ORIGINAL RESEARCH

Spectrophotometric Evaluation of Translucency of Various Commercially Available Zirconium Oxide Ceramic Systems: An *In Vitro* Study

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Received on: 09 May 2022; *Accepted on*: 11 June 2022; *Published on*: 23 September 2022

Abstract

Aim: To evaluate and compare the translucency of various commercially available zirconium oxide ceramic systems, i.e., Ceramill® Zolid Classic, Ceramill® Zi, and DD Bio ZX²71 by using a dual beam UV-visible spectrophotometer.

Materials and methods: The present study comprised of 21 disk-shaped samples of zirconia for every group, i.e., group I-Ceramill® Zolid Classic, group II-Ceramill Zi®, and group III-DD Bio ZX²71. Furthermore, each group was split into three subgroups and every subgroup had seven samples each one of 0.7, 0.8, and 0.9 mm thickness. The samples were prepared by computer-aided design/computer-aided manufacturing (CAD/CAM) system devised by Amann Girrbach AG in accord with the steps provided by the manufacturer. The entire sample was designed having 10 mm in diameter with 0.7, 0.8, and 0.9 mm thickness for every group. The UV-visible dual beam spectrophotometer equipped with D2 lamp and W lamp was used for the measurement of absorbance and transmittance in order to assess the translucency of the fabricated zirconia samples.

Results: The mean value of transmittance % for Ceramill® Zi at 0.8 mm came out to be 0.849 ± 0.024, i.e., the least among all, whereas the mean value of Ceramill® Zolid Classic was 1.408 ± 0.033, being the highest for the same thickness. DD Bio ZX²71 had an intermediate value of 1.274 ± 0.012. The mean value of absorbance for Ceramill® Zi at 0.8 mm came out to be 2.086 ± 0.013, i.e., the maximum among all, whereas the mean value of Ceramill® Zolid Classic was, being the lowest for the same thickness. DD Bio ZX²71 had an intermediate value of 1.902 ± 0.004.

Conclusion: The present study data suggest that all the materials subjected to evaluation exhibited a substantial translucency. We attempted to study few of the desirable properties, these materials should possess when used for prosthetic rehabilitation with esthetic contentment a clinical setup. There has been an ambiguous distinction that Ceramill® Zi Zirconia supersedes the Ceramill® Zolid Classic and DD Bio ZX²71. Furthermore, 0.8 mm thickness substantiates to be the most ideal among 0.7, 0.8, and 0.9 mm.

Clinical significance: The desired outcome of the procedure becomes dependent solely on the clinician's judgment to opt for the material whose properties are most fitting as per the demands of the esthetics. While a clinician should always be ambitious, but a good clinician should also bear in mind that the success of any treatment procedure not only depends on the assortment of properties of these materials but also the host response and satisfaction evoked by these materials.

Keywords: Absorbance, Spectrophotometer, Transmittance, Zirconium oxide ceramic.

The Journal of Contemporary Dental Practice (2022): 10.5005/jp-journals-10024-3352

Introduction

Zirconium belongs to the mineral group of silicates ($ZrSiO_4$), and was discovered in 1789 by the German chemist MH Klaproth. Zirconium dioxide (Zirconia, ZrO_2) is a zirconium compound, which occurs in nature. Zirconia has been used for over 40 years for industrial purposes and has been used in dentistry for up to 15 years. Its exceptional durability and 100% biocompatibility are the reasons for its increasing use in surgery for ear, finger, and hip prosthesis. Applications for dentistry are found in zirconia pins, crowns, bridges, and implants. The material's natural white base allows individual coloring in prescribed dentin shades. The biotechnical characteristics of zirconia result in high quality crowns, bridges, and implants with excellent biocompatibility and esthetic appearance.

In exploration for a superlative esthetic restorative material, numerous all-ceramic schemes come into play. Dental research is currently focused on metal-free prosthetic restorations beneficial for the esthetic outcome of fixed partial dentures. Natural appearance of soft tissue in relation with fixed partial dentures is determined by two factors—mucosal thickness and typology of restorative material. All-ceramic restorations aid the preservation of soft tissue color complementing the natural appearance more than the porcelain fused to metal restorations. Reinforced ceramics

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How to cite this article: Singh A, Bhargava A, Mathew J, *et al*. Spectrophotometric Evaluation of Translucency of Various Commercially Available Zirconium Oxide Ceramic Systems: An *In Vitro* Study. J Contemp Dent Pract 2022;23(6):646–651.

Source of support: Nil

Conflict of interest: None

can solely be used to supplant anterior teeth with single crown restorations or with three unit fixed partial dentures at the peak. Contrarily, ZrO_2 restorations have an expanded utilization. Other ceramic technologies permit only the creation of units that are insusceptible to chewing stresses on anterior teeth. On the contrary, Zr-ceramic fixed partial dentures can be further applied on molars.[1]

Awareness of the optical properties of procurable ceramic systems empowers the clinician to make better choices when faced with various esthetic challenges and this forms as one of the core reasons for the need of this particular study. Clinicians should reserve zirconia restorations with high translucency for clinical applications in areas where high-level esthetics are required and the restoration can be bonded to tooth structure. Ceramics with high strength tend to be more opaque and pose a challenge when trying to match natural tooth color, this can be minimized by attaining a thorough knowledge about the core material (Zr-ceramic) including its optical properties so that they can mask discoloration when present.[2]

Certain studies suggest that the translucency of composite resin increases ascendingly as the thickness decreases. Previous evaluations of the contrast ratio either transmission coefficient of glass ceramics at other thicknesses established that the contrast ratio of dental ceramics was directly related to the thickness, but a different evaluation found an exponential increase of the transmission coefficient of porcelain with a reduction in thickness. Nonetheless, it is not clear if the relationship between the thickness of ceramic and its contrast ratio is linear or exponential.[3] Zirconia was formerly treated to be an opaque material, but has recently been proclaimed to allow some light to traverse. It is the dental ceramic with the maximal mechanical properties, furthermore the translucency of polycrystalline zirconia can be improved by activated pressure-assisted densification.[4]

The completed restoration frequently does not match the shade guide, as the esthetic appearance of many ceramics is affected by translucency. Ceramic translucency can be affected by many factors, including thickness and the difference in the manufacturing of the various commercially available systems. Although the same core material is used by all the manufacturers and the products are widely used, there is still a lack of information on how the translucency differs from product to product at a particular thickness. Color matching problems may be encountered in a definitive restoration despite careful shade selection. In this study, the color stability of various commercially available zirconium oxide ceramic systems is studied *in vitro* to provide important information regarding the difference caused in translucency by varying the brands.[5]

Thus, the goal of the study was to examine the translucent parameter of zirconia ceramics conforming to different thicknesses and to investigate the relationship between translucency and ceramic thickness. The alternate assumption was that the translucency of ceramics was unaltered by ceramic type or thickness.

Materials and Methods

The present study was an *in vitro* comparative study of evaluation of translucency of various commercially available zirconium oxide ceramic systems at varying thicknesses by using a spectrophotometer; conducted in Department of Prosthodontics and Crown & Bridge, People's College of Dental Sciences and Research Centre; the samples were fabricated at Smile Kraft CAD/CAM Dental Laboratory; after obtaining ethical clearance from the institutional review board of People's University. The sample testing was carried out in the Department of Biological Science and Engineering, Maulana Azad National Institute of Technology, Bhopal, under the guidance and permission of the institutional authority.

Sample Preparation for Group I, Group II, and Group III (Flowchart 1)

The present study comprised of 21 disk-shaped samples of zirconia for every group, i.e., group I-Ceramill® Zolid Classic (Amann Girrbach AG, Germany), group II-CeramillZi® (Amann Girrbach AG, Germany), and group III-DD Bio $ZX^2$71 (Dental Direct UK). Each group was further subdivided into three subgroups and every subgroup had seven samples each of 0.7, 0.8, and 0.9 mm thickness (Table 1).

The samples were prepared by CAD/CAM system devised by Amann Girrbach AG according to the steps following the manufacturer's instruction.

The computer aided designing was carried out by Ceramill® Mind, CAD Unit for zirconia (Amann Girrbach AG, Germany) for the disk-shaped sample for each commercial brand used. An STL software program compatible with Ceramill® Mind (Fig. 1), CAD unit for zirconia; was generated so as to achieve the standard milling required. All the samples were designed to be of 10 mm in diameter with 0.7, 0.8, and 0.9 mm thickness for every group.

Flowchart 1: Flowchart of the present study

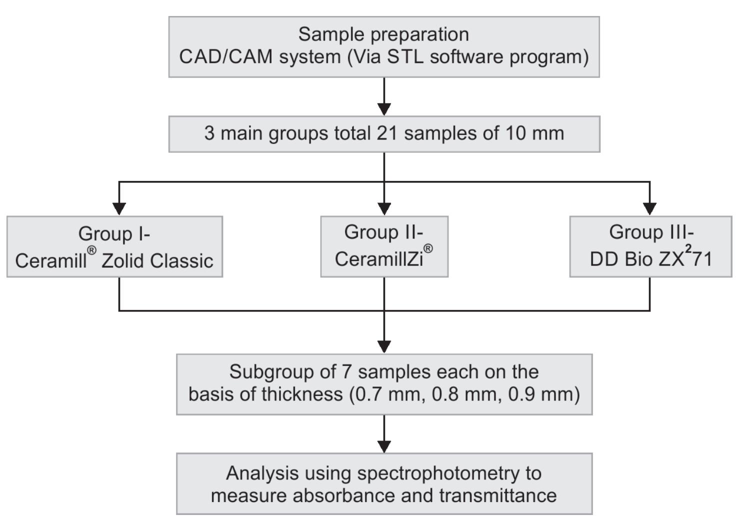

Table 1: Sample distribution of the present study

Commercial brand	*No. of samples for 0.7 mm*	*No. of samples for 0.8 mm*	*No. of samples for 0.9 mm*	*Total samples per group*
Ceramill Zolid Classic	7	7	7	21
Ceramill Zi	7	7	7	21
DD Bio ZX^{2}71	7	7	7	21

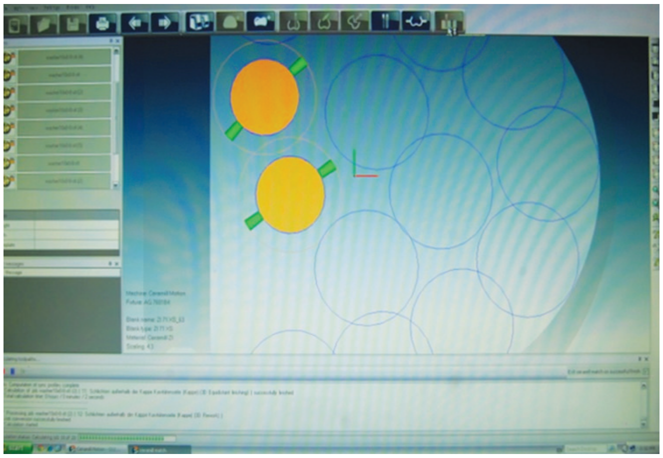

Fig. 1: Ceramill® Mind, CAD Unit for Zirconia

Table 2: Comparison of transmittance % at 600 nm wavelength in three different zirconia ceramics for different thicknesses

	Transmittance percentage (mean ± SD) in different materials		
Thickness	*DD Bio ZX^{2}71*	*Ceramill® Zi*	*Ceramill® Zolid Classic*
0.9 mm	1.234 ± 0.020	1.036 ± 0.032	1.312 ± 0.006
0.8 mm	1.274 ± 0.012	0.849 ± 0.024	1.408 ± 0.033
0.7 mm	1.239 ± 0.016	1.144 ± 0.028	1.389 ± 0.052

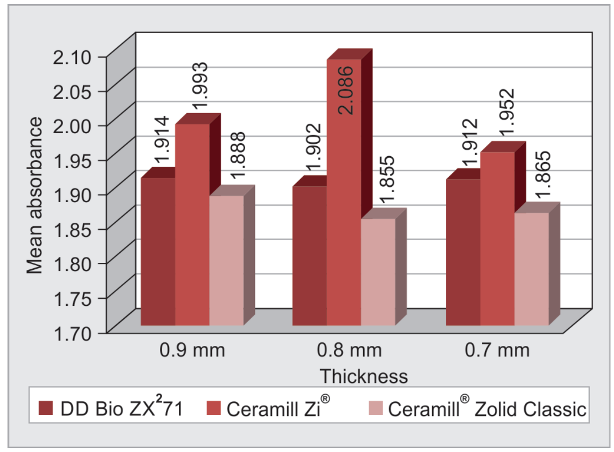

Fig. 2: Comparison of absorbance at 600 nm wavelength in three different zirconia ceramics at three different thicknesses

The computer aided milling of the zirconia blanks was executed by Ceramill® Motion 2 (4X), 4-Axis milling unit for zirconia (Amann Girrbach AG, Germany). It was taken into account that all the Zirconia CAD/CAM blanks used should be for Amann Girrbach Ceramill® motion system and the following samples were generated. A total of 63 samples were milled and then sintered in the Ceramill® Therm, sintering furnace for zirconia (Amann Girrbach AG, Germany) according to the manufacturer's instructions. After the completion of sintering the dimensions of the final 63 samples were confirmed using a Digital Vernier Caliper (Mitutoyo Digimatic Caliper, Japan) for the diameter 10 mm in conjunction with 0.7, 0.8, and 0.9 mm thickness for every group.

Evaluation of Samples Using Spectrophotometry

The UV-visible dual beam spectrophotometer (UV–Vis Spectrophotometer, Thermo Scientific Chemito Spectroscan UV 2100, Chemito Technologies Pvt. Ltd., Mumbai) equipped with D2 lamp and W lamp was used for the measurement of absorbance and transmittance in order to assess the translucency of the fabricated zirconia samples.

The spectrophotometer works on the principle of Beer–Lambert law. The Beer–Lambert law was an amalgamation of two laws each dealing independently with the absorption of light associated to the concentration of the absorber (the substance responsible for absorbing light) and the path length or thickness of the layer (related to absolute amount of the absorber). Provided an absorbing substance was partially transparent it transmits a portion of the radiation incident upon it. The ratio of the intensities of transmitted and incident light gives the transmittance *T*, expressed as:

$$T = I/I_{o,}$$

where I_o was the intensity of incident radiation and I was the intensity of transmitted radiation.

In order to carry out the analysis of the samples, the wavelength range of 400–800 nm was set and the spectrophotometer was set on the required mode, then a blank cuvette was placed in the spectrophotometer and autozeroing of the machine was done. After the machine was set to autozero, the sample was placed in the cuvette followed by the analysis of every sample at the set wavelength range. The analysis leads to the reproduction of absorbance and transmittance values for every sample at each thickness in every group.

Statistical Analysis

The data analysis was done using statistical package for social sciences (SPSS) v.21 for Windows. Mean and standard deviation (SD) of absorbance and transmittance percentage at 600 nm wavelength in three different zirconia ceramics in 0.9, 0.8, and 0.7 mm thicknesses were calculated. Shapiro–Wilk test showed that absorbance and transmittance percentage follow normal distribution hence parametric test, Two-way ANOVA (analysis of variance) followed by least significant difference (LSD) *post hoc* test was used for the comparison between different groups. Correlation between thickness and transmittance percentage of three zirconia ceramics was evaluated by Pearson's Correlation test. *p*-value <0.05 was considered statistically significant.

Results

Table 2 and Figure 2 show the mean value of transmittance % for Ceramill® Zi at 0.8 mm came out to be 0.849 ± 0.024, i.e., the least among all whereas, the mean value of Ceramill® Zolid Classic was 1.408 ± 0.033, being the highest for the same thickness. DD Bio ZX^{2}71 had an intermediate value of 1.274 ± 0.012. Henceforth, Ceramill® Zi at 0.8 mm is established as the most translucent among the three.

Table 3: Two-way ANOVA statistics for mean transmittance % at 600 nm wavelength

		f-value	*p-value*	*LSD post hoc test*
Main effect	Materials (Ceramill® Zolid Classic, Ceramill® Zi andDD Bio ZX^{2}71)	897.189	0.0001 (<0.001), Sig. diff.	Ceramill® Zolid Classic > DD Bio ZX^{2}71 > Ceramill® Zi
	Thicknesses	47.757	0.0001 (<0.001), Sig. diff.	0.7 > 0.9, 0.8 mm
Interaction effect (materials, thicknesses)		89.135	0.0001 (<0.001), Sig. diff	At 0.9 mm Ceramill® Zolid Classic > DD Bio ZX^{2}71 > Ceramill® Zi At 0.8 mm Ceramill® Zolid Classic > DD Bio ZX^{2}71 > Ceramill® Zi At 0.7 mm Ceramill® Zolid Classic > DD Bio ZX^{2}71 > Ceramill® Zi

Table 3 depicts the main effect of materials (Ceramill® Zolid Classic, Ceramill® Zi, and DD Bio ZX^{2}71) on transmittance at 600 nm wavelength was significant, $f = 897.189$, $p = 0.0001$. Mean transmittance differs significantly between different zirconia systems used. When LSD posthoc test was applied it showed that mean transmittance (overall) was significantly higher in Ceramill® Zolid Classic than DD Bio ZX^{2}71 and Ceramill® Zi. Also, in DD Bio ZX^{2}71 it was higher than Ceramill® Zi. The main effect of thicknesses on transmittance at 600 nm wavelength was significant, $f = 47.757$, $p = 0.0001$. The interaction between materials and thicknesses was established to be significant on transmittance, $f = 89.135$, $p = 0.0001$. When LSD *post hoc* test was applied it showed that at 0.9, 0.8, and 0.7 mm transmittance was significantly higher in Ceramill® Zolid Classic than DD Bio ZX^{2}71 and Ceramill®Zi. Also at 0.9, 0.8, and 0.7 mm in DD Bio ZX^{2}71's transmittance was higher than that of Ceramill® Zi.

Table 4 and Figure 3 reveal the mean value of absorbance for Ceramill® Zi at 0.8 mm came out to be 2.086 ± 0.013, i.e., the maximum among all whereas, the mean value of Ceramill® Zolid Classic was, being the lowest for the same thickness. DD Bio ZX^{2}71 had an intermediate value of 1.902 ± 0.004. Henceforth, as Ceramill® Zi at 0.8 mm is established as the most translucent among the three.

Table 5 shows the main effect of materials (Ceramill® Zolid Classic, Ceramill® Zi, and DD Bio ZX^{2}71) on absorbance at 600 nm wavelength was significant, $f = 1282.027$, $p = 0.0001$. Mean absorbance differs significantly between different zirconia systems used. When LSD posthoc test was applied it showed that mean absorbance (overall) was significantly higher in Ceramill® Zi than DD Bio ZX^{2}71 and Ceramill® Zolid Classic. Also, in DD Bio ZX^{2}71 it was higher than Ceramill® Zolid Classic. The main effect of thicknesses on absorbance at 600 nm wavelength was significant, $f = 88.170$, $p = 0.0001$. The interaction between materials and thicknesses was established to be significant on absorbance, $f = 158.353$, $p = 0.0001$. When LSD posthoc test was applied it showed that at 0.9, 0.8, and 0.7 mm absorbance was significantly higher in Ceramill® Zithan DD Bio ZX^{2}71 and Ceramill® Zolid Classic. Also at 0.9, 0.8, and 0.7 mm in DD Bio ZX^{2}71's absorbance was higher than that of Ceramill® Zi.

Correlation value of −0.080 was obtained for DD Bio ZX^{2}71, reflects negative correlation at >0.05 probability. Such values convey no significant correlation with the factors taken into account. However, when correlation using Ceramill® Zi was calculated between all the three thicknesses and transmittance percentage, the correlation value of −0.354 at >0.005 probability reflects moderately negative correlation. Similarly, Ceramill® Zolid Classic was also studied correlation analysis and was found to have a negative correlation value of −0.591 at a probability of <0.001 (Table 6).

Table 4: Comparison of absorbance at 600 nm wavelength in three different zirconia ceramics for different thicknesses

	Absorbance (mean ± SD) in different materials		
Thickness	*DD Bio ZX^{2}71*	*Ceramill® Zi*	*Ceramill® Zolid Classic*
0.9 mm	1.914 ± 0.007	1.993 ± 0.010	1.888 ± 0.002
0.8 mm	1.902 ± 0.004	2.086 ± 0.013	1.855 ± 0.010
0.7 mm	1.912 ± 0.006	1.952 ± 0.010	1.865 ± 0.014

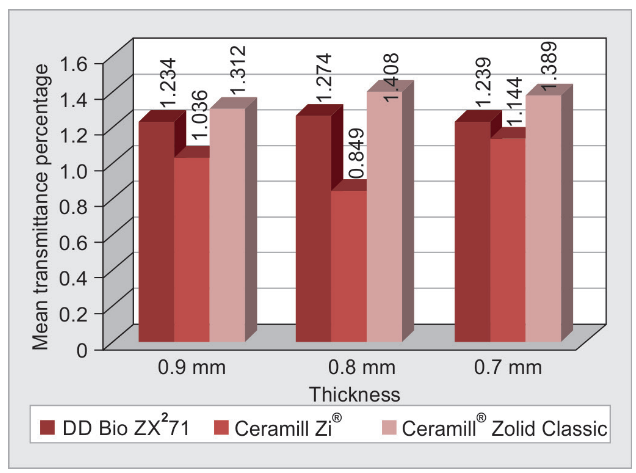

Fig. 3: Comparison of transmittance at 600 nm wavelength in three different zirconia ceramics at three different thicknesses

Discussion

The esthetic value of a ceramic crown is based on its ability to harmonize with the natural tooth. Key optical factors that permit a pleasing harmony are color, surface texture, and translucency. The amount of light directly transmitted through specified zirconia samples ranges from 0.661 to 2.042%, where the former being of Ceramill® Zi (Amann Girrbach AG, Germany) and the latter of Ceramill® Zolid Classic (Amann Girrbach AG, Germany). The results show that the main factor of translucency in zirconia all ceramics is due to multiple scattering of light in the zirconium oxide sets. Scattering of light decreases with increasing wavelength. This is in accordance with the Rayleigh scattering equation which states

Table 5: Two-way ANOVA statistics for mean absorbance at 600 nm wavelength

		f-value	*p-value*	*LSD post hoc test*
Main effect	Materials (Ceramill® Zolid Classic, Ceramill® Zi andDD Bio ZX²71)	1282.027	0.0001 (<0.001), Sig. diff.	Ceramill® Zi > DD Bio ZX²71> Ceramill® Zolid Classic
	Thicknesses	88.170	0.0001 (<0.001), Sig. diff.	0.8 > 0.9 > 0.7 mm
Interaction effect (materials, thicknesses)		158.353	0.0001 (<0.001), Sig. diff	At 0.9 mm Ceramill® Zi > DD Bio ZX²71> Ceramill® Zolid Classic
				At 0.8 mm Ceramill® Zi > DD Bio ZX²71> Ceramill® Zolid Classic
				At 0.7 mm Ceramill® Zi > DD Bio ZX²71> Ceramill® Zolid Classic

Table 6: Correlation between thickness and transmittance percentage in Ceramill® Zolid Classic, Ceramill® Zi, andDD Bio ZX²71 groups

Groups	*Correlation coefficient (Pearson's correlation)*	*p-value*
DD Bio ZX²71	−0.080 No or negligible relationship	0.731 (>0.05) Not significant correlation
Ceramill® Zi	−0.354 Moderate negative relationship	0.115 (>0.05) Not significant correlation
Ceramill® Zolid Classic	−0.591 Strong negative relationship	0.005 (<0.01) Significant correlation

that higher scattering occurs at lower wavelengths.[6] This would result in an increase in transmission at higher wavelengths as it has been observed.

The data obtained in this study support rejection of the null hypothesis, as the translucency of all of the zirconia groups was found to be statistically different at different thicknesses. Heffernan et al.[5,7] established that the array of translucency in ceramics at clinically relevant thicknesses came from varied crystalline compositions. Result of the observations further confirms the variation in the translucency. Due to this variation in the crystalline composition, the mean transmittance and absorbance obtained at 600 nm differ. Therefore, Ceramill® Zi with highest mean absorbance, i.e., 1.993 ± 0.010, 2.086 ± 0.013, and 1.952 ± 0.010 at 0.9, 0.8, and 0.7 mm thickness, respectively, and least mean transmittance, i.e., 0.989 ± 0.019, 0.800 ± 0.077, and 1.071 ± 0.023 at 0.9, 0.8, and 0.7 mm thickness, respectively, is established as the best among the three brands compared, i.e., Ceramill® Zolid Classic (Amann Girrbach AG, Germany), Ceramill® Zi (Amann Girrbach AG, Germany), and DD Bio ZX²71 (Dental Direct UK).

To enhance esthetics, it is essential that the translucency of restorative materials is foreseeable for a given dental restoration. In reports by Kamishima et al.[2] and Kim et al.,[8] the translucency of composite resins elevated exponentially as the thickness was reduced. In contrary to this declaration, an ideal thickness 0.8 mm among 0.7, 0.8, and 0.9 mm was affirmed in all the products on the basis of the analysis of transmittance and absorbance for all the commercial brands tested, i.e., Ceramill® Zolid Classic (Amann Girrbach AG, Germany), Ceramill® Zi (Amann Girrbach AG, Germany), and DD Bio ZX²71 (Dental Direct UK). The capability of some measure of light to pass through the disks of zirconia is prone to give the restoration a natural presentation and yet mask the shade defect at this proven thickness. The dearth of translucency of the In-Ceram material will likely have reflectance ability comparable to that of a metal ceramic restoration. Dozic et al.[9] determined quantitatively the effect of different thickness ratios of opaque porcelain (OP) and translucent porcelain (TP) layers on the overall shade of all-ceramic specimens. They concluded small changes in thickness and shade of opaque and translucent porcelain layers can influence the final shade of the layered porcelain specimen.

Similarly, Ozcelik et al.[10] determined and compared the influence of various commercially available base metal alloys (excluding titanium-based systems) on the resulting color of opaque porcelain with the use of a colorimetric device. They found that a 0.1 mm thick layer of opaque porcelain applied on the Ni-Cr and Co-Cr alloys did not reliably reproduce the color of opaque porcelain. The present study results are similar to the study conducted by Douglas RD and Brewer JD[11] stated that the color reproduction was significantly different (p <0.0001) among laboratories for both sites. Most crowns fabricated by the laboratories in this study, when compared to the prescribed shade tab, were above the clinical threshold for an acceptable shade match under intraoral conditions (ΔE 3.7). Another studies by Yilmaz et al.[12] and Kourtis et al.[13] stated that zirconia cores are reported to be less translucent than glass, lithium disilicate, or alumina cores. This could affect the esthetic appearance and the clinical choices made when using zirconia-based restorations.

Clinical relevance of a disk-shaped specimen when compared to measurements performed on specimens in the shape of abutment copings is further relevant due to the standardization, if the surface thickness all through the sample. This is similar to the study conducted by Baldissara et al.[14] stated that the effects of the variables related to the production process for an abutment-shaped coping, such as grinding, sintering, finishing, and definitive ceramic thickness are incorporated in the sample. The above mentioned causes are diminished in the current study in the disk-shaped specimens due to the ease of fabrication and standardization for homogeneity.

Liu et al.[15] explains the human awareness of translucency and contrast ratio. The writers stated that the human eye has the skill to identify differences in contrast ratio that are greater than or equal to 0.07. Appearing, that the human eye cannot tell apart between light, medium and intense shades that are lesser or equal to 0.008. coming from which, it could be stated that the use of the base shades of zirconia tested in the current study was of great relevance rather than those of shaded core zirconia because a minor difference in the shade of core zirconia does not vary the translucency that the human eye can grasp; they provide a backdrop that complements the shade of the veneering porcelain which will be utilized while fabricating the definitive restoration.[16]

The limitation of the present study was that, the specimens with monolayer form were examined in the current study, despite the fact that the ceramic restorations mostly take the form of bilayer structure in clinical practice. And the translucency of core veneering ceramic groupings as a function of thickness was not considered. Added investigation should be performed using additional variables of thicknesses and dispose of possible errors. Optical properties must be studied at a larger number of thicknesses so as to establish an improved correlation between it and the other parameters, i.e., absorbance and transmittance, which will further add to the coherence of the effective outcome.

Conclusion

The present study data suggest that all the materials subjected to evaluation exhibited a substantial translucency. We attempted to study few of the desirable properties these materials should possess when used for prosthetic rehabilitation with esthetic contentment a clinical set-up. There has been an ambiguous distinction that Ceramill® Zi Zirconia supersedes the Ceramill® Zolid Classic and DD Bio ZX²71. Furthermore, 0.8 mm thickness substantiates to be the most ideal among 0.7, 0.8, and 0.9 mm. The desired outcome of the procedure becomes dependent solely on the clinician's judgment to opt for the material whose properties are most fitting as per the demands of the esthetics.

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