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Mechanical Behavior of Ceramic Monolithic Systems With Different Thicknesses

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Clinical Relevance

Highly translucent fully stabilized zirconia can be less fracture resistant than lithium disilicate and partially stabilized zirconia depending on the thickness.

SUMMARY

Objectives: This study assessed the fully stabilized zirconia (FSZ) Prettau Anterior, the partially stabilized zirconia (PSZ) Prettau, and the lithium disilicate IPS e.max CAD (LD) through microstructural and mechanical characterization and effect of thickness on fracture load of the ceramics.

Methods and Materials: Disk-shaped specimens (12 mm diameter and 1.2 mm thickness) were prepared for biaxial flexural strength (BFS) and Weibull statistics (n=30). For the fracture load static test (FLST) and Weibull statistics (n=30), disk-shaped specimens 12 mm in diameter and thicknesses of 0.5 mm, 1 mm, and 1.5 mm were cemented on an epoxy-resin substrate.

Results: BFS (MPa) results were PSZ: 683.0 ± 70.23; FSZ: 438.6 ± 64.1; and LD: 248.6 ± 37.3. One-way analysis of variance (ANOVA) for BFS was significant ($p<0.001$), and the Tukey post hoc test showed differences among all ceramics. There was difference in characteristic strength, but there was no difference in Weibull modulus. Two-way ANOVA for FLST was significant for ceramic ($p<0001$), thickness ($p<0001$), and interaction ($p<0001$). There was no difference among all ceramics at the 0.5 mm thickness. PSZ had higher values for the 1.0 mm and 1.5 mm thicknesses. LD of 1.5 mm thickness exhibited a higher FLST than FSZ.

Conclusions: PSZ had the highest BFS, but when cemented on a substrate, all ceramics

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with 0.5 mm thickness behaved similarly. Despite the lower BFS, LD had a fracture load similar or superior to FSZ when cemented on a substrate.

INTRODUCTION

Veneer chipping is the most common cause of failure in all-ceramic restorations.[1-9] This failure occurs mainly because of residual tension developed during cooling in firing schedules due to differences in thermal properties between substructure ceramics and porcelain veneers.[3,8,10,11]

Monolithic materials were developed to avoid the use of veneer porcelain in all-ceramic restorations. Among these materials, lithium disilicate ceramics are the most popular because of their high translucency, strength,[12] and relative simplicity of the technique[13]; they also have a survival rate up to 100% in two-year clinical usage for single crowns.[14] However, the survival rate of fixed partial dentures does not exceed 84% after two-years of clinical use, and the rate is 78.1% after a five-year clinical follow-up.[14] An alternative is monolithic zirconia with higher translucency and color techniques, aiming to associate high strength with better optical properties.[15,16]

The high opacity of conventional zirconia is due to light-scattering factors (alumina used as a sintering additive, oxygen vacancies, porosity, grain size),[17-19] as well as the intrinsic characteristics of tetragonal zirconia crystals, which are optically anisotropic, where refraction occurs in different crystallographic directions. Conventional yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) grains have sizes in the range of 0.2 to 0.8 μm, and because translucency is dependent on the number of grain boundaries, Y-TZPs with a smaller grain size have more grain boundaries and, thus, tend to have lower translucency because light refracts at each intersecting grain boundary. Larger tetragonal grains have fewer grain boundary areas; however, these are more susceptible to low temperature degradation.[20] One approach to reduce the birefringence is to use specific tetragonal grain sizes[21] only slightly larger than conventional ones, and with reduced alumina concentrations. An opposite approach to obtain translucent Y-TZP is by using nano-scale grain size (<100 nm) because once they are smaller than the wavelength range of visible light (400-700 nm), it is possible to achieve almost transparent ceramics.[21]

Another strategy to increase the translucency of monolithic zirconia is the development of fully stabilized zirconia (FSZ), acclaimed as the most translucent zirconia. While the partially stabilized zirconia (PSZ) tetragonal phase is stabilized with 2-5 mol% yttria content, in FSZ, yttria is present in concentrations >8 mol%.[22,23] The higher availability of yttria leads to increased cubic phase concentration.[22] Cubic grains have isotropic optical refraction, and they are larger than tetragonal crystals (ie, fewer grain boundary interceptions).

Monolithic systems allow minimally invasive tooth preparation compared with preparations for restorations with porcelain veneering.[24,25] This reduces the pulp damage risk[24,26] and allows for tooth preparation with higher axial height.[27] Usually, it is recommended that a tooth be reduced by 1.5 mm at the occlusal area for a lithium disilicate restoration, but there is uncertainty around how much smaller the occlusal reduction could be for a stronger ceramic, such as monolithic zirconia, and if a thinner zirconia restoration could be stronger and as translucent as a thicker lithium disilicate restoration.[24,26,28-31] It has been shown that monolithic Y-TZP crowns with 1 mm thickness possess strength similar to 1.5 mm thick porcelain fused to metal crowns.[26] Another study found that monolithic zirconia crowns of 0.6 mm thickness had a fracture load similar to lithium disilicate crowns, which were 1.5 mm thick.[32] Some studies using PSZ indicate that a thickness of 0.5 mm at the occlusal face in monolithic zirconia is enough to resist fracture in the molar region.[24,26,27,31,33] However, FSZ is different from PSZ because translucency is obtained by changes in composition and microstructure that may impair mechanical properties.[34]

The clinical success of ceramics is dependent on mechanical resistance.[35] According to the ISO 6872:2015,[36] flexural strength is the selected testing for mechanical evaluation, which is mainly indicated for materials with brittle behavior, typical of ceramics. Nevertheless, mechanical testing for ceramics results in a wide range of tension values because of the effect of internal defects, as pores and inclusions.[37] The material is more reliable when the stress values are less dispersed.[37] A way to evaluate the reliability is to calculate the Weibull modulus and characteristic resistance.[37]

In addition, it is important to understand how those ceramic materials behave in a functional simulation. An all-ceramic restoration is bonded to a dental substrate, and the mechanical performance can be modulated by the material's modulus of elasticity, cement properties, adhesion to the substrate, and restoration thickness.[38]

The esthetic and mechanical behavior of lithium disilicate, and mechanical properties of translucent PSZ are relatively well understood.[12,39,40] However, considering that FSZ is more translucent than PSZ, but presumably less resistant,[34] this study aims to characterize the mechanical properties and microstructure of a lithium disilicate, a translucent PSZ, and a highly translucent FSZ, as well as the fracture load of different ceramic thicknesses bonded to an epoxy-resin substrate. The null hypothesis was that there is no statistical difference between the materials in relation to biaxial flexural strength (BFS) and fracture load of bonded specimens in different thicknesses.

METHODS AND MATERIALS

Three monolithic ceramics were investigated: 1) PSZ Prettau (Zirkonzahn GmbH, Bruneck, Italy), 2) FSZ Prettau Anterior (Zirkonzahn GmbH), and 3) lithium disilicate IPS e.max CAD (Ivoclar Vivadent, Schaan, Liechtenstein).

BFS Testing, Weibull Analysis, and Scanning Electron Microscopy

Zirconia disks (PSZ and FSZ) were milled 20% larger than the final dimensions required for BFS testing according to ISO 6872:2015.[36] Specimens were smoothed with silicon carbide grinding paper 1200, 2400, and 4000 (Struers LaboPol 21, Struers, Rodovre, Denmark),[41] ultrasonically cleaned in distilled water for 15 minutes, and dried for 2 hours at 37 °C. Sintering was conducted according to the manufacturer's instructions, and final specimens were 12 mm in diameter and 1.2 mm thick.

Lithium disilicate IPS e.max CAD LT (Low Translucency) A2 samples were prepared in a manner similar to zirconia specimens, but they were cut in the final dimensions (12 mm diameter and 1.2 mm thickness), as there is no change in dimensions after sintering according to the manufacturer's instructions.[39]

BFS testing (piston on three balls) was carried out according to ISO 6872:2015[36] for dental ceramics, performed in a universal testing machine (MTS 810 – MTS System Corporation, Eden Prairie, MN, USA) at a crosshead speed of 1.0 mm/min until failure. The specimens (n=30) were placed concentrically on three hardened steel balls with 2.5 mm diameter, and positioned 120° apart on a support circle with a diameter of 10 mm. The load was applied with a flat punch with a diameter of 1.4 mm at the center of the specimen. The load to failure was registered in N and then calculated in MPa according to the following equation (ISO 6872:2015)[36]:

$$S = -0.2387\frac{P(X-Y)}{d^2}$$

where S represents the maximum tensile stress in MPa, P is the total load to fracture in Newtons, and d is the specimen thickness (mm). The X and Y values were obtained as follows:

$$X = (1+\upsilon)In\left(\frac{r_2}{r_3}\right)^2 + \left[\left(\frac{1-\upsilon}{2}\right)\right]\left(\frac{r_2}{r_3}\right)^2$$

$$Y = (1+\upsilon)\left[1 + In\left(\frac{r_2}{r_3}\right)^2\right] + (1-\upsilon)\left(\frac{r_1}{r_3}\right)^2$$

where v is the Poisson ratio (= 0.23), r_1 is the radius of the support circle, r_2 is the radius of the loaded area, and r_3 is the radius of the specimen (all radii expressed in millimeters).

Weibull regression analysis was performed based on the flexural strength data to determine the Weibull modulus and characteristic strength. The Weibull distributions were calculated according to the following equation:

$$P = 1 - \exp\left[\left(-\frac{\sigma}{\sigma_0}\right)^m\right]$$

where P is the probability of fracture, σ is the flexural strength, σ_0 is the characteristic strength at a fracture probability of 63.21%, and m is the Weibull modulus, which is the slope of the line plotted on the "ln(ln [1/(1-P)]) vs ln σ" Cartesian plane.

$$In\left(\frac{1}{1-P}\right) = mIn\sigma - mIn\sigma_0$$

The correction factor was used to adjust the sample size following the DIN 51 110 standard.

Surface analyses were performed by scanning electron microscopy (SEM; JMS-T33A Scanning Microscope, JEOL USA Incorporation, Peabody, MA, USA) on three representative samples for each material and treatment. The specimens of lithium disilicate were etched with 10% hydrofluoric acid for 60 seconds. The zirconia specimens were heated to 1400°C for 30 minutes to reveal the microstructure.[42] The following parameters were used: low

Table 1: *Biaxial Flexural Strength (MPa), Characteristic Strength and Weibull Modulus With a Confidence Interval of 95% for the Materials*[a]

Material	BFS	Characteristic Strength	Confidence Intervals	Weibull Modulus	Confidence Intervals
PSZ Prettau	683.0 ± 70.23 A	700.31 A	678.79-721.90	13.30 A	9.75-17.91
FSZ - Prettau Anterior	438.6 ± 64.1 B	461.27 B	438.61-484.43	8.24 A	6.04-11.10
IPS e.max CAD	248.6 ± 37.3 C	257.21 C	245.53-269.10	8.94 A	6.55-12.04

[a] *Within the same column, the same letters correspond to statistical similarity. Different letters correspond to statistical difference.*

gentle-beam mode, 2 kV of acceleration voltage, and a gold-sputtered conductive layer.

Fracture Load of Bonded Specimens

Disks of the ceramics (n=30) were obtained as described before, but in different thicknesses (0.5 mm, 1.0 mm, and 1.5 mm). The substrate disks (12 mm diameter × 3 mm) were prepared with Epoxy-resin G10 (Epoxyglas; NEMA Grade FR4, Accurate Plastics Inc, New York, NY, USA), which was selected because it has an elastic modulus similar to that of human dentin.[43]

The zirconia specimens were airborne particle abraded with 100 μm Al_2O_3 for 15 seconds with an air-abrasion unit Basic Classic (Renfert GmbH, Hilzingen, Baden-Württemberg, Germany) at 0.2 MPa air pressure at a distance of 10 mm from the surface of the specimen at 90° to the abrasion tip. The zirconia and epoxy-resin disks were ultrasonically cleaned in isopropyl alcohol for 5 minutes, followed by 5 minutes in distilled water, and dried with oil-free air, before cementation with RelyX Ultimate Adhesive Resin Cement (3M ESPE, St Paul, MN, USA).

The lithium disilicate specimens were prepared by 10% hydrofluoric acid etching for 20 seconds. Single Bond Universal (3M ESPE) was applied for 20 seconds on lithium disilicate, PSZ, FSZ, and epoxy-resin surfaces. The cement was prepared and applied on the epoxy-resin surface, on which the ceramic disk was subjected to a load of 10 N for 10 minutes.[26] The photoactivation was performed with a light-emitting diode device (Radii Cal; SDI Brasil Industria e Comércio LTDA, São Paulo, Brazil) for 20 seconds at three different sites around the specimen. After 6 minutes, the specimens were stored in distilled water at 37°C for 24 hours.[26]

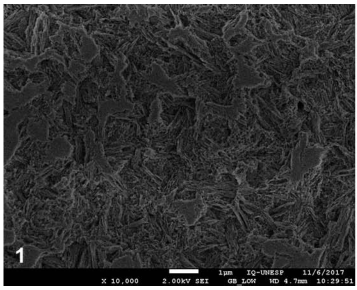
The fracture load testing was performed in an MTS 810 universal testing machine. The load was applied by a stainless steel flat punch with a diameter of 1.4 mm at the center of the specimens with the ceramic on the top surface, and the fracture load was recorded in Newtons. Weibull statistics were applied as described for BFS.

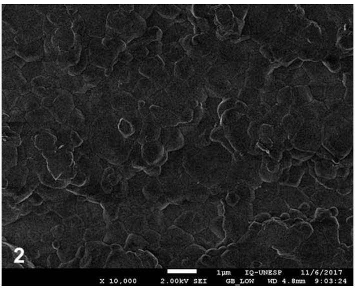
RESULTS

BFS and Weibull Analysis

Table 1 presents values of the BFS, characteristic strength and confidence intervals, and Weibull modulus (m) and confidence intervals. The one-way analysis of variance (ANOVA) ($F_{2,87}$ =410.807, $p<0.001$) was statistically significant, and the Tukey post hoc test showed significant differences among all ceramics. There was a difference among the ceramics in characteristic strength, but there was no difference in the Weibull modulus.

Figure 1 shows the SEM image for lithium disilicate, with its typical needle-like crystal structure. FSZ (Figure 2) showed remarkably larger grains than PSZ (Figure 3).





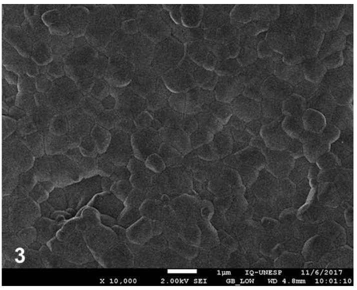


Figure 1. *SEM image at 10,000× magnification of lithium disilicate IPS e.max CAD.*
Figure 2. *SEM image at 10,000× magnification of polycrystalline FSZ Prettau Anterior.*
Figure 3. *SEM image at 10,000× magnification of polycrystalline PSZ Prettau.*

Table 2: *Two-way ANOVA Analysis*

Source	Sum of Squares	df	Mean Square	F	*p* Value
Ceramic	16179006.75	2	8089503.377	54.296	<0.001
Thickness	52160115.90	2	26080057.95	175.048	<0.001
Interaction ceramic thickness	12541238.24	4	3135309.560	21.044	<0.001
Error	38885943.55	261	148988.289		
Total	2068066896	270			
Corrected total	119766304.4	269			

Abbreviations: ANOVA, analysis of variance; df, degrees of freedom.

Fracture Load and Weibull Analysis of Bonded Specimens

Two-way ANOVA (Table 2) was significant for ceramic type ($p<0.001$), ceramic thickness ($p<0.001$), and interaction between variables ($p<0.001$). Table 3 shows the mean values, standard deviations, and Tukey post hoc comparison. PSZ Prettau had a higher fracture load except with the 0.5 mm thickness, where there was no difference among all ceramics. There was no significant difference between lithium disilicate and FSZ Prettau Anterior ceramic with 0.5 mm and 1.0 mm thicknesses, but at 1.5 mm, lithium disilicate had a higher fracture load.

Weibull analysis results are shown in Table 4. Weibull plots are presented in Figures 4 through 6. The characteristic strength was proportional to the ceramic thickness. For the 0.5 mm thickness, lithium disilicate had a higher value than FSZ. PSZ at 1 mm thickness was more resistant than the other ceramics with the same thickness. There was no significant difference among ceramics with 1.5 mm thickness. Regarding the Weibull modulus, there was no significant difference among all ceramics with the different thicknesses, except that PSZ 0.5 showed the lowest value.

DISCUSSION

The null hypothesis was rejected once significant differences in the BFS among all the materials were established. The two studied zirconia ceramics are different materials. FSZ - Prettau Anterior has higher content of yttria (8% to 12% mol)[23] which makes it fully stabilized in the tetragonal phase, arising from cubic grains, which improves translucency. PSZ - Prettau has 4–6 mol% of yttria,[23] and hence, it is partially stabilized in the tetragonal phase and is capable of undergoing tetragonal to monoclinic phase transformation toughening.[9] Thus, PSZ is more resistant than FSZ because the cubic phase is not prone to the phase transformation toughening phenomenon.[22,23,34] Regarding the lithium disilicate ceramic, lower values were expected due to the glass-ceramic characteristics. Zirconia has a polycrystalline structure, which provides higher strength than vitreous ceramics such as lithium disilicate (Figures 1 through 3). The Weibull modulus (m) is used as a statistical parameter to assess structural reliability, and high "m" values correspond to high levels of integrity and structural reliability.[37] In the present study, there was no difference among the Weibull moduli of the ceramics in BFS.

Table 3: *Mean Fracture Strength Values (MPa) for Ceramics With Different Thicknesses Cemented on an Epoxy Substrate* [a]

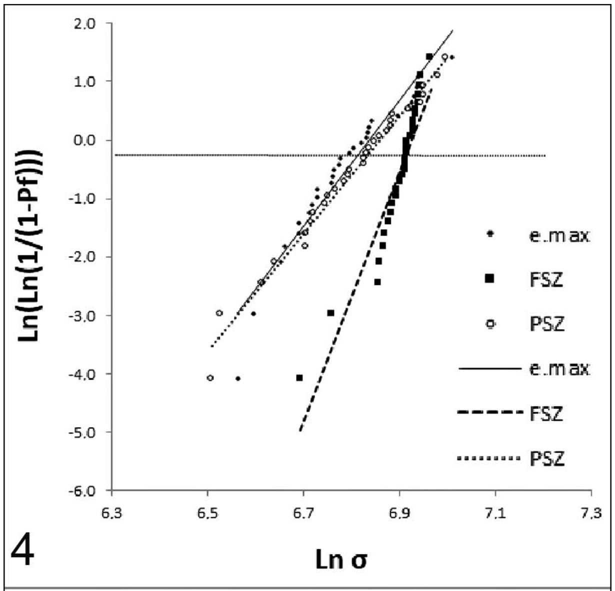
Thickness, mm	e.max	Prettau Anterior	Prettau
0.5	2271 ± 241^{Aa}	2070 ± 275^{Aa}	2181 ± 457^{Aa}
1.0	2617 ± 346^{Ba}	2432 ± 394^{Ba}	2863 ± 315 ^{Bb}
1.5	3022 ± 400^{Cb}	2741 ± 446^{Ca}	3979 ± 515^{Cc}

[a] *Different superscript uppercase letters in columns, and lowercase letters in rows indicate significant difference (p$<$0.05, Tukey test, n=30).*

Although BFS is an appropriate test to assess the long-term clinical performance of ceramics,[9,23] it is also important to evaluate the fracture resistance of ceramics bonded on a substrate, as mechanical behavior can be modulated by the modulus of elasticity, cement properties, adhesion to the substrate, and restoration thickness.[38]

In this study, bonded specimens for fracture load were made using the G10 epoxy resin to simulate a dentin substrate, based on the study of Kelly and others,[43] who found no differences in the modulus of elasticity of the G10 epoxy-resin (E=18.6 GPa) and dentin (E=18 GPa), as well as other studies that used this epoxy resin as a substitute for dentin in mechanical tests.[27,44-48]

Minimal thickness of a ceramic restoration is important to preserve dental tissues[24-26] and to allow higher height in the axial wall for short tooth



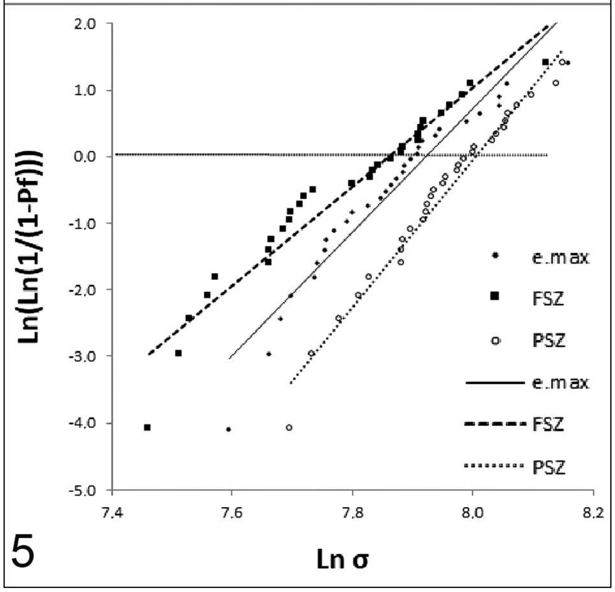


Figure 4. *Weibull plots for ceramics in 0.5 mm thickness.*
Figure 5. *Weibull plots for ceramics in 1 mm thickness.*

preparation.[27] Recent studies have discussed the influence of thicknesses on the mechanical strength of ceramic crowns.[24,26-33] Reduction in occlusal thickness decreased the fracture strength,[27,49] but it is important to determine how thin the restoration can be to maintain clinical effectiveness. Although some studies showed appropriate results at 0.5 mm for translucent monolithic zirconia in molar regions,[24,26,27,31,33] these studies were conducted with PSZ, which is believed to be stronger. The authors were not able to find studies regarding FSZ.

The null hypothesis for the fracture load of bonded specimens test was also rejected. It was demonstrated that the resistance of the bonded ceramic was not necessarily related directly to the ceramic strength, as there is no difference in the fracture load for the 0.5-mm-thick ceramic bonded to the epoxy-resin substrate, irrespective of the studied ceramic. Furthermore, lithium disilicate showed fracture loads equivalent or even superior to FSZ for selected thicknesses. Weibull analysis showed that a 0.5-mm-thick ceramic tends to decrease the Weibull modulus, especially for PSZ. Moreover, when esthetics are important, FSZ should not be employed instead of lithium disilicate.

The positive behavior of lithium disilicate, despite its lower BFS, may be related to the more effective adhesion to the substrate.[50] A resin luting agent can promote a bridging effect on the interfacial surface defects by the effect of volumetric shrinkage of composite resin that causes a tension stress on the cement layer and a compressive stress at the ceramic, thereby strengthening the material and increasing the fracture strength.[51] Lithium disilicate can be etched with 10% hydrofluoric acid to improve surface roughness and wettability, in contrast to zirconia, which is acid-resistant[52] and has lower adhesion compared with vitreous ceramics. Considering the lower incidences of debonding in the fracture load test in comparison mainly with PSZ, it can be concluded that lithium disilicate has apparently benefited from cementation. A recent study showed that the fracture load of lithium disilicate crowns was directly related to the resin cement properties, whereas a PSZ (Vita YZ T) crown was not affected by the resin and cement; FSZ was not studied.[53]

The manufacturer of Prettau and Prettau Anterior (Zirkonzahn) indicates a general procedure for cementation but does not recommend any specific adhesive system or cement. However, the manufacturer stresses that the adhesive system and cement instructions must be followed. In this investigation researchers selected the RelyX Ultimate resin adhesive cement that is indicated for zirconia and lithium disilicate ceramics. The cement procedures were followed according to the manufacturer's instructions (3M ESPE), which indicate different pretreatments for zirconia and lithium disilicate. The recommended primer/adhesive, Single Bond Universal, creates a phosphate monomer-based (10-MDP) bond that is capable of bonding to metallic oxides as zirconium oxide.[54,55] This monomer is present in most zirconia primers,[56,57] and its application over an airborne particle-abraded zirconia surface has led to effective adhesion.[54,58] In

Table 4: *Weibull Modulus and Characteristic Strength With a Confidence Interval of 95% for the Materials*[a]

Material, mm	Characteristic Strength, N	Confidence Intervals	Weibull Modulus, m	Confidence Intervals
LD 0.5	2449.42 C	2333.30-2567.88	8.55 A,B	6.27-11.51
LD 1.0	2675.51 B	2578.55-2773.29	11.25 A	8.25-15.15
LD 1.5	2893.98 A	2790.08-2998.72	11.36 A	8.33-15.29
FSZ 0.5	2134.43 D	2050.04-2219.82	10.29 A	7.55-13.86
FSZ 1.0	2558.14 B,C	2422.74-2697.06	7.64 A	5.60-10.28
FSZ 1.5	2781.43 A,B	2673.57-2890.48	10.50 A	7.70-14.14
PSZ 0.5	2341.67 C,D	2173.76-2517.37	5.58 B	4.09-7.51
PSZ 1.0	2956.26 A	2853.19-3060.06	11.70 A	8.58-15.76
PSZ 1.5	2781.43 A,B	2675.57-2890.48	10.50 A	7.70-14.14

Abbreviations: LD, lithium disilicate; FSZ, fully stabilized zirconia; PSZ, partially stabilized zirconia.

[a] Within the same column, the same letters correspond to statistical similarity. Different letters correspond to statistical difference.

addition to 10-MDP monomer, Single Bond Universal has silane, which is important for adhesion to the lithium disilicate glass ceramic.

An issue to be considered is the dependence of the self-cure mechanism on the amount of blue light passing through the ceramics in dual-cure luting cement polymerization.[59] Thickness and translucency of the ceramic layer, curing light unit intensity, and exposure time affect dual-cure cement polymerization. Considering that zirconia ceramics are less translucent than glass ceramic, lower transmitted irradiance in zirconia is expected compared with lithium disilicate. Moreover, differences among optical properties of monolithic zirconia should be considered. Sulaiman and others[41] studied the light irradiance of monolithic zirconia ceramics at variable thicknesses and observed that the FSZ Prettau Anterior allowed significantly higher values of light irradiance than the PSZ Prettau, but the energy transmitted through ceramics decreased as the layer thickness increased, irrespective of ceramic brand.

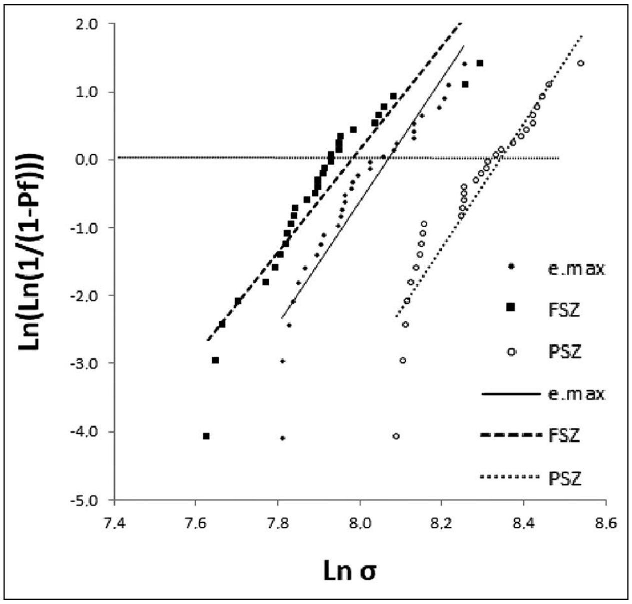


Figure 6. *Weibull plots for ceramics in 1.5 mm thickness.*

Another issue is that accelerated artificial aging was not evaluated in this study. The effect of aging in different properties of PSZ ceramics has been studied by several authors who discussed methods and mechanisms of aging and showed that tetragonal to monoclinic transformation can be induced by steam autoclave to produce hydrothermal degradation, which is believed to be similar to the low temperature degradation. The effect of hydrothermal degradation depends on the zirconia ceramic composition, grain size, stress conditions, and primarily on the steam autoclave temperature and running time. Mechanical properties decreasing on PSZ is evident only in more severe protocols. However, the correlation of artificial aging methods and its effective correspondence with clinical performance of zirconia is controversial.[60] Moreover, FSZ is not affected by artificial aging once supersaturation by yttria increases the amount of cubic phase and provides more stability to the tetragonal phase.[34,61]

It is important to highlight limitations of this *in vitro* study. The fracture load test was performed in simple geometry specimens with a short-term storage and limited to a particular luting system. Even at 0.5 mm thickness, irrespective of the ceramic material, the fracture loads were higher than 1000 N, which is higher than those required to ensure proper clinical performance.[62] Moreover, the shape of the actuator used in the fracture load of bonded specimens produces contact surface damage with much cone cracking, which does not simulate clinical failure that is typically produced by subsurface radial cracking.[43] Further studies, including different cementation protocols, aging challenges, and fatigue testing, could ensure a more realistic approach to the clinical conditions.

In summary, the performance of ceramic materials bonded to a substrate does not seem to rely solely on the mechanical properties of the ceramics but may be governed by a complex scenario consisting of several variables, such as mechanical properties of ceramic and substrate, bonding efficacy of resin cement, ceramic translucency, quality of curing light, and effective self-cure activation, among others factors.

CONCLUSIONS

With the limitations of this study, it was concluded that despite the higher BFS values of PSZ and FSZ compared with lithium disilicate, there was no difference among the ceramics in the fracture load in bonded specimens at 0.5 mm thickness. Moreover, fracture load of bonded lithium disilicate was equivalent or superior to that of FSZ at the same thickness. Regarding reliability, there was no difference in the Weibull modulus of the ceramics in the BFS test or in the fracture load of bonded specimens.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the Araraquara Dental School, Univ Estadual Paulista – UNESP in Brazil.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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