



Comparative analysis of transmittance for different types of commercially available zirconia and lithium disilicate materials

Husain Hatim Harianawala^{1*}, Mohit Gurunath Kheur¹, Sanjay Krishnaji Apte², Bharat Bhanudas Kale², Tania Sanjeev Sethi¹, Supriya Mohit Kheur³

¹M.A.Rangoonwala College of Dental Sciences and Research Center, Pune, Maharashtra, India

²Centre for Materials for Electronics Technology, Pune, Maharashtra, India

³D.Y.Patil Dental College, Pune, Maharashtra, India

PURPOSE. Translucency and colour stability are two most important aspects for an aesthetic dental restoration. Glass ceramic restorations are popular amongst clinicians because of their superior aesthetic properties. In the last decade, zirconia has generated tremendous interest due to its favorable mechanical and biological properties. However, zirconia lacks the translucency that lithium disilicate materials possess and therefore has limitations in its use, especially in esthetically demanding situations. There has been a great thrust in research towards developing translucent zirconia materials for dental restorations. The objective of the study was to evaluate and compare the transmittance of a translucent variant of zirconia to lithium disilicate. **MATERIALS AND METHODS.** Two commercially available zirconia materials (conventional and high translucency) and 2 lithium disilicate materials (conventional and high translucency) with standardized dimensions were fabricated. Transmittance values were measured for all samples followed by a microstructural analysis using a finite element scanning electron microscope. One way analysis of variance combined with a Tukey-post hoc test was used to analyze the data obtained ($P=.05$). **RESULTS.** High translucency lithium disilicate showed highest transmittance of all materials studied, followed by conventional lithium disilicate, high translucency zirconia and conventional zirconia. The difference between all groups of materials was statistically significant. The transmittance of the different materials correlated to their microstructure analysis. **CONCLUSION.** Despite manufacturers' efforts to make zirconia significantly more translucent, the transmittance values of these materials still do not match conventional lithium disilicate. More research is required on zirconia towards making the material more translucent for its potential use as esthetic monolithic restoration. [*J Adv Prosthodont 2014;6:456-61*]

KEY WORDS: Aesthetics; Lithium disilicate; Translucency; Transmittance; Zirconia

INTRODUCTION

The success of a dental restoration depends upon a number of factors such as the material chosen, its mechanical

properties, anatomical form, surface texture, translucency and colour. The most common aesthetic restorative material used in day to day practice for crown and bridge work is porcelain fused to metal (PFM) because of its excellent mechanical properties.¹ However, the much superior aesthetic outcome of metal-free ceramic restorations has led to their increasing popularity, especially in the anterior regions of the mouth.²

The major drawbacks of porcelain fused to metal restorations are lack of aesthetics, the possibility of metal allergies and the delamination of the veneering porcelain. In order to overcome the unaesthetic metallic hue seen in PFM restorations, dental research began to be directed towards metal-free ceramic restorations to improve the aesthetic outcome. Research and development led to the development of many metal-free ceramic systems, wherein

Corresponding author:
Husain Hatim Harianawala
Department of Prosthodontics M.A.Rangoonwala College of Dental Sciences and Research Center, 504, B Heritage, 4th Lanem Lokhandwala Complex, Andheri West, Mumbai- 400053, Maharashtra, India
Tel. 919833683432; e-mail, husain.harianawala@gmail.com
Received 9 May, 2014 / Last Revision 26 June, 2014 / Accepted 7 August, 2014

© 2014 The Korean Academy of Prosthodontics
This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

ceramic substructures were introduced which were subsequently veneered with porcelain providing relatively superior aesthetics.¹ However; these newer ceramics are prone to failures owing to their poor mechanical properties.^{3,4}

Glass ceramics with leucite and lithium disilicate reinforced crystals have proven to be successful aesthetic options in the anterior aesthetically demanding regions of the jaw.⁵ However, these restorations cannot withstand the mechanical load of more than one pontic in the anterior region and are contraindicated in the load bearing posterior regions because of their poor flexural strength.⁶

The search for a material with mechanical properties similar to PFM, superior biocompatibility and aesthetics similar to glass ceramics has led to the rapid evolution of dental zirconia. 3 mol% yttrium stabilized tetragonal zirconia polycrystalline (3Y-TZP) ceramics have gained tremendous popularity as restorative materials as a result of their excellent mechanical properties,^{3,4,7} good biocompatibility, and relatively good aesthetic properties.⁷

However, the conventionally available 3Y-TZP restorations are quite opaque owing to the large grain size and the presence of porosity which is evident at the microstructural level of these materials.^{8,9} The esthetic outcomes with these restorations are not as superior to lithium disilicate and leucite reinforced ceramics.⁷ Newer translucent varieties of zirconia have been developed recently, with the objective of improving their transmittance, so that they can be used in esthetically demanding clinical situations.

Studies done on these newer materials have shown that they are more translucent than conventional zirconia and demonstrated approximately two thirds more flexural strength than lithium disilicate.¹⁰

Use of translucent zirconia has the potential to eliminate delamination of the veneering ceramic, which has been known to be a common clinical problem and also reduce the amount of tooth preparation required.¹¹ This study was undertaken to evaluate the light transmittance of this translucent variety of 3Y-TZPs at different wavelengths and compare it to lithium disilicate.

MATERIALS AND METHODS

Four groups of materials were prepared and evaluated in this study. Group 1- Conventional zirconia (Metoxit Dental Pre-Sintered Zirconia Blocks, High Tech Ceramics, Liechtenstein Lot No. 0019481), Group 2- High translucency zirconia (Metoxit Dental Pre-Sintered Zirconia Blocks, High Tech Ceramics, Liechtenstein Lot No. 0019832), Group 3- Conventional lithium disilicate (IPS e.max LT Shade A2, Ivoclar Vivadent, Liechtenstein Lot No. P83594.) and Group 4- High translucency lithium disilicate (IPS e.max HT Shade A2, Ivoclar Vivadent, Liechtenstein Lot No. P76936). 12 circular discs of 1 millimeter thickness and 1 centimeter diameter were fabricated for each group.

The linear sintering shrinkage for the batch of conventional pre-sintered zirconia batch was 21%. The pre-sintered zirconia was milled using diamond discs and sintered

diamonds attached to a mandrel into discs of 1.28 mm height and 1.2 cm diameter. These discs were then sintered as per the manufacturer's guidelines. The thickness of the pre-sintered samples and samples post sintering were verified using a digital vernier calliper (0-200 mm, Aerospace, China). Following finishing and polishing, the dimensions of all the samples were maintained at 1mm thickness and 1cm diameter, with a variation up to ± 0.01 mm.

A similar procedure was followed for fabrication of samples of the high translucency zirconia using a pre-sintered high translucency zirconia block.

A cobalt chromium mould having height of 1 mm and diameter 1 cm was used for fabrication of wax patterns for the lithium disilicate samples. The mould was CAD-CAM milled from a block of cobalt chromium (Cobalt-Chromium alloy-d.Sign, Ivoclar Vivadent, Asia). The thickness of the wax patterns was verified using a digital vernier calliper. The patterns were then invested and pressed as per the manufacturer's instructions. After the pressing was completed the ring was divested and cleaned using 1% hydrofluoric acid in an ultrasonic cleaner. The discs were then finished using porcelain finishing burs and their dimensions were reconfirmed. The dimensions were kept exactly the same as those of the zirconia samples. The high translucency lithium disilicate samples were prepared following the same protocol.

Transmittance is a measure of the fraction of incident light at a specified wavelength that passes through a sample. The translucency of dental porcelains can be studied by measuring direct transmission (when light goes through without a change in direction or quality), total transmission (combination of direct and diffuse light transmission) and spectral reflectance (fraction of incident light that is reflected at an interface such as porosity). The transmittance of the samples was measured using a dual beam UV-Spectrophotometer equipped with an integrating sphere (Beckman Acta C III UV-visible spectrophotometer, Beckman Instruments, Inc., Irvine, CA9266, USA)(Fig. 1). Air



Fig. 1. UV spectrophotometer.

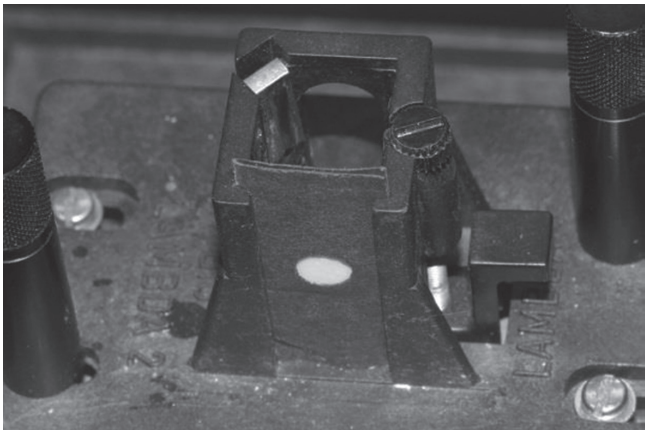


Fig. 2. Sample holder with 8.5 mm slot placed in the UV spectrophotometer.

was used as the reference. Diffuse light transmittance measurements were made from the 200 nm to 800 nm wavelength range. A black cardboard sample holder (1.25 cm × 1.25 cm × 4.5 cm) with a central orifice of 8.5 mm diameter was used to position the specimens in front of the sphere holder (Fig. 2). Data was recorded with a computer connected to the spectrophotometer, and a graph of light transmittance percentage per nanometer was obtained by using Origin 6.1 software (Microcal Software Inc., Northampton, MA, USA) for each ceramic specimen. Digital readings at 525Å were recorded and used for the calculations.

One way analysis of variance (ANOVA) test was used for multiple group comparisons followed by Tukey-Post Hoc test for group wise comparisons.

Field emission scanning electron microscope (FE-SEM)



Fig. 3. Samples of Group 1 - 4 arranged sequentially from left to right held against daylight.

(JEOL JSM 7600F Field Emission Scanning Electron Microscope) was used to study the microstructure of both the zirconia and lithium disilicate material.

RESULTS

The transmittance values for the samples from all groups and their comparisons are presented in Table 1. Transmittance values were highest for Group 4 (high translucency lithium disilicate) showing mean transmittance values of 0.207759. Group 3 (conventional lithium disilicate) had mean transmittance value of 0.158738 which was marginally higher than Group 2 (high translucency zirconia samples) whose mean value was 0.143969. Group 1 samples (conventional zirconia) had the least values of 0.065015. The relative translucency of the different groups of samples is represented in Fig. 3.

High translucency lithium disilicate showed highest direct transmittance values which were statistically highly significant ($P=0.000$)(Table 2). Conventional lithium disilicate showed transmittance ($P=0.000$) values higher than

Table 1. Transmittance values (Angstrom units –Å) for various groups studied

Group	N	C	SD	ANOVA F	P
Group 1 Conventional Zirconia	12	0.06510558	0.00368295	289.373	0.000 HS
Group 2 High translucency zirconia	12	0.14396933	0.13083695	579.870	0.000 HS
Group 3 Conventional Lithium disilicate	12	0.15873866	0.00551693	36.864	0.000 HS
Group 4 High translucency Lithium disilicate	12	0.20775941	0.00864425	725.119	0.000 HS

*HS = Highly Significant.

Table 2. Tukey-Post Hoc test (Pairwise comparison)

	Conventional zirconia	Zirconia high translucency	Conventional lithium disilicate	Lithium disilicate high translucency
Conventional zirconia	-	0.0 HS	0.000 HS	0.000 HS
Zirconia high translucency	-	-	0.001 HS	0.000 HS
Conventional lithium disilicate	-	-	-	0.000 HS
Lithium disilicate high translucency	-	-	-	-

*HS = Highly Significant.

highly translucent zirconia which was statistically significant ($P=.000$). Conventional zirconia had the least transmittance ($P=.000$).

Scanning electron microscopy (SEM) of the high translucency zirconia samples showed nano sized crystals, with the external outline of the crystals depicting a polyhedral structure. Minimal nano sized porosity was seen. The grain sizes varied ranging from 50 nm to 400 nm for the high translucency zirconia samples (Fig. 4) as compared to the conventional zirconia which showed diffuse porosity ranging from 200 nano microns to 1.5 microns (Fig. 5).

The lithium disilicate samples on scanning electron microscopy showed that the crystals were well merged with the matrix (Fig. 6). The crystals could not be differentiated from the matrix. Arrangement of the crystals was irregular with some spacing seen. The high translucency lithium dis-

ilicate samples showed well aligned parallel crystals with no spacing. The white spots seen are the colouring dopants (Fig. 7).

DISCUSSION

The translucency of the core is one of the most important determinants of the aesthetic properties of metal-free ceramic restorations.^{12,13} The zirconia core is not as translucent as other dental metal-free ceramic materials such as glass-ceramics.^{14,15} Therefore, by increasing the translucency of the zirconia core, the aesthetic properties of a dental restoration can be improved. The ultimate aim is to eliminate the use of veneering porcelain, thereby eliminating the problem of porcelain delamination¹⁶ and enabling the clinician to employ more conservative tooth preparation designs.

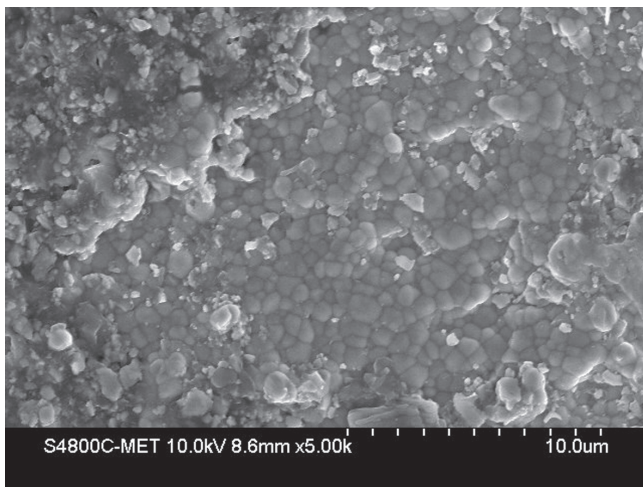


Fig. 4. Scanning electron microscopic image of high translucency zirconia.

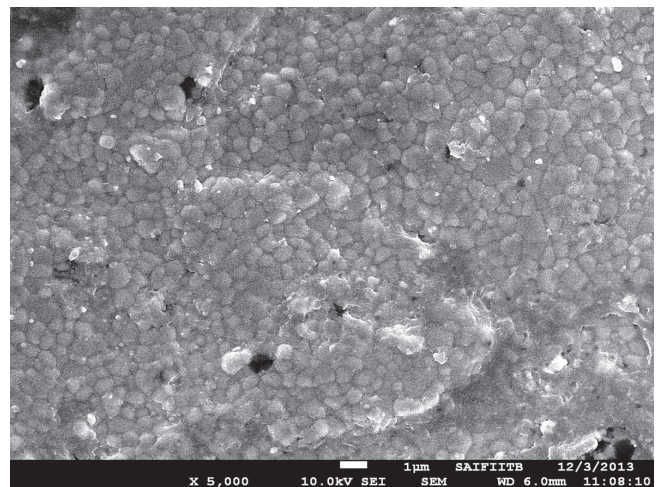


Fig. 5. Scanning electron microscopic image of conventional zirconia.

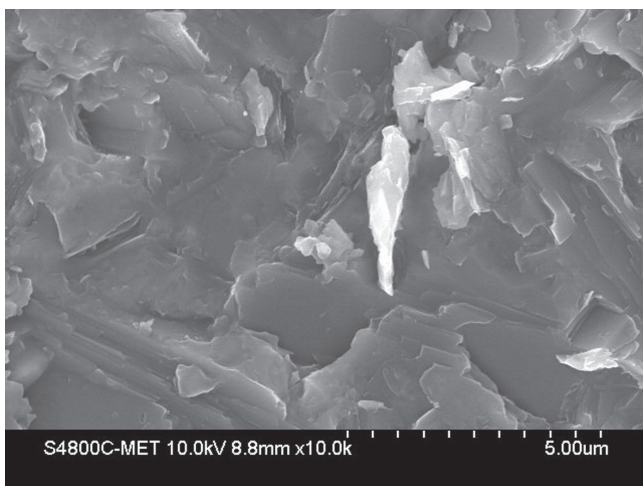


Fig. 6. Scanning electron microscopic image of commercially available lithium disilicate.

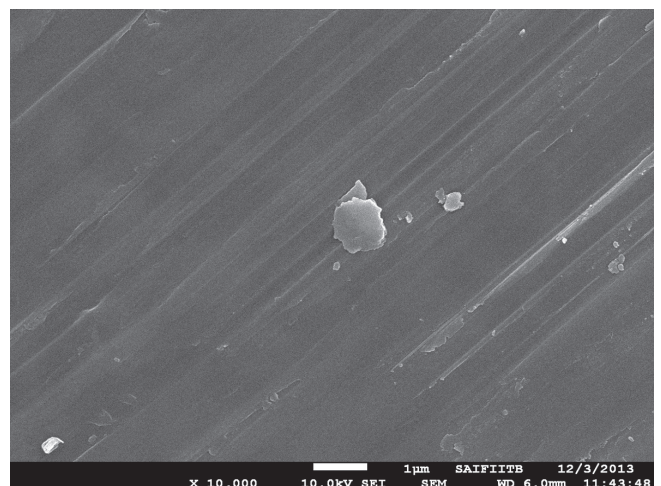


Fig. 7. Scanning electron microscopic image of high translucency lithium disilicate.

The translucency of dental ceramics can be evaluated through direct transmission, total transmission and via spectral reflectance. Total transmission increases with increasing wavelength of light as mentioned by the Rayleigh scattering equation. The transmittance of all the samples were studied at a wavelength of 525 Å in accordance with Brodbelt's methodology of studying translucency of dental porcelains.¹⁷

Translucency of dental porcelains is known to be affected by various factors such as grain boundaries, pores, second-phase of component, and light scattering from rough surfaces.¹⁸ The translucency of glass ceramics depends largely on the amount of crystals within the glassy matrix^{14,19} and the size of the particles compared with the incident light wavelength.²⁰ Another factor that interferes with light transmission is the difference in the refractive index between the crystals and the glassy matrix. The refractive index is measured as the amount of reduction in the speed of light when passing through a medium. Leucite (1.51) and lithium (1.55) have similar refractive indices to the glassy matrix (1.50).¹⁵ Presence of porosity in these glass ceramics tends to have a higher influence on the light transmission than the crystals themselves. The mismatch between the refractive indices of the air porosity (1.00) and that of the glassy matrix may lead to a significant light scattering effect.¹⁵

High translucency lithium disilicate showed the highest transmittance values (0.207759Å). This could be attributed to the refractive index of the lithium disilicate glass crystals matching to that of the glassy matrix. The absence of porosity prevents scattering of the light, thereby improving transmittance values. A linear well-organized crystalline structure was seen with the high transmittance glass ceramics. The significantly lower transmittance values for the conventional lithium disilicate may be attributed to the irregular arrangement of the crystals leading to increased scattering and reflectance.

The significantly superior mechanical and biological properties of 3 mol% yttrium stabilized zirconia along with its biocompatible features have resulted in its increasing popularity amongst clinicians and researchers. Polycrystalline materials are known to show high transmittance when the grain sizes are small and uniform in size with minimal porosity.¹⁸ Dopants such as alumina are added to improve the phase stability and to reduce ageing. However the presence of alumina because of its different refractive index to zirconia increases the scattering of light and reduces the translucency.

Lowest transmittance values (0.065015 Å) were seen with conventional zirconia. This is attributed to the presence of porosities larger than 50 nano microns which affect transmittance²¹ (Fig. 5). The high translucency zirconia showed a significant increase in transmittance values (0.143969 Å) over that of conventional zirconia. This is due to the significantly reduced frequency and size of the porosity seen with this newer material (Fig. 4). The material also showed a more uniform grain size and configuration

than the conventional zirconia.

Conventional lithium disilicate showed higher transmittance values (0.158738 Å) than the high translucency zirconia (0.143969 Å). This difference was statistically significant. Lithium disilicate restorations with opaque cores are currently used for cases wherein the tooth to be restored is non-vital or discoloured to mask the hue of the prepared stump.^{22,23} Zirconia having similar optical properties can be a better substitute for glass ceramic restorations because of its superior mechanical properties.

The aesthetic demands of clinicians and patients have led manufacturers to improve upon the translucency of zirconia and lithium disilicate ceramics. This study clearly demonstrates that the high translucency zirconia and lithium disilicate have significantly more transmittance than the conventional variants. This can be attributed to the manufacturing procedures of these materials. Some of the methods documented in the literature for obtaining more dense, less porous, more translucent zirconia are hot isostatic pressing, microwave sintering, spark plasma sintering etc.^{9,18,24} However despite the significant improvement in transmittance, high translucency zirconia is still below par when compared with today's aesthetic gold standard material, lithium disilicate.

One of the greatest drawbacks of zirconia restorations compared to lithium disilicate is the tendency for delamination of veneering ceramic from the core.¹⁶ The ability of bonding lithium disilicate to tooth structure is also an advantage over zirconia restorations. Monolithic restorations used popularly today are not as esthetic as core veneered zirconia restorations or lithium disilicate restorations. The authors believe that if the translucency of zirconia could be increased, thereby favorably reducing its refractive index values from 2.2 to that of the aesthetic glass ceramics whose refractive index is 1.5, the need for using veneering ceramic can potentially be eliminated.⁹ This would permit life like restorations with larger spans providing aesthetics similar to glass ceramics. This would also reduce the amount of tooth preparation required, thus help conserve more tooth structure. It will broaden the horizons for use of zirconia as laminates and veneers.

CONCLUSION

Within the limitations of the study, it can be concluded that high translucency lithium disilicate is the most translucent material amongst the materials studied. High translucent zirconia is significantly more translucent than conventional zirconia. However, the increase in transmittance achieved with high translucency zirconia is significantly less compared to even conventional lithium disilicate. Further research is needed on improving the microstructural features of zirconia materials in order to enhance their translucency.

REFERENCES

- Kelly JR, Benetti P. Ceramic materials in dentistry: historical evolution and current practice. *Aust Dent J* 2011;56:84-96.
- Durán P, Villegas M, Fernández JF, Capel F, Moure C. Theoretically dense and nanostructured ceramics by pressureless sintering of nanosized Y-TZP powders. *Mater Sci Eng A* 1997;232:168-76.
- Chen YM, Smales RJ, Yip KH, Sung WJ. Translucency and biaxial flexural strength of four ceramic core materials. *Dent Mater* 2008;24:1506-11.
- Tinschert J, Natt G, Mautsch W, Augthun M, Spiekermann H. Fracture resistance of lithium disilicate-, alumina-, and zirconia-based three-unit fixed partial dentures: a laboratory study. *Int J Prosthodont* 2001;14:231-8.
- Mizrahi B. The anterior all-ceramic crown: a rationale for the choice of ceramic and cement. *Br Dent J* 2008;205:251-5.
- Raigrodski AJ. Contemporary materials and technologies for all-ceramic fixed partial dentures: a review of the literature. *J Prosthet Dent* 2004;92:557-62.
- Conrad HJ, Seong WJ, Pesun IJ. Current ceramic materials and systems with clinical recommendations: a systematic review. *J Prosthet Dent* 2007;98:389-404.
- Dias MC, Piva E, de Moraes RR, Ambrosano GM, Sinhoreti MA, Correr-Sobrinho L. UV-Vis spectrophotometric analysis and light irradiance through hot-pressed and hot-pressed-veneered glass ceramics. *Braz Dent J* 2008;19:197-203.
- Tsukuma K, Yamashita I, Kusunose T. Transparent 8 mol% Y_2O_3 - ZrO_2 (8Y) Ceramics. *J Am Ceram Soc* 2008;91:813-8.
- Chen YM, Smales RJ, Yip KH, Sung Wj. Translucency and biaxial flexural strength of four ceramic core materials. *Dent Mater* 2008;24:1506-11.
- Sailer I, Fehér A, Filser F, Lüthy H, Gauckler LJ, Schärer P, Franz Hämmerle CH. Prospective clinical study of zirconia posterior fixed partial dentures: 3-year follow-up. *Quintessence Int* 2006;37:685-93.
- Rosenstiel SF, Land MF, Fujimoto J. Contemporary Fixed Prosthodontics. 4th ed. St. Louis; Mosby; 2006. p. 262-643.
- Yu B, Ahn JS, Lee YK. Measurement of translucency of tooth enamel and dentin. *Acta Odontol Scand* 2009;67:57-64.
- Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part I: core materials. *J Prosthet Dent* 2002; 88:4-9.
- Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part II: core and veneer materials. *J Prosthet Dent* 2002;88:10-5.
- Kelly JR, Tesk JA, Sorensen JA. Failure of all-ceramic fixed partial dentures in vitro and in vivo: analysis and modeling. *J Dent Res* 1995;74:1253-8.
- Brodbelt RH, O'Brien WJ, Fan PL. Translucency of dental porcelains. *J Dent Res* 1980;59:70-5.
- Kim MJ, Ahn JS, Kim JH, Kim HY, Kim WC. Effects of the sintering conditions of dental zirconia ceramics on the grain size and translucency. *J Adv Prosthodont* 2013;5:161-6.
- Antonson SA, Anusavice KJ. Contrast ratio of veneering and core ceramics as a function of thickness. *Int J Prosthodont* 2001;14:316-20.
- Zhang Y, Griggs JA, Benham AW. Influence of powder/liquid mixing ratio on porosity and translucency of dental porcelains. *J Prosthet Dent* 2004;91:128-35.
- Alaniz JE, Perez-Gutierrez FG, Aguilar G, Garay JE. Optical properties of transparent nanocrystalline yttria stabilized zirconia. *Opt Mater* 2009;32:62-8.
- Succaria F, Morgano SM. Prescribing a dental ceramic material: Zirconia vs lithium-disilicate. *Saudi Dent J* 2011;23:165-6.
- Vichi A, Louca C, Corciolani G, Ferrari M. Color related to ceramic and zirconia restorations: a review. *Dent Mater* 2011; 27:97-108.
- Johnson LD. Microwave and plasma sintering of ceramics. *Ceram Int* 1991;17:295-300.