Research Article:

COMPARISON OF SHADE OF CERAMIC WITH THREE DIFFERENT ZIRCONIA SUBSTRUCTURES USING SPECTROPHOTOMETER

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ABSTRACT:

Objective: This study assessed how changing the Zirconia (Zr) substructure affected the colour samples after they have been overlaid by the same shade of veneering ceramic.

Methods: Three commercial Zr materials were tested in this study: Prettau® Zirconia (ZirKonZahn, Italy), Cercon (Dentsply, Germany) and InCoris ZI (Sirona, Germany). For each system, fifteen disc-shaped specimens (10*1 mm) were fabricated. Three shades of A1, A2 and A3.5 of porcelain (IPS e.MaxCeram, IvoclarVivadent, USA) were used for layering the specimens. 5 specimens from each type of Zr were layered with same shade of ceramic. Color measurements were recorder by a spectrophotometer Color-Eye® 7000A (X-Rite, Grand Rapids, MI). Mean values of L, a, b color coordinates and ΔE were recorded and comparisons were made.

Results: Differences in the ΔE were recorded for the same porcelain shade with different Zr substructures and affected the color of the specimens ($p<.01$, ANOVA). The maximum difference between the ΔE values for the A1, A2 and A3.5 shades with three types of Zr substructures was found to be 1.59, 1.69 and 1.45 respectively. Multiple comparisons of the ΔE with PostHoc Tukey test revealed a statistically significant difference ($p<.05$) between the three types of Zr, except between Type2 Zr and Type3 Zr for the Shade A1. The mean values of L, a, b and ΔE for the Prettau® Zirconia substructure were found to be the least among the three types.

Conclusions: The brand of Zr used influences the final color of the all ceramic Zr based restorations and this has clinical significance.

Key words: Zirconia color; Zirconia Shade; Zirconia; Ceramic Shade; Zirconia substructure.

INTRODUCTION

One of the most challenging aspects of restorative dentistry is to achieve a natural looking restoration and the color matching of the restoration with the existing teeth is a difficult task. The difficulty of achieving good esthetics with metal ceramic crowns which is widely used over the last few decades has resulted in the increased use of all ceramic crowns. Ceramics are, however, brittle materials and cannot withstand deformation of > 0.1% without fracturing. To overcome this issue, high strength ceramic copings based on Zirconia (Zr) have been introduced.[1-4]

The use of Zr has increased tremendously during the last few years which is due to its peculiar mechanical, optical, physical properties and its biocompatibility.[5-7] Although the properties of Zr are promising, the tooth restoration unit forms a laminate system which consists of veneering ceramic, the coping material, the luting cement and the abutment tooth. All of these units may influence the ability of Zr based restorations to match the color with the adjacent natural teeth.[8-16] Zr substructures (copings) manufactured by different companies mostly are yttria-stabilized tetragonal Zr polycrystals (Y-TZP) with comparable compositions and may have slightly different microstructures.[17] Because of this slight variation in the microstructure which results in light scattering they could have different degree of opacities. From an esthetic viewpoint a ceramic material should allow light transmission (be translucent) to simulate the optical characteristics of a natural tooth.[3, 5, 10, 11]

Kelly et al[3] demonstrated that core translucency was one of the primary factors in controlling esthetics. Only few data is available on the translucency of different Zr substructures. Heffernan et al[10, 11] reported the Zr to be a completely opaque material and it was later confirmed by Chen et al.[12] In a study by Baldissara et al[18], light transmission through Zr was significantly lower than

through lithium disilicate glass ceramics. The authors also reported different translucency values for different Zr materials. The current literature shows that Zr should be considered as low translucent to semi translucent core material.[18, 19]As reported by Conrad et al[20] it should be taken into consideration that the translucency measurements for Zr cores are carried out on core material in the absence of veneering material and are not representative of usual clinical conditions in which the presence of veneering porcelain also influences the final color of the restoration. In a study by Choi et al[13] it was reported that the degree of masking ability of Zr coping can be further modified with the veneering porcelain. Suputtamongkol et al[21] studied the effect of the color of a background substructures on the overall color of Zr based all ceramic crowns. No significant differences were observed between the Zr crowns cemented either on a metal cast post and core or a prefabricated post and composite core in their study. However, Kumagai et al[22] in a study reported that the translucency of a Zr based all ceramic crowns may influence its esthetic outcome when it is used on a discolored abutment tooth.

Studies regarding the color of Zr based restorations are mostly focused on translucency of different Zr materials with various thicknesses, effect of the luting cements and various fabrication procedures.[15-23] Studies related to the effect of Zr copings on the final shade of Zr based all ceramic restorations are scarce and the subject requires to be more widely investigated.[1] With the availability of various brands of Zr substructures in the market, it is possible that altering the substructure may alter the color of the final veneering ceramic. It is therefore important to investigate the effect of different brands of Zr substructures on the final color of the restoration with the same shade of veneering ceramic. The aim of this in vitro study therefore was to evaluate and compare the effect of three brands of Zr substructures manufactured by different manufacturers on the resulting color of ceramic with the use of a spectrophotometer.

The null hypothesis was that there would be no differences in the CIELAB color coordinates and ΔE of a 1-mm-thick layer of ceramic fired on different Zr substructures.

MATERIALS AND METHODS

Three commercial Zr core materials were tested in this study: Cercon, Dentsply, Germany, InCoris ZI, Sirona, Germany and Prettau® Zirconia, ZirKonZahn, Italy. For each system, fifteen disc-shaped specimens were designed and fabricated (10 mm diameter and 1 mm thickness). A power calculation was run on results from a previous study to determine the number of specimens (SD<0.40) needed to achieve an 80% power.

Two different techniques were used to fabricate the Zr discs. Zr discs of Cercon and InCoris Zirconia blocks were prepared using water-cooled thin diamond discs in a low-speed straight headpiece (KaVo Dental). The specimens were rinsed to remove residue, and dried prior to sintering procedure. For the ZirKonZahn, the discs were prepared using a computer-aided milling process after scanning and digitizing a metal disc analog. The total number of the specimens was 45. Each of the specimens was examined and measured twice in three different locations with a digital caliper (Mitutoyo Co, Kawasaki, Japan) to verify the shape, size and thickness.

Sintering procedure of all specimens were completed using a high-temperature furnace according to manufacturer instructions of each material (Sintramat furnace, Ivoclar Vivadent) resulting in approximately 20% shrinkage. The Zirconium discs were placed in the furnace and sintered at 1500^{o}C for 7 hours. The shape and thickness of the specimens were adjusted after sintering with a cylindrical diamond flat-end bur (Dentsply Ltd, York, PA) and finishing disc (Indenco, Coirona, CA), to the final required shape and thickness. For the standardization, a digital caliper (Mitutoyo Co, Kawasaki, Japan) with an accuracy of 0.05 mm was used twice to measure the thickness in five different areas of each specimen and adjustments made if required. All

specimens were ultrasonically cleaned in distilled water for 10 minutes and dried to be free of dirt and grease.

The specimens were divided into three groups of 15 samples with 5 specimens from each type of the Zr material. The Zr types were coded as Type 1 Prettau® Zirconia (ZirKonZahn, Italy), Type 2 Cercon (Dentsply, Germany) and Type 3 InCoris ZI (Sirona, Germany). Three different shades of A1, A2 and A3.5 of IPS E.Max Ceram, low-fusing nano-flourapatite dentine porcelain (Ivoclar Vivadent, Schaan, Liechtenstein) were used for layering the specimens. Each of the group was layered with the same shade of ceramic to investigate the effect of the different types of Zr substructure on the shade of the ceramic. The veneering process began with a wash firing. Dentin porcelain powder was mixed with all round build-up liquid. A thin layer was applied on the entire surface of ZirLiner. The dentin porcelain slurry was condensed with vibration, and excess moisture was removed with paper tissue to minimize porosity. Group specimens were fired together in the sintering furnace (Multimat Touch & press; Dentsply Ltd, York, PA) at 750^{o}C for 1 minute. The addition of porcelain and a second dentine firing cycle was carried out to compensate for peripheral shrinkage of the initial veneering porcelain. Finally, the discs were ground and polished on the veneer side to the designated thickness of 1.0 mm. The specimen’s thickness was measured twice by a digital caliper (Mitutoyo Co, Kawasaki, Japan) with an accuracy of 0.05 mm in five different areas and adjustments made if required.

Glazing cycle was not performed. The porcelain surface was polished using three types of sand paper discs; s320-, 600- and 1200-grit sand paper discs in order to obtain a similar finishing surface in all the specimens. Specimens were then cleaned ultrasonically with distilled water for 5 minutes.

Color measurements were made by a laboratory spectrophotometer, Color-Eye® 7000A (X-Rite, Grand Rapids, MI). The machine was designed to hold the sample in front of 10 mm X 3mm screen. Measurement procedure started by calibration of the machine and then measuring the color of three A1, A2 and A3.5 shade tabs (used for calculating ΔE) for the same porcelain system (IPS e.max Ceram shade guide) used with the Zr specimens. Three measurements were recorded for each shade tab and for each specimen, and the average was used for statistical analysis.

Statistical analysis

Data was analyzed using SPSS V18.0.1 software package (SPSS, Inc., Chicago, IL, USA). The descriptive statistics included the mean values of L, a, b color coordinates and recording of ΔE for each specimen of the three groups and comparison of these latter means (95% CIs) across all three independent groups using one-way ANOVA and Tukey's *post hoc* test. The probability for statistical significance was set at $\alpha < 0.05$.

RESULTS

The descriptive statistics of the spectrophotometric readings for same type of ceramic shade of A1, A2 and A3.5 with different types of Zr substructures are presented in Tables 1. The Table describes the mean values for L, a, b color coordinates and ΔE for each of the Ceramic-Zirconia combination.

The mean values of L, a, b and ΔE for the Zr (Prettau® Zirconia) substructure with ceramic layers of different shades A1, A2 and A3.5 were found to be the least and for the Zr (InCoris ZI) substructure were found to be the highest (Table 1).The maximum difference between the ΔE values for the A1, A2 and A3.5 shades ceramic with three types of Zr substructures was found to be 1.59, 1.69 and 1.45 respectively.

[Table 1]

Table 2, 3 and 4 shows the comparison of mean values of ΔE for the three types of Zr substructures with different ceramic shades of A1, A2 and A3.5 showed a statistically significant difference $p<0.05$with one way analysis of variance.

Multiple comparisons of the three types of Zr with different ceramic shades with Post Hoc Tukey test revealed a statistically non-significant difference between the Type 2 Zr and Type 3 Zr for the Shade A1. All the rest of the comparisons revealed a statistically significant difference between the three types of the Zr substructures. The results of the Tukey's multiple comparison tests are listed in Table 2, 3&4.

[Table 2]

[Table 3]

[Table 4]

DISCUSSION

For the restorations in the esthetic zone, all ceramic crowns are popular and widely used. Zr is currently choice of substructure used for all ceramic crowns, if high flexural strength or masking a heavily discolored tooth is desired.[1, 4, 5] However, the color of the Zr substructure may influence the final shade of the veneering ceramic because of the availability of a number of Zr brands in the market.[20, 21, 22] The selection of the brand of Zr substructure for a particular case is therefore a concern for the dentist.[3] Samples of three brands of Zr substructures with same shade of veneering ceramics under standardized conditions were prepared and tested in the current study. To the authors knowledge no such study has been reported in the literature.

The results of this study supports rejection of the null hypothesis, as significant differences in CIELAB color coordinates (L*, a*, b*) and ΔE values of ceramic fired on different types of Zr substructures were noted. The CIELab* system was developed in 1976 and 1978 and it was possible to express color by numbers and calculate the differences between two colors in a way that corresponded to visual perception. In this system, which is regarded as the benchmark for scientific purposes, color is expressed by three coordinates: L* value is the degree of lightness of an object, a* value is the degree of redness/greenness, and b* value is the degree of yellowness/blueness. In the CIELab* system a formula is used to calculate color differences:[1,15,21,22]

$$\Delta E_{ab} = [(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2]^{1/2}.$$

This "ΔE" value became pivotal in color science, for both industry and dentistry. Since spectrophotometers can detect small differences in color at a level that is not appreciable by the human eye, an important issue of color science in dentistry is to establish a reference value for

the evaluation of study results in terms of ∆E. In other words, if in a study a certain difference in terms of ∆E has been measured, it is important to understand whether this difference can be perceived by the human eye and, if so, whether this difference can be considered clinically relevant. ∆E values of less than 1 unit were regarded as not appreciable by the human eye; ∆E values greater than 1and less than 3.3 units were considered appreciable by skilled operators, but clinically acceptable; ∆E values greater than3.3 were considered perceivable by untrained observers (e.g. patients), and for that reason were regarded as not acceptable.[1,24,25,26,27] The results of the current study revealed a maximum difference between the ∆E values for the A1, A2 and A3.5 shades ceramic with three types of Zr substructures was found to be 1.59, 1.69 and 1.45 respectively. Although, the comparison between the ∆E of the three types of Zr substructures with same ceramic shade revealed a statistically significant difference $p<0.05$, the clinical value of these results are unclear because the maximum difference in the ∆E values observed in the current study (1.59, 1.69 and 1.45) are close to 1 and therefore, not appreciable by a human eye.

Studies have shown that the shade of the core material and the luting cements has little effect on the final color of the ceramic restorations. This also depends on the thickness of the porcelain used. If the thickness is more than 1.5mm, its effect will be negligible. A thickness of 1mm ceramics or less will have the effect of the shade of the core or cement on the final color of the ceramic restoration. This effect is because of the translucency of the all ceramic crowns.[26,27,28] A similar conclusion can be drawn for the effect of the Zr substructures on the overall shade of the Zr based restorations with ceramic thickness of 1mm. This was tested in the current study and a statistically significant difference was observed between the ∆E of the three types of the Zr

substructures. However, the perceptible color difference is not clear because of the difference of ΔE between the three types close to 1.

There are some limitations of the study. 1 mm thick Zr substructure specimens were used. However, the translucency of the Zr may vary with its thickness. In the clinical situations a Zr substructure as thin as 0.3mm can be used.[22,28] This variation in thickness of the substructure can have influence on the final color of the restoration. Each specimen was prepared by same technician and verified for thickness of the Zr and ceramic layer applied. But the chances of human error during the sample preparation cannot be ignored. The translucency value for the different Zr materials varies and can be influenced by the luting cement and the core material.[26,28] In the current study spectrophotometric readings were recorded without the use of the luting cement and core material which can result in variation of the readings. Oral condition is very complex and it is almost impossible to mimic the actual clinical situation with this in vitro study. So the interpretation of the current results should be made with caution.

There are a number of Zr materials available in the market manufactured by different companies. However, studies about Zr based all ceramic crowns are limited. The physical and optical properties of these materials vary and the clinicians should keep this in mind while selecting a Zr based all ceramic crowns for their patients. Further studies in this regard are recommended to draw more relevant conclusions which can help the clinicians while choosing the materials for their patients.

CONCLUSIONS

Within the limitations of the study it can be concluded that; The final color of the all ceramic crowns with Zr substructure is influenced by the type of Zr used. Human eye may not detect the differences of the final shade. However, thickness of the porcelain layer and Zr substructure may affect the ability to detect the differences of the shade.

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Table 1. Descriptive statistics of L, a, b and ΔE values for different ceramic-zirconia combinations. (n=5/group)

Ceramic Shade	Zirconia Substructure	Mean values			
		L	a	b	ΔE
A1	Prettau®	134.81	-1.93	7.05	12.37
	Cercon	139.05	-1.89	12.07	13.11
	InCoris ZI	135.41	1.15	19.12	13.44
A2	Prettau®	129.46	-1.20	9.70	12.00
	Cercon	131.34	1.22	20.20	13.17
	InCoris ZI	133.12	3.13	23.43	13.69
A3.5	Prettau®	129.25	-0.84	14.36	12.02
	Cercon	128.46	2.48	23.86	12.98
	InCoris ZI	129.65	3.94	27.70	13.47

L=degree of lightness, a=degree of redness/greenness, b=value is degree of yellowness/blueness, ΔE=Color differences between the shade tab and the samples.

Table 2. Comparison of ΔE values for combination of A1 ceramic with different Zirconia Substructures. (n=5/group)

Ceramic Shade	Zirconia Type	Mean ΔE	Std. Deviation	95% Confidence Interval for Mean		ANOVA	Multiple Comparisons With Post Hoc Tukey			
				Lower Bound	Upper Bound					
A1	Prettau®	12.23	.20	11.98	12.48	.000		**T1A1**	**T2A1**	**T3A1**
	Cercon	13.08	.14	12.90	13.25		**T1A1**	0	.004	.000
	InCoris ZI	13.46	.51	12.83	14.10		**T2A1**	.004	0	.192
Total	15	12.92	.28	12.59	13.26		**T3A1**	.000	.192	0

T1A1=Prettau®Zirconia with A1 shade ceramic, T2A1=Cercon Zirconia with A1 shade ceramic, T3A1=InCoris ZI with A1 shade ceramic.

Table 3. Comparison of ΔE values for combination of A2 ceramic with different Zirconia Substructures. (n=5/group)

Ceramic Shade	Zirconia Type	Mean ΔE	Std. Deviation	95% Confidence Interval for Mean		ANOVA	Multiple Comparisons With Post Hoc Tukey			
				Lower Bound	Upper Bound					
A2	Prettau®	12.00	.07	11.91	12.09	.000		**T1A2**	**T2A2**	**T3A2**
	Cercon	13.17	.16	12.97	13.38		**T1A2**	0	.000	.000
	InCoris ZI	13.69	.04	13.63	13.75		**T2A2**	.000	0	.000
Total	15	12.96	.09	12.55	13.36		**T3A2**	.000	.000	0

T1A2=Prettau®Zirconia with A1 shade ceramic, T2A2=Cercon Zirconia with A1 shade ceramic, T3A2=InCoris ZI with A1 shade ceramic.

Table 4. Comparison of ΔE values for combination of A3.5 ceramic with different Zirconia Substructures. (n=5/group)

Ceramic Shade	Zirconia Type	Mean ΔE	Std. Deviation	95% Confidence Interval for Mean		ANOVA	Multiple Comparisons With Post Hoc Tukey			
				Lower Bound	Upper Bound					
A3.5	Prettau®	12.02	.08	11.91	12.13	.000		**T1A3.5**	**T2A3.5**	**T3A3.5**
	Cercon	12.98	.12	12.83	13.13		**T1A3.5**	0	.000	.000
	InCoris ZI	13.47	.16	13.26	13.68		**T2A3.5**	.000	0	.000
Total	15	12.82	.12	12.47	13.17		**T3A3.5**	.000	.000	0

T1A3.5=Prettau®Zirconia with A1 shade ceramic, T2A3.5=Cercon Zirconia with A1 shade ceramic, T3A3.5=InCoris ZI with A1 shade ceramic.