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RESEARCH AND EDUCATION

A comparative evaluation of the translucency of zirconias and lithium disilicate for monolithic restorations

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ABSTRACT

Statement of problem. Studies comparing the translucency of zirconias and lithium disilicates are limited.

Purpose. The purpose of this in vitro study was to measure the translucency of recently developed translucent zirconias and compare them with lithium disilicate.

Material and methods. Five types of zirconia, Prettau Anterior (Zirkonzahn GmbH), BruxZir (Glidewell Laboratories), Katana HT, Katana ST, and Katana UT (Kurary Noritake Dental Inc), and 1 type of lithium disilicate, e.max CAD LT (Ivoclar Vivadent AG), were assessed. Non-colored zirconia test specimens (n=5) were prepared as rectangles with dimensions of 15×10×0.5 and 15×10×1.0 mm. The shade of lithium disilicate was B1. A spectrophotometer (Evolution 300 UV-Vis) with an integrating sphere was used to evaluate the total transmittance of light as a percentage (T_t%) at a wavelength of 555 nm for comparison among groups. The Welch robust test for equality of means was used to compare group means (α=.025) and post hoc pairwise comparisons among groups were performed with the Dunnett T3 method.

Results. For the 0.5 mm thickness groups, the T_t% was 31.90 ±0.49 for Prettau Anterior, 28.82 ±0.22 for BruxZir, 28.49 ±0.14 for Katana HT, 31.67 ±0.24 for Katana ST, 33.73 ±0.13 for Katana UT, and 40.32 ±0.25 for e-max CAD LT. Post hoc tests indicated that all groups were significantly different from each other, except for between BruxZir and Katana HT, and between Prettau Anterior and Katana ST. Katana UT was significantly more translucent than all other zirconias, and e-max CAD LT was significantly more translucent than all zirconias. For the 1.0 mm thickness groups, the Tt% was 22.58 ±0.41 for Prettau Anterior, 20.13 ±0.22 for BruxZir, 20.18 ±0.39 for Katana HT, 21.86 ±0.39 for Katana ST, 23.37 ±0.27 for Katana UT, and 27.05 ±0.56 for e-max CAD LT. Post hoc tests indicated that all materials were significantly different from each other, except for between BruxZir and Katana HT, and among Prettau Anterior, Katana ST and Katana UT which were significantly more translucent than all other zirconias and less translucent than e-max CAD LT.

Conclusion. At a thickness of 0.5 mm, Katana UT was significantly more translucent than all other zirconias, and e-max CAD LT was significantly more translucent than all zirconias. At a thickness of 1.0 mm, Prettau Anterior, Katana ST, and Katana UT were significantly more translucent than all other zirconias and less than e-max CAD LT. (J Prosthet Dent 2016;116:257-263)

INTRODUCTION

Lithium disilicate glass ceramic has more favorable mechanical properties compared with conventional dental porcelains and has excellent optical properties. Although, the mechanical properties of lithium disilicate are inferior compared with zirconia, it has been considered superior in terms of translucency. With its variety of translucency levels and shades, lithium disilicate can be fabricated as a monolithic restoration with surface characterization.[1,2] Therefore, lithium disilicate has been widely used for esthetic monolithic ceramic crowns.[3] However, results from clinical studies have demonstrated that these restorations have to be bonded if conservative tooth reduction of 1.0 to 1.5 mm or 1.5 to 2.0 mm is considered the ultimate clinical goal.[4-6]

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Clinical Implications

The translucency levels of high translucency zirconias vary depending on the brands used. Although further research is required, clinicians may consider the use of high translucency zirconia for monolithic zirconia restorations with relatively conservative tooth reduction.

Recently, high translucency zirconia has been developed for clinical use. In addition, the advent of computer-assisted design and computer-assisted manufacturing (CAD-CAM) technology has facilitated the design of frameworks and complete contour restorations as well as the processing of monolithic zirconia crowns and fixed dental prostheses (FDPs).[7-9] Two design alternatives to address durability and esthetics are available for zirconia-based restorations. One is the complete-contour monolithic zirconia, which may be characterized with external staining. Complete-contour monolithic zirconia restorations may provide adequate esthetics in the molar area.[10] Alternatively, the "hybrid design", the lingual/palatal and occlusal surfaces are designed for monolithic zirconia contours, and the buccal and incisal aspects are virtually cut back and veneer with the corresponding veneering porcelains to enhance an esthetic outcome.[10]

Recent studies on the wear of antagonist enamel by opposing zirconia have found that polished zirconia restorations result in the least wear of antagonist enamel among veneering feldspathic porcelains and natural enamel compared with glazed zirconia.[11,12] In addition, in some in vitro studies polished zirconia showed a similar wear rate of the opposing enamel compared with Co-Cr alloy and less wear than lithium disilicate glass ceramic.[13,14]

To enhance the translucency of zirconia, residual pores and impurities which create volumes of differing refractive indexes and lead to optical scattering on the surface and reduction of translucency must be reduced.[15-22] Alumina, which is added to zirconia improve the mechanical properties and prevent low temperature degradation (LTD), is the most common impurity.[23-29] In addition, the yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) used for dental applications contains 3 mol% Y_2O_3. Y_2O_3 in zirconia also enhance mechanical properties of zirconia.[30,31]

The translucency of dental ceramics is of primary importance in esthetics.[32,33] Previous studies have reported on methods for evaluating the translucency and opacity of restorative materials using a spectrophotometer.[32,34,35,37-39] The contrast ratio is the ratio of the reflectance from an object resting on a black backing to the reflectance obtained for the same material against a white backing.[34,35] The translucency parameter (TP) is the color difference between uniform thicknesses of the material on black and white backings, and corresponds directly to common visual assessments of translucency.[36,37] Transmittance percentage (T%) is also considered a valid tool for evaluating translucency and is assessed by measuring both the light that reaches the detector and the light that passes through the object and then scattered. Two types of T% may be used for evaluating the translucency of dental ceramics: direct transmittance (T_d%), and total transmittance (T_t%).[32,33,38,39] T_d% assesses light that passes directly through the specimen without scattering or diffusing. T_d% may be used when the specimen to be measured is transparent or clear and has few factors of scatter or diffusion. T_t% assesses all the light that passes through the specimen, which includes direct transmittance and diffuse transmittance. Thus, T_t% may be used when the specimen to be measured is translucent or hazy, such as with dental ceramics.[32,39]

A recent in vitro study, demonstrated that monolithic zirconia can sustain higher fracture loads than monolithic lithium disilicate, layered zirconia, or metal ceramics. Fracture resistance of monolithic zirconia with 1.0 mm thickness is equal to that of metal ceramic crowns.[40] In addition, the recommended thickness of the margins of complete cast alloy crown is considered to be approximately 0.5 mm.[41] Consequently, zirconia with higher translucency (compared with zirconia for copings and frameworks) may serve as a conservative tooth-colored alternative in the posterior segments for crowns and FDPs. As it may require only 1.0 mm of occlusal thickness, it can provide a minimal occlusal reduction and 0.5 mm of margin thickness while providing a functional and esthetic solution.

Since data with regard to the translucency of zirconia as compared with lithium disilicate are limited,[42,43] the purpose of this in vitro study was to assess and compare the translucency of recently introduced zirconias and low translucency (LT) lithium disilicate. The null hypotheses were that no significant differences would be found in the T_t% measured with a spectrophotometer in the 5 different zirconia materials and LT lithium disilicate at thickness of 0.5 mm and 1.0 mm.

MATERIAL AND METHODS

Five zirconia products by 3 manufactures and 1 type of lithium disilicate were assessed in this study. Prettau Anterior (Zirkonzahn GmbH), BruxZir (Glidewell Laboratories), and Katana HT (Kurary Noritake Dental Inc) were used as an experimental high translucency zirconia. Katana ST and Katana UT (Kuraray Noritake Dental Inc) were used as a new high translucency zirconia. Lithium disilicate was used as a positive control (e.max CAD LT; Ivoclar Vivadent AG) (Table 1).

Table 1. Characteristics of materials investigated

Brand	Manufacturer	Batch No.	Sintering/Heating Conditions Temperature (°C)	Dwell Time
Zirconia Prettau Anterior	Zirkonzahn GmbH	ZZA-0006	1450	2 h
Zirconia BruxZir	Glidewell Laboratories	B34392	1530	2 h
Zirconia Katana HT	Kuraray Noritake Dental Inc	DGTLT	1500	2 h
Zirconia Katana ST	Kuraray Noritake Dental Inc	LN2401	1550	2 h
Zirconia Katana UT	Kuraray Noritake Dental Inc	LN2431	1550	2 h
Lithium disilicate e.max CAD LT	Ivoclar Vivadent AG	S03715	845	10 min

Blocks of partially-sintered zirconia were sintered, and blocks of the green stage of lithium disilicate glass ceramics were heated according to the manufacturer's specifications. (Table 1) The test specimens (each n=5) were prepared with 15 mm (length) × 10 mm (width) × 0.5 or 1.0 mm (thicknesses). The shade selected for the zirconia specimens was non-colored (without addition of dye) and the shade for the lithium disilicate specimens was B1. A specimen thickness of 0.5 mm was selected as the recommended margin thickness of a complete cast crown, and the thickness of 1.0 mm was selected based on the suggested occlusal thickness of monolithic zirconia restorations.[40] The specimens were cut from each block with a diamond wheel, ground with a surface grinding sheet (#100, #600) on a grinding machine (PSG-63DX; Okamoto), and polished with water-resistant abrasive papers #1000 and #2000 to produce thicknesses of 0.5 mm and 1.0 mm. The thickness of the specimens was measured and verified with a digital caliper (external digital caliper; Bowers). The molecular compositions of the zirconias were investigated with energy dispersive spectroscopy with scanning electron microscopy (SEM) at 20 kV (80 mm^2 XMAX; Oxford Instruments).

A spectrophotometer (Evolution 300 UV-Vis; ThermoFisher) with an integrating sphere was used to evaluate the total transmittance of light in percentage (T_t%) according to the manufacturer's specifications. Measurement conditions were set as follows: wavelength range of 380 to 780 nm, band width 4.0 nm, scan speed 240 nm, data interval 1.0 nm, and a xenon light source. The mean T_t% values at the wavelength of 555 nm were used to compare the specimens. This wavelength was selected based on the definition of the International Commission on Illumination (CIE S 017)[44] and the Japanese industrial standard (JIS Z 8113).[45] Since the human eye is sensitive to wavelengths ranging between 380 and 780 nm with being most sensitive to 555 nm, 555 nm was defined as the maximum spectral luminous intensity by CIE and JIS.

All specimens were analyzed for each group at thickness of 0.5 mm and 1.0 mm. To determine the error of measurement, all measurements were redone for one time in random order. The error of the measurements was calculated using the Dahlberg formula, except 4n was used in the denominator instead of the traditional 2n to account for using the average of 2 measurements to compare groups.[46] In addition, the coefficient of variation was used to described the measurement error. A priori it was decided to compare the groups separately at 0.5 mm and 1.0 mm thickness because we expected the materials to behave differently at 0.5mm and 1.0 mm not only in the average T_t% but also in the variability of T_t%. A test for the group by thickness interaction was highly significant ($F(5,48)=79.0$; $P<.001$), indicating the group comparisons were different for the 2 thicknesses. All significant levels were adjusted for the separate testing by thickness. Given that measurements varied substantially among the groups, the Welch robust test for equality of means, which does not require equal variances, was used to compare group means and a significance level of .025 was used to account for the 2 omnibus tests.[47] Post hoc pairwise comparisons among all groups were performed using the Dunnett T3 method, which does not assume equal variances, and conservatively adjusted for a potential of 66 pairwise comparisons among the 6 groups and 2 thicknesses.[48] All analyses were performed using software (IBM SPSS Statistics for Windows, v19; IBM Corp).

RESULTS

An image of representative specimens assessed in this study is shown in Figure 1. The compositions of the different zirconias are shown Table 2.

Table 3 reports on the measurement error. The average measurement error for T_t% ranged from 0.128 to 0.277 nm with a coefficient of variation of 0.1 to 0.4%.

For the 0.5 mm thickness groups, the descriptions of the measured values of Tt% at the wavelength of 555 nm are listed in Table 4. The wavelength distribution of the T_t% for all groups is shown in Figure 2. The post hoc tests indicated that all the materials were significantly different from each other, except for between BruxZir and Katana HT, and between Prettau Anterior and Katana ST. Katana UT was significantly more translucent than all other zirconias and e-max CAD LT was significantly more translucent than all the zirconias. ($P<.05$)

For the 1.0 mm thickness groups, the descriptions of measured values of T_t% at the wavelength of 555nm are listed in Table 5. The wavelength distribution of T_t% for all groups is shown in Figure 3. The post hoc tests indicated that all materials were significantly different from each other, except for between BruxZir and Katana HT, and among Prettau Anterior, Katana ST and Katana UT,

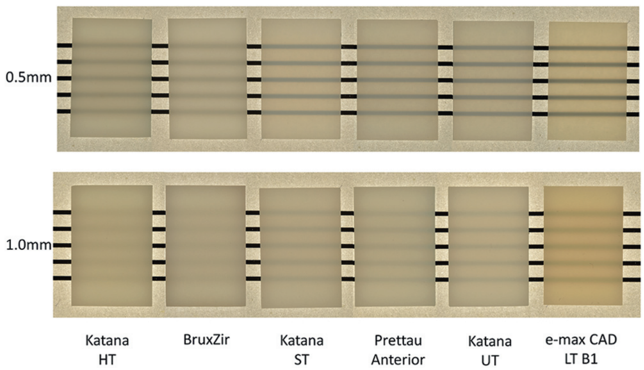

Figure 1. Appearance of specimens.

Table 3. Error of measurement

Brand	0.5-mm Thickness Average (CV%)*	1.0-mm Thickness Average (CV%)*
Prettau Anterior	0.202 (0.4)	0.164 (0.3)
BruxZir	0.277 (0.8)	0.138 (0.3)
Katana HT	0.145 (0.2)	0.158 (0.4)
Katana ST	0.150 (0.2)	0.177 (0.4)
Katana UT	0.128 (0.1)	0.175 (0.4)
E.max CAD LT	0.167 (0.2)	0.197 (0.4)

CV%, coefficient of variation. *Average error of measurement (nm) was found using the Dahlberg formula.[46]

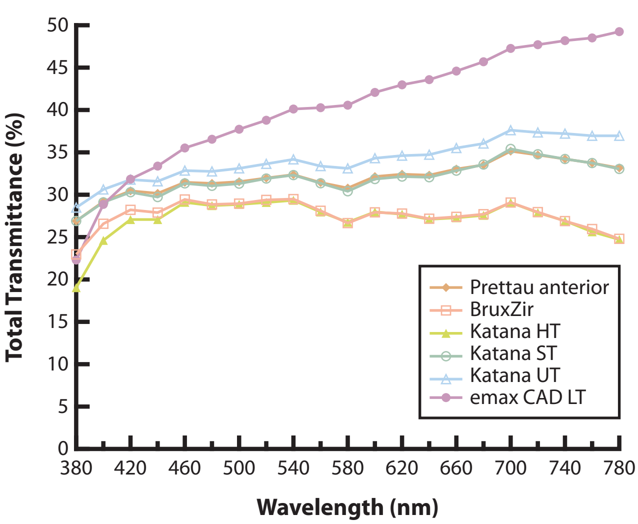

Figure 2. Wavelength distribution of T_t% for 0.5-mm-thickness groups. CAD, computer-assisted design; LT, lithium disilicate; Tt%, total transmittance of light as a percentage.

and e-max CAD LT was significantly more translucent than all the zirconias. (P<.05)

DISCUSSION

This study investigated the translucency of translucent zirconias and an LT lithium disilicate. The null hypothesis was partially rejected for the 5 different zirconias and the lithium disilicate, except for between BruxZir and Katana HT, and between Prettau Anterior and Katana ST for the 0.5-mm-thickness groups and between BruxZir and Katana HT, and among Prettau Anterior, Katana ST, and Katana UT for the 1.0-mm-thickness groups.

Table 2. Elemental concentration (wt%) of dopants in different zirconias (mean ±SD)

Brand	Al_2O_3	Y_2O_3	ZrO_2	HfO_2
Prettau Anterior	0.18 ±0.04	8.38 ±0.27	89.46 ±0.16	1.97 ±0.10
BruxZir	0.11 ±0.08	3.90 ±0.13	94.09 ±0.28	1.91 ±0.14
Katana HT	0.26 ±0.03	5.66 ±0.69	92.41 ±0.64	1.68 ±0.10
Katana ST	0.14 ±0.05	8.15 ±0.69	89.89 ±0.72	1.83 ±0.09
Katana UT	0.16 ±0.08	9.32 ±0.65	88.63 ±0.66	1.90 ±0.07

Table 4. Description of T_t% measured at 555 nm for 0.5-mm-thickness groups*

Brand	Mean†	±SD	95% CI	Minimum	Maximum
Prettau Anterior (zirconia)	31.88^B	0.49	31.28-32.49	31.45	32.55
BruxZir (zirconia)	28.82^A	0.22	28.55-29.09	28.65	29.20
Katana HT (zirconia)	28.49^A	0.14	28.31-28.66	28.35	28.66
Katana ST (zirconia)	31.67^B	0.24	31.37-31.97	31.25	31.86
Katana UT (zirconia)	33.73^C	0.13	33.54-33.89	33.52	33.87
E-max CAD LT (lithium disilicate)	40.32^D	0.25	40.02-40.62	39.94	40.60

CAD, computer-assisted design; CI, confidence interval; SD, standard deviation; Tt%, total transmittance of light as a percentage. *Welch (robust) test was used for equality of means, $F_{(5,10)}$ = 1751.5, P<.001. †Groups with different superscript letters are significantly different from each other according to Dunnett's T3 post hoc comparisons, P<.05.

Table 5. T_t% measured at 555 nm for 1.0-mm-thickness groups*

Brand	Mean†	±SD	95% CI		Minimum	Maximum
Prettau Anterior (zirconia)	22.58^B	0.41	22.07	23.09	22.15	23.12
BruxZir (zirconia)	20.13^A	0.22	19.85	20.40	19.84	20.39
Katana HT (zirconia)	20.18^A	0.39	19.70	20.66	19.64	20.56
Katana ST (zirconia)	21.86^B	0.14	21.69	22.03	21.67	21.97
Katana UT (zirconia)	23.37^B	0.27	23.04	23.70	23.08	23.70
E-max CAD LT (lithium disilicate)	27.05^C	0.56	26.35	27.74	26.58	27.91

CAD, computer-assisted design; CI, confidence interval; SD, standard deviation; Tt%, total transmittance of light as a percentage. *Welch (robust) test was used for equality of means, $F_{(5,10)}$ = 161.4, P<.001. †Groups with different superscript letters are significantly different from each other according to Dunnett's T3 post hoc comparisons, P<.05.

For the 0.5-mm-thickness groups, the study demonstrated that Katana UT, Prettau Anterior, and Katana ST have higher T_t%, particularly Katana UT. For the 1.0mm thickness groups which is the suggested thickness at the occlusal aspect of monolithic zirconia restorations, Katana UT, Prettau Anterior, and Katana ST showed significantly higher levels of T_t% compared with BruxZir and Katana HT. The results may correlate

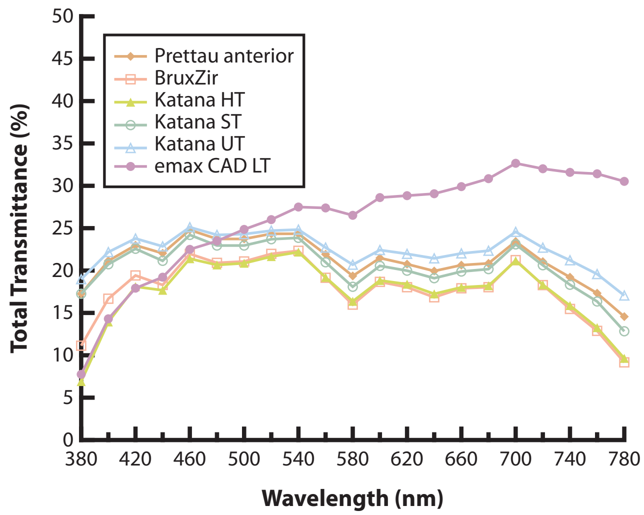

Figure 3. Wavelength distribution of T_t% for 1.0-mm-thickness groups. Tt%, total transmittance of light as percentage.

with the Figure 1. Although, none of the zirconias that were used in this study reached the T_t% of e-max CAD LT, lithium disilicate requires at least 1.5 to 2.0 mm of occlusal thickness for its success and survival as demonstrated in previous clinical studies.[4-6] Therefore, Katana UT, Prettau Anterior, and Katana ST may be successfully used for monolithic restorations with less occlusal thickness and thus less occlusal tooth reduction. BruxZir and Katana HT may be used in patients whose the tooth is discolored and has to be crowned or when an implant is restored with a metallic abutment and a crown; the higher opacity zirconias may be required to mask the underlying abutment. However, further in vitro studies on the aging of these zirconias because of low temperature degradation (LTD) and further clinical studies are required before definitive clinical recommendations can be made.

In order to enhance the translucency of zirconia, residual pores and impurities must be reduced because they create volumes of differing refractive index and lead to optical scattering on the surface zirconia and a reduction in its translucency.[15-19] Residual pores are formed as gaps between the zirconia grains at the time of molding. Some studies have reported that improving the properties of the zirconia powder and modifying its pressing methods at the time of molding can heighten the translucency of zirconia.[17-19]

In addition, grain size and sintering temperatures may also influence the translucency of zirconia.[20,21,43] When light proceeds into the zirconia, it may scatter from the grain boundaries, with smaller grain sizes because of the larger number of grain boundaries. Thus, larger grains of zirconia show higher translucency than smaller ones. The grain size depends on sintering conditions. If the sintering temperature is increased, grain sizes become larger. The sintering of all the zirconias used in this study was performed at a temperature range of 1450 to 1550°C. Generally, the sintering temperature for conventional zirconia is set at 1200 to 1350°C. Therefore, high translucency zirconias may require higher sintering temperature compared with conventional zirconia to achieve larger grains.

Generally, conventional zirconia contains 0.5 to 1.0wt % of Al_2O_3 and 3 to 6wt% of Y_2O_3, such as compositions from Zirkonzahn (Zirkonzahn GmbH), which contains 4 to 6wt% of Y_2O_3 and less than 1 wt% of Al_2O_3 and Zirprime (Kurary Noritake Dental Inc), which contains 3 to 6wt% of Y_2O_3 and less than 0.5wt% of Al_2O_3.[23] As far as impurities are concerned, alumina is the most common. High translucency zirconias are achieved with much lower alumina content compared with conventional zirconia. The zirconias used in this study contain 0.11 to 0.26 wt% of Al_2O_3. However, previous studies have reported that the small amount of alumina contained in zirconia is effective for the prevention of LTD.[24-27] According to these studies on accelerated aging resistance, the radial propagation of phase transformations from the metastable tetragonal phase to the monoclinic phase of Y-TZP is blocked by the addition of alumina and the phase transformation occurs in a scattered manner. In addition, lager grains are more susceptible to phase transformation and decrease the resistance to LTD.[21] Even conventional zirconia has been suspected of LTD, which is associated with the spontaneous transformation of metastable tetragonal phase to monoclinic phase in the oral environment.[28,29] Therefore, the high translucency zirconias used in this study may be more susceptible to LTD because of the reduced alumina content and the larger grain sizes. To counter LTD, the amount of Y_2O_3 was increased to 3.90 to 9.32wt% in the high translucency zirconias used in this study, especially in Prettau Anterior, Katana ST, and Katana UT which showed high values of T_t%. A previous study reported the effects of the mechanical properties of zirconia with differing amounts of Y_2O_3 after accelerated aging.[30] The study showed the reduction of the transformation from the tetragonal to monoclinic phase after accelerated aging with the higher amount of Y_2O_3. Based on the above, translucent zirconia may be produced by reducing the Al_2O_3 content to improve light transmittance and an increase in Y_2O_3 content to minimize LTD.

Additionally, previous studies have reported that Al_2O_3 in zirconia is also enhance the mechanical properties of zirconia.[24,26] Takaki[30,31] reported that mechanical properties, such as the flexural strength and the fracture toughness, were markedly decreased from 2.5 to 5.0 mol% by Y_2O_3 increasing. Therefore, the mechanical properties of high translucency zirconia may be of concern, since high translucency zirconias may be produced with such compositions. Further in vitro studies on the flexural strength and fracture toughness of such translucent zirconias after accelerated aging are required.

Clinicians may consider the use of high translucency zirconia for monolithic restorations in the posterior segments, with a hybrid design in the premolar areas and less occlusal tooth reduction translating into less occlusal thickness and with conventional cementation rather than bonding. This study demonstrated that e-max CAD LT was significantly more translucent than all zirconias, with an approximately 20% difference in translucency compared with Katana UT at 0.5 mm thickness and approximately 15 to 20% at 1.0 mm thickness for Katana UT, Prettau Anterior, and Katana ST. However, as stated by the manufacturer, the recommended thickness for monolithic lithium disilicate crowns is 1.5 mm because of its inferior mechanical properties to high strength zirconia ceramics.[4-6] Moreover, such differences may not be as clinically significant for ceramic crowns with the monolithic or hybrid design, since other parameters such as value, shade, contour and surface texture may all collectively and individually significantly affect restoration match. Therefore, further clinical studies are required to assess the esthetics and translucency of such restorations with different zirconias and various ceramic materials.

CONCLUSIONS

Within the limitations of this in vitro study the following conclusions may be drawn.

1. For the 0.5-mm-thickness groups, significant differences were found among the 5 different zirconias and the LT lithium disilicate, except for between BruxZir and Katana HT, and between Prettau Anterior and Katana ST. Katana UT was significantly more translucent than all other zirconias and e-max CAD LT significantly was more translucent than all zirconias.
2. For the 1.0-mm-thickness groups, significant differences were found the 5 different zirconias and the LT lithium disilicate, except for between BruxZir and Katana HT, and among Prettau Anterior, Katana ST and Katana UT. The e-max CAD LT was significantly more translucent than all zirconias.

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Noteworthy Abstracts of the Current Literature

Anteroposterior spread and cantilever length in mandibular metal-resin implant-fixed complete dental prostheses: A 7- to 9-year analysis

Purcell BA, McGlumphy EA, Yilmaz B, Holloway JA, Beck FM
Int J Prosthodont 2015;28:512-8

The purpose of this preliminary in vitro study was to evaluate the effect of an opaque layer and application of resin composite in dual colors on the ΔE values of resin composites used to fill access openings of screw-retained implant restorations. Sixty cylindrical nickel-chromium metal molds with a central channel simulating a posterior screw-retained, implant-supported, porcelain-fused-to-metal crown were cast. Access openings were filled with combinations of opaquer, enamel composite (A2E), dentin composite (A2B and A3B), and resilient composite. ΔE values differed significantly among the groups ($P<.01$). The combination of opaque layer and dual color resin composites of shades A2E and A3B resulted in significantly lower ΔE values than the other groups ($P<.01$).

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