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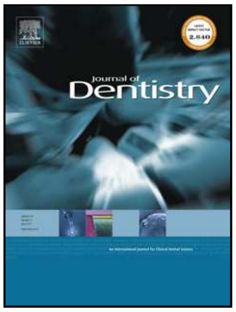

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Translucent zirconia in the ceramic scenario for monolithic restorations: A Flexural Strength and Translucency comparison test.

Short Title: Flexural Strength and Contrast Ratio comparison for translucent Zirconia.

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Key Words: Translucent Zirconia, Y-TZP, Lithium Disilicate, Contrast Ratio, Flexural Strength, Translucency, Monolithic restoration, Grain Size.

Abstract

Objective: To compare three different compositions of Yttria-Tetragonal Zirconia Polycrystal (Y-TZP) ceramic and a lithium disilicate ceramic in terms of flexural strength and translucency.

Methods: Three zirconia materials of different composition and translucency, Aadva ST [ST], Aadva EI [EI] and Aadva NT [NT](GC Tech, Leuven, Belgium) were cut with a slow speed diamond saw into beams and tabs in order to obtain, after sintering, dimensions of 1.2x4.0x15.0mm and 15.0x15.0x1.0mm respectively. Blocks of IPS e.max CAD LT were cut and crystallized in the same shapes and dimensions and used as a reference group [LD]. Beams (n=15) were tested in a universal testing machine for three-point bending strength. Critical fracture load was recorded in N, flexural strength (σ in MPa), Weibull modulus (m) and Weibull characteristic strength (σ^0 in MPa) were then calculated. Tabs (n=10) were measured with a spectrophotometer equipped with an integrating sphere. Contrast Ratios were calculated as CR=Yb/Yw. SEM of thermally etched samples coupled with lineal line analysis (n=6) was used to measure the tested zirconia grain size. Data were statistically analyzed.

Results: Differences in translucency, flexural strength and grain size were found to be statistically significant. CR increased and flexural strength decreased in the following order ST(σ 1215±190MPa, CR 0.74±0.01)>EI(σ 983±182MPa, CR 0.69±0.01)>NT(σ 539±66MPa, CR 0.65±0.01) > LD (σ 377±39Mpa, CR 0.56±0.02) . The average grain size was different for the three zirconia samples with NT(558±38nm)>ST(445±34nm)>EI(284±11nm).

Conclusions: The zirconia composition heavily influenced both the flexural strength and the translucency. Different percentages of Yittria and Alumina result in new materials with intermediate

properties in between the conventional zirconia and lithium disilicate. Clinical indications for Zirconia Aadva NT should be limited up to three-unit span bridges.

Introduction

Yttria-Tetragonal Zirconia Polycrystal (Y-TZP) is considered one of the most versatile bioengineering ceramics due to its mechanical, optical and physical proprieties [1],[2],[3].

High hardness and fracture toughness are the main reasons for the adoption of Y-TZP in dentistry as a material indicated for fabrication of fixed partial denture frameworks, monolithic crowns and bridges, implant abutments or screw-retained prostheses [4]. As an advantage in fixed prosthodontics, the Y-TZP structure is responsible for characteristic optical properties like favourable colour and translucency.

Translucency is considered one of the most important factors in matching the appearance of natural teeth with restorative materials and has been defined as the relative amount of light transmission [5] and [6].

At clinically indicated thicknesses, the material does not offer a complete barrier to light transmission through the structure, unlike the metal in porcelain fused to metal restorations [7].

Nevertheless, the absence of a glass matrix in the dense sintering polycrystalline zirconia results in lower translucency compared with other ceramic materials [8] . The ability of light to pass thorough zirconia structure is related to several factors: particle and grain size [9], [10],[11], density [11], and crystal structure [12], [13], [14].

The sintering temperature influences the grain size and density; the smaller the particle and higher the temperature the denser the structure with a larger grain size that influences the translucency [10]. The use of different quality and quantity of dopants and stabilizers has been reported to affect the structure of grain and crystals with consequent influence on both optical and mechanical properties [14], [15], [16], [17].

The need for "high translucency" zirconia is related to the possibility of aesthetic improvement for monolithic restorations. Monolithic zirconia restorations could moreover represent an advantage in terms of simplification of procedure, cost reduction and could overcome the problem of veneer chipping [18].

New compositions of Y-TZP with claimed different optical and mechanical properties for dental CAD/CAM machining systems were recently introduced to the market with the indication for monolithic restorations with limited span and conservative tooth preparation. Due to the increased translucency and the adequate mechanical properties, the "high translucent" zirconia, has been proposed as an alternative material to lithium disilicate for monolithic restoration. The aim of this study was to compare translucency, as measured by Contrast Ratio, with mechanical properties in terms of flexural strength (σ), Weibull modulus (m) and Weibull characteristic strength (σ^0) for three different Y-TZP samples and compare these to a lithium disilicate glass ceramic considered as the alternative ceramic material for monolithic single restoration[19] and [20].

The tested null hypotheses were that:

There are no statistically significant differences in terms of flexural strength and translucency between the tested materials and there is no correlation between the two tested properties.

Materials and Methods

CAD/CAM pre-sintered disks of zirconia (98,5 x 18 mm disk, Aadva, GC Tech, Leuven, Belgium) characterized by different translucencies and composition (Table 1) were selected for the study; these were Aadva ST (standard translucency – ST group), Aadva EI (Enamel Intensive – EI group) and Aadva NT (natural translucent – NT group).

These zirconia disks were cut by a slow speed water cooled diamond saw (IsoMet Low Speed Saw, Buehler, Lake Bluff, IL, USA); cutting dimensions of the specimens were determined taking in to account that a 20% shrinkage occur during dense sintering.

All the specimens were sintered in a sintering furnace (Sirona InFire HTC Speed, Sirona Dental, Bensheim, Germany) following the manufacturer’s instructions. Briefly, the furnace temperature rose at 5-6°C per minutes until 900°C, it was then held at 900°C for 30 minutes, before increasing very slowly to 1500°C over 4.5 hours, 2 hours at 1500°C, decrease until 1000°C in one hour, then to room temperature very slowly.

Lithium Disilicate blocks for CEREC® (IPS e-max CAD LT, Ivoclar Vivadent AG, Schaan, Liechtenstein) were used as a control material (LD group). With the use of a proprietary device, blocks were perpendicularly cut in order to obtain the desired shape. Specimens were submitted to crystallization firing in a ceramic furnace (Vacumat® 6000M, Vita Zahnfabrik, Bad Säckingen, Germany) following the manufacturer’s instructions.

Flexural Strength - 3Point Bending Test

Beam-shaped specimens (n = 15 per group) were prepared and wet-finished in a grinder/polisher machine with 600 grit paper until dimensions of 15 ± 0.2 mm length, 4 ± 0.2 mm width, and 1.2 ± 0.2 mm height were obtained. Specimens were then wet-polished with 1,200 and 2,400 grit paper. According to ISO 6872:2015, a 45° edge chamfer was made at each major edge [21]. Specimens were ultrasonically cleaned in distilled water for 10 minutes before measurement procedure.

Tests were performed in a universal testing machine (Triax 50, Controls, Milano, Italy) with a cross-head speed of 1 mm/minute and the span was set at 13.0 mm. Specimens were tested dry at room temperature. The fracture load was recorded in N, and the flexural strength (σ) was calculated in MPa by using the following equation:

$\sigma = Pl / 2\mathrm{wb}^2$

where P in the fracture load in N, l is the span in mm, w is the specimen width in mm, and b is the specimen height in mm.

The Weibull characteristic strength (σ^0) and the Weibull modulus (m) were calculated according to the following equation:

$P_f = 1 - \exp [- (\sigma / \sigma^0)^m]$

where P_f is the probability of failure between 0 and 1, σ is the flexural strength in MPa, σ^0 is the Weibull characteristic strength in MPa, and m is the Weibull modulus.

Translucency measurement – Contrast Ratio (CR)

For optical evaluation, tab shaped specimens (n = 10 per group) with final dimension of 15 ± 0.5 mm in length, 15 ± 0.5 mm in width, and 1.0 ± 0.1 mm thick were obtained and wet-polished with 600 and 1,200 grit paper in a grinder/polisher machine. Specimens were ultrasonically cleaned in distilled water for 10 minutes before measurement procedure.

The measurements were performed with a spectrophotometer (PSD1000, OceanOptics, Dunedin, FL, USA), equipped with an integrating sphere (ISP-REF, OceanOptics) with a 10-mm opening. The spectrophotometer was connected to a computer running color measurement software (OOILab 1.0, OceanOptics). D65 illumination and 10° standard observation angle were selected.

Data were recorded in CIEXYZ colorimetric systems. A quantitative measurement of translucency was made by comparing the reflectance of light “Y” in CIEXYZ colorimetric system (ratio of the intensity of reflected radiant flux to that of the incident radiant flux) through the test specimen over a backing with a high reflectance (White backing – Y_w) to that of low reflectance or high absorbance (Black backing – Y_b). For every specimen evaluation over the white and black backings the instrument output recorded ($Y_{b/w}$) was a single value corresponding to the mean of 10 automatic consecutive measurements. Contrast Ratio was calculated with the following equation [22]:

$CR = Y_b/Y_w$.

SEM Evaluation

An extra specimen per group was produced for microscopic ceramic microstructural evaluation.

Zirconia specimens were thermally etched in air in order to show grain boundaries. Thermal etching was performed in sintering furnace, the firing temperature was set 150°C below the sintering temperature and maintained for 20 minutes [23].

A LD specimen was etched for 60 seconds with 4.9% hydrofluoric acid (IPS Ceramic Etching Gel, Ivoclar Vivadent AG, Schaan, Liechtenstein), and cleaned under running water.

Specimens were ultrasonically vibrated in a 95% alcohol solution for 3 minutes (CP104, CEIA, Italy), and air dried with an oil-free stream and then secured to SEM (JSM-6060LV, JEOL, Tokyo, Japan) tabs with gold conducting tape. After gold coating in a vacuum sputter coater (SC7620 Sputter Coater, Polaron Range, Quorum Technologies, Newhaven, UK) samples were submitted to SEM observation. The LD surface was observed at x5000 while the zirconia groups were examined under x35000 magnification for crystal morphology evaluation. Grain size measurement for the three zirconia samples was conducted by the lineal intercept method which involved counting the number of interceptions made by a known-length test line [24] on a digitally calibrated SEM image of the sample surface using Image J software; six lines in different orientations were used for each analyzed image, and average grain size calculated as:

$D = 1.56\ [C/MN]$

Where D was the average grain size, 1.56 was the proportionality constant due to non-spherical grains, C the total length of test line used, N the number of intercepts and M the magnification of the photomicrograph (=1 in this study as the image was already digitally calibrated).

Statistical Analysis

The flexural strength (σ) and Translucency data were statistically analyzed. Two different One Way ANOVA were applied, followed by the Tukey test for post-hoc comparisons, whereas the level of significance was set at $\alpha = 0.05$ for both the analyzed variables CR and σ. Furthermore the Pearson correlation test was applied to analyze a possible correlation between the tested variables.

The recorded mean grain size of the tested zirconia were analyzed. A One Way ANOVA was applied, followed by the Tukey test for post-hoc comparisons, whereas the level of significance was set at $\alpha = 0.05$.

Results

The mean of CR, flexural strength (σ), Weibull characteristic strength (σ^0), Weibull modulus (m), grain size and statistical significances are reported in Table 2.

All the differences between groups were found to be significant for all the tested variables ($p<0,01$). Translucency and flexural strength acted as inversely related variables; this relationship was linear with a correlation co-efficient of 0.89. Materials resulted in the following order from the most opaque and strongest to the most translucent and weakest: ST (σ 1215±190 MPa, CR 0.74±0.01) > EI (σ 983±182 MPa, CR 0.69±0.01) > NT (σ 539±66 MPa, CR 0.65±0.01) > LD (σ 377±39 MPa, CR 0.56±0.02) (Figure 1 and Figure 2). Regarding the Weibull modulus (m), the higher value was obtained by NT (10.1) followed by LD (9.8), ST (7.1) and EI (5.0), Weibull graphs are shown in Figure 3.

The SEM evaluation (Figure 4) of the various zirconia ceramic surfaces highlighted the structural differences between groups. The smallest grains were observed for EI (445±34nm), intermediate grain dimensions were reported for ST (285±11nm) and larger grains were observed on the NT zirconia surface (558±38nm). The average grain sizes for each material were statistically different to each other. The control group LD highlights the differences between polycrystalline ceramics and glass ceramics. After the glass matrix dissolution by acid etching, elongated crystals of lithium disilicate were evident. Elongated crystals were randomly oriented and were interspersed with a little amount of small spherical crystals (Figure 4).

Discussion

Flexural strength and translucency between groups showed statistically significant differences and there was a clear inverse relationship between these variables, therefore the null hypotheses has been rejected.

Flexural strength was not related to mean grain size which is perhaps not surprising given there were also differences compositionally between the samples in terms of stabilizers added. Weibull plots showed distinctive shoulders and S shaped curves which may be indicative of residual stress or different populations of flaws being present in the samples.

Translucency is one of the main parameters in matching the appearance of the natural tooth and was identified as pivotal factor in controlling aesthetics and in a critical consideration for material selection [22].

In the traditional composition of the ST group most of the light passing through the material is intensively scattered and diffusely reflected, leading to an opaque appearance, reaching the limit between a “low translucent” and a “medium translucent” material according to Vichi et al. [8]. Translucency of a material involves directly three parameters: the contrast ratio (CR), transmittance and translucency parameter (TP). CR has been selected in the present study in order to easily compare results with the most recent literature. CR is the ratio of the reflectance of a specimen over a black backing to that over a white backing of a known reflectance, and is an estimate of opacity. CR ranges from 0 to 1, with 0 corresponding to transparency (totally translucent) and 1 corresponding to total opacity (absence of translucency). The mean measured values of CR and flexural strength of ST were similar to that reported for other 3Y-TPZ [25], [26], [27].

The difference in CR between the ST and EI (CR 0.05) and between EI and NT (CR 0.04) even if statistically significant should be considered from a clinical point of view. Differences below 0.07 in CR should be considered not visible by the human eye based on the mean translucency perception threshold (TPT) defined by Liu et al. [28] although the authors recognized that there were significant variations depending upon the observer, e.g. a clinician with 10 years of shade-matching experience could have a TPT of 0.04. Accordingly, even if below the 0.07 mean TPT, the increased translucency of EI compared to ST could be perceived by expert clinicians and technicians and it could accordingly be classified as a “medium translucent” material [8].

It has been reported by Samodurova et al. [29] that the presence of alumina positively influences the nucleation of zirconia and promotes strong grain boundaries. The absence of Al_2O_3 and the small grains generated after dense sintering (Figure 4) of EI could induce an increased ability for the light to pass through the material in contrast to the larger grain sizes seen for ST, which contains Al_2O_3 and may justify the decreased flexural strength obtained by the Al_2O_3-free composition.

The recorded differences for mean flexural strength between EI and ST do not influence the clinical indications of EI according to ISO 6872:2015 (Table 3). Both the ST and EI zirconia compositions fulfill the highest requirements (ISO Class 5) and are accordingly indicated for up to four or more unit FPDs [21].

Further investigations will be necessary to evaluate the long term stability of the tetragonal phase (t-ZrO_2) and the influence of phase stability on mechanical and optical properties. The exposed surface of zirconia is susceptible to a phase change from t-ZrO_2 to monoclinic (m-ZrO_2). This aging phenomenon, called low temperature degradation (LTD), may affect the mechanical properties of the material; the presence of alumina was reported to have a preventative role in in zirconia LTD [16] and [13] and accordingly there may be differences between EI and ST following LTD.

The formulation of NT differed from that of ST or EI with an absence of Al_2O_3 and moreover an increased level of Y_2O_3 from 5% to 9% in weight (corresponding respectively to 3% and 5.5% mole) used as a stabilizer. The increment of yttria induced, during dense sintering, the development of a certain amount of cubic (c-ZrO_2) and tetragonal (t-ZrO_2) zirconia grains (Figure 3).

An increment of yttria as stabilizer from 3% to 8% mole has been associated with an increment of cubic phase in zirconia structure and to an increment in translucency [14]; at this level there is a change in the zirconia from partially stabilized (PSZ) to fully stabilized (FSZ) with several structural implications [12], [17], [30]. The GC Aadva NT, however, with a yttria content of 5.5% mol does not achieve this and should be considered a PSZ even if contains both t-ZrO_2 and c-ZrO_2.

The level of translucency reached by NT was significantly higher if compared to the other two zirconia but moreover significantly lower compared to LD. NT has a positive difference in CR of 0.09 with ST and the same negative difference with LD; both of these differences are above the TPT. Together with EI, NT could be classified as “medium translucent” material. In a monolithic restoration the ceramic material was used for restore part of the dentin and all the enamel lost. Y-TPZ materials reported to be similar to dentin [31]. Their use as monolithic material in aesthetic areas should not to be recommended because they are unable to replace enamel. The reported CR for Enamel and Dentine was about 0.45 and 0.65 respectively [32].

Accordingly, in order to obtain a tooth like appearance, a veneering process for all the tested materials is highly recommended. These findings are in general agreement with several studies involving other “translucent zirconia” that reported a significant lower level of translucency when compared with lithium disilicate [13], [33], [34], [35]. Furthermore unlike the lithium disilicate, the tested zirconia had their natural white colour. It has been widely reported by several authors that the use of coloring liquids or pre-coloured material with an increased chroma had a significant negative influence for CR and light transmittance [35], [36], [37], [38]. Further studies should be performed to clarify the influence of different shades of coloring liquids on the translucency of the tested zirconia materials.

The 3Y-TPZ ST and EI reported similar values in terms of flexural strength compared to other 3Y-TPZ with normal or increased level of translucency [8], [25], [26]. The significant lower strength achieved by NT compared to ST and EI, has been correlated with the presence of c-ZrO_2 crystals. Lower flexural strength has been reported also for other “translucent zirconia” containing cubic phase, such as the FSZs [12]. Due to the higher stability induced by yttria, it has been reported however that the zirconia surface was less susceptible to LTD [15]. These consideration should be evaluated for NT with further investigations.

The clinical indications for NT are limited up to three unit FPDs, corresponding to ISO Class 4 (Table 3). The LD samples with a significant lower mean flexural strength compared to the other tested materials, fulfill the requirements of Class 3 materials; clinical indications are limited up to three unit FPDs not involving molar region [21].

The well known relationship that correlates mechanical properties, translucency and material thickness should be carefully evaluated by clinicians during material selection. Lowering the thickness of the restoration would allow the material to be more translucent [39] but minimal indicated thickness should always be respected in order to avoid the risk of material fracture failure. Precise indications for minimal thickness should be provided by the manufacturer with respect to the wide range of available materials in fixed prosthodontic. The bonding ability of the new translucent zirconia was not yet investigated. The higher grain size and the different compositions could have an role on the surface treatments and on the bonding ability of cements. Even if adhesive cementation was not required for ISO Class3 and 4 materials, the possibility of reduce the ceramic thickness in single restorations and support the restoration by an adhesive resin cementation could enhance the esthetic but nowadays was not yet investigated.

In order to achieve excellent aesthetics, material thickness should not be excessive because increased thickness is related to lower translucency. For this reason, achieving the optimal natural appearance of a human tooth with a monolithic restoration that guarantees adequate mechanical and optical properties, requires further investigation. Zirconia due to its versatility as a bioengineered ceramic could be easily influenced by the use of different dopants and stabilizers, interesting results as been recently reported by Zhang et al. [16] by the experimental introduction of 0.2% mole La_2O_3 in conventional Al_2O_3-doped 3Y-TZP, which resulted in a translucency close to that of lithium disilicate, absence of LTD and excellent mechanical properties. These findings, even if encouraging, need further investigation in order to validate the use of different dopants in dentistry.

Conclusions

Within the limitation of this in-vitro study, the following conclusions could be drawn:

There was an inverse relationship between strength and translucency for the materials tested.

Addition of Al_2O_3 and increasing yttria content strongly influence mechanical and optical properties of Y-TZP ceramics which will affect their clinical indications.

The NT zirconia has a significant higher translucency than the other zirconia materials tested but a lower flexural strength that limits its clinical indication up to three unit FPDs (ISO 6872:2015).

References

[1] JE Alaniz, FG Perez-Gutierrez, G Aguilar, JE Garay, Optical properties of transparent nanocrystalline yttria stabilized zirconia, Opt. Mater. 32 (2009) 62–68.

[2] M Guazzato, M Albakry, SP Ringer, MV Swain, Strength, fracture toughness and microstructure of a selection of all-ceramic materials. Part II. Zirconia-based dental ceramics, Dent. Mater. 20 (2004) 449–456.

[3] J Tinschert, D Zwez, R Marx, KJ Anusavice, Structural reliability of alumina-, feldspar-, leucite-, mica- and zirconia-based ceramics, J. Dent. 28 (2000) 529–535.

[4] T Miyazaki, Y Hotta, J Kunii, S Kuriyama, Y Tamaki, A review of dental CAD/CAM: current status and future perspectives from 20 years of experience, Dent. Mater. J 28 (2009) 44–56.

[5] JR Kelly, I Nishimura, SD Campbell, Ceramics in dentistry: historical roots and current perspectives, J. Prosthet. Dent. 75 (1996) 18–32.

[6] RH Brodbelt, WJ O’Brien, PL Fan, Translucency of dental porcelains. J. Dent. Res. 59 (1980) 70–75.

[7] Q Li, H Yu, YN Wang, Spectrophotometric evaluation of the optical influence of core build-up composites on all-ceramic materials, Dent. Mat. 25 (2009) 158-165.

[8] A Vichi, M Carrabba, R Paravina, M Ferrari, Translucency of materials for CEREC CAD/CAM system, J. Esthet. Restor. Dent. 26 (2014) 224–231.

[9] B Stawarczyk, M Ozcan, L Hallmann, A Ender, A Mehl, CH Hämmerlet, The effect of zirconia sintering temperature on flexural strength, grain size, and contrast ratio, Clin. Oral. Investg. 17 (2013) 269–274.

[10] L Jiang, Y Liao, Q Wan, W Li, Effects of sintering temperature and particle size on the translucency of zirconium dioxide dental ceramic, J. Mater. Sci. Mater. Med. 22 (2011) 2429–2435.

[11] MJ Kim, JS Ahn, JH Kim, HY Kim, WC Kim, Effects of the sintering conditions of dental zirconia ceramics on the grain size and translucency, J. Adv. Prosthodont. 5 (2013) 161–166.

[12] Y Zhang, Making yttria-stabilized tetragonal zirconia translucent, Dent. Mater. 30 (2014) 1195-1203.

[13] K Harada, AJ Raigrodski, KH Chung, BD Flinn, S Dogan, LA Mancl, A comparative evaluation of the translucency of zirconias and lithium disilicate for monolithic restorations, J. Prosthet. Dent. 116 (2016) 257-263.

[14] U Anselmi-Tamburini, JN Woolman, ZA Munir, Transparent Nanometric Cubic and Tetragonal Zirconia Obtained by High-Pressure Pulsed Electric Current Sintering, Adv. Funct. Mater. 17 (2007) 3267–3273.

[15] M Inokoshi, K Vanmeensel, F Zhang, J De Munck, G Eliades, S Minakuchi, I Naert, B Van Meerbeek, J Vleugels, Aging resistance of surface-treated dental zirconia, Dent. Mater. 31 (2015) 182-194.

[16] F Zhang, K Vanmeensel, M Batuk, J Hadermann, M Inokoshi, B Van Meerbeek, I Naert, J Vleugels, Highly-translucent, strong and aging-resistant 3Y-TZP ceramics for dental restoration by grain boundary segregation, Acta. Biomater. 16 (2015) 215-222.

[17] TA Sulaiman, AA Abdulmajeed, TE Donovan, AV Ritter, PK Vallittu, TO Närhi, LV Lassila, Optical properties and light irradiance of monolithic zirconia at variable thicknesses, Dent. Mater. 31 (2015) 1180-1187.

[18] A Ioannidis, A Bindl, Clinical prospective evaluation of zirconia-based three-unit posterior fixed dental prostheses: Up-to ten-year results, J. Dent. 47 (2016) 80-85.

[19] F Huettig, UP Gehrke, Early complications and performance of 327 heat-pressed lithium disilicate crowns up to five years, J. Adv. Prosthodont. 8 (2016) 194-200.

[20] Y Zhang, Z Mai, A Barani, M Bush, B Lawn, Fracture-resistant monolithic dental crowns, Dent. Mater. 32 (2016) 442-449.

[21] International Organization for Standardization. ISO 6872:2015—dentistry—ceramic materials. 2015.

[22] Y Miyagawa, JM Powers, WJ O'Brien, Optical properties of direct restorative materials, J. Dent. Res. 60 (1981) 890–894.

[23] U Täffner, V Carle, U Schäfer, MJ Hoffmann, Preparation and Microstructural Analysis of High-Performance Ceramics, Metallography and Microstructures 9 (2004) 1057 – 1066.

[24] MI Mendelson, Average Grain Size in Polycrystalline Ceramics. J. Amer. Ceram. SOC. 52 (1969) 443-446.

[25] M Sedda, A Vichi, F Del Siena, C Louca, M Ferrari, Flexural resistance of Cerec CAD/CAM system ceramic blocks. Part 2: outsourcing materials, Am. J. Dent. 27 (2014) 17–22.

[26] A Vichi, M Sedda, R Fabian Fonzar, M Carrabba, M Ferrari, Comparison of Contrast Ratio, Translucency Parameter, and Flexural Strength of Traditional and "Augmented Translucency" Zirconia for CEREC CAD/CAM System, J. Esthet. Restor. Dent. 28 (2016) S32-39.

[27] MJ Heffernan, SA Aquilino, AM Diaz-Arnold, DR Haselton, CM Stanford, MA Vargas, Relative translucency of six all-ceramic systems. Part I:core materials, J. Prosthet. Dent. 88 (2002) 4–9.

[28] MC Liu, SA Aquilino, PS Lund, MA Vargas, AM Diaz-Arnold, DG Gratton, F Qian, Human perception of dental porcelain translucency correlated to spectrophotometric measurements, J. Prosthodont. 19 (2010) 187-193.

[29] A Samodurova, A Kocjan, MV Swain, T Kosmač, The combined effect of alumina and silica co-doping on the ageing resistance of 3Y-TZP bioceramics, Acta Biomater. 11 (2015) 477-487.

[30] TA Sulaiman, AA Abdulmajeed, TE Donovan, PK Vallittu, TO Närhi, LV Lassila, The effect of staining and vacuum sintering on optical and mechanical properties of partially and fully stabilized monolithic zirconia, Dent. Mater. J. 34 (2015) 605-610.

[31] OE Pecho, R Ghinea, AM Ionescu, Jde L Cardona, RD Paravina, Mdel M Pérez, Color and translucency of zirconia ceramics, human dentine and bovine dentine, J. Dent. 40 Suppl 2 (2012) e34-40.

[32] D Dietschi, S Ardu, I Krejci, A new shading concept based on natural tooth color applied to direct composite restorations, Quintessence Int. 37 (2006) 91-102.

[33] P Baldissara, A Llukacej, L Ciocca, FL Valandro, R Scotti, Translucency of zirconia copings made with different CAD/CAM systems, J. Prosthet. Dent. 104 (2010) 6-12.

[34] HH Harianawala, MG Kheur, SK Apte, BB Kale, TS Sethi, SM Kheur, Comparative analysis of transmittance for different types of commercially available zirconia and lithium disilicate materials, J. Adv. Prosthodont. 6 (2014) 456-461.

[35] S Kurtulmus-Yilmaz, M Ulusoy, Comparison of the translucency of shaded zirconia all-ceramic systems, J. Adv. Prosthodont. 6 (2014) 415-422.

[36] PE Spyropoulou, EC Giroux, ME Razzoog, RE Duff, Translucency of shaded zirconia core material, J. Prosthet. Dent. 105 (2011) 304-307.

[37] I Tuncel, E Eroglu, T Sari, A Usumez, The effect of coloring liquids on the translucency of zirconia framework, J. Adv. Prosthodont. 5 (2013) 448-451.

[38] HK Kim, SH Kim, Effect of the number of coloring liquid applications on the optical properties of monolithic zirconia, Dent. Mater. 30 (2014) e229-237.

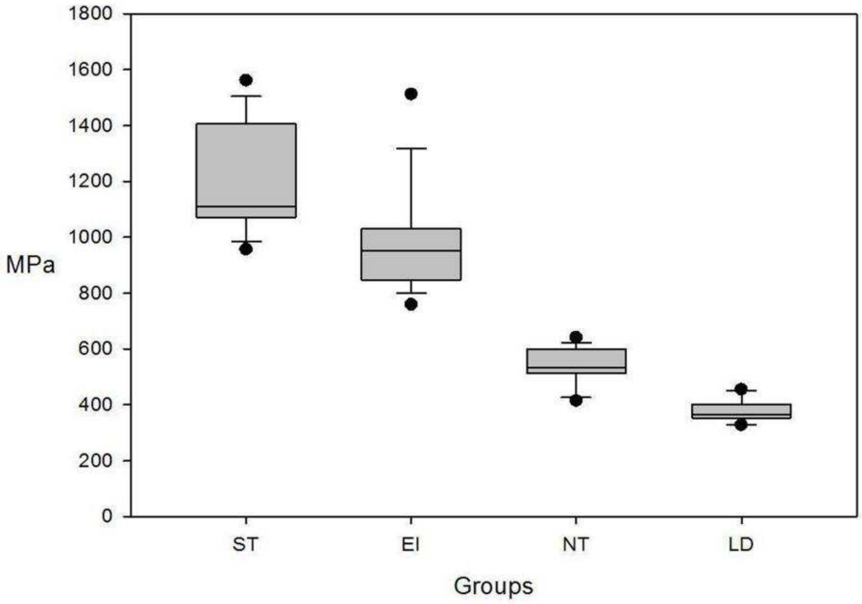
[39] ID Jeong, SY Bae, DY Kim, JH Kim, WC Kim, Translucency of zirconia-based pressable ceramics with different core and veneer thicknesses, J. Prosthet. Dent. 115 (2016) 768-772.

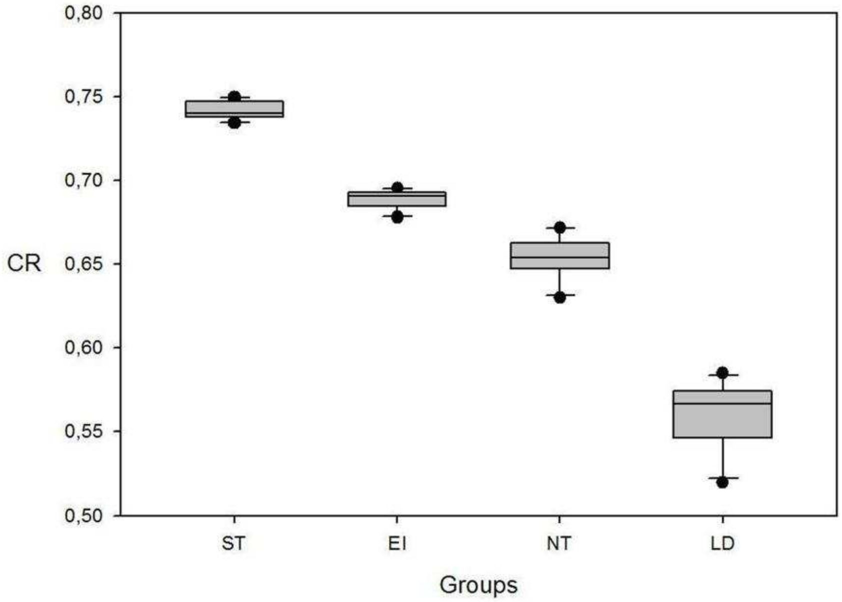
Figure 1: Box Plot for Flexural Strength data.

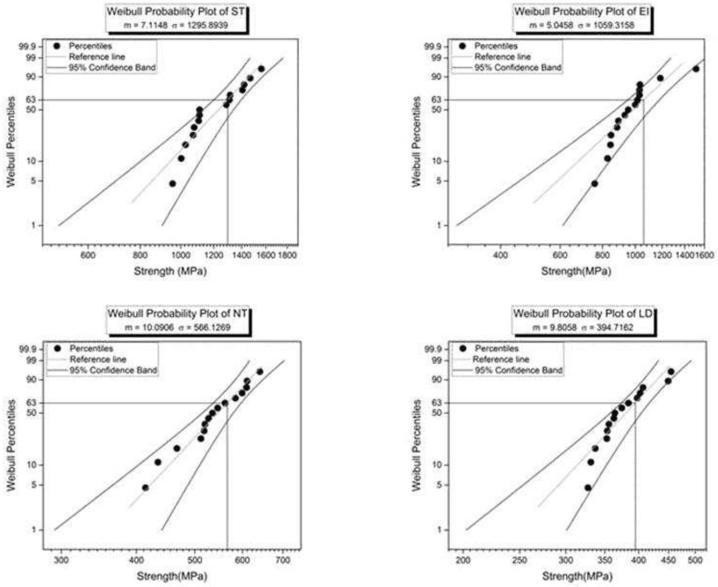
Figure 2: Box Plot for Translucency data.

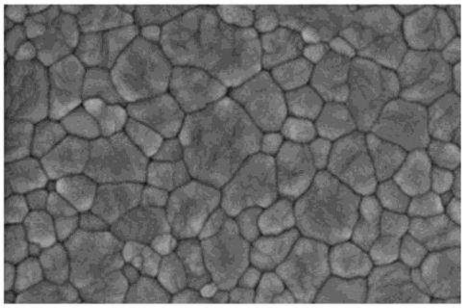
Figure 3: Weibull distributions for each of the groups.

Figure 4: SEM evaluation of ceramic structure.

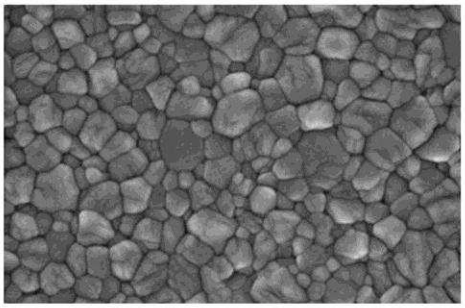



CR
0,80
0,75
0,70
0,65
0,60
0,55
0,50
ST
EI
NT
LD
Groups

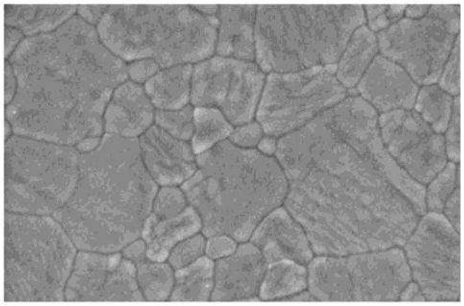

Weibull Probability Plot of ST
m = 7.1148 σ = 1295.8939
Weibull Probability Plot of EI
m = 5.0458 σ = 1059.3158
Weibull Probability Plot of NT
m = 10.0906 σ = 566.1269
Weibull Probability Plot of LD
m = 9.8058 σ = 394.7162
Percentiles
Reference line
95% Confidence Band
Weibull Percentiles
99.9
99
90
63
50
10
5
1
600
800
1000
1200
1400
1600
1800
Strength (MPa)
400
600
800
1000
1200
1400
1600
Strength(MPa)
300
400
500
600
700
Strength(MPa)
200
250
300
350
400
450
500
Strength(MPa)



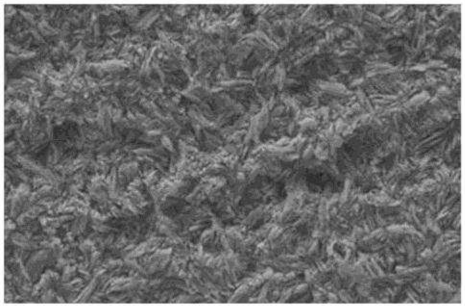
Aadva ST x35000



Aadva EI x35000



Aadva NT x35000



IPS e.max CAD LT x5000

Table 1: Composition of tested Aadva Zirconia Disks.

Components	**ST**	**EI**	**NT**
ZrO_2 wt%	94.8	95	91
Y_2O_3 (wt%) [mole]	(5) [3%]	(5) [3%]	(9) [5.5%]
Al_2O_3 wt%	0.2	trace	trace
Crystal structures	Tetragonal	Tetragonal	Tetragonal & Cubic

Table 2: Results and statistical significance, different letters indicate different statistical significance.

Translucency - CR			Flexural Strength - 3PBT				Grain Size	
Groups	Mean	SD	Mean σ (MPa)	SD	m	σ^0 (MPa)	Mean (nm)	SD
Aadva ST	0.74^d	0.01	1215^a	190	7.1	1296	445^b	34
Aadva EI	0.69^c	0.01	983^b	182	5.0	1059	284^c	11
Aadva NT	0.65^b	0.01	539^c	66	10.1	566	558^a	38
IPS e.max LT	0.56^a	0.02	377^d	39	9.8	395		

Table 3: Clinical recommendation proposed by ISO 6872:2015 for dental ceramics.

Class Recommended clinical indications Flexural strength minimum (mean) MPa		
1	(a) Ceramic for coverage of a metal framework or a ceramic substructure. (b) Monolithic ceramic for single-unit anterior prostheses, veneers, inlays, or onlays.	50
2	(a) Monolithic ceramic for single-unit, anterior or posterior prostheses adhesively cemented (b)Partially or full covered substructure ceramic for single-unit anterior or posterior prostheses adhesively cemented.	100
3	(a) Monolithic ceramic for single-unit anterior or posterior prostheses and three-unit prostheses not involving molar restoration adhesively or non-adhesively cemented (b) Partialy or fully covered substructure for single-unit anterior or posterior prostheses and for three-unit prostheses not involving molar restoration adhesively or non-adhesively cemented	300
4	(a) Monolithic ceramic for three-unit prostheses involving molar restoration. (b) Partially of fully covered substructure for three-unit prostheses involving molar restoration.	500
5	Monolithic ceramic for prostheses involving partially or fully covered substructure for four or more units or fully covered substructure for prostheses involving four or more units.	800