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Comparison of shear bond strength and color reproduction of two different high-performance polymers veneered with two different thicknesses of resin composite: an in-vitro study

Comparação da resistência ao cisalhamento e reprodução de cor de dois diferentes polímeros de alto desempenho revestidos com duas diferentes espessuras de resina composta: um estudo in vitro

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ABSTRACT

Objective: to evaluate the effect of material type and veneer thickness on the final color and shear bond strength of PEEK bilayered restorations. **Material and Methods:** sixty-four square-shaped core specimens (7×7×2), were fabricated by CAD/CAM technology from two high-strength polymers, BioHPP (High-Performance Polymer, group B n=32), and Pekkton® ivory (PolyEtherKetoneKetone, group P n=32) then were veneered with resin composite (crea.lign dentin A3). Specimens from each group were divided (n=16) according to the veneer layer thickness (0.5 & 1 mm), then according to the test applied (n=8), either ΔE or shear bond strength (SBS). Specimen surfaces were treated according to the manufacturer's instructions. Specimens were veneered according to the manufacturer's instructions.The mode of failure was evaluated under a stereomicroscope at 40 x magnification after the shear bond strength test. **Results:** data showed parametric distribution and variance homogeneity and were analyzed using two-way ANOVA. The significance level was set at $p<0.05$ for all tests. Statistical analysis was performed with the R statistical analysis software version 4.3.1.Results of two-way ANOVA showed that material types and veneer thicknesses had an individual significant effect on the color change. For the shear bond strength, only the sample thickness (1mm) had a significant effect ($p=0.033$). The majority of samples in different groups presented a mixed failure mode with all the differences being not statistically significant ($p>0.05$). **Conclusion:** the thickness of the resin composite veneer can significantly affect the final esthetic outcome and shear bond strength of a bilayered restoration.

KEYWORDS

Composite resins; Polymers; Polyetheretherketone; Polyetherketoneketone; Shear strength.

RESUMO

Objetivo: avaliar o efeito do tipo de material e da espessura do revestimento na cor final e na resistência ao cisalhamento de restaurações em duas camadas de PEEK. **Material e Métodos:** foram fabricados 64 espécimes com núcleo de formato quadrado (7x7x2) usando tecnologia CAD/CAM a partir de dois polímeros de alta resistência, BioHPP (Polímero de Alto Desempenho, grupo B n=32) e Pekkton ivory (Polieterecetona cetona, grupo P n=32), que foram então revestidos com resina composta (crea.lign dentin A3). Os espécimes de cada grupo foram divididos (n=16) de acordo com a espessura do revestimento (0,5 e 1 mm), e depois de acordo com o teste aplicado (n=8), seja ΔE ou resistência ao cisalhamento (SBS). As superfícies dos espécimes foram tratadas de acordo com as instruções do fabricante. Os espécimes foram revestidos de acordo com as instruções do fabricante. O modo de falha foi avaliado sob um estereomicroscópio com ampliação de 40x após o teste de resistência ao cisalhamento. **Resultados:** os dados apresentaram distribuição paramétrica e homogeneidade de variância e foram analisados por ANOVA de duas vias. O nível de significância foi estabelecido em p<0,05 para todos os testes. A análise estatística foi realizada com o software de análise estatística R, versão 4.3.1. Os resultados da ANOVA de duas vias mostraram que os tipos de materiais e as espessuras do revestimento tiveram um efeito significativo individual na mudança de cor. Para a resistência ao cisalhamento, apenas a espessura da amostra (1mm) teve um efeito significativo (p=0,033). A maioria das amostras em diferentes grupos apresentou um modo de falha misto, com todas as diferenças não sendo estatisticamente significativas (p>0,05). **Conclusão:** a espessura do revestimento de resina composta pode afetar significativamente o resultado estético final e a resistência ao cisalhamento de uma restauração em duas camadas.

PALAVRAS-CHAVE

Resinas compostas; Polímeros; Polieteretercetona; Polietercetonacetona; Resistência ao cisalhamento.

INTRODUCTION

PEEK is (-C6 H4 -OC6 H4 -O-C6 H4 -CO-) [1] a polycyclic, aromatic, thermoplastic polymer that is semi-crystalline with a linear structure [2]. It's obtained as a result of the binding of ketone and ether functional groups between aryl rings [3]. It's highly resistant to high temperatures (over 300c°), because of its chemical structure [4]. PEEK has excellent chemical resistance, thermal insulation, poor electrical and thermal conductivity, low friction, low density (1.32g/cm^3) [3] and tensile strength of 90-100 MPa similar to that of enamel and dentin, which makes it a suitable material for fixed prosthodontics restorations [5]. It has a Young's modulus of 3.6GPa, which is close to that of bone [6], and is an opaque material with low plaque affinity and a sterilizing capability. PEEK becomes an alternative material for titanium alloy in implant dental restorations (fixture, abutments, crowns, fixed & removable denture frameworks) because it solves most problems associated with titanium [3]. The off-white color of PEEK requires to be veneered either with resin composite or ceramics to mimic the natural tooth color with better light reflectivity and increased esthetics [7].

BioHPP is a high-tech thermoplastic polymer based on PEEK. It consists of an aromatic backbone molecular chain interconnected by ketone & ether functional groups with a density of 1.3-1.5 g/cm^3 [8]. It contains ceramic micro fillers which occupy about 20% of its volume [5]. These ceramic fillers increase the material strength optimizing its mechanical properties, allowing occlusal forces to be transmitted from the weak organic matrix to the stronger inorganic fillers, decreasing the probability of incidence of cracks, fracture, and plastic deformation or even fracture [9]. It has a modulus of elasticity (~ 4 GPa), very close to bone which makes BioHPP a successful treatment modality in implantology [9]. It permits the chewing forces to be easily transmitted between the BioHPP implant and surrounding bone (shock-absorbing action), decreasing the risk of fracture [8]. BioHPP could be processed by modern CAD/CAM technology and the conventional lost wax method [10].

PEKK is a new material produced by Cendres+Metaux, a top product among thermoplastics. It was launched for fixed dental prosthesis due to the double ketone bond in its chemical structure which increases its compressive strength up to 80% higher than PEEK [11]. PEKK is characterized by a crystalline and amorphous structure which improves its mechanical and chemical properties [12]. BioHPP & PEKK polymers are of great interest for dental applications. Despite their superior properties, their opaque color is considered a limitation to be used as monolithic restorations [13].These polymers must be veneered either with ceramic (indirectly) or with resin composite (directly or indirectly), to enhance the final esthetic outcome of dental restorations.

In the present study, direct composite veneers were applied on a core of BioHPP &PEKK with two different thicknesses. Resin composite material has many benefits when used as a veneering material, such as improving the esthetics of restorations made of opaque white polymers to a degree that could mimic the neighboring tooth structure, being less abrasive to natural teeth, being bio-compatible with surrounding tissues and could be easily repaired in clinics or labs [14].

According to previous studies, only limited information is available on the effect of varying the thickness of resin composite veneer in bi-layered restorations regarding shear bond strength. The mechanical performance of bi-layered restorations depends not only on the nature of the veneering material used but also on the thickness of the material. It was shown that a thicker veneer yields a lower value of flexural strength [15].

According to the polymer pyramid, high-performance polymers (HPP) and PEKK (PolyEtherEtherKetone), belong to the highest-performance plastics based on their chemical structure which is made up of repeating units of macro-molecules that give rise to a long polymeric chain structure in 3 dimensions, the process that provides them with superior mechanical and biological properties. Because of their inferior coloration, they can't be used to restore anterior teeth for the sake of esthetics unless they are veneered with highly esthetic material such as resin composite [16]. Thus, it was a goal to study the effect of varying thicknesses of resin composite on the ΔE color factor.

Recently, the utilization of PEKK in the medical and dental fields has increased due to its promising high biomechanical properties such as compressive, tensile, and flexural strength. The reason is the addition of ketone groups within its molecular structure which makes the material more versatile in surface modification, bonding, and improved temperature compared to PEEK [16].

High-strength polymers present low surface energy and resistance to any surface modification by different chemical treatments, so it becomes difficult to achieve adequate bond strength with resin composite veneers without being classically treated first [17]. Different methods of surface treatments were discussed by previous studies to show the effects of mechanical and chemical treatments on PEEK surfaces. A scoping review by Machado et al. [18] discussed the available surface treatments and adhesives for PEEK to increase its bond strength with resin-based materials. It was concluded that sulphuric acid etching and alumina particle air abrasion followed by applications of bonding agents containing MMA, PETIA, and dimethacrylates are the most effective choices to increase resin-based materials' adhesion to PEEK.

Spectrophotometers are the most widely used devices in measuring color for research work because these devices enable the dentist to perform an accurate and reliable objective analysis [19]. The spectrophotometer functions on the principle of measuring light energy reflected from an object in the visible spectrum [20]. It contains an optical system for measuring, a detector, and a means of converting the light obtained into a signal that could be analyzed [21].

Since spectrophotometers can detect small color differences at a level that is not possible with the human eye, an important issue of color science in dentistry is to establish a reference value for the evaluations of results detected by the color device in terms of ΔE. Thus, it's important to understand whether this color difference can be considered clinically relevant or not. If the ΔE is greater than 1 and less than 3.3, it's considered to be detectable by a skilled operator, but clinically accepted. But if the ΔE is greater than 3.3, it's regarded to be unacceptable because it could be detected by untrained observers [22].

A study by Shiraishi and Watanabe [23] mentioned that the average transmittance of light, translucency, and opalescence parameters of the ceramics are significantly affected by the type of ceramic and its thickness. When light passes through a material, it gradually loses intensity and interacts in 2 ways, either scattering and/or absorption. Thus, the larger the thickness of the material, the greater the degree of scattering and/or absorption of light.

Therefore, the purpose of the present in vitro study was to evaluate the color reproduced from veneering two different thermoplastic polymeric materials (BioHPP & PEKKTON), with two different thicknesses of Crea.lign resin composite material (0.5 & 1mm), followed by an evaluation of the shear bond strength. The hypothesis is null since there was no difference in shear bond strength and color reproduction between different tested groups concerning the material and thickness.

MATERIALS AND METHODS

Preparation of specimens

Sixty-four Specimens of BioHPP® (Bredent GmbH & Co.KG, Germany), in addition to PEKK (Cendres+Métaux), were cut from BreCAM blank and Pekkton® ivory blank, respectively (Table I).

A design of rectangular-shaped blocks with dimensions of 7×7×16 mm (5 blocks for each material), was designed by a software program

Table I - Sample grouping

Acc. For material		Biohpp (Gp B) n=32		Pekk (Gp P) n=32	
Acc. For composite thickness		Gp I n=16 (0.5 mm)	Gp II n=16 (1mm)	Gp III n=16 (0.5 mm)	Gp IV n=16 (1 mm)
Acc. For testing	SBS	Sub-Gp I n=8	Sub-Gp II n=8	Sub-Gp III n=8	Sub- Gp IV n=8
	ΔE	Sub-Gp I n=8	Sub-Gp II n=8	Sub-Gp III n=8	Sub- Gp IV n=8

(Exocad GmbH, Germany). The STL files were exported to the milling machine to fabricate the blocks of both materials. Blocks were embedded into ready-made plastic mold tubes (Ø13mm 20 mm). Cold cure acrylic resin material was injected into the tubes & left to bench cured for 2 hours (This step was done to facilitate the sectioning step of the peek blocks). Blocks were sectioned with a water-cooled slow-speed precision saw (IsoMet 4000; Buehler). The sample size was determined using the R statistical analysis software version 4.1.3 for Windows (R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.) Thirty two specimens from each material were ready to form the core parts. The PEEK core disc thickness was verified using an electronic digital caliper (INSIZE, Jiangsu, China)

Air borne-particle abrasion with 110- μm aluminum oxide grit at a distance of (10-15 mm), with a pressure of 5 to 6 bars in a sandblasting device (Oxyker TRIO, Manfredi, Italy) was performed for 20 seconds for each sample. Subsequently, the discs were cleaned ultrasonically in a bath with deionized water (L&R, Kearny, NY, USA)

Veneering with resin composite

Resin composite (crea.lign, Bredent, Senden, Germany), and dentin shade A3 were selected. Custom-made split Teflon metal molds were designed with 2 designs according to the applied test. The first design (for color reproduction testing), is square in shape with dimensions of 7×7×2.5 mm and 7×7×3 mm to apply 0.5 & 1 mm composite layers respectively. The second design (for SBS testing), is circular in shape Ø3×0.5 mm and Ø3×1 mm to standardize 0.5 & 1 mm resin composite layers. Thicknesses were verified using an electronic digital caliper (INSIZE, Jiangsu, China).

Air-abraded surfaces of all discs ware then conditioned with a thin layer of Visio.link (Bond-lign; bredent GmbH & Co KG), and light polymerized (bre-Lux Power Unit, bredent GmbH & Co KG), for 90 seconds (wavelength range 370 - 400 nm), according to the manufacturer's Recommendations.

For the color reproduction test, square-shaped discs, placed into the Teflon metal mold, were additionally coated with a thin layer of Crea.lign Opaker (Bredent GmbH, Germany), and light-cured for 360 seconds (Brelux Power Unit). Crea.lign paste (Bredent GmbH, Germany), of A3 shade was then injected to fill the mold where the final thickness of each bi-layered specimen was determined by the mold thickness. The final polymerization was performed for 360 seconds according to the manufacturer's instructions.

For the shear bond strength test, veneering resin composite (Crea.lign; bredent GmbH & Co KG), was injected into circular shaped molds located at the center of the PEEK surface. To place a uniform thickness, a smooth and bubble-free layer of composite, a clean glass slab was added over the composite layer to be initially cured for 15 seconds using hand-held lamp light curing followed by final polymerization in a Bre-lux power2 unit box for 360 seconds, according to manufacturer's instructions. .

Finally, the color specimens were polished according to the manufacturer's instructions (Toolkit, Bredent GmbH, Germany).

All specimens were stored in distilled water for 24 hours at 37c°according to ISO recommendation (International Organization for Standardization), thermo cycled for 5000 cycles between 5c° and 55c° with a 30-second dwell time in a thermocycling machine (Thermocycler THE-1100; SD Mechatronics).

Spectrophotometric analysis

Color (ΔE) measurement was carried out against a white background in an Agilent Cary 5000 UV-Vis-NIR spectrophotometer (Agilent Technologies, USA). It is a double-beam direct ratio recording system based on the emission of a light beam from a tungsten halogen lamp. The light beam passes through the double monochromator, and then it is chopped by a chopper mirror into the sample beam and reference beam. The light beam is then detected by a photo-multiplier which is sensitive to the visible/ultraviolet region where the wavelength scan in our measurements was carried out from 380 nm to 780 nm.

CIELab color parameters for each specimen were then calculated from the diffuse reflectance data by using the color software application and the ΔE was calculated via the equation:

$$\Delta E=\left[\left(L^*1-L^*2\right)^2+\left(a^*1-a^*2\right)^2+\left(b^*1-b^*2\right)^2\right]^{1/2} \quad (1)$$

where L* is a measure of the lightness of an object, ranging from 0 (black), to 100(white). The a*coordinate is a measure of redness (a measure of HUE along the red-green axis), where positive a* is related to the amount of redness, while negative a* is related to the amount of greenness. The b* coordinate is a measure of chroma along the yellow-blue axis where positive b* is related to the amount of yellowness, and negative b* is related to the amount of blueness of the specimen.

Shear bond strength evaluation (SBS)

The shear bond strength was measured with a universal testing machine (Model 2719-113; Instron Corp), at a 1-mm/min crosshead speed and converted to MPa by using the equation s=F/S, where s is the shear bond strength, F the load (N) at failure, and S the surface area of the PEEK core/veneering composite resin interface (mm^2) N/mm^2 =MP.

Readymade plastic mold tubes of 13 mm and 10 mm thicknesses were used to fix the specimens. Cold cured acrylic resin was poured into the molds and left to bench cure. Before it reached to the final curing stage, the specimen core was fixed into its top part until complete curing. The samples were positioned in the machine's lower jaw so that it was parallel to the direction of the shear force. The testing device's upper moveable compartment was attached to a stainless-steel rod with a mono-beveled chisel configuration, and this rod was precisely positioned on the interface. The universal testing machine displayed the shear force at fracture in Newton (N) (the force level at which the specimen debonds), using a 2.5 kN load cell connected to a computer. By dividing the fracture load (F) in Newton by the bonded surface area (A) in mm^2, the SBS in megapascals (MPa) was computed.

Failure mode analysis

The tested specimens were collected and visually inspected under a stereomicroscope (Zeiss Discovery V20; Zeiss) at × 40 magnifications to determine the failure mode. An adhesive failure mode at the PEEK/ veneering composite resin interfaces in addition to a mixed failure mode within the PEEK and the veneering composite resin was observed. Cohesive failures were not observed (Figure 1).

Statistical analysis

Categorical data were presented as frequency and percentage values and were analyzed using Fisher's exact test. Numerical data were presented as mean and standard deviation (SD) values. Normality and homogeneity of variances assumptions were tested using the Shapiro-Wilk's and Levene's tests, respectively. Data showed parametric distribution and variance homogeneity and were analyzed using two-way ANOVA. The significance level was set at $p<0.05$ for all tests.

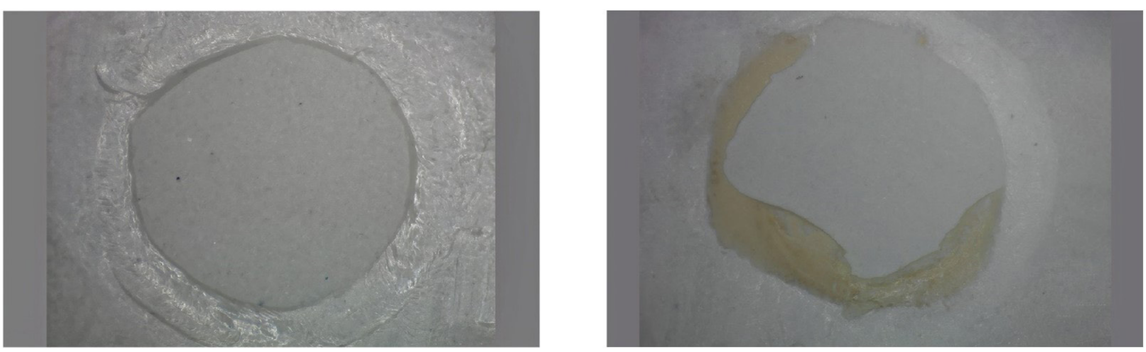

Figure 1 - Representative stereomicroscopic images representing failure between the veneering composite resin and PEEK specimen (Adhesive & Mixed).

Table II - Descriptive statistics

Measurement	Material	Thickness	Mean	95% CI		SD	Min.	Max.
				Lower	*Upper*			
Color change (ΔE)	(B)	*0.5 mm*	2.75	2.54	2.96	0.26	2.42	3.11
		1 mm	2.14	1.97	2.31	0.21	1.87	2.34
	(P)	*0.5 mm*	3.26	3.08	3.44	0.23	2.98	3.55
		1 mm	2.46	2.35	2.57	0.14	2.32	2.69
Shear bond strength (MPa)	(B)	*0.5 mm*	11.99	10.94	13.04	1.31	10.06	13.88
		1 mm	14.43	12.39	16.47	2.55	10.31	16.93
	(P)	*0.5 mm*	12.74	12.13	13.36	0.77	11.43	13.60
		1 mm	14.23	11.86	16.60	2.96	10.48	18.69

95%CI = 95% confidence interval for the mean; SD = standard deviation; Min. = minimum; Max. = Maximum.

RESULTS

Descriptive statistics for color change and shear bond strength values are presented in Table II and in Figures 2-4. Results of two-way ANOVA presented in Table III showed that both the material type and sample thickness had an individual significant effect on the color change (i.e., with group (P) and 0.5 mm thick samples having significantly higher color change) ($p<0.001$). However, the interaction effect was not statistically significant ($p=0.261$). For the shear bond strength, only the sample thickness had a significant effect, with the 1 mm thick samples having significantly higher strength values ($p=0.033$). Summary statistics and results of intergroup comparisons for failure mode distribution are presented in Table IV. Results showed the majority of samples in different groups to have a mixed failure mode with all the differences being not statistically significant ($p>0.05$).

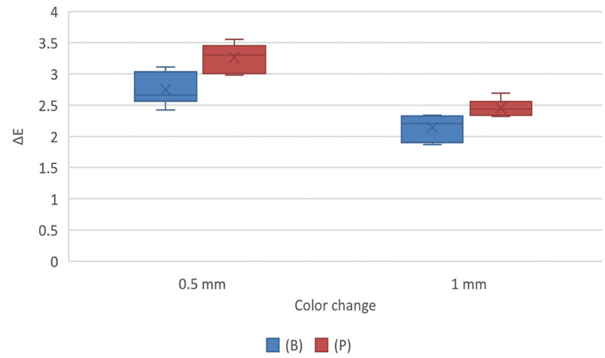

Figure 2 - Box plot showing color change (ΔE) values.

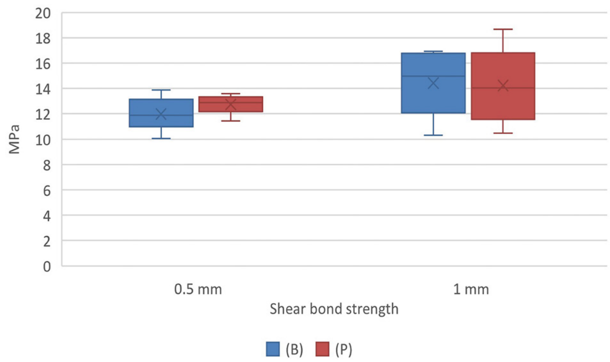

Figure 3 - Box plot showing shear bond strength (MPa) values.

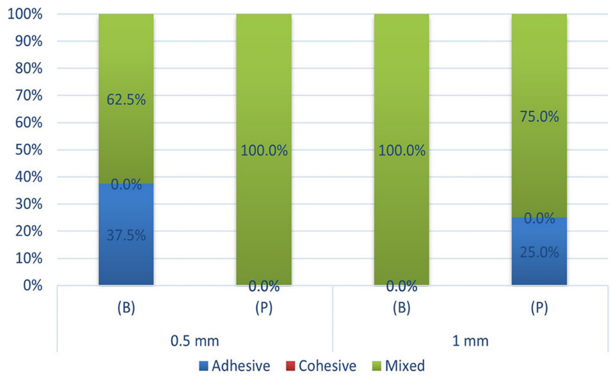

Figure 4 - Stacked bar chart showing failure modes' distribution.

DISCUSSION

Many studies have pointed out the potential of PAEK (Polyaryletherketone) materials in dental applications since their mechanical properties are close to those of human hard tissue and bone, making them a good substrate for dental restorations and teeth [24].

Currently, dental appearance and esthetics constitute a significant concern for the practitioner and are a major requirement for the patient. This has encouraged many researchers to study different esthetic parameters and factors that affect optical properties such as translucency, the color of the core, and thickness of the

Table III - Two-way ANOVA test results

Measurement	Variable	Sum of squares	df	Mean square	f-value	p-value
Color change (ΔE)	*Material*	1.03	1	1.03	22.59	<0.001*
	Thickness	2.98	1	2.98	65.21	<0.001*
	*Material * Thickness*	0.06	1	0.06	1.34	0.261
	Error	0.91	20	0.05		
Shear bond strength (MPa)	*Material*	0.47	1	0.47	0.11	0.748
	Thickness	23.19	1	23.19	5.27	0.033*
	*Material * Thickness*	1.36	1	1.36	0.31	0.584
	Error	88.08	20	4.40		

*Significant (p<0.05); df = degree of freedom.

Table IV - Summary statistics and intergroup comparisons of failure modes

Thickness	Failure mode	n (%) *(B)*	*(P)*	χ^2	p-value
0.5 mm	*Adhesive*	3 (37.5%)	0 (0.0%)	3.69	0.200
	Cohesive	0 (0.0%)	0 (0.0%)		
	Mixed	5 (62.5%)	8 (100.0%)		
1 mm	*Adhesive*	0 (0.0%)	2 (25.0%)	2.29	0.467
	Cohesive	0 (0.0%)	0 (0.0%)		
	Mixed	8 (100.0%)	6 (75.0%)		
χ^2		3.69	2.29		
p-value		0.200	0.467		

restorative material [25]. It was clear in other studies that the comparison between two high-strength polymeric materials such as BioHPP and PEKK lacks information in terms of their difference in color parameters and their effect as core materials on the final esthetic outcomes. Through the results of the present study, the null hypothesis was rejected since both the type of core material and thickness of the veneering material had a significant impact on the color reproduction (p<0.001), while only the resin composite thickness had a significant effect on the shear bond strength (p=0.033).

The ΔE values in the present study showed that the CIELab parameters for the Pekkton veneered group, have statistically higher values than the BioHPP veneered group (p value<0.001). However, these values are not perceptible to the naked eye because ΔE values are > 3.3. Alsadon et al. [26] confirmed that ΔE values ranging from 1→3 are perceptible to the naked eye & ΔE < 3.3 are critical values and therefore clinically unacceptable. It was the first study to evaluate the optical properties of a composite veneered PEKK indirect restoration. Hussain et al. [27] approved that detectable color differences are normally nondiscernible below ΔE values of 1, which convert to unacceptable color at ΔE< 3.3.

Hsu et al. [28] showed that using PAEK (PEEK & PEKK), as a substrate material was deduced to have the best color accuracy (ΔE < 2.9), among all the specimens tested in the present study. The results of various color attributes show that PAEK materials have a better color balance, higher color saturation, and lower hue compared to those of the other groups.

In the current study, samples veneered with 0.5 mm resin composite had statistically higher values than 1mm thick samples. Such a result was supported by the El-Sawaf et al. [22] study that showed that increasing the thickness of composite veneer will reduce the ΔE values significantly. It was then concluded that a 0.5 mm thickness of a composite veneer layer is considered unacceptable because it allows for a significant increase in light transmission with a significant decrease of masking ability. The same findings were in accordance with Ellakany et al. [29]. The outcome of the present study demonstrated that these two variables (the type of core material and thickness for composite veneer), are considered essential criteria for optical properties and variations in color [25]. Therefore, they have a significant effect on the color change (ΔE).

The results of the present study also showed that the type of core material had no significant effect on the shear bond strength values, while veneer thickness was significantly effective. According to ISO 10477.23 standardization [30], the minimum acceptable threshold for the shear bond strength values is 5MPa, and the optimal clinical service limit for SBS is 10MPa. In the present study, all the tested groups reached a high threshold ranging from (11.99:14.33MPa), so the results were accepted for clinical requirements.

Graupner et al. [31] stated that a highly brittle material shows higher toughness with larger sample thickness, a behavior that seems to correlate with the elongation at fracture. Gouda et al. [15] agreed with the present results, showing that different veneering materials behaved differently when considering different thickness ratios between the BioHPP core and the veneering material. Other studies concluded that the thicker the restoration, the higher the tensile stress concentration in the restoration. Thicker occlusal veneers present superior mechanical performance than thinner restorations. Direct conventional and flow resin composite occlusal veneers present a promising mechanical behavior when bonded on enamel or dentin. However, caution is advised when preparing 0.5-mm minimal thickness restorations [32,33]. Other studies showed that multiple factors are known to affect the entire strength of bi-layered restorations other than the thickness of the veneering material such as residual stress, interfacial bonding strength, the direction of loading, as well as the modulus of elasticity and fracture resistance of each layer [34].

Considering the effect of the material's modulus of elasticity, and the fact that materials having a more compatible modulus of elasticity are more likely to bend under load and distribute stresses more evenly [34], Crea.lign resin composite was used as a veneering material in the present study because it has an elastic modulus of 4.4 GPa which showed significantly high flexural strength values [35]. Additionally, the presence of 50% Nano ceramic fillers in the Crea.lign resin composite matrix played a role in improving its mechanical properties and contributing to the high flexural strength values [34]. All the specimens' surfaces are pretreated by air abrasion with 110 μm AL_2O_3 particles followed by the application of Visio.link adhesive primer. Küçükekenci et al. [13] revealed in their study, the importance of surface pretreatment of PEAK and its significance on the shear bond strength with resin composite veneers. Hata et al. [36] concluded that the combination of MMA containing adhesive primer (Visiolink and Signum bond), and resin cement after air abrasion with alumina particles could significantly improve the bond strength. Turkkal et al. [37] concluded that surface pretreatment had a significant role in the adhesive failure of bi-layered restorations regardless of the veneering material strength. They agreed that bonding between the PEEK surface and adhesive is only and solely of a mechanical nature therefore, the use of air abrasion is recommended to enhance the surface micro-roughness of PEEK, thus permitting better infiltration of the adhesive material. On the other hand, it was stated that the use of Visio.link as an adhesive primer is capable of modifying the PEEK surface, and thereby create a chemical bond between the veneering material and the adhesive [18].

All specimens in the present study were exposed to artificial aging in an attempt to simulate the oral conditions in agreement with previous studies which claim that thermal cycling did not affect the flexural strength or load-bearing capacity of PEEK [38]. However, other studies in the literature showed a significantly lower fracture resistance for the Crea.lign veneered PEEK cores after aging [34].

Regarding the mechanical behavior of both PEEK and PEKK, previous studies revealed that both materials had some differences in their stress responses. Results by Villefort et al. [39] showed that PEKK has lower stress concentration values as a prosthetic screw & base in full arch prosthesis under the" all-on-four" concept while lower stress concentration was observed on PEEK frameworks. A study by El Hussieny et al. [40] was in contrast to findings by Alsadon et al. [11] as the first reported that the PEEK group showed lesser strain values in comparison to PEKK. while Alsadon showed that PEKK had better mechanical values when compared to PEEK in terms of tensile, flexural, and compressive strengths with better stress distribution.

The limitations of the study included only one-way surface pretreatment using air abrasion with Al_2O_3 particles. Only one material was used for veneering. Further investigations are needed for a better understanding of the effectiveness of different methods of surface treatment on bonding to PEEK and PEKK. More clinical studies are required concerning different veneering materials.

CONCLUSIONS

In light of the limitations inherent to this study, it can be deduced that a resin composite veneer with a 0.5 mm thickness plays a pivotal role in bilayer PEAK restorations, significantly influencing color reproduction and shear bond strength, thereby highlighting its critical importance in achieving desired clinical outcomes.

Author's Contributions

GAA: Original draft preparation, Investigations, Methodology, Resources, Conceptualization, Writing - Original Draft Preparation, and Writing - Review & Editing. AEE: Supervision, Validation, and Writing - Review & Editing. GAF: Project Administration, Methodology, Writing - Review & Editing, and Formal Analysis. All authors have read and agreed to the manuscript.

Conflict of Interest

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in the present article.

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Regulatory Statement

The present research was approved by the committee of the Faculty of Dentistry Ain Shams University Research Ethics Committee (FDASU-REC).

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