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RESEARCH AND EDUCATION

Computable translucency as a function of thickness in a multi-layered zirconia

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ABSTRACT

Statement of problem. Determining the relationship between variable thicknesses and the translucency of dental ceramics is essential for optimizing esthetics in different clinical situations.

Purpose. The purpose of this in vitro study was to analyze the relationship between layer thickness and translucency of 2 multi-layered monolithic zirconia materials and to develop an equation by which the grade of translucency can be calculated dependent on the materials' layer thicknesses in advance.

Material and methods. Two semisintered multi-layered zirconia blanks, namely KATANA Zirconia Super Translucent Multi-Layered Disk (Noritake Dental Supply Co, Ltd) and Zirconia Ultra Translucent Multi-Layered Disk (UTML) (Noritake Dental Supply Co, Ltd), were sectioned (N=96) to separate the 4 layers (n=12 per layer): enamel layer, transition layer 1, transition layer 2, body layer. All specimens were sintered in a furnace (M2 Plus; Thermo-Star) at 1500°C for 2 hours and automatically polished under water cooling up to P2400 for the thicknesses of 1.6, 1.3, 1.0, 0.7, and 0.4 mm. Transmittance of visible light was measured using a spectrophotometer (Lambda 35; Perkin Elmer). Data were analyzed using the Kolmogorov-Smirnov, 2-way ANOVA, and Scheffé post hoc tests (α=.01) and curve fitting.

Results. Analyzing the fitting of the values of the 8 material groups to the linear, exponential, and logarithmic curves, 7 of the 8 groups (not UTML body layer) fitted the most (R-square value closer to 1.0) to the logarithmic curve. Constants were obtained from the distance to the x-axis and the curvature.

Conclusions. The methodology of this study provided the materials' specific constants *a* and *b* by analyzing the translucency behavior of KATANA Super Translucent Multi-Layered Disk and Ultra Translucent Multi-Layered Disk in different thicknesses, allowing further translucency calculation by applying the developed formula and the constants. (J Prosthet Dent 2019;121:683-9)

With the increase in esthetic demands, the search for materials that can match the characteristics of natural teeth and achieve a natural appearance has led to the development of ceramic materials.[1] Feldspathic porcelains and glass-ceramics can achieve excellent esthetics to match the optical characteristics of dentin and enamel, including color, surface texture, and translucency.[2] Translucency is the ability of a restoration to transmit light, a primary factor related to the esthetics of a ceramic restoration.[3] A light beam passing through a restoration or tooth is scattered, reflected, and/or transmitted, leading to a natural appearance. The higher the transmitted part, the more translucent the object.[3]

Despite the excellent optical properties of ceramic materials, feldspathic and glass-ceramics have poor mechanical properties, which vary according to the type of ceramic material.[4,5] The use of a high-strength ceramic core material covered by a high-esthetic glass-ceramic is an option. Zirconia, a high-strength material, is often the

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Clinical Implications

By using the elaborated formula with the materials' specific constants, the practitioner can predict both the necessary thickness of a restoration for the desired translucency and resulting translucency for a certain restoration thickness.

material of choice. Zirconia restorations have increased in popularity especially because of their excellent mechanical properties and favorable esthetics.[6] However, chipping of the veneering ceramic is the most reported complication in these types of fixed dental prostheses; this led to the development of monolithic zirconia restorations made from zirconia with higher translucency to enhance optical appearance[1,5] and the ability to be colored.[7,8] Studying the translucency of monolithic zirconia is essential to optimize the clinical application of these materials.

Translucency is related to the transmission and absorption of light, both of which are dependent on the amount, size, and chemical nature of the crystals in the matrix of a material compared with the wavelength of an incident light beam.[7] The conventional 3-mol yttria-stabilized zirconia polycrystal has a high refractive index. The light beam passes through many interfaces because of small and dispersed crystals, causing the material to have a low translucency.[9,10] New types of zirconia have been developed with improved optical properties to be used in monolithic restorations. First, the number of alumina grains as well as their size were reduced, and alumina grains were repositioned at the boundaries of zirconia grains. These modifications provided not only a more translucent material because of higher transmittance of the light but also a higher strength and longer term stability. Nevertheless, in this type of zirconia, the quantity of yttrium oxide remained the same (3 mol%), so it still lacked translucency when compared with glass-ceramics.[9] For this reason, new monolithic zirconias were developed and named "fully stabilized zirconia" with a mixed cubic and tetragonal structure and a cubic content of more than 50% up to 53%.[9] This cubic content was achieved by adding a higher quantity of yttrium oxide (approximately 5 mol%).[9] Light scattering is reduced with the presence of a cubic portion because the cubic grains have a higher volume than the tetragonal ones.[9] The lower light scattering and the more even emission of light increase the translucency considerably in a fully stabilized zirconia.[9,10] KATANA Zirconia Super Translucent Multi-Layered Disk (STML) and Zirconia Ultra Translucent Multi-Layered Disk (UTML) are fully stabilized zirconia and are different from each other because of the yttrium oxide content—higher in the UTML—which makes this zirconia more translucent. KATANA UTML is recommended for anterior crowns and veneers, inlays/onlays, and posterior single crowns, whereas STML is recommended for posterior fixed partial dentures of up to 3 units by the manufacturer.

Translucency can be measured and quantified using a spectrophotometer by means of the contrast ratio (CR), translucency parameter (TP), and transmittance percentage (T%). CR is the ratio of light reflectance of the object on a white and a black background; TP is the color difference between uniform thicknesses of the material also over a white and a black background; and T% is the measurement of the amount of light that passes through the object and reaches the detector.[7,11] A relationship has been reported between translucency and the thickness of the object.[3,7,12-14] Antonson and Anusavice[13] compared core and veneering ceramics of different thicknesses using the CR method. A direct linear relation between the layer thicknesses and the CR of the selected materials was reported. In another study comparing the grade of translucency of different types of glass-ceramic and zirconia, an increase in the TP with a decrease in thickness in different levels between the materials was found and considered to be an exponential relationship.[3] A logarithmic relation was described by Brodbelt et al[14] when they compared ceramics using the total T% and stated that the translucency of dental porcelain is a function of thickness.

Knowledge of the translucency of ceramic materials becomes essential for optimizing esthetics in dentistry and having a more predictable outcome of the planned restoration.[15,16] Determining the relationship between thickness and translucency is essential because of the variable thicknesses of clinical restorations. The purpose of this in vitro study was to analyze the relationship between thickness and translucency of 2 multilayered monolithic zirconias, calculate the specific constants of the materials, and provide an equation in which the grade of translucency could be calculated in advance by applying the constants. The null hypothesis was that these materials (KATANA STML and UTML) would not present a logarithmic relation between thickness and translucency.

MATERIAL AND METHODS

Two semisintered multi-layered zirconia blanks, namely KATANA Zirconia Super Translucent Multi-Layered Disk (STML) (Lot N° DKOVV) (Noritake Dental Supply Co, Ltd) and Zirconia Ultra Translucent Multi-Layered Disk (UTML) (Lot N° DKAQZ) (Noritake Dental Supply Co, Ltd), were used in this study. Tables 1 and 2 represent the distribution and composition of the blanks. Both materials were gradational multicolored

Table 1. Distribution of specimens in groups and subgroups

Group/Disk (N=96/n=48)	Subgroups/Layer (n=12)	Thicknesses of Each Layer (mm)
STML	Enamel Layer	1.6
UTML	Transition Layer 1	1.3
	Transition Layer 2	1.0
	Body Layer	0.7
		0.4

STML, Super Translucent Multi-Layered Disk; UTML, Ultra Translucent Multi-Layered Disk.

Table 2. Chemical composition of KATANA STML and UTML

Chemical Compounds	UTML	STML
ZrO_2+HfO_2	87-92%	88-93%
Y_2O_3	8-11%	7-10%
Others	0-2%	0-2%

STML, Super Translucent Multi-Layered Disk; UTML, Ultra Translucent Multi-Layered Disk.

zirconia disks with 4 different color layers to imitate the appearance of layered porcelain over a monolithic zirconia restoration. The disks were selected in an "A light" color that corresponded to VITA shade A2. The layers of the disks were divided into enamel layer (EL), transition layer 1 (TL1), transition layer 2 (TL2), and body layer (BL). The disks had the following dimensions: (1) diameter of 98.5 mm and (2) a thickness of 18 mm.

The STML and UTML disks were sectioned to separate the 4 layers. Using a laboratory handpiece with a diamond wheel (Dia-Scheiben Gips; Komet Dental Gebr Brasseler GmbH & Co KG), 48 presintered disk-shaped specimens were prepared from the 4 layers, that is, 12 per layer for each disk, generating a total of 96 specimens. Tables 1 and 2 present the distribution and composition of the groups. Specimens were then completely sintered in a furnace (M2 Plus; Thermo-Star) at a temperature of 1500°C for 2 hours with a temperature increase and decrease rate of 10°C/min. After sintering, all specimens had a thickness of 1.8 mm. Grinding was performed in an automatic polishing machine (Abramin; Struers) under water irrigation and controlled conditions using diamond pads (MD Rondo; Struers) with a particle roughness of 40 μm as first and of 20 μm as final surface grinding. Polishing was performed in the same machine over a polishing pad (MD Largo; Struers) with diamond suspensions of 9, 3, and 1 μm (DP-Suspension M; Struers) without water irrigation. After polishing, all specimens were cleaned in an ultrasonic cleaner (Ultrasonic cleaner T-14; L&R Manufacturing Co) to remove residual diamond suspension. The same specimens were used to evaluate the translucency in different thicknesses. First, they were ground and polished to 1.6 mm and measured. Then, the same procedure was performed for the thicknesses of 1.3, 1.0, 0.7, and 0.4 mm. A tolerance of ±0.05 mm was considered for all thicknesses.

A spectrophotometer (Lambda 35 Perkin Elmer; Perkin Elmer Inc) was used to measure the light transmittance with the parameter T%. The specimens were placed at the entrance port of the integrating sphere after an initial calibration measurement without any specimen to perform 100% transmission. Measurements of the intensity of monochromatic light (I0) and transmitted light through the specimen were made at visible light wavelengths (from 400 to 700 nm, intervals of 2 nm). The spectrophotometer's software calculated the transmittance coefficients t_c (%) for each wavelength, applying the following equation: $I/I0=t_c^x$. The overall transmittance (T%) for each layer of the material was calculated as the integration (t_c (λ) dλ [10^{-5}]). The overall light transmittance value for each material divided by the overall light transmittance value was used as the baseline measurement. One hundred percent of transmittance corresponded to transparent and 0% to opaque. The relationship between the thickness of the material and translucency was calculated as considered linear, exponential, and logarithmic to analyze which would be the most applicable relation curve in a regression analysis.

Normality of data distribution was analyzed using the Kolmogorov-Smirnov test. The curve fitting was performed with Analyze/Curvefit. Descriptive statistics (mean and standard deviation) were calculated, and data were compared with 2-way ANOVA and the Scheffé post hoc test (α=.01). All data were analyzed using the statistical software (IBM SPSS Statistics, v23.0 IBM Corp).

RESULTS

All analyzed values with mean and standard deviation of the translucency (%) of KATANA STML and UTML are presented in Table 3. Translucency of both KATANA STML and UTML decreased with the increase of material thickness (Fig. 1).

When the fitting of the 8 material groups' values to the linear, exponential, and logarithmic curves was analyzed, 7 of the 8 groups fitted the most (R-square closer to 1.0) to the logarithmic curve, except for UTML-EL (Table 4). The 3 regression curves are presented as an example in Figure 2. Therefore, the translucency of all KATANA material groups for the different thicknesses can be calculated in advance with the help of the following logarithmic formula and the necessary material's specific constants (a and b presented in Table 5) according to Schweiger and Erdelt: $f(x) = a + b * \ln(x)$, where a is the distance from the curve to the x-axis when x=1; in other words, a is the translucency value for a specimen with 1 mm of thickness. The constant b represents the curvature of the curve in the graph, and (x) is the thickness of the object. Therefore, translucency values can be calculated for different material thicknesses. Table 6 displays these calculated translucency percentages for a thicknesses

Table 3. Mean ±standard deviation (SD) of translucency results of KATANA SMTL and UTML for different material thicknesses

	Mean ±SD of Translucency (%)				
	Material Thickness (mm)				
Material	**0.4**	**0.7**	**1.0**	**1.3**	**1.6**
STML-EL	49.21 ±0.77^{cA}	37.99 ±0.77^{cB}	33.94 ±0.38^{dC}	31.32 ±0.36^{cD}	28.73 ± 0.62^{cE}
STML-TL1	46.91 ±0.63^{bA}	35.63 ±0.44^{bB}	31.12 ±0.64^{cC}	28.22 ±0.51^{bD}	24.52 ± 1.73^{bE}
STML-TL2	42.10 ±0.60^{aA}	33.94 ±1.06^{aB}	29.33 ±0.14^{aC}	25.70 ±0.74^{aD}	22.93 ± 1.08^{bE}
STML-BL	42.11 ±0.55^{aA}	33.64 ±0.74^{aB}	28.17 ±0.40^{aC}	25.76 ±0.54^{aD}	21.36 ± 1.27^{aE}
UTML-EL	54.88 ±0.85^{cA}	50.25 ±1.38^{fB}	40.23 ±0.76^{hC}	37.62 ±0.40^{fD}	33.71 ± 0.34^{eE}
UTML-TL1	52.61 ±0.50^{dA}	45.67 ±0.67^{eB}	39.20 ±0.59^{gC}	35.52 ±0.43^{eD}	31.83 ± 0.29^{dE}
UTML-TL2	52.19 ±1.08^{dA}	44.32 ±0.30^{eB}	38.28 ±0.38^{fC}	34.08 ±0.43^{dD}	30.48 ± 0.40^{dE}
UTML-BL	52.71 ±1.10^{dA}	42.41 ±0.59^{dB}	35.76 ±0.47^{eC}	30.99 ±0.31^{cD}	28.06 ± 0.52^{cE}

BL, body layer; EL, enamel layer; STML, Super Translucent Multi-Layered Disk; TL1, transition layer 1; TL2, transition layer 2; UTML, Ultra Translucent Multi-Layered Disk. Lowercase letters indicate statistically significant differences among materials, and uppercase letters indicate statistically significant differences among material thicknesses.

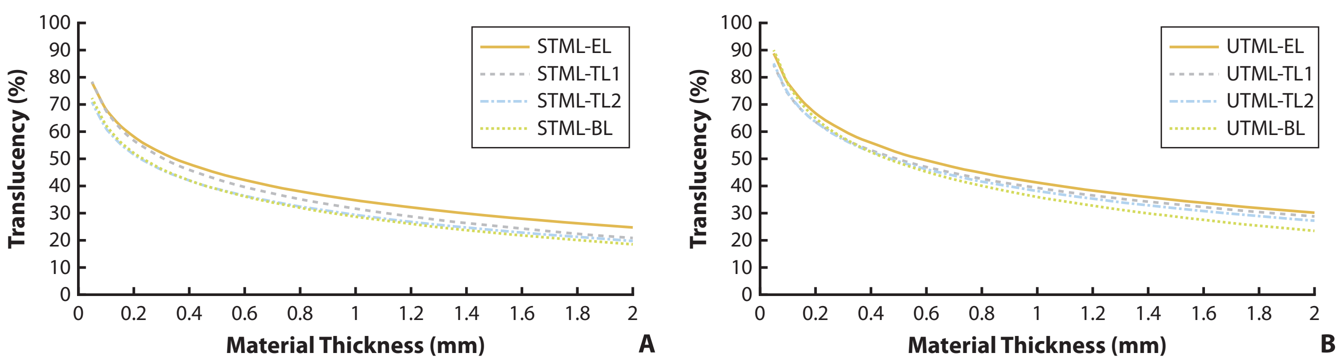

Figure 1. Translucency values with increasing material thickness (mm). A, STML groups (EL, TL1, TL2, and BL). B, UTML groups (EL, TL1, TL2, and BL). BL, body layer; EL, enamel layer; STML, Super Translucent Multi-Layered Disk; TL1, transition layer 1; TL2, transition layer 2; UTML, Ultra Translucent Multi-Layered Disk.

between 0.3 and 2.0 mm (with a 0.1 mm increase). In addition, Figure 3 presents a diagram for the intensity of monochromatic (I0) and transmitted light through the representative specimen of 1 mm in thickness at visible light wavelengths.

According to the Kolmogorov-Smirnov test, 95% of the data were normally distributed. Therefore, parametric tests were performed. The influence of layer thickness, material, and combination of layer thickness/material on the translucency showed significant differences for all groups (all $P<.001$) (Table 7). Within the thickness of 0.4 mm, all values of the diverse material groups were significantly different ($P\leq.001$) except STML-TL2/STML-BL ($P>.999$) and UTML-TL1/UTML-TL2/UTML-BL ($P\geq.925$).

Within the material thickness of 0.7 mm, all values of the material groups had significantly different results ($P\leq.006$) except for STML-BL/STML-TL2 ($P=.998$) and UTML-TL1/UTML-TL2 ($P=.031$). For the thickness of 1.0 mm, all results were significantly different ($P\leq.004$) except for UTML-TL1/UTML-TL2 ($P=.015$). When material thickness of 1.3 mm was analyzed, all values showed significant differences ($P\leq.001$) except 2 groups with STML-TL2/STML-BL ($P>.999$) and UTML-BL/STML-EL ($P=.913$). Within the material thickness of 1.6 mm, all results had significant differences ($P\leq.001$) except for UTML-BL/STML-EL ($P=.869$), UTML-TL2/UTML-TL1 ($P=.066$), and STML-TL2/STML-BL ($P>.038$).

In summary, all the material groups were statistically independent within the different material thicknesses ($P\leq.001$). Therefore, an assumption can be made that every material layer can be described with its own logarithmic mathematic function (Table 3).

DISCUSSION

The null hypothesis of this study was rejected because data revealed that both the materials (KATANA STML and UTML) presented a logarithmic relation (curve fitting) between thickness and translucency instead of an exponential one.

A difference in translucency levels was found among the different layers of the disks. For both the materials (STML and UTML), BL showed the lowest values of translucency for all material thicknesses, whereas EL showed the highest values for all thicknesses. These results are consistent with the results of Ueda et al,[1] who reported that the pigmentation of the layers influences

Table 4. R-square values of linear, logarithmic, and exponential curves of all material groups

Material	Linear	Logarithmic	Exponential
STML-EL	0.880	***0.969**	0.924
STML-TL1	0.902	***0.972**	0.937
STML-TL2	0.943	***0.987**	0.968
STML-BL	0.946	***0.985**	0.967
UTML-EL	0.946	0.950	***0.960**
UTML-TL1	0.972	***0.990**	0.988
UTML-TL2	0.968	***0.993**	0.988
UTML-BL	0.943	***0.994**	0.976

BL, body layer; EL, enamel layer; STML, Super Translucent Multi-Layered Disk; TL1, transition layer 1; TL2, transition layer 2; UTML, Ultra Translucent Multi-Layered Disk. *Translucency values most fitting to curve. Bold values indicate that the value is closer to one and fitting the most the specific curve.

Table 5. Values of constants *a* and *b* ±standard deviation (SD) for logarithmic formula

	Logarithmic	
Material	*a* ±SD	*b* ±SD
STML-EL	34.71 ±0.19	−14.45 ±0.38
STML-TL1	31.59 ±0.19	−15.59 ±0.39
STML-TL2	29.31 ±0.12	−13.78 ±0.23
STML-BL	28.64 ±0.13	−14.57 ±0.26
UTML-EL	41.62 ±0.24	−15.91 ±0.45
UTML-TL1	39.34 ±0.10	−15.08 ±0.19
UTML-TL2	38.18 ±0.09	−15.70 ±0.18
UTML-BL	36.04 ±0.09	−18.00 ±0.19

BL, body layer; EL, enamel layer; STML, Super Translucent Multi-Layered Disk; TL1, transition layer 1; TL2, transition layer 2; UTML, Ultra Translucent Multi-Layered Disk.

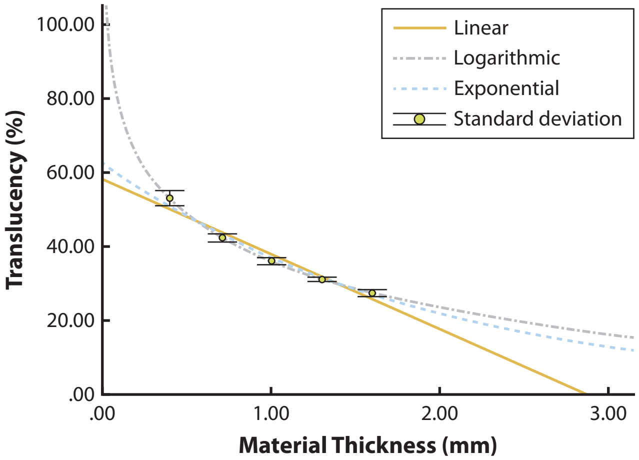

Figure 2. Distribution of translucency values in 3 curves of graph (UTML-BL group; R-square=0.994) for diverse material thicknesses. BL, body layer; UTML, Ultra Translucent Multi-Layered Disk.

the light transmittance (consequently, the translucency). Spyropoulou et al[15] compared the translucency of 3 different shades for the same zirconia core material by using the CR method and reported a statistically significant difference between the light and intense shades. Although the difference was not clinically perceptible, their results indicate that color influences translucency.

A relationship between thickness and translucency has been reported for dental ceramics.[2,3,7,11,13,14,16] In the present study, 5 different thicknesses were evaluated for 2 monolithic zirconia materials with the purpose of identifying the kind of relationship. The results confirm that there is a relationship because the translucency values decreased as the thickness increased. Wang et al[3] described an exponential relationship after testing the translucency of 8 glass-ceramics and 5 zirconia ceramics. Thus, the translucency of the materials increased exponentially as the thickness decreased. Other studies also reported an exponential relationship. Sulaiman et al[7] evaluated the translucency of 5 monolithic zirconia and reported an inverse relationship between thickness and translucency that varied among the different brands, but it was considered an exponential relationship for all materials. Nevertheless, this translucency-thickness relationship has also been described as being linear and logarithmic. In the study of Antonson and Anusavice,[13] the authors evaluated 4 core ceramics and 4 veneering ceramics in variable thicknesses (0.7, 1.10, 1.25, and 1.5 mm) and described a linear relation, that is, for each increase in thickness, the same amount of decrease in translucency occurred. However, monolithic zirconia was not tested in their study, unlike in the present study.

Kim et al[16] evaluated a monolithic zirconia colored with a coloring liquid and also reported a linear relation between CR and thickness. The authors successively reduced the thickness of the specimens while performing measurements and reached the conclusion that the higher the reduction of thickness, the higher the achieved translucency for monolithic zirconia ceramics. A logarithmic relation was first described by Brodbelt et al,[14] where specimens of a dental porcelain (Ceramco Incisal Porcelain) were prepared with different thicknesses (1.4, 1.0, and 0.8 mm), and after measuring the light transmission through the specimens, the authors reported a logarithmic relation regarding light transmission and thickness. However, how a linear relationship was reached in the first place was not clear. A logarithmic relationship is present if the changes between both the factors (light transmission and thickness) behave similarly to the exponential relationship, but the graph tends to infinity. Therefore, the zero point cannot be crossed because there cannot be a specimen with a thickness that is equal to zero.

In view of the variety of reports regarding possible relationships, in the present study, all translucency measurements for all thicknesses were tested with the 3 formulas for each relationship, such as exponential, linear, and logarithmic. Through statistical analysis, the distribution of the values in the 3 curves of the graph was possible (Fig. 2). The closer the R-square value was to 1, the more regular was the distribution of the translucency values in the curve (less spreading of the points). This

Table 6. Translucency percentage of KATANA SMTL and UTML for different commonly used thicknesses calculated by logarithmic formula

	Translucency (%)																	
	Material Thickness (mm)																	
Material KATANA	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
STML-EL	52.11	47.95	44.73	42.09	39.86	37.93	36.23	34.71	33.33	32.08	30.92	29.85	28.85	27.92	27.04	26.22	25.44	24.69
STML-TL1	50.37	45.88	42.40	39.56	37.16	35.07	33.24	31.59	30.11	28.75	27.50	26.35	25.27	24.26	23.32	22.43	21.58	20.79
STML-TL2	45.90	41.94	38.86	36.35	34.22	32.38	30.76	29.31	28.00	26.80	25.69	24.67	23.72	22.83	22.00	21.21	20.47	19.76
STML-BL	46.18	41.99	38.74	36.08	33.84	31.89	30.18	28.64	27.25	25.99	24.82	23.74	22.74	21.80	20.91	20.08	19.29	18.55
UTML-EL	60.78	56.20	52.65	49.75	47.30	45.17	43.30	41.62	40.10	38.72	37.44	36.27	35.17	34.14	33.18	32.27	31.41	30.59
UTML-TL1	57.49	53.15	49.79	47.04	44.72	42.70	40.93	39.34	37.90	36.59	35.38	34.26	33.22	32.25	31.34	30.47	29.66	28.88
UTML-TL2	57.08	52.56	49.06	46.20	43.78	41.68	39.83	38.18	36.68	35.31	34.06	32.89	31.81	30.80	29.85	28.95	28.10	27.29
UTML-BL	57.72	52.54	48.52	45.24	42.46	40.06	37.94	36.04	34.33	32.76	31.32	29.99	28.74	27.58	26.49	25.46	24.49	23.56

BL, body layer; EL, enamel layer; STML, Super Translucent Multi-Layered Disk; TL1, transition layer 1; TL2, transition layer 2; UTML, Ultra Translucent Multi-Layered Disk.

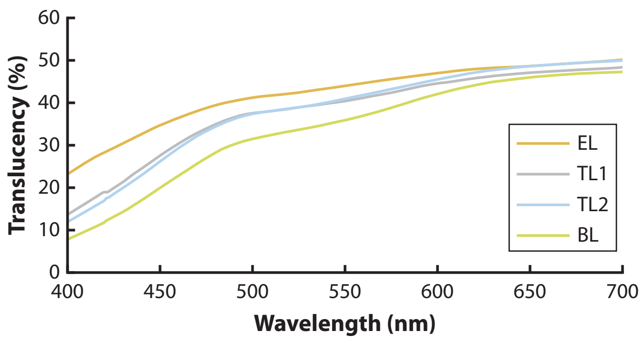

Figure 3. Intensity of monochromatic (I0) and transmitted light through UTML specimen of 1 mm thickness at visible light wavelengths (from 400 to 700 nm, 2-nm intervals). BL, body layer; EL, enamel layer; TL1, transition layer 1; TL2, transition layer 2; UTML, Ultra Translucent Multi-Layered Disk.

analysis showed that the best fitting for the results was in the logarithmic relationship for all groups, except for the UTML-EL group that exhibited the R quadrat value closest to 1 in the exponential relationship. This finding is probably related to a variation in the thickness allowed by the tolerance of ±0.05 mm present in the fabrication of the specimens, which caused changes in the translucency values of this group. These results also indicate that for the logarithmic relationship of the material, the relationship between thickness and translucency is dictated by the constants *a* and *b*, representing the materials' basis translucency and its variation with changes in thickness.

The present article introduces an option for helping in the planning of restorative treatments in dentistry. Using the formula and material constants provided by this study, the translucency of KATANA STML and UTML materials can possibly be calculated in advance. Knowing the desired definitive thickness of a restoration can help predict how translucent will be, or knowing how translucent the restoration should be can help the dental team plan how thick the restoration needs to be. To promote a clinical application of the study and simplify the work of the clinician, a translucency for several commonly used thicknesses was calculated for these 2 materials (KATANA STML and UTML) and is presented in Table 6. The authors recommend that the same research be carried out with other restorative materials, especially monolithic zirconia with different levels of translucency for a better comparison. Furthermore, the calculation algorithms and determined material-specific parameters should be implemented in a CAD software program.

Table 7. Two-way ANOVA results for influence of layer thickness, material, and combination of layer thickness/material on translucency for all groups

Variation of Factors	df	F	*P*
Layer thickness	4	11 743.06	<.001
Material	7	2367.33	<.001
Material×layer thickness	28	29.45	<.001

CONCLUSIONS

Within the limitation of this in vitro study, the following conclusions were drawn:

1. Values for the translucency of KATANA STML and UTML followed a logarithmic curve, and in consequence, the translucency of these materials can be calculated by applying the formula presented in this article with the materials' specific constants.
2. The constants *a* and *b* are completely material specific and will dictate the translucency behavior of the materials.
3. Calculating translucency in advance can help achieve predictable esthetic results in restorations made of monolithic zirconia.

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