.000
Total thickness * Presence of the opaque porcelain layer	21.607	0.002

Note: The differences with $P<0.05$ are considered statistically significant

Table 6 ANOVA results obtained for the opalescence values of Body/opaque porcelain and Body/opaque porcelain–resin cement composite specimens with different thicknesses

	F	P
Total thickness	505.195	0.000
Presence of luting resin cement	43.046	0.000
Total thickness * Presence of luting resin cement	0.509	0.613

Note: The differences with $P<0.05$ are considered statistically significant

and the difference in opalescence between the different thickness groups is statistically significant ($P<0.05$). In the body/opaque porcelain group, the opalescence value increases with an increase in the thickness of the ceramic body; however, no statistically significant difference between the groups with total thicknesses of 0.75 and 1.00 mm is observed ($P=0.128$). For the body/opaque porcelain–resin cement composite specimens, the opalescence value increases with increasing porcelain layer thickness, and the opalescence difference between the different thickness groups is statistically significant ($P<0.05$).

The two-way ANOVA results obtained for the opalescence values of the porcelain veneer specimens with different thicknesses are listed in Table 5. The effects of the layer thickness and presence/absence of an opaque porcelain layer on the opalescence value are statistically significant ($P<0.05$), and a correlation is observed between the total thickness and presence/absence of an opaque porcelain layer ($P<0.05$).

The two-way ANOVA results obtained for the opalescence values of the porcelain laminate veneer–resin cement composite specimens with different thicknesses are listed in Table 6. The effects of the porcelain veneer thickness and presence/absence of the luting resin cement on the opalescence are statistically significant ($P<0.05$). However, no correlation is observed between the total thickness and presence/absence of the luting resin ($P>0.05$).

Microstructural analysis

The fracture surface morphology of the porcelain laminate veneer–luting resin cement composite is displayed (Fig. 2A-D).

Discussion

Based on the obtained results, the null hypothesis was rejected. The opaque porcelain and luting resin cement significantly affected the opalescence properties of the porcelain laminate veneer restorations for discolored teeth prepared via the powder–paste coating and sintering techniques.

Ceramics are multiphase materials composed of the crystalline, glassy, and gaseous phases, and the structure, proportion, and distribution of each component significantly affect their optical properties. Sintering, glazing, and powder-to-liquid ratios during the powder–paste coating process influence the final optical properties of porcelain veneers [20, 21]. The number of sintering cycles and sintering temperature strongly affects the crystalline phase of the porcelain material. At high temperatures, the surfaces of solid particles in the porcelain powder melt and particles fuse together, gradually reducing the pore size, increasing the density of the ceramic, and reducing its volume. Simultaneously, the increased crystalline phase decreases the light transmission and increases the reflectance and scattering degree, which in turn affects the opalescence properties of the final restorations [17, 22]. In addition, the surface texture is an important factor that influences optical properties. Different interface textures can change the direction of the incident light, which in turn affects the optical properties of porcelain restorations [23]. Therefore, in the present study, the porcelain veneers were sintered in strict accordance with the manufacturer's recommended temperatures, and the number of sintering cycles was standardized to one for the opaque porcelain layer and two for the body porcelain. All specimens were polished stepwise with sandpapers to control their thicknesses and surface morphologies. IPS d.SIGN low-temperature porcelain powder contains apatite crystals that endow it with excellent optical properties, high brightness, colour stability, and realistic fluorescence. Therefore, in this study, IPS d.SIGN porcelain powder was used to fabricate the porcelain laminate veneer specimens of different thicknesses and analyze changes in their opalescence properties to establish a

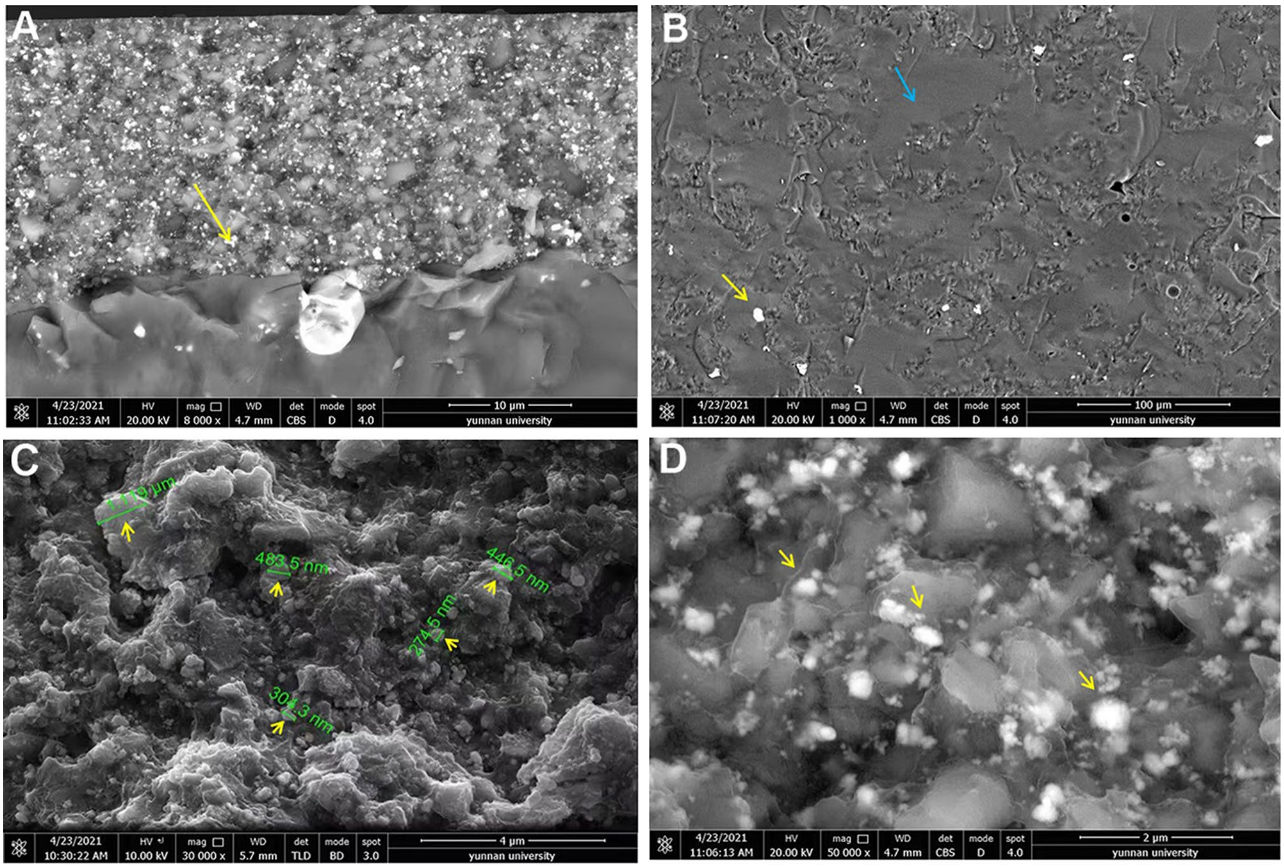

Fig. 2 **A**, The porcelain layer and luting resin cement are closely connected, and their interface is continuous and complete. (The arrow indicating that the interface of porcelain veneer–luting resin cement veneer–luting resin cement) **B**, The crystals in the porcelain layer are scattered across the glass matrix, the crystal (yellow arrows)and the glass matrix(blue arrows). **C**, The luting resin cement filler particles are uniformly dispersed in the resin matrix, and the particle sizes are below 500 nm (The arrows indicating that the size of filler particle). **D**, small colourant particles are visible in the resin matrix (The arrows indicating that the colourant particle)

foundation for the restoration of discolored teeth with porcelain veneers.

Various methods have been used to evaluate opalescence properties [12, 24, 25]. In the present study, the method described by Kobashigawa et al. was selected to calculate opalescence values based on the colour difference between the transmission and reflectance modes, which is consistent with the definition of opalescence as orange for the transmitted light and blue for the reflected light. The opalescence of a material cannot be observed if the opalescence value is less than four. For tooth restoration materials, the opalescence value must be at least nine before the material opalescence can be perceived by the naked eye, thus achieving an aesthetic effect similar to that of a natural tooth. When the opalescence value is between four and nine, only weak opalescence is perceived by the naked eye. Higher opalescence values indicate more pronounced opalescence of the material [17, 24–26]. Lee et al. [8] found that both the spectrophotometer configuration and enamel type affected the opalescence properties. When a spectrophotometer is used to measure the chromatic value of enamel in the transmitted light, a piece of opaque cardboard used for masking during measurements may affect the obtained results owing to the measurement aperture diameter of 22 mm and small enamel size. Therefore, to eliminate the influence of the measurement process on the obtained results, the measurement aperture of the spectrophotometer was set to 20 mm in the transmission mode, and the diameter of the porcelain specimen was 22 mm to minimize errors.

Researchers have demonstrated that the type of ceramic restoration, its microstructure and thickness, and luting resin cement affect the final colour of the tooth restoration [9, 14, 16, 19, 27–31]. In this study, the light reflectance of the porcelain veneers in the body porcelain group increased while their transmittance decreased with increasing body porcelain thickness. Thus, the difference between the chromatic values of the reflectance and transmission modes increased, causing an increase in the opalescence value. After applying a 0.05-mm opaque porcelain layer, the opalescence value of the porcelain laminate veneer increased significantly, indicating that opaque particles in the opaque porcelain layer significantly increased the chromaticity difference between the reflectance and transmission modes, thus improving the opalescence. When the thickness of the body/opaque porcelain group reached 0.75 mm, the thickness of the body porcelain continued to increase, and the change in the chromatic values of the porcelain veneers in the reflectance and transmission modes was not significant. Thus, the change in the opalescence value observed for the 0.75-mm body/opaque porcelain group was not significant compared with that of the 1.00-mm group, which may be related to the more transparent body porcelain composition. The 1.00 mm body/opaque porcelain group (0.95/0.05 mm) exhibited the highest opalescence value of 17.38, which is closer to the opalescence value of 19.8–27.6 obtained for the natural tooth enamel with thicknesses of 0.9–1.3 mm, as reported by Lee et al. [8]. This phenomenon was observed because the IPS d.SIGN low-temperature porcelain powder contained hydroxyapatite crystals similar to those found in natural teeth, as indicated by the SEM data. The grains in the sintered IPS d.SIGN porcelain material were uniformly dispersed, which increased the degree of light scattering. Moreover, the microstructure of the IPS d.SIGN low-temperature porcelain powder contained leucite and predominant fluorapatite crystals with sizes of 1–3 and 0.4–1.2 μm, respectively. Because fluorapatite is composed of the same needle-like crystals as those present in natural teeth, it produces the same optical effect. Della et al. [15] found that the opalescence properties of ceramic materials were enhanced with increasing contents of ZrO_2, Y_2O_3, SnO_2, and V_2O_5 in the material structure. Shiraishi [32] concluded that the ZrO_2 and V_2O_5 contents in ceramic materials were closely related to their opalescence properties. The results of the present study are consistent with those reported by Della et al. and Shiraishi et al.

For discolored teeth, it is often necessary to select a luting resin cement with a certain colour-shading effect to achieve high-quality aesthetic restoration. Variolink N is a dual-cure/light-cure luting cement material with an organic matrix consisting of bisphenol A–glycidyl methacrylate, urethane dimethacrylate, and triethylene glycol dimethacrylate and inorganic filler composed of barium glass, ytterbium mixed oxides, barium–aluminium fluoride glass, spheroid mixed oxides, initiators, stabilisers, and pigments. The particle size of this cement is 0.04–3 μm, and its mean particle size is 0.7 μm. Owing to the strong aesthetic bonding effect of Variolink N, it has been recently used for bonding ceramic restorations. Variolink N Bleach XL exhibits a certain degree of opacity and is used in the case of a large difference between chromatic values of the abutment and restoration. In this study, the Variolink N Bleach XL luting resin was utilized to produce veneer–luting resin cement composite specimens to analyze the effect of this colour-masking luting resin on the opalescence properties of porcelain veneers.

After the porcelain laminate veneer was coated with the luting resin cement, the opalescence value of the porcelain veneer–luting resin cement composite increased with increasing specimen thickness. Meanwhile, the difference between the chromatic values of the reflectance and transmission modes increased, and the corresponding opalescence values also increased because of the increased reflectance and decreased transmission of the porcelain veneer–luting resin cement composite. Note that the porcelain veneer–luting resin cement composite specimens with the same thickness exhibited higher opalescence values than those of the porcelain laminate veneers. The observed increase in the opalescence of the composite specimens after the application of the luting resin cement was mainly due to the presence of a large number of fillers and other particles, which likely included pigments or oxides, such as barium glass, ytterbium mixed oxides, barium–aluminium fluoride glass, and spheroid mixed oxides. Their refractive indices, which differed from that of the substrate, resulted in a higher degree of light scattering, lower transmission, and significantly greater difference between the chromatic values of the transmission and reflectance modes.

The opalescence values of all body porcelain groups and the 0.50-mm body/opaque porcelain group of the porcelain veneers in this study were less than nine. In contrast, when the thickness of the porcelain veneers in the body/opaque porcelain group exceeded 0.75 mm, the opalescence values were greater than nine, and significant opalescence was observed. The total thickness of the porcelain veneers in the 1.00-mm thickness group (0.95/0.05 mm) combined with the Variolink N Bleach XL luting resin cement exhibited the highest opalescence value of 18.85, which was still lower than the opalescence values obtained for the enamels with thicknesses of 0.9–1.3 mm.

The present study also has several limitations. First, only the effects of the thickness of the 0.05-mm A3 opaque paste and IPS d.SIGN low-temperature porcelain powder on the opalescence properties of porcelain veneers were considered. Second, only the effect of Variolink N Bleach XL opaque luting resin cement on the opalescence properties of the porcelain laminate veneers was analyzed. In future works, different colours of the IPS d.SIGN low-temperature porcelain powder and opaque paste as well as different types and colours of the luting resin cement should be evaluated in terms of their effects on opalescence properties to improve the clinical restorative efficacy.

Conclusions

The opaque porcelain layer and opaque resin cement can significantly improve the opalescence properties of porcelain laminate veneers for discolored teeth, but the opalescence performance is still poor than natural teeth. The body porcelain only contributes to opalescence within a certain thickness range.

Author contributions
Zhemin Li: Methodology, Investigation, Writing - Original draft preparation. Yuchun Chen: Investigation, Data curation. Wanni Fu: Investigation, Formal analysis. Congchong Shi: Investigation, Formal analysis. Yunhong Lin: Validation, Supervision. Jianhua Wu: Validation, Supervision. Xingxing Li: Conceptualization, Project administration, Funding acquisition, Writing - Reviewing and Editing.

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Data availability
All data underlying the findings and outcome are presented as part of the article and no supplementary source data are required.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Conflict of interest
The authors declare no conflict of interest.

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