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# Translucent zirconia in the ceramic scenario for monolithic restorations: A flexural strength and translucency comparison test

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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 1.2 × 4.0 × 15.0 mm and 15.0 × 15.0 × 1.0 mm 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 ($\sigma$ in MPa), Weibull modulus (m) and Weibull characteristic strength ($\sigma^0$ 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($\sigma$ 1215 ± 190 MPa, CR 0.74 ± 0.01) > EI($\sigma$ 983 ± 182 MPa, CR 0.69 ± 0.01) > NT($\sigma$ 539 ± 66 MPa, CR 0.65 ± 0.01) > LD ($\sigma$ 377 ± 39 Mpa, CR 0.56 ± 0.02). The average grain size was different for the three zirconia samples with NT (558 ± 38 nm) > ST(445 ± 34 nm) > EI(284 ± 11 nm).
*Conclusions:* The zirconia composition heavily influenced both the flexural strength and the translucency. Different percentages of Yttria 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.



## 1. Introduction

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

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 [9–11], density [11], and crystal structure [12–14].

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

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[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 [14–17].

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 ($\sigma$), Weibull modulus (m) and Weibull characteristic strength ($\sigma^0$) 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.

## 2. Materials and methods

CAD/CAM pre-sintered disks of zirconia (98,5 × 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 min, before increasing very slowly to 1500 °C over 4.5 h, 2 h 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® 6000 M, Vita Zahnfabrik, Bad Säckingen, Germany) following the manufacturer's instructions.

**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 |

### 2.1. 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 1200 and 2400 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 min before measurement procedure.

Tests were performed in a universal testing machine (Triax 50, Controls, Milano, Italy) with a cross-head speed of 1 mm/min 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 ($\sigma$) was calculated in MPa by using the following equation:

$$\sigma = Pl/2wb^2$$

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 ($\sigma^0$) and the Weibull modulus ($m$) were calculated according to the following equation:

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

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

### 2.2. 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 1200 grit paper in a grinder/polisher machine. Specimens were ultrasonically cleaned in distilled water for 10 min 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]:

$$CR = Y_b/Y_w.$$

### 2.3. 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 min [23].