

Light Transmission through Three Types of Translucent Zirconia

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Abstract

Objective: Zirconia cores have limited light transmittance and data are scarce on light transmission through zirconia cores with and without the veneering ceramic.

Methods: In this *in vitro* study, Disc-shaped specimens (11.5 mm in diameter and 0.4 (0.05) mm in thickness) were fabricated of three types of zirconia namely Mamut, Heany and ZirkonZahn (n=5). A disc-shaped specimen (11.5 mm in diameter and 0.65 (0.05) mm in thickness) of veneering ceramic (Cerabien ZR, Kuraray, Noritake, Japan) was also fabricated. The intensity of light transmitted through the zirconia specimens with and without the veneering ceramic was recorded using a light curing unit (LED, SDI Raddi Plus, Australia) and its respective radiometer (LED Radiometer, SDI, Australia). Data were analyzed using repeated measures ANOVA and Tukey's HSD test.

Results: A significant difference was noted in light transmission among different types of zirconia before and after veneering. After veneering, light transmission decreased in all specimens and the reduction in light transmission in Zirkonzahn group was significantly greater than that in Heany and Mamut groups ($p < 0.001$).

Conclusion: Veneered zirconia systems have limited translucency and ceramic veneering significantly decreases light transmission through zirconia.

Key words: Dental ceramics, Opacity, Porcelain veneer, Thickness, Translucency, Zirconium.

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Introduction:

Ceramics are recommended as the restorative dental material of choice for optimal matching with natural teeth. The ability of a ceramic crown to match the color of natural teeth depends on the size, shape, base, translucency and color of restoration (1, 2). Popularity of metal ceramic restorations is due to their predictable strength and logical esthetics. However, the main drawback of these restorations is high reflection of light due to the presence of opaque porcelain used to mask the

color of metal substrate (3). Full-ceramic restorations were introduced to match the color of ceramics with that of natural teeth. They provide greater esthetics than metal ceramic restorations (4).

Kelly and Benetti (2011) introduced the core translucency as the primary factor responsible for esthetics and selection of materials (5). The degree of translucency of a ceramic restoration depends on the properties of the core and veneer (6). Light transmission is inversely correlated with the thickness of restoration (7) and the light scattering rate of ceramic (8). Light scattering

depends on several factors such as the refractive index (6), high porosity, crystalline content (9) and number and size of crystals (6). Zirconia and alumina that show high laboratory strength (6) usually have high opacity due to increased crystalline content for higher strength (1, 6, 9). Nonetheless, most of them are esthetically superior to metal ceramic restorations (10).

In strong full ceramic restorations, alumina and zirconia are mainly used for fabrication of a core and the translucency and light transmission vary in these systems (11). Knowledge about the difference in translucency of these systems enables the clinician to achieve a better match between the restoration and natural teeth. Translucency of a restoration is important not only for esthetics, but also for polymerization of resin cement used for cementation of these restorations (12).

Previous studies on the translucency of different zirconia ceramics and other types of ceramics showed that zirconia ceramics, depending on their color, show variable degrees of translucency (13). However, in general, translucency of these ceramics was less than that of ceramics containing alumina (6, 10, 14) or glass (6, 9). In-Ceram zirconia is an aluminum oxide based ceramic and contains 35% zirconium oxide. The light transmission through this ceramic is similar to that of a metal ceramic restoration (6). Among non-zirconia cores, Procera® AllCeram containing 99.9% aluminum oxide and IPS Empress containing lithium disilicate glass are reported to have ideal esthetic properties (15, 16). Alumina and glass have moderate and good translucency, respectively (6). However, their mechanical properties are less than those of zirconia ceramics limiting their application in posterior or long-span

edentulous areas (10); whereas, zirconia has the highest mechanical properties (17) and can be used in full ceramic restorations for the posterior areas (18). Recent advances in full ceramic zirconia-based systems have resulted in the manufacture of new types with greater light transmission capability as claimed by the manufacturers (10, 19). Wang *et al.* in 2013 compared the translucency of different types of translucent zirconia, opaque zirconia and glass ceramics and showed that although the translucent types of zirconia allow light transmission more than opaque types, this value is significantly less than that of glass ceramics (20). Kanchanasavita *et al.* in 2014 evaluated light transmission through 6 types of zirconia ceramics and showed that inCoris TZI was more translucent than other types of zirconia (21).

Different methods are available to measure light transmission through ceramics; it can be done directly using a spectrophotometer (21) and radiometer (14) or indirectly by measuring the properties of the underlying polymerized resin cement (22). Considering the limited information about the new types of commercially available zirconia, this study assessed light transmission through these new systems. This study measured light transmission through zirconia coping directly using a radiometer.

Methods:

In this *in vitro* study, three types of zirconia ceramics namely Mamut, ZirkonZahn and Heany and their respective veneering ceramic were used. All three types of ceramics were translucent according to the manufacturers' claims.

Table 1- Characteristics of translucent zirconia ceramics

Ceramic	Main composition	CAD/CAM system	Temperature for sintering	Manufacturer
Mamut Zz series	Y-ZrO ₂	imes-icore	1350 C°	Mamut, Germany
Zirconzahn	Y-ZrO ₂	imes-icore	1400 C°	Degos, Germany & Italy
Heany	Y-ZrO ₂	imes-icore	1450 C°	Heany, USA

Table 1 summarizes the characteristics of ceramics including their main composition, method of fabrication and baking temperature.

Fabrication of specimens:

Disc-shaped specimens measuring 11.5 mm in diameter and 0.4 ± 0.05 mm in thickness were fabricated of three types of translucent zirconia ceramics by CAD/CAM (imes-iCore, GmbH, Germany) according to the manufacturer's instructions (Table 1). Five discs were fabricated for each group (6). After baking at the temperatures recommended by the manufacturer, the specimens were trimmed and polished by 0, 600 and 1000 grit silicon carbide abrasive papers in order to achieve a smooth surface and the required thickness. This thickness was confirmed using a digital caliper (Micrometer Mitutoyo Digital, Japan).

For clinical assessment of the effect of light curing, a disc-shaped specimen measuring 0.65 ± 0.05 mm in thickness and 11.5 mm in diameter was fabricated of layering porcelain used for veneering of zirconia copings (Cerabien ZR, Kuraray Noritake, Japan) according to the manufacturer's instructions. After preparation, specimens were immersed in an ultrasonic bath containing 75% ethanol for 10 minutes to eliminate superficial impurities. The specimens were then stored in a dry environment.

Measurement of light transmission through the specimens:

To measure light transmission, a light curing unit (LED, SDI Raddi Plus, Australia) and its

respective radiometer (LED radiometer, SDI, Australia) were used. The light curing unit was set on no ramp mode and in a dark room, the tip of the light curing unit was fixed relative to the radiometer using a mold made of addition silicone. After measurement of the output of the device by the radiometer, discs of each group were placed on the radiometer and in the same previous position, the amount of light transmitted through each specimen was measured in absence and in presence of the porcelain veneer for three times. The values were recorded by the radiometer.

Statistical analysis:

Data were expressed as mean and standard deviation (SD) (descriptive statistics) in each group. Repeated measure ANOVA was used to determine light transmission through the specimens before and after veneering. The value of light transmitted before and after veneering was considered as the repeated factor and type of ceramic was considered as the between subject factor. Tukey's HSD test was applied for pairwise comparison of the three types of ceramics. Data were analyzed using SPSS 15 and $p < 0.05$ was considered statistically significant.

Results:

Table 2 shows the light transmitted through the zirconia specimens in three groups before and after veneering.

Table 2- Light transmission through zirconia restorations before and after veneering

Type of ceramic	Light transmission before veneering	Light transmission after veneering
Heany	997 (46.5)	331 (33.6)
Zirconzhan	1096 (61.2)	421 (24.2)
Mamut	962 (44.5)	315 (20.4)

As seen in Figure 1, light transmitted through the ZirkonZahn ceramic before and after veneering was greater than that in the other two groups. Also, significant differences were noted

in light transmission among the three groups both before and after veneering.

Comparison of reduction in light transmission after veneering among the three groups showed

that light transmission in all groups significantly decreased after veneering ($p < 0.001$). Also, this reduction was significantly different among the

three groups ($p < 0.001$) and ZirconZahn showed a greater reduction in light transmission than the other two groups (Table 3).

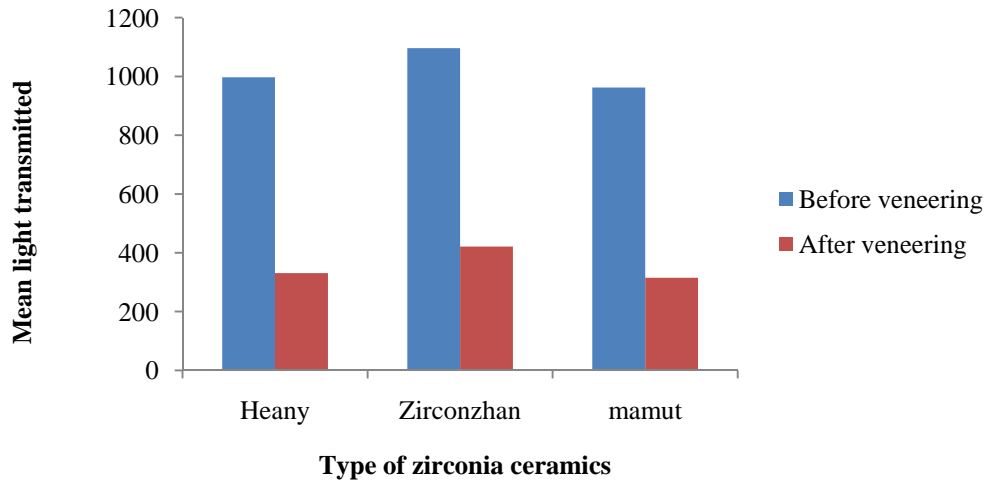


Figure 1- The mean light transmitted through the three types of zirconia ceramics before and after veneering.

Table 3- Comparison of reduction in light transmission after veneering among the three groups (negative symbol indicates reduction in light transmission after veneering)

Type of ceramic	Reduction in light transmission
Heany	-665 (22.07)
Zirconzhan	-675 (44.4)
Mamut	-646 (34.4)

Discussion:

Demand for zirconia restorations has increased due to their high strength. However, high opacity is their major drawback. Thus, this study aimed to assess light transmission through reportedly translucent zirconia restorations. Three types of highly popular translucent zirconia were evaluated in this study.

To assess light transmission, a LED light curing unit and its respective radiometer were used and light transmission through three types of zirconium core ceramics before and after veneering was measured. In a study by Baldissara *et al.* in 2010 light transmission through 8 types of zirconia including Lava Frame 0.3 and 0.5, IPSe.max ZirCAD, VITA YZ, ProceraAllZircon, Digizon, DC Zircon, and Cercon Base in 0.3 to 0.6 mm thickness was

evaluated and light transmission was reported in 7.38% to 12.5% only; Cercon Base zirconia had 42.1% of the translucency of glass ceramic control group (10).

Wang *et al.* (2013) showed that opaque ceramics (standard, Lava Standard FS3, ZenotecZr Bridge, Cercom ®) allowed significantly lower light transmission than translucent ceramics (Lava™ Base, Lava™ Plus). Their primary hypothesis that translucency would not be affected by the type and thickness of ceramics was refuted and a significant increase in translucency was noted when the thickness decreased. These findings were in accord with our study results indicating that veneering and increased thickness of ceramic decrease light transmission and subsequently, the translucency (20). Wang *et al.* (2013) in their study used a spectrophotometer and 2.2-25.3 range of

translucency parameter (TP) for different thicknesses of ceramics was obtained. Also, changes in TP of highly translucent dental ceramics were evident in greater changes in thickness (20). The TP of human dentin is 16.4 in 1mm thickness. This value is 18.1 for human enamel, which is close to the TP of glass ceramics (14.9-19.6). However, the TP of zirconia in 1mm thickness is 5.5-13.5, which is lower than that of human enamel and dentin. It shows that glass ceramics continue to provide superior light matching with natural teeth and zirconia alone has yet to be used for restoration of natural teeth. In the clinical setting, ceramic veneers are often used over zirconia specimens. Thus, in the current study, 0.4 mm thickness of zirconia was used in order to assess the effect of ceramic veneering on light transmission through zirconia specimens. In contrast, Wang *et al.* (2013) used variable thicknesses of zirconia ranging from 0.4 to 1mm. Specimens were evaluated with 0.1mm increment in their thickness without a veneering ceramic (20). Kamishima *et al.* (2005) and Kim *et al.* (2009) evaluated the changes in translucency of composite resins by a reduction in their thickness and found that by a reduction in the thickness of composite, its translucency increased. The same result was obtained in the current study on ceramics (23, 24).

Analysis of the light transmission coefficient of dental porcelain by Peixoto *et al.* (2007) revealed a linear correlation in the Neper's logarithm of light transmission coefficient and porcelain thickness (25). Thus, we conclude that small changes in thickness must be taken into account when a translucent ceramic is used for the fabrication of thin restorations in the clinical setting because the ultimate esthetic result mainly depends on thickness.

Color of the tooth to be restored is also an important consideration when it comes to choosing a ceramic. In clinical studies, non-discolored teeth have been better restored with

translucent ceramics while discolored teeth or those with metal posts required opaque ceramics.

Kanchanavasita *et al.* in 2014 assessed the translucency of zirconia using contrast ratio method and showed that inCoris TZI followed by LavaTM and LavaTM Plus allowed greater transmission of light than Zeno@Zr, ZENO@ Translucent and Cercon® (21).

To directly assess light transmission through ceramic restorations, spectrophotometer, radiometer and electrical diode can be used. In the current study, similar to many previous investigations, light transmission was measured using a radiometer (26, 27).

Radiometer showed that all types of ceramics allowed the transmission of light. In contrast to our findings, Chen *et al.* in 2008 revealed that Cercon Base zirconia was opaque and had a contrast ratio as high as that of metals (14). Haffernan *et al.* in 2002 demonstrated that In-Ceram zirconia with 33% zirconia content did not allow the transmission of light (6, 9); whereas, Pecho *et al.* in 2012 compared light transmission through a new zirconia ceramic and dentin and showed that the new ceramic had a translucency as high as that of dentin and in case of selection of correct shade, it may be a good substitute for dentin (28). Kilinic *et al.* in 2011 evaluated the effect of color and thickness of different ceramics on polymerization of light-cure and dual-cure resin cements. They also used a radiometer to assess the intensity of light. Such controversial results may be due to the manufacturers' attempts to produce more translucent ceramics as well as different methods used for evaluation of light transmission. The translucency of zirconium depends on the size of particles, heating temperature and baking conditions. The smaller the size of particles and the greater their coordination with the wavelength of radiated light, the higher the translucency values. Also, with slight changes in time, conditions and temperature of zirconia

baking, the number of oxygen-containing colored foci, which are the main sites of light absorption, decreases and consequently, light transmission through the zirconium improves (29,30). In our study, all three groups of zirconium core ceramics had similar thickness and surface polish. Thus, difference in light transmission directly relates to the type of ceramic. The core materials used in this study were fabricated of the commercially available highly translucent zirconia. Based on the results, ZirkonZahn ceramic before and after veneering had greater light transmission than Heany and Mamut ceramics. This result is probably due to the optical properties of each type of zirconia and as mentioned earlier, it is also influenced by the composition and baking condition of the materials.

In order to be able to generalize the results to the clinical setting, a specimen was also fabricated of the porcelain veneering the zirconia core and was placed on discs. Light transmission was evaluated in three groups in presence and absence of porcelain disc using a radiometer. Light transmission decreased in all groups after porcelain veneering. This reduction is probably attributed to the structure of veneering porcelain, porcelain veneer baking conditions, increased thickness of specimen, light reflection at the core-veneer interface and the porosity in-between layers (6, 9). Rasetto *et al.* (2004) in their study in 2004 assessed light transmission through ceramic core and veneer. Their study had a methodology similar to ours. They reported that light transmission through alumina coping after veneering with three different types of veneering ceramics decreased by different magnitudes. They reported greater light transmission when using IPS Empress veneering ceramic compared to feldspathic porcelain and Vitadur Alpha veneering ceramics (31). In addition to the type, thickness of veneering ceramic also affects the transmission of light because by an increase in thickness of ceramic,

the distance from the tip of the light curing unit to detector increases and since the intensity of light is inversely correlated to the distance square root (32), the intensity of received light decreases.

Light transmission also depends on the type of light curing unit, the intensity of radiated light and its wavelength. Rasetto *et al.* (2004) stated that only high-intensity light curing units such as plasma arc and high-intensity halogen lights are capable of transmitting light through alumina-based ceramic discs (31). Considering the fact that the confounding factors were matched in the current study, the difference in reduction of light transmission among the three groups depends on the difference in core ceramic. In other words, the veneering ceramic used was the same in terms of thickness, optical properties and the interface conditions in all groups and the same high-intensity light-curing unit (LED) was used for all tests.

Illie and Stawarczyk (2014) showed that the color shade of the zirconia restoration also affects light transmission and suggested that more than 0.5 mm thickness of opaque zirconia ceramic provided inadequate light transmission (32).

The current study had an in-vitro design and therefore, suffered the limitations of in-vitro studies. Further studies are required to assess the efficacy of zirconia restorations. To evaluate the clinical conditions, considering the unequal thickness of core and the veneering porcelain in the ceramic crowns and its effect on light transmission through the restoration, a model simulating a full ceramic crown is recommended for use in future studies. Also, polymerization of dual-cure cements via a zirconia restoration should be evaluated as well.

Conclusion:

Within the limitations of this study, the results showed that recently introduced zirconia cores

allowed light transmission and provided some degrees of translucency. ZirkonZahn showed the greatest transmission of light. The veneering porcelain placed over the zirconia significantly decreased light transmission. By further attention to selection of the type and baking conditions of the veneering porcelain, its optical properties can be enhanced to a great extent. Although application of zirconia restorations in

the esthetic zone does not provide optimal esthetic results, with ongoing advances in zirconia ceramic restorations, these systems may be qualified for use in the esthetic zone in near future to benefit from their high strength and optimal esthetics.

Conflict of Interest: “None Declared”

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