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ASSESSING THE COLOR DIFFERENCE AND TRANSLUCENCY OF BILAYERED RESTORATIONS AFTER VARYING THE FRAMEWORK MATERIAL AND THICKNESS RATIO BETWEEN THE FRAMEWORK AND VENEERING LAYERS

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ABSTRACT

Objective: To assess the influence of changing the thickness ratio between the framework material which was either 3-YTZP or PEEK, and the veneering milled lithium disilicate on color difference and translucency parameter of bilayered restorations.

Materials and Methods: Sixty disc-shaped specimens composed of partially stabilized tetragonal nano-crystalline zirconia or PEEK veneered with milled lithium disilicate (IPS e.max CAD) were randomly divided into two groups (n=30) according to the framework material implemented. Each group was split into 3 subgroups based on the thickness ratio between the framework and the overlying lithium disilicate. The thickness ratios of the framework to the lithium disilicate (T_{FM}: T_{VLD}) were 0.5mm:1mm, 0.7mm:0.8mm, and 1mm:0.5mm. Color difference (ΔE) and translucency parameter (TP) of all specimens were measured using a laboratory spectrophotometer.

Results: Two-way ANOVA results showed that the type of framework, the thickness ratio, and the interaction between both variables, had a significant effect ($p<0.001$) on (ΔE). T_{FM}: T_{VLD} =0.5mm:1mm subgroup showed the lowest (ΔE) values in both groups. For (TP), two-way ANOVA results showed that only the framework material and thickness ratio had a significant effect ($p<0.001$) on (TP). (ZIR) group specimens showed statistically significantly ($p<0.001$) higher (TP) values than (PK) group specimens when all thickness ratios were considered. T_{FM}: T_{VLD} =0.5mm:1mm subgroup in both groups displayed the highest (TP) values.

Conclusions: Changing the ratio between the framework thickness and that of IPS e.max CAD had a significant impact on color difference and translucency parameter with both materials in all thickness ratios.

KEYWORDS Color, Lithium Disilicate, PEEK, Translucency, Zirconia

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INTRODUCTION

Nowadays, with the expeditious and ongoing innovations taking place in the field of CAD/CAM technology together with the versatility of dental materials, implant-supported fixed partial dentures as well as implant-supported full-arch rehabilitations have become a predictable treatment modality[1]. However, it has been documented in the literature that mechanical and biological complications are more likely to happen in implant-supported restorations than in natural tooth-supported fixed prostheses; a thing that intensifies the supreme importance of a proper design of the implant-supported restoration as well as the careful selection of the prosthetic materials [2,3].

One major reason behind the importance of proper prosthetic material selection and its pivotal role in determining the long-term clinical success and stability of the implant-supported prosthesis is the effect of the material on the transmission mechanism of stress created during function [4].

For decades, base metal alloys have served as the gold standard framework material for implant-supported fixed restorations because of their good mechanical properties in terms of high modulus of elasticity, and fracture strength, as well as the outstanding porcelain-to-metal bond strength [5,6]. Nevertheless, the greyish shadow of such base metals serving as frameworks limited their esthetic performance and called for the necessity to implement more esthetic substitutes, especially when considering the esthetic zone [7,8].

Consequently, Yttria-stabilized tetragonal zirconia polycrystalline (3Y-TZP) frameworks were introduced as an esthetic alternative to metal frameworks for implant-supported fixed dental prosthesis owing to the high flexural strength (900-1200 MPa), as well as the high fracture toughness (6.4 Mpa $m^{1/2}$) of 3Y-TZP. However, it displays a major drawback of having a very high modulus of elasticity (200-210 GPa), and a relatively high density (6.05 g cm-3) [9]. Moreover, 3-YTZP frameworks display high strain concentration which implies careful use in situations that might display a potential risk for mechanical complications such as parafunctional habits [10].

Recently and with the ongoing attempts trying to overcome the drawbacks of metal and zirconia frameworks, Polyetheretherketone (PEEK) has appeared as an alternative. It is a high-impact polymeric material with reduced weight, high biocompatibility, and low modulus of elasticity (4 Gpa); all of which promoted its use as an alternative to metal alloys and zirconia, especially with the implant-supported prosthesis, to reduce the risk of mechanical complications by allowing gentle transmission of the chewing pressure to the bone and consequently reducing the risk of failure [11-13]. Additionally, it has a lower density compared to zirconia frameworks which is reflected clinically as less weight of the restoration, a thing that may be favorable in patients requiring extensive full arch prosthesis [14,15].

Further improvements were made to pure PEEK through the incorporation of 20% nano-ceramic fillers and resulted in the introduction of BioHPP which is a modified PEEK material reported to have improved mechanical properties, a better degree of polishability, and superior color stability over time [11,13].

Considering that 3-YTZP, even its nano-crystalline variant, is a relatively opaque material and that modified PEEK is characterized with a distinctive highly opaque greyish color; an esthetic downfall emerges that makes veneering of both materials indispensable particularly in the esthetic zone. [9,16]. However, the inertness of both materials represents a challenge during the conventional framework veneering process [9,12,16-18]. To eliminate such veneering problems, as well as to improve the mechanical, biological and esthetic performance of implant-supported fixed prosthesis, a design composed of single monolithic lithium disilicate full-contour crowns cemented on top of the CAD-milled high-strength 3-YTZP or modified PEEK frameworks was introduced [11,19,20]. Consequently, in addition to omitting the veneering step and problems associated with it, an esthetic gain was achieved through the individually cemented lithium disilicate glass-ceramic crowns since lithium disilicate glass-ceramic consists of approximately 70% of lithium disilicate crystals ($Li_2Si_2O_5$) embedded in a glassy matrix. The glass matrix and crystals have a comparable refractive index of light as well as one similar to that of the dental structure, thus resulting in high translucency [21].

However, multiple studies showed that thickness and combination of ceramic layers affect the esthetic outcome of the final restoration through exerting an effect on color and translucency which are deemed as two highly correlated properties. In bilayered restorations, both the framework material as well as the overlying veneer affect the color match as well as the translucency of the final restoration.[22-34]. However, through literature, there has been a debate regarding the perceptible and acceptable thresholds for color difference where the perceptibility threshold denotes a limit for the color difference identified by an expert clinician while the acceptability threshold points to the amount of color difference detected by an untrained observer [35-37]. On the other hand, multiple methods have been verified in the literature for translucency measurement. One of those methods is the translucency parameter (TP) that is correlated directly to the common visual evaluation of translucency where as the (TP) value increases, the translucency of the material is said to increase [23,25].

Though several studies had emphasized the effect of the framework material and thickness on the final color and translucency of the restoration, very limited data are available comparing both 3-YTZP and modified PEEK regarding their esthetic outcome when used in combination with milled lithium disilicate [27,28,38,39]. Consequently, this study was carried out with the aim of investigating the effect of changing the ratio between 3-YTZP or modified PEEK frameworks, and the overlying CAD milled lithium disilicate on color difference and translucency parameter of the bilayered structure. The null hypothesis was that neither the framework material nor the thickness ratio would have an effect on color difference or translucency parameter.

MATERIALS AND METHODS

For the current study, a total of sixty bilayered disc-shaped specimens 12 mm in diameter and 1.5 mm thick were implemented. The specimens were randomly divided into two equal groups (n=30) according to the type of the framework material that was either 3-YTZP (Group ZIR) or modified PEEK (Group PK). Each of the two groups was then split into three equal subgroups (n=10) based on the difference in the thickness ratios of the framework material and the milled lithium disilicate (Table1).

TABLE (1) Materials used in the study

Material	Type	Composition	Shade	Manufacturer
Bre.CAM BioHPP	Modified Poly-Ether-Ether Ketone	• Poly-Ether-Ether Keton 80% • Aluminum Oxide & Zirconuim Oxide 20%	Dentin Shade	Bredent GmbH & Co KG. Germany
Nacera Pearl Shaded	Nano-crystalline partially stabilized tetragonal Zirconia	$ZrO_2 + HfO_2 + Y_2O_3 > 99\%$, Y_2O_3 4,5% – 6%	Pre-shaded A2	Doceram GmbH. Dortmund, Germany
IPS e.max CAD	Lithium disilicate glass-ceramic (CAD-milled)	SiO_2 57.0 – 80.0 %, Li_2O 11.0 – 19.0%, K_2O 0.0 – 13.0%, P_2O_5 0.0 – 11.0%, ZrO_2 0.0 – 8.0%, ZnO 0.0 – 8.0%,Other and coloring oxides 0.0 – 12.0%	A2, High Translucency (HT)	Ivoclar Vivadent. Schaan, Liechtenstein

Thickness ratios of the framework (T_{FM}): veneering lithium disilicate (T_{VLD}) were 0.5:1 mm, 0.7:0.8 mm, and 1:0.5mm. Such sample size was selected based on the results of previous studies with an 80% power and a .05 level of significance [40,41].

For the construction of the bilayered specimens, different disc designs for the 3-YTZP and modified PEEK, according to the previously selected thicknesses, were CAD designed (Exocad GmbH, Germany), and saved as standard tessellation language (STL) files. The designs made for the 3-YTZP discs had a diameter of 15mm and thicknesses of 0.65mm, 0.9mm, and 1.5mm to permit a 20% shrinkage during sintering. On the other hand, modified PEEK discs were designed with dimensions of 12 mm diameter and thicknesses of either 0.5 mm, 0.7 mm or 1 mm. All STL files were then sent for wet milling (CORiTEC 250i, imes-icore GmbH. Germany) of the discs from their respective blanks.

To fabricate the IPS e.max CAD discs, a cylindrical form was designed using the same CAD software as that used for designing the framework discs. The generated STL file was then exported for milling of the IPS e.max CAD block into a cylindrical form with a 12 mm diameter utilizing the same milling machine. Thirty discs having the same 12 mm diameter and 3 different thicknesses (0.5, 0.8, and 1 mm) were cut from their respective cylinders (Isomet 4000 precision cut, Buchler. USA) under water coolant.

Following the verification of each disc thickness for all three materials using a digital caliper, all 3-YTZP discs were sintered in a high-temperature zirconia furnace (Tabeo-1/M/ZIRKON-100, MIHM-VOGT GmbH&C) following the manufacturer's specifications. On the other hand, IPS e.max CAD discs were placed in a special ceramic furnace; Programat P300/G2 (Ivoclar Vivadent, Schaan, Liechtenstein) for crystallization as per the manufacturer's recommendations. Subsequently, all IPS.emax CAD discs received their intended surface treatment according to the manufacturer's instructions. One surface of each disc was acid etched with 5% hydrofluoric acid (BISCO, USA) for 20 seconds, washed, and air dried. A layer of silane coupling agent (BISCO, USA) was then applied to the etched surface and left to air dry for 60 seconds.

On the other hand, all 3-YTZP and modified PEEK discs were sandblasted on the surface designated for veneering with 50 μm alumina powder at a distance of 10 mm and 0.25 MPa with the help of a specially fabricated holder for the sake of standardization. Following sandblasting, a thin layer of Visio.link (Bond.lign; bredent GmbH & Co KG) was applied on the air abraded surface of all modified PEEK discs and light polymerized (bre.Lux Power Unit, bredent GmbH & Co KG) for 2 minutes following the manufacturer's recommendations. Simultaneously, a thin layer of universal adhesive (All-Bond Universal, BISCO, USA) was applied on the air-abraded surface of all 3-YTZP specimens, air dried for 10 seconds and then light cured for 10 seconds according to the manufacturer's guidelines.

For creation of the bilayered specimens, a special mold 12 mm in diameter and of thickness 1.56 mm, thus preserving a cement space of 60 μm was used. Each zirconia disc, for the group (ZIR) and each modified PEEK disc for the group (PK) was assembled with an IPS e.max CAD disc of the corresponding thickness according to the pre-specified thickness ratios, and the two discs were luted together using dual-cured resin cement of universal shade (Duo-Link, BISCO, USA). For standardization of the pressure applied during cementation, the luted discs were pressed together between two glass plates under a 5 Kg loading device. Excess cement was removed and the IPS e.max CAD surface of all specimens was polished according to the manufacturer's instructions with OptraFine ceramic polishing system (Ivoclar Vivadent, Schaan, Liechtenstein) with a low-speed handpiece under water coolant for 15 seconds.

Measurement for all specimens for color difference (ΔE) was executed in Agilent Cary 5000 UV-Vis-NIR spectrophotometer (Agilent Technologies, USA) against a white background and the CIELab color parameters for each specimen were calculated by using the spectrophotometer pre-set color software. (ΔE) was subsequently calculated through the equation;

$$\Delta E=[(\Delta L)^2+(\Delta a)^2+(\Delta b)^2]½$$

Where; L* value is the lightness-darkness of an object, a* value is the chroma along the red-green axis, and b* value expresses chroma along the yellow-blue axis. ΔL, Δa* and Δb* denote the differences between the color parameters of the A2 shade tab of the Vita Classical shade guide (Vita, Zahnfabrik H. Rauter GmbH&Co. KG) and the measured color parameters for each specimen.

Consequently, each specimen was measured against a white and a black background in Agilent Cary 5000 UV-Vis-NIR spectrophotometer for translucency parameter (TP), and (TP) was calculated through the equation;

$$TP = ((L^*_B-L^*_W)^2 +(a^*_B-a^*_W)^2 + (b^*_B-b^*_W)^2)^{1/2}$$

Where; the subscript "B" denotes the color coordinates over a black background while the subscript "W" denotes the color parameters over a white background

After all (ΔE) and (TP) values were recorded, numerical data were represented as mean, standard deviation (SD), median an interquartile range values. Shapiro-Wilk's test was used to test for normality. The homogeneity of variances was tested using Levene's test. Data showed parametric distribution and variance homogeneity for both (ΔE) and (TP).

Data were analysed using two-way ANOVA followed by Tukey's post hoc test. Comparisons of simple main effects were done utilizing the error term of the two-way model with *p*-values adjustment using Bonferroni correction. The significance level was set at $p<0.05$ within all tests.

RESULTS

Two-way ANOVA results presented in table (2) showed that the framework material, the thickness ratio, as well as the interaction between both variables had a significant effect ($p<0.001$) on (ΔE). It was clear that there was a statistically significant difference ($p<0.001$) between the three thickness ratios in either (ZIR) or (PK) groups with the T_{FM}: T_{VLD} =0.5mm:1mm subgroup showing the lowest (ΔE) values of 9.43±0.37 for (ZIR) group and 9.66±0.31 for (PK) group. On the other hand, T_{FM}: T_{VLD} =1mm:0.5mm subgroup showed the highest (ΔE) values which were 13.10±0.12 for the (ZIR) group and 14.49±0.21 for the (PK) group. However, there was only a statistically significant difference ($p<0.001$) in the amount of color difference between the two framework materials when T_{FM}: T_{VLD} =1mm:0.5mm was used as presented in table (3).

TABLE (2) Two-way ANOVA results for the effect of different variables on mean color difference (ΔE).

Parameter	Sum of squares	df	Mean square	f-value	p-value
Material	1.53	1	1.53	13.66	0.001*
Thickness ratio	92.20	2	46.10	412.29	<0.001*
Martial * ratio	3.62	2	1.81	16.18	<0.001*
Error	2.68	24	0.11		

****significant (p<0.05)***

Looking at the (TP) results, two-way ANOVA results shown in table (4) revealed that only the framework material and thickness ratio had a significant effect ($p<0.001$) on (TP) values, yet their interaction was not statistically significant ($p=0.142$). Results showed that specimens with 3-YTZP framework showed statistically significantly ($p<0.001$) higher (TP) values than specimens with the modified PEEK framework when all thickness ratios were considered. For both materials, the subgroup with the lowest framework thickness displayed the highest (TP) values, while that with the greatest framework thickness showed the lowest values of (TP) as shown in table (5).

TABLE (3) The mean, standard deviation (SD) values, and Bonferroni's post hoc test results for comparison between (ΔE) of the two framework materials with different thickness ratios

Thickness Ratio \ Material	Color Difference (ΔE) (Mean±SD)		*p*-value
	ZIR	PK	
TFM: TVLD =0.5mm:1mm	9.43±0.37^{C}	9.66±0.31^{C}	0.288
TFM: TVLD =0.7mm:0.8mm	11.26±0.51^{B}	11.00±0.35^{B}	0.219
TFM: TVLD =1mm:0.5mm	13.10±0.12^{A}	14.49±0.21^{A}	<0.001*
***p*-value**	<0.001*	<0.001*	

Means with different superscript letters within the same vertical column are significantly different *significant (p<0.05)

TABLE (4) Two-way ANOVA results for the effect of different variables on mean (TP)

Parameter	*Sum of squares*	*df*	*Mean square*	*f-value*	*p-value*
Material	162.83	1	162.83	1489.46	<0.001*
Thickness ratio	4.71	2	2.36	21.55	<0.001*
Martial * ratio	0.46	2	0.23	2.12	0.142
Error	2.62	24	0.11		

*significant (p<0.05)

TABLE (5): The mean, standard deviation (SD) values, and Bonferroni's post hoc test results for comparison between (TP) of the two framework materials with different thickness ratios

Thickness Ratio \ Material	Translucency parameter (TP) (Mean±SD)		*p*-value
	Zir	PK	
TFM: TVLD =0.5mm:1mm	6.24±0.03^{A}	1.68±0.18^{A}	<0.001*
TFM: TVLD =0.7mm:0.8mm	6.12±0.51^{A}	1.12±0.09^{A}	<0.001*
TFM: TVLD =1mm:0.5mm	5.21±0.59^{B}	0.79±0.07^{B}	<0.001*
***p*-value**	<0.001*	0.001*	

Means with different superscript letters within the same vertical column are significantly different *significant (p<0.05)

DISCUSSION

Esthetic restorations, especially those associated with implant-supported prostheses, are usually challenging for clinicians and technicians. Such a challenge is typical in cases of fully edentulous maxillae restored with implant-supported fixed prosthesis where single individual lithium disilicate full-contour crowns are bonded to a CAD-milled high-strength framework. In such a scenario, a challenge is manifested, especially in the anterior region where there is a restricted restorative space to accommodate the thickness of the abutment and the overlying bonded superstructure while attaining the best color match and translucency. However, through literature, it has been documented that multiple factors could affect the final esthetic outcome of the fixed restoration, such as the ceramic material type, thickness of the framework material, and the veneering superstructure, as well as other multiple factors (38,42,43). Accordingly, this study was conducted to shed the light on the role played by the framework material, as well as the thickness of both this framework substructure and the overlying bonded lithium disilicate in shaping the final color and translucency of the restoration.

According to the results obtained, the null hypothesis was rejected where it was demonstrated that both the framework material as well as the thickness ratio between the framework material and the overlying IPS e.max CAD had a significant impact on both the color difference and translucency parameter. Such an outcome is in accordance with previous studies that emphasized the influence of the ceramic thickness on the esthetic outcome of the restorations (22-24).

Through the aforementioned results, it was clear that an increase in framework material thickness together with decreasing the thickness of the IPS e.max CAD would lead to decreased translucency as well as an increase in the color difference compared to the A2 shade tab color parameters. Such results reveal an intertwining relationship between both translucency and color which has been consistent with previous studies (25,30-32,34). Fahmy A et al (33) in one past research showed that the amount of color difference between a restoration and the selected shade increased when the thickness of the veneering material decreased. They attributed that to the increased translucency and consequently reduced ability of the veneering layer to mask underlying core material color when the thickness of the veneering material was reduced. Hence, more light has been allowed to reach the underlying core affecting the final color. Such effect of the underlying framework on the final color of the restoration has been best supported by Dozic A et al (44) who stated that there was a strong correlation between the thickness ratio of the opaque/veneering porcelain and the a* and b* color parameters. They showed that there was a tendency for the a* and b* values, which represent the chromatic character of the color, to increase associated with increasing the thickness of opaque porcelain.

However, all (ΔE) values recorded in the current study, despite the thickness ratio or the framework material used, were beyond the perceptible and acceptable threshold values documented in the literature (35-37). In the present study, the perceptibility, as well as the acceptability thresholds adopted, were described by Douglas et al (37) who considered them to be (ΔE)=2.6 and (ΔE)=5.5 respectively. Such high values of color difference obtained in our study compared to reported threshold values are possibly multi-factorial. In accordance with our results, Ongun S et al (45) reported a pronounced mismatch between the tested ceramic assemblies used in their study and the A2 shade tab where all values were reported to be beyond the acceptable threshold. They suggested that such mismatch was due to the combined influence of the ceramic material used, its thickness, and the cement shade. Hernandes DK (46) et al in a previous study have proved the impact of the resin cement shade on the final color of the restoration. They stated that the cement shade could alter the color of the restoration through affecting the chroma and they emphasized that such effect of the cement is influenced by the ceramic thickness as well as its degree of translucency. Therefore, another suggested reason for such color difference in our study is the use high translucency IPS.emax CAD blocks rather than low translucency ones for the veneering super-structure. Accordingly, it could be postulated that the high translucency of the IPS e.max CAD allowed higher transmission of light together with less masking of the underlying framework and cement colors and thus emphasizing their effect on the final shade of the restoration [21,29].

Bearing in mind the precedent fact that color and translucency are two highly correlated properties, the translucency parameter results obtained in that study become quite understandable when looking at the influence imparted by the different thickness ratios employed in the study. It was noted that the increase in the framework material thickness and the decrease in the thickness of the overlying lithium disilicate has been associated with a significant drop in the translucency parameter of specimens in both (ZIR) and (PK) groups. Considering that 3-YTZP is a semi-translucent material and that modified PEEK is a relatively opaque, therefore increase in their thickness caused a decrease in the direct transmission of light and was associated with a reduction in translucency parameter values. This finding was consistent with Wang F et al [25] who reported that reducing the thickness of zirconia led to an increase in its relative translucency. On the other hand, IPS e.max CAD is characterized by its high translucency due to its relatively low volume of the spindle-shaped lithium disilicate crystals (70%) and their relatively lower refractive index, thus when its thickness increased at the expense of the relatively opaque framework material, translucency increased [47].

However, although the two framework materials employed in the study had an impact on the translucency parameter, that impact was not the same in both groups. It was evident that modified PEEK caused a more significant reduction in (TP) values than the 3-YTZ despite the thickness ratio used which was probably reverted to the highly opaque nature of modified PEEK compared to 3-YTZP. Zeighami S et al [48] in their study reported (TP) values ranging between 0.64 and 0.94 for PEEK specimens of different thicknesses thus confirming the high opacity of PEEK cores. However, that was opposed by the findings reported by Stawarczyk B et al [49] who claimed comparable colorimetric properties of PEEK to those of zirconia cores. The different results could be due to the large core thickness adopted in the later study causing very low transmission of light through both materials; where Spink et al [26] affirmed that as the thickness of the material increased, light must travel farther within the material and therefore, the light would be subjected to increased absorption and scattering and decreased transmission.

Regardless of the significantly different values of (TP) either when comparing the two framework materials used in the study or when comparing the different thickness ratios, they were all in the interval of 0.79-6.24. Compared to natural teeth translucency, such values are considered relatively opaque where the mean (TP) values of 1mm thick human enamel and dentin were reported to be 18.7 and 16.4 respectively [50]. Therefore, these differences reported in the present study may not be significant in clinical practice.

Lately, there has been a confusion among clinicians weighing the pros of using modified PEEK frameworks with their favorable modulus of elasticity and low density and their cons of relatively poor esthetics against zirconia frameworks. Findings drawn through the current study can help end such confusion especially when either of those two materials is used in conjugation with the IPS e.max CAD as a superstructure material. That's typical because although 3-YTZP frameworks displayed better color match and translucency parameter than modified PEEK in all thickness ratios, this superior performance was of no clinical significance with the ΔE values being perceptible and clinically unacceptable, and the TP values being much lower than those of natural teeth. Accordingly, clinicians can choose the framework material based on the functional demands of each case given that the esthetic performance is comparable.

Though some shortcomings could have been there in this study where the effect of the IPS e.max CAD translucency and cement shade were not investigated, the author was trying to limit the variables implemented to focus on the material and thickness effect. Additionally, disk-shaped specimens were chosen over the intended design of anatomical crowns over a framework thus not typically simulating the clinical setup. However, such a design was chosen to facilitate dimensions standardization and assure maintaining an equal distance between the flat specimen surface and the lens of the spectrophotometer thus allowing accurate measurements [51,52]. Authors, hereby advocate that future research is carried out implementing the specimens simulating the actual prosthesis design, as well as investigating the effect of different commercially available superstructure materials of different translucencies, and cement shades.

CONCLUSIONS

Within the limitations of the present study, it was concluded that changing the thickness ratio between the 3-YTZP or modified PEEK frameworks, and the veneering IPS e.max CAD had a significant impact on color difference and translucency parameter. It was also clear that the use of 3-YTZP as a framework rendered better color match and translucency compared to modified PEEK in all thickness ratios. However, no esthetic gain is achieved from 3-YTZP over modified PEEK when either of them is used as a framework in combination with milled lithium disilicate.

REFERENCES

1. Pera P, Menini M, Pesce P, Bevilacqua M, Pera F, Tealdo T. Immediate Versus Delayed Loading of Dental Implants Supporting Fixed Full-Arch Maxillary Prostheses: A 10-year Follow-up Report. Int J Prosthodont. 2019; 32:27-31
2. Pjetursson BE, Sailer I, Zwahlen M, Hämmerle CH. A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years. Part I: Single crowns. Clin Oral Implant Res. 2007; 18:73-85
3. Delucchi F, De Giovanni E, Pesce P, Bagnasco F, Pera F, Baldi D, Menini M . Framework Materials for Full-Arch Implant-Supported Rehabilitations: A Systematic Review of Clinical Studies. Materials (Basel). 2021;14(12):3251.
4. Bacchi A, Consani RL, Mesquita MF, dos Santos MB. Stress distribution in fixed-partial prosthesis and peri-implant bone tissue with different framework materials and vertical misfit levels: a three-dimensional finite element analysis. J Oral Sci. 2013;55(3):239-44.
5. Oyague RC, Sanchez-Turrion A, Lopez-Lozano JF, Suarez-Garcia MJ. Vertical discrepancy and microleakage of laser-sintered and vacuum-cast implant-supported structures luted with different cement types. J Dent. 2012;40(2):123-30.
6. Chandrashekar S, Savadi R, Dayalan M, Prashanth Reddy G. A comparative evaluation of the marginal adaptation of zirconium coping and nickel-chromium coping using shoulder finish line design: an invitro study. J Indian Prosthodont Soc. 2012;12(4):248-51.
7. Kamlesh RD, Nallaswamy D, Ganapathy D. Effectiveness of PEEK Framework in Comparison to Metal Framework for Fixed Dental Prosthesis: A Systematic Review. World J Dent. 2022;13 (1):80-6
8. Castorina G. Carbon-Fiber Framework for Full-Arch Implant-Supported Fixed Dental Prostheses Supporting Resin-Based Composite and Lithium Disilicate Ceramic Crowns: Case Report and Description of Features. Int J Periodontics Restor Dent. 2019; 39:175-84.
9. Ozcan M, Bernasconi M. Adhesion to zirconia used for dental restorations: a systematic review and meta-analysis. J Adhes Dent 2015;17:7-26
10. Tiossi R, Gomes É.A, Faria ACL, Rodrigues RCS, Ribeiro RF. Biomechanical behavior of titanium and zirconia frameworks for implant-supported full-arch fixed dental prosthesis. Clin. Implant Dent Relat Res. 2017; 19: 860-6.

11. Cabello-Domínguez G, Pérez-López J, Veiga-López B, González D, Revilla- León M. Maxillary zirconia and mandibular composite resin-lithium disilicate-modified PEEK fixed implant-supported restorations for a completely edentulous patient with an atrophic maxilla and mandible: a clinical report. J Prosthet Dent. 2020;124(4):403-10.

12. Jin HY, Teng MH, Wang ZJ, Li X, Liang JY, Wang WX, et el. Comparative evaluation of BioHPP and titanium as a framework veneered with composite resin for implant-supported fixed dental prostheses. J Prosthet Dent. 2019;122(4):383-88

13. Georgiev J, Vlahova A, Kissov H, Aleksandrov S, Kazakova R. Possible application of Biohpp in prosthetic dentistry: a literature review. J of IMAB. 2018; 24: 1896-8

14. Alexakou E, Damanaki M, Zoidis P, Bakiri E, Mouzis N, Smidt G, Kourtis S. PEEK High Performance Polymers: A Review of Properties and Clinical Applications in Prosthodontics and Restorative Dentistry Eur J Prosthodont Restor Dent. 2019;27:113-21.

15. Cokic SM, Vleugels J, Van Meerbeek B, Camargo B, Willems E, Li M, Zhang F. Mechanical properties, aging stability and translucency of speed-sintered zirconia for chairside restorations. Dent Mater 2020; 36: 959-72

16. Papathanasiou I, Kamposiora P, Papavasiliou G, Ferrari M. The use of PEEK in digital prosthodontics: A narrative review. BMC Oral Health. 2020;20(1):217

17. Adem N, Bal B, Kazazoğlu E. Comparative Study of Chemical and Mechanical Surface Treatment Effects on The Shear Bond Strength of Polyether-Ether-Ketone to Veneering Resin. Int J Prosthodont. 2022;35(2):201-7

18. Sloan R, Hollis W, Selecman A, Jain V, Versluis A. Bond strength of lithium disilicate to polyetheretherketone. J Prosthet Dent. 2021;17:21-35

19. Pozzi A, Tallarico M, Barlattani A. Monolithic Lithium Disilicate Full-Contour Crowns Bonded on CAD/CAM Zirconia Complete-Arch Implant Bridges With 3 to 5 Years of Follow-Up. J Oral Implantol. 2015;41(4):450-8

20. Cho Y, Raigrodski AJ. The rehabilitation of an edentulous mandible with a CAD/CAM zirconia framework and heat-pressed lithium disilicate ceramic crowns: a clinical report. J Prosthet Dent. 2014;111(6):443-7

21. Tysowsky GW. The science behind lithium disilicate: a metal-free alternative. Dent Today. 2009;28:112-13.

22. Tabatabaian F, Jafari A, Namdari M, Mahshid M. Influence of coping and veneer thickness on the color of zirconia-based restorations on different implant abutment backgrounds. J Prosthet Dent. 2019;121(2):327-32

23. Jeong ID, Bae SY, Kim DY, Kim JH, Kim WC. Translucency of zirconia-based pressable ceramics with different core and veneer thicknesses. J Prosthet Dent. 2016;115:768-72.

24. Oh SH, Kim SG. Effect of abutment shade, ceramic thickness, and coping type on the final shade of zirconia all-ceramic restorations: in vitro study of color masking ability. J Adv Prosthodont 2015;7:368-74.

25. Wang F, Takahashi H, Iwasaki N. Translucency of dental ceramics with different thicknesses. J Prosthet Dent. 2013;110:14-20.

26. Spink LS, Rungruanganut P, Megremis S, Kelly JR. Comparison of an absolute and surrogate measure of relative translucency in dental ceramics. Dent Mater. 2013;29: 702-7

27. Wahba MM, El- Etreby SA, Morsi ST. Effect of core/veneer thickness ratio and veneer translucency on absolute and relative translucency of CAD-On restorations. Future Dent J. 2017;3(1):8-14.

28. Shokry T, Shen C, Elhosary M, Elkhodary A. Effect of core and veneer thicknesses on the color parameters of two all-ceramic systems. J Prosth Dent. 2006;95(2):124-9.

29. Rasetto FH, Driscoll CF, Prestipino V, Masri R, von Fraunhofer JA. Light transmission through all-ceramic dental materials: a pilot study. J Prosth Dent. 2004;91(5):441-6.

30. Wahba MM, El- Etreby SA, Morsi ST. Evaluation of color change in CAD-On restorations using different core/veneer thickness ratios and different veneer translucencies. Future Dent J. 2018;4(1):90-95

31. Tabatabaian F, Taghizade F, Namdari M. Effect of coping thickness and background type on the masking ability of a zirconia ceramic. J Prosthet Dent. 2018;119(1):159-65

32. Choi YJ, Razzoog ME. Masking ability of zirconia with and without veneering porcelain. J Prosthodont. 2013;22:98-104

33. Fahmy AR, Zohdy M, Abd El Fattah G. Color reproduction of PEEK material veneered with IPS e. max and Visio. lign and composite blocks with different thicknesses. Al-Azhar Journal of Dental Science 2020; 23(1); 87-94.

34. Wan J, Yang J, Lv K, Zhang H, Huang H, Jiang X. Can we use the translucency parameter to predict the CAD/CAM ceramic restoration aesthetic? Dent Mater. 2023;39(3): e1-e10

35. Ishikawa-Nagai S, Yoshida A, Sakai M, Kristiansen J, Da Silva JD. Clinical evaluation of perceptibility of color differences between natural teeth and all-ceramic crowns. J Dent. 2009;37(Suppl 1):e57-63

36. Ghinea R, Pérez MM, Herrera LJ, Rivas MJ, Yebra A, Paravina RD. Color difference thresholds in dental ceramics. J Dent. 2010;38(suppl 2):e57-64.

37. Douglas RD, Steinhauer TJ, Wee AG. Intraoral determination of the tolerance of dentists for perceptibility and acceptability of shade mismatch. J Prosthet Dent. 2007;97:200-8.

38. Alayad AS, Alqhatani A, Alkatheeri MS, Alshehri M, AlQahtani MA, Osseil AEB, et al. Effects of CAD/CAM ceramics and thicknesses on translucency and color masking of substrates. Saudi Dent J. 2021;33:761-8.

39. Basso GR, Kodama AB, Pimentel AH, Kaizer MR, Della Bona A, Moraes RR, et al. Masking colored substrates using monolithic and bilayer CAD-CAM ceramic structures. Oper Dent. 2017;42:387-95.

40. Ashy LM, Al-Mutairi A, Al-Otaibi T, Al-Turki L. The effect of thermocyclic aging on color stability of high translucency monolithic lithium disilicate and zirconia ceramics luted with different resin cements: an in vitro study. BMC Oral Health. 2021;21(1):587.

41. Alameldin A, Shokry T, El-Kouedi A. Effect of Thickness Variation on the Translucency of Two Recent High Translucent Monolithic Zirconia Ceramics. Al-Azhar Journal of Dental Science. 2020; 23(4), 321-6

42. Pérez MM, Della Bona A, Carrillo-Pérez F, Dudea D, Pecho OE, Herrera LJ. Does background color influence visual thresholds? J Dent. 2020;102:103475

43. Iravani M, Shamszadeh S, Panahandeh N, Sheikh-Al- Eslamian SM, Torabzadeh H. Shade reproduction and the ability of lithium disilicate ceramics to mask dark substrates. Restor Dent Endod. 2020;45:e41

44. Dozic A, Kleverlaan CJ, Meegdes M. The influence of porcelain layer thickness on the final shade of ceramic restorations. J Prosthet Dent. 2003;90:563-70.

45. Ongun S, Önöral Ö, Günal-Abduljalil B. Evaluation of shade correspondence between current monolithic CAD/CAM blocks and target shade tab by considering the influence of cement shade and restorative material thickness. Odontology.2021; 109: 393-402

46. Hernandes DK, Arrais CA, Lima Ed, Cesar PF, Rodrigues JA. Influence of resin cement shade on the color and translucency of ceramic veneers. J Appl Oral Sci. 2016;24(4):391-6.

47. Ding Y, Jiang S, Luo T, Miura Y, Peyghambarian N. Lithium disilicate crystalline slab wave guides from surface crystallised glass. Electronic letters. 1999;35;504-5.

48. Zeighami S, Mirmohammadrezaei S, Safi M, Falahchai SM. The Effect of Core and Veneering Design on the Optical Properties of Polyether Ether Ketone. Eur J Prosthodont Restor Dent. 2017;25(4):201-8.

49. Stawarczyk B, Schmid P, Roos M, Eichberger M, Schmidlin PR. Spectrophotometric Evaluation of Polyetheretherketone (PEEK) as a Core Material and a Comparison with Gold Standard Core Materials. Dent Mater J. 2016;9:491.

50. Yu B, Ahn JS, Lee YK. Measurement of translucency of tooth enamel and dentin. Acta Odontol Scand. 2009; 67(1):57-64.

51. Gupta R, Parkash H, Shah N, Jain V. A spectrophotometric evaluation of color changes of various tooth colored veneering materials after exposure to commonly consumed beverages. The Journal of Indian Prosthodontic Society. 2005; 5(2):72-8.

52. Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part I: core materials. J Prosthet Dent. 2002;88(1):4-9.