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Fracture Load of Monolithic Zirconia Crowns with Varying Occlusal Thicknesses

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Abstract

Newer translucent zirconia materials may have different minimum occlusal thickness requirements based on type of cement. **Objective:** The purpose of this study was to evaluate the effect of occlusal thickness and cement type on the fracture load of crowns made with three all-ceramic materials. **Methods:** One-hundred twenty extracted maxillary human third molar teeth were divided into three groups and restored with crowns using cubic-containing (4Y- PSZ and 5Y- PSZ) zirconia (Katana STML/UTML Kuraray) and lithium disilicate (IPS e.max CAD LT, Ivoclar Vivadent) (control). Teeth were prepared with 0.5 or 1.0mm occlusal reduction and scanned (Omnicam, Dentsply/Sirona). The crowns were designed and milled. Half the crowns of each occlusal thickness in each material group were cemented with RMGI and the other half with a resin cement according to their respective manufacturer's recommendations. The specimens were stored for 24 hrs in 37°C distilled water, then subjected to thermocycling and cyclic loading. Each crown specimen was loaded to failure in a universal testing machine (Instron) with a stainless-steel rod at 90 degrees to the occlusal surface. Data were analyzed with T-tests and ANOVAs/Tukey post hoc tests (alpha=0.05). **Results:** Significant differences between groups were found based on type of ceramic, thickness, and cement ($p<0.05$). **Conclusions:** The use of a resin cement significantly increased the fracture load compared to the use of the glass ionomer cement at each occlusal thickness for both ceramic types. Increasing the occlusal thickness from 0.5 to 1.0mm

significantly increased the fracture strength per ceramic and cement type. In addition, yttria mol% content of zirconia had a significant impact in the fracture load of the material.

Introduction

Zirconia offers the advantage of high strength and toughness over other dental ceramics, which allows preservation of tooth structure for crown preparations. Monolithic traditional zirconia crowns can have a thickness as low as 0.5 mm and still provide adequate strength [1]. Conversely, a major drawback of traditional zirconia is its low translucency which is a concern especially for anterior restorations.

One option for increasing the esthetics of zirconia restorations is to veneer a more translucent feldspathic porcelain to a zirconia framework. However, these bilayered zirconia-based restorations require more tooth reduction to allow adequate thickness for the veneered porcelain and there is also the risk of chipping or delamination of the veneered porcelain [2]. Bilayered zirconia-based restorations also have lower fracture resistance than monolithic lithium disilicate [3]. Therefore, a monolithic zirconia restoration with improved translucency would be more ideal.

One method of increasing the translucency of zirconia involves lowering the alumina content used as a sintering additive. By decreasing the alumina content from 0.25wt% to 0.05wt%, no difference in strength properties were observed but the improved translucency was still not comparable to lithium disilicate [4]. Traditional zirconia is 3Y-TZP (mol% yttria-stabilized tetragonal zirconia) and its excellent mechanical properties are enhanced by phase transformation toughening of the tetragonal crystals [5]. Introduction of cracks into the material result in tetragonal to monolithic transformation that compresses the crack and reduces further propagation. [6]. Although, a significant source of opacity is due to the large birefringence of tetragonal zirconia crystals and the size of these tetragonal grains which cause light scattering at the grain boundaries [2]. Traditional zirconia products with decreased grain size to improve translucency had no significant effect on its strength properties. However, the translucency is still not comparable to lithium disilicate and the extremely small grain size required for optimum esthetics is extremely challenging to synthesize with little defects [7].

Alternatively, increasing the cubic crystals of zirconia can reduce opacity and has led to the development of 4Y-, and 5Y-PSZ (mol% yttria partially stabilized zirconia) where increasing the yttrium content causes increased cubic phase fraction and translucency [8]. These new cubic zirconia materials, at the manufacturer's recommended occlusal thickness of 1mm, demonstrated greater translucencies than low translucency lithium disilicate of 1.5mm thickness [9]. Unfortunately, decreasing the tetragonal crystals reduces phase transformation toughening and will also decrease its strength when compared to 3Y-TZP [10, 11]. 5Y-PSZ is significantly weaker compared to 3Y-TZP and less resistant to fatigue testing and thermocycling [12].

Despite the decrease in strength, cubic zirconia can still have clinical advantages over lithium disilicate. With higher flexural strength than lithium disilicate and comparable translucency [13], cubic zirconia could be a better option especially for anterior restorations over lithium disilicate. The lower strength of cubic zirconia may require more occlusal material thickness than 0.5mm for 3Y-TZP but less than 1.5mm for lithium disilicate which would allow for less tooth reduction than lithium disilicate. Another consideration is how lithium disilicate ceramics are reinforced through resin-bonding to achieve lower thicknesses such as 1.0mm for IPS e.max CAD [14], especially when etched with hydrofluoric acid and used with a silane coupling agent [15]. These pretreatment steps cannot be used for traditional zirconia. Instead, traditional zirconia relies on air-particle abrasion with alumina oxide, application of 10-methacryloyloxydecyl dihydrogenphosphate (MDP) monomer and resin cement for adequate bonding [16]. Due to the lower flexural strength of cubic zirconia compared to 3Y-TZP, resin bonding could strengthen cubic zirconia and have a significant effect on minimum occlusal thickness [17].

Currently there are no studies examining the minimum occlusal thickness for cubic zirconia materials. The purpose of this study was to evaluate the fracture load of crowns with different zirconia materials of varying occlusal thicknesses using conventional and resin-bonded cements. Two zirconia materials that were investigated in this study were Katana STML and UTML (Kuraray America, New York, NY). Katana STML is a 4Y-PSZ material and Katana UTML is a 5Y-PSZ material and both have a recommend minimum reduction of 0.8 mm for anterior crowns and 1.0 mm for posterior crowns. Air-abrading

the intaglio surface of the crown with aluminum oxide is recommended before cementation and either conventional RMGI or resin-bonded cements can be applied. Using conventional cements results in mostly micro-mechanical retention and may not increase the strength of the restoration. However, there needs to be proper taper and wall height for adequate retention. Using resin-bonded cements results in both micro-mechanical and chemical bonding and has the potential to increase the strength and retention of the restoration. This study also evaluated restorations cemented with conventional cements compared to resin-bonded cements to determine if resin-bonded cements can significantly increase the fracture load of a restoration. The null hypothesis was that there would be no difference in fracture load based on (1) type of material (Katana STML, Katana UTML, or IPS e.max CAD) or (2) occlusal thickness (0.5 or 1.0mm) or (3) type of cement (RMGI or resin cement).

Materials and Methods

One hundred and twenty extracted, caries-free maxillary third molars of similar size were used in this study. Each tooth was embedded in self-cured acrylic resin (Vitacrylic, Fricke Dental, Streamwood, IL) to 2.0 mm below the cementoenamel junction in a custom cylindrical block. The molars were divided into three groups according to restorative material IPS e.max CAD (Group 1), Katana UTML (Group 2) and Katana STML (Group 3). Each group was further divided into the following subgroups (n=10 per subgroup) according to occlusal thickness and cement type:

Subgroup A: 0.5 mm thickness, RMGI cement

Subgroup B: 0.5 mm thickness, resin cement

Subgroup C: 1.0 mm thickness, RMGI cement

Subgroup D: 1.0 mm thickness, resin cement

A CAD/CAM acquisition unit (CEREC Omnicam Acquisition Unit, Dentsply Sirona, Charlotte, NC) was used to scan all teeth before preparations were made. Then, axial teeth preparations for all groups were performed under water spray using a modified tapered diamond bur (LG15847KR.31.016; Brassler USA). All crowns were prepared with a 1 mm chamfer finish line 1 mm coronal to the CEJ and 8° axial wall inclination. Sixty teeth were prepared occlusally with depth cuts from a #1/4 round bur to achieve 0.5 mm

occlusal reduction and the remaining sixty teeth were prepared occlusally with depth cuts from a #2 round bur to achieve 1.0 mm occlusal reduction. The angles were rounded according to the manufacturer's recommendations. After the teeth preparations were scanned, crowns were designed with InLab software (version 18.1, Dentsply Sirona) using the reduce feature to achieve an even minimal occlusal thickness of 0.5 or 1.0 mm and 1mm radial thickness based on the amount of occlusal reduction.

Following completion of the digital design, 40 Katana STML, 40 Katana UTML and 40 IPS e.max CAD crown restorations were milled from their respective blocks (MCXL, Dentsply Sirona) or pucks (Imes iCore, Eiterfeld, Germany) using a milling unit. Zirconia crowns were sintered (Programat S1, Ivoclar Vivadent) and IPS e.max crowns were crystalized (Programat P500, Ivoclar Vivadent) according to manufacturer's recommendations and then polished. After all crowns were fitted, sixty crowns were cemented with a RMGI cement (RelyX Luting, 3M ESPE, St. Paul, MN), thirty with 0.5 mm thickness, subgroup A, and thirty with 1.0 mm thickness, subgroup C. A uniform layer of RelyX Luting was mixed and applied to the restorations and seated, then tack cured for 1 second with a curing light (VALO, Ultradent Products, South Jordan, UT). Irradiance was recorded with a radiometer (Bluephase Meter, Ivoclar Vivadent) and considered acceptable if greater than 1000 mW/cm^2. Excess cement was removed with a sharp instrument before light curing for 20 seconds on each surface.

The remaining sixty crowns were cemented with an adhesive resin cement according to their respective manufacturer's recommendations, thirty with 0.5 mm thickness, subgroup B, and thirty with 1.0 mm thickness, subgroup D. In groups 1, and 2 the intaglio surfaces of the Katana STML and UTML crowns were air-abraded with 50 μm aluminum oxide at 2 bar (Basic Quattro IS, Renfert, Hilzingen, Germany), and steam cleaned (i700B, Reliable, Toronto, Canada). Next, Clearfil Ceramic Primer Plus (Kuraray, Tokyo, Japan) was applied to the internal surface and dried. Panavia V5 Tooth Primer (Kuraray) was applied to the prepared teeth for 20 seconds and dried. Then, a uniform layer of Panavia V5 (Kuraray) resin cement was applied to the crowns and fully seated. In group 3, the intaglio surfaces of the IPS e.max CAD crowns were etched with 5% hydrofluoric acid (IPS Ceramic Etching Gel, Ivoclar Vivadent) for 20 seconds, rinsed, and thoroughly dried. Next, Monobond Plus (Ivoclar Vivadent) was applied to the restorations,

allowed to react for 60 seconds, and dried. A mixture of Multilink primers A and B (Ivoclar Vivadent) was applied to the prepared teeth. Then, a uniform layer of Multilink Automix resin cement (Ivoclar Vivadent) was applied directly to the crowns and seated. All restorations were then tack cured for 1 second with a curing light and excess cement was removed with a sharp instrument. The restorations were light cured for 20 seconds on each surface.

All teeth in the three groups were stored in distilled water solution at 37°C for 24 hours in an incubator (model 20 GC, Quincy Labs, Chicago, IL). After storage in distilled water, each tooth specimen was thermocycled in distilled water for 2000 cycles at 5°C and 55°C with a dwell time of 30 seconds at each temperature (Sabri Dental Enterprises, Downers Grove, IL). All teeth were then mechanically loaded in a chewing simulator (Sabri Dental Enterprises) to simulate clinical loading. The machine subjected the mounted teeth, still submerged in distilled water, to a cycling force of 10-150 N at a rate of 1 cycle per second (1 Hz) for 100,000 cycles. The force was applied parallel to the long axis via a 12.7-mm-diameter, flat-ended cylindrical piston resting on the cusp tips. Each group (consisting of 10 teeth) was loaded separately from the other groups. The load was verified with a digital force meter (Infinity CS, Cooper Instruments, Warrenton, VA) before each load sequence.

Static fracture loading was initiated subsequent to fatigue loading. The teeth were removed from the water and oriented so that a 6-mm-diameter, round-ended probe applied a load to the center and long axis of the molars. Loading was performed in a universal testing machine (Model 5543, Instron, Norwood, MA) at a crosshead speed of 1 mm/min until the first fracture occurred. The fracture force was recorded in Newtons, and a mean and standard deviation was determined for each group. Failure mode was determined by visual examination to determine if the failure was Type 1- due to fracture of the ceramic only, Type 2- fracture of the tooth structure above the margin, Type 3- fracture of tooth structure involving the margin, Type 4- or severe root and crown fracture (catastrophic failure).

Statistical Analysis

Data was analyzed with a 3-way analysis of variance (ANOVA) and Tukey's post hoc test to evaluate the main effects of ceramic material, occlusal thickness, and cement type and the interaction effects among ceramic material, occlusal thickness, and cement type on fracture load (alpha = 0.05). Multiple T-Tests and one-way ANOVAs with Tukey's post hoc tests were conducted between groups based on occlusal thickness, ceramic, or cement type (alpha = 0.05). See table 1 and 2.

Results

The results of the three-way ANOVA found significant differences in fracture load base on ceramic material ($p < 0.001$), occlusal thickness ($p < 0.001$), and cement type ($p < 0.001$) with significant interactions between ceramic material and cement ($p < 0.001$) and between cement and thickness ($p = 0.004$). The results of the multiple one-way ANOVAs found that the fracture loads of the Katana STML crowns were significantly greater ($p < 0.05$) than Katana UTML or IPS e.max CAD crowns at both thicknesses and with both cement types. The 1.0mm-thick Katana STML crowns bonded with resin cement had the greatest fracture load (3434.5 ± 512.7 N) and was significantly greater than the fracture load of the 0.5mm-thick crowns (2462.1 ± 232.8 N), which was also significantly greater than the 1.0mm (1912.8 ± 475.0 N) or 0.5mm-thick crowns (1159.2 ± 251.4 N) cemented with RMGI. The lowest fracture load was found with the 0.5mm-thick IPS e.max CAD crowns (884.5 ± 151.7 N) cemented with RMGI, but it was not significantly different than the 0.5mm-thick (863.5 ± 221.5 N) Katana UTML crowns. All crowns regardless of ceramic material demonstrated significantly higher fracture loads when occlusal thickness was increased from 0.5mm to 1mm regardless of cement type used. Also, all crowns regardless of ceramic material, demonstrated significantly higher fracture loads when cemented with resin cement compared to RMGI cement at the same occlusal thickness for both 0.5mm and 1mm occlusal thickness. See tables 1 and 2.

Ceramic	**Fracture Load (Newtons)** Mean (st dev)			
	RMGI		Resin Cement	
	0.5 mm	1.0 mm	0.5 mm	1.0 mm
IPS e.max CAD	884.5 (151.7) Aa	1274.0 (273.1) Ba	1854.6 (474.6) Ab	2590.1 (418.0) Ba
Katana UTML	863.5 (221.5) Aa	1278.3 (361.3) Ba	1191.8 (225.8) Aa	2178.8 (433.6) Ba
Katana STML	1159.2 (251.4) Ab	1912.8 (475.0) Bb	2462.1 (232.8) Ac	3434.5 (512.7) Bb
Per cement type, groups with the same upper case letter by row and lower case letter by column are not significantly different P>0.05				

Table 1: Fracture load of all-ceramic crowns based on thickness per cement.

Ceramic	**Fracture Load (Newtons)** Mean (st dev)			
	0.5 mm		1.0 mm	
	RMGI	Resin Cement	RMGI	Resin Cement
IPS e.max CAD	884.5 (151.7) Aa	1854.6 (474.6) Bb	1274.0 (273.1) Aa	2590.1 (418.0) Ba
Katana UTML	863.5 (221.5) Aa	1191.8 (225.8) Ba	1278.3 (361.3) Aa	2178.8 (433.6) Ba
Katana STML	1159.2 (251.4) Ab	2462.1 (232.8) Bc	1912.8 (475.0) Ab	3434.5 (512.7) Bb
Per thickness, groups with the same upper case letter by row and lower case letter by column are not significantly different P>0.05				

Table 2: Fracture load of all-ceramic crowns based on cement per thickness.

All crowns cemented with RMGI cement resulted in Type 1 fractures only, while Type 2 to Type 4 fractures were only observed when a resin cement was used. All Type 4 fractures were only observed in the Katana STML group when a resin cement was used, with the most Type 4 fractures observed in the 1mm occlusal thickness group.

		Failure Mode			
		Type 1	Type 2	Type3	Type 4
Ceramic	Thickness	RMGI			
IPS e.max CAD	0.5	10	0	0	0
	1.0	10	0	0	0
Katana UTML	0.5	10	0	0	0
	1.0	10	0	0	0
Katana STML	0.5	10	0	0	0
	1.0	10	0	0	0
Ceramic	Thickness	Resin Cement			
IPS e.max CAD	0.5	9	0	1	0
	1.0	7	0	3	0
Katana UTML	0.5	10	0	0	0
	1.0	8	1	1	0
Katana STML	0.5	3	2	4	1
	1.0	2	1	2	5

Table 3: Various failure modes based on ceramic, thickness and cement.

Discussion

The first null hypothesis was rejected as significant differences were found in fracture load based on type of ceramic material due to the differences in strength of the materials. Kuraray America, Inc. reports the flexural strengths of Katana HTML, STML and UTML are 1125 MPa, 748 MPa and 557 MPa respectively while IPS e.max Press is 427 MPa based on a three point bending test. Therefore it would be expected in this study that Katana STML would have the highest fracture load, followed by Katana UTML and IPS e.max CAD with the lowest fracture load. Katana STML had a significantly greater fracture load then both Katana UTML and IPS e.max CAD regardless of occlusal thickness or cement type used. Multiple studies evaluating flexural strength of 3Y-TZP and 5Y-PSZ have shown 3Y-TZP to be at least twice as strong as 5Y-PSZ [10, 13]. The high strength of 3Y-TZP is attributed to a higher composition of tetragonal phase crystals that can undergo transformation toughening but the material can be more opaque. Increasing yttria mol% will stabilize more of the zirconia in the cubic phase which will increase translucency [18]. However higher cubic content will also reduce its ability to undergo transformation toughening and as a result decrease strength. While 3Y-TZP is the strongest and least translucent and 5Y-PSZ is the weakest and most translucent, 4Y-PSZ represents a balance between the two for strength and translucency. Studies evaluating biaxial flexural strength of 3Y-TZP, 4Y-PSZ and 5Y-PSZ have shown a significant decrease in strength as yttria mol% increases [19, 20].

In contrast, no significant differences in fracture loads were found between Katana UTML and IPS e.max CAD, except Katana UTML had a significantly lower fracture load at 0.5mm occlusal thickness cemented with resin cement. When compared to lithium disilicate, a study by Kwon et al. [13] reported flexural strength of Katana UTML (688 MPa) to be greater than IPS e.max CAD (450 MPa). Even though the flexural strength of Katana UTML is higher than IPS e.max CAD as demonstrated through a 3-point bending test, this difference may not be clinically significant when compared to crowns cemented on tooth substructure as shown in this study.

The second and third null hypothesis were also rejected as significant differences were found in fracture load based on occlusal thickness and type of cement. One mm occlusal thickness was chosen due to the manufacturer's recommendation that minimal

occlusal thickness for both Katana STML and Katana UTML for posterior crowns should not be less than 1mm. This can then be compared to lithium disilicate with 1mm occlusal thickness using resin cement which has shown to have adequate strength. Half mm was also chosen for occlusal thickness to see if 4Y-PSZ and 5Y-PSZ would have adequate strength at those thicknesses similar to 3Y-TZP. Nakamura et al. demonstrated that 3Y-TZP with an occlusal thickness of 0.5mm using a resin cement had significantly higher fracture resistance than lithium disilicate with an occlusal thickness of 1.5mm. Other studies have also supported 0.5mm occlusal thickness for 3Y-TZP [21, 22]. All materials demonstrated a significant increase in strength when occlusal thickness was increased from 0.5mm to 1mm, regardless of cement type. These findings were also similar to study by Nakamura et al. [23] where increasing occlusal thickness from 0.5mm to 1mm resulted in significant fracture resistant of 3Y-TZP crowns. When comparing IPS e.max CAD at 1mm occlusal thickness with resin cement, only Katana STML at 1mm occlusal thickness with resin cement had a significantly higher fracture load. Katana STML at 0.5mm occlusal thickness with resin cement also had a similar fracture load to IPS e.max CAD at 1mm occlusal thickness with resin cement. Conversely, the fracture load of Katana UTML at 1mm occlusal thickness with resin cement was not statistically different than IPS e.max with the same thickness and cement. These findings are different than a study by Yan et al. [24] which found load-bearing properties of lithium disilicate bonded to a dentin-like substrate similar to 4Y-PSZ but superior to 5Y-PSZ. However, these differences could be due to a different brand of zirconia that could have different cubic content and manufacturing processes that could affect its properties despite being labeled as 4Y-PSZ or 5Y-PSZ.

All materials also demonstrated a significant increase in strength when using a resin cement compared to a RMGI cement at the same thickness. Luting cements are easy to apply without additional pretreatment steps or application of a bonding agent. However, they provide little to no adhesion [17]. On the other hand, resin bonding cements not only have the advantage of increasing retention of crowns with less than ideal axial wall height, but have also been shown to reinforce weaker silica-based ceramics [25]. Treatment of lithium disilicate with hydrofluoric acid etch and silane results in very high bond strengths however, this protocol cannot be applied to metal-oxide

ceramics. Instead bonding to zirconia involves air-abrasion with aluminum oxide and application of a 10-MDP primer. In this study, doubling the occlusal thickness increased fracture load by approximately 1.5 times for all materials. In contrast, a higher increase was seen when using a resin cement, approximately 2 times, for Katana STML and IPS e.max CAD. A study by Kwon et al. [13] showed no difference in bond strength with resin cement between 3Y-TZP, 5Y-PSZ and lithium disilicate with the appropriate bonding protocol. Therefore, it would be expected that similar increases in strength would be observed regardless of material and all materials of this study had significant increases in fracture load when using a resin cement compared to RMGI cement. These findings were similar to a study by Lawson et al. [26] where fracture loads of 3Y-TZP and 5Y-PSZ crowns were significantly increased with the use of a resin cement compared to a RMGI cement; however, the study also found no significant difference between 5Y-PSZ and lithium disilicate cemented with resin cement. Even though Katana UTML and IPS e.max CAD had similar fracture loads using RMGI cement, the same was not observed when using a resin cement. Katana UTML had a significantly lower fracture load at 0.5mm occlusal thickness but not statistically different at 1mm occlusal thickness. Possible explanations could include the use of different cements between the two materials based on manufacturer's recommendations. Also, a study by Inokoshi et al., found a decrease in strength of Katana UTML after air-abrasion while an increase in strength was noted for Katana STML and HTML [27].

Failure modes of all groups cemented with RMGI resulted in fracture of the ceramic crown only without fracture of the underlying tooth structure. The severity of failure mode increases with the use of a resin cement, which resulted in more fractures that not only involved the ceramic but also tooth structure. All of the catastrophic failures occurred with Katana STML cemented with resin cement, with the most castasttrophic failures at 1mm occlusal thickness due to the high fracture load and bond strength of the cement.

Based on the results of this study, selecting a RMGI cement for 1mm occlusal thickness for Katana STML may not provide adequate fracture resistance given the lower fracture load compared to IPS e.max CAD at 1mm occlusal thickness with resin cement. On the other hand, using a resin cement for Katana STML at 1mm occlusal thickness showed significantly higher fracture load than IPS e.max CAD. Therefore, the increase in

fracture resistance by using a resin cement could suggest that minimum occlusal thickness for Katana STML could possibly be lower than 1mm. Even Katana STML at 0.5mm occlusal thickness with resin cement had similar fracture loads to IPS e.max CAD at 1mm occlusal thickness with resin cement. Given the similar fracture loads of Katana UTML with IPS e.max CAD, using a RMGI would not be indicated for Katana UTML at these occlusal thicknesses. However, fracture resistance of Katana UTML at 1mm occlusal thickness is adequate with use of a resin cement as it was not statistically different than IPS e.max CAD. It is important to note that although the manufacturer recommends 1mm minimum crown thickness for posterior crown thickness when using Katana UTML, the recommended indications only include veneers, inlays/onlays, and anterior crowns. It is not specified whether the recommendations are based on the high translucency of the material not suited for posterior crowns or the strength of the material not adequate to withstand posterior function.

Advantages of this study include testing crowns cemented on actual tooth structure which would be more clinically relevant than using resin dies. Use of thermo-mechanical loading can also represent aging and fatiguing of restorative materials to prevent over estimation of the success of ceramic materials. Limitations of this study include variations in individual teeth such as tooth size, axial wall height, occlusal table, cusp height, etc. These variations may contribute to differences in fracture load rather than only based on occlusal thickness or cement type. To minimize the effect from differences in tooth preparations, crowns were fabricated similar to anatomic copings with even occlusal thickness, thereby allowing the force of the probe to always contact the same occlusal thickness for each tooth. Other limitations include only evaluating 4Y-PSZ and 5Y-PSZ from one manufacturer and their recommended resin cement. Other brands of 4Y-PSZ and 5Y-PSZ may have different strength properties and different resin cements may reinforce ceramic crowns to different degrees.

Conclusions

The use of a resin cement significantly increased the fracture load compared to the use of the glass ionomer cement at each occlusal thickness for both ceramic types. Increasing the occlusal thickness from 0.5 to 1.0mm significantly increased the fracture

strength per ceramic and cement type. In addition, yttria mol% content of zirconia had a significant impact in the fracture load of the material.

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