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The Effect of Lithium Disilicate Glass-Ceramic Core Thickness on Fracture Thickness of All-ceramic Restorations

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Statement of the Problem: Fracture strength is fundamental for the long-term success and clinical service of all-ceramic restorations. Core thickness is an important factor affecting fracture strength.
Purpose: The main objective of this study was to assess and compare the fracture strength of 0.4 mm and 0.7 mm core thicknesses.
Materials and Methods: In this *in vitro*, experimental study, one brass die was prepared with classic chamfer finish line design (0.8 mm depth). An impression was made from the metal die and poured with epoxy resin. The epoxy resin die was scanned and lithium disilicate glass ceramic core was fabricated by the computer-aided design/computer-aided manufacturing (CAD/CAM) technique. IPS e.max cores with 0.4 and 0.7 mm thicknesses were fabricated using CAD/CAM

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technique. Ten samples were fabricated of each thickness and veneered with IPS e.max. After adhesive bonding onto the die, they were vertically loaded using a universal testing machine until fracture. The data were statistically analyzed using the Kolmogorov-Smirnov test and t-test.

Results: The mean and standard deviation (SD) of fracture strength were 1754±313.47 and 1073±202.81 N, for 0.7 mm and 0.4 mm cores, respectively. The Kolmogorov-Smirnov test showed normal distribution of data; thus, t-test was applied for comparison of the two groups ($p<0.001$). The fracture strength of 0.7 mm core was significantly greater than that of 0.4 mm core.

Conclusions: Within the limitations of this study, it was concluded that increasing the core thickness improves the fracture strength. However, the mean fracture strength values obtained for 0.4 and 0.7 mm core thicknesses were far greater than the load threshold applied in the oral cavity; thus, both thicknesses can be successfully used in the clinical setting.

Keywords: IPS e.max; CAD / CAM; core thickness; fracture strength.

1. INTRODUCTION

Fracture strength and durability are important determinants of the success and clinical service of all-ceramic restorations. In the oral environment, restorations should have adequate strength to resist masticatory forces. Quite a wide range has been reported for maximum masticatory forces (216–847 N) and it has been reported that posterior tooth restorations bear a mean load of 500 N [1].

Increasing the fracture strength of restorations may prolong their clinical service and decrease complications such as secondary caries and periodontal disease. There has been growing interest in ceramic restorations due to their optimal esthetics and biocompatibility [2]. However, their use is associated with some shortcomings. Chipping of the veneering porcelain is the most frequently encountered complication of all-ceramic restorations [3]. The second most common clinical failure may be gross fracture of restoration [4]. Several factors affect the fracture strength of all-ceramic restorations such as preparation design, thickness and material of core, microscopically heterogeneous material structure, force direction and magnitude, propagation of superficial cracks and oral environment [5]. Core material and its thickness are the most influential factors on fracture strength [2]. Ceramic cores provide acceptable esthetics and translucency under all-ceramic restorations. However, veneering porcelain is often used to improve esthetics of all-ceramic restorations fabricated with CAD/CAM technology, which decreases the mechanical strength of crowns [6,7].

There has been growing interest in glass ceramic systems because of their optimal esthetics, excellent fracture strength against occlusal forces, durability of the bond between the prepared tooth surface and ceramic and simplified fabrication technique using CAD/CAM technology. In the early 1990s, a leucite reinforced glass ceramic (IPS Empress 1, Ivoclar Vivadent, Schaan, Liechtenstein) was introduced, which had increased strength due to inhibition of crack propagation. A lithium disilicate glass ceramic was later introduced (IPS Empress 2, Ivoclar Vivadent, Schaan, Liechtenstein), which was mainly composed of quartz, lithium dioxide, phosphorus oxide, alumina oxide and potassium oxide. In 2001, a castable lithium disilicate glass ceramic (IPS e.max Press) was launched with improved mechanical and optical properties. Four years later, another form of lithium disilicate glass ceramic (IPS e.max CAD) was introduced for CAD/CAM restorations [8].

Considering the effects of porcelain firing on marginal adaptation of all-ceramic restorations, three core thicknesses of 0.3, 0.5, and 0.7 mm have been proposed. These thicknesses have been used to evaluate the effect of different core thicknesses and porcelain firing on marginal adaptation of all-ceramic restorations. The results showed that 0.3 and 0.5 mm core thicknesses did not have any effect on marginal gap while 0.7 mm core thickness increased the marginal gap [2,3,5,7]. In another study on the effect of variations in core thickness on the post-fatigue fracture strength of veneering porcelain on zirconia crowns, three core thicknesses [0.6, 1.2, and 1.7 mm) were used [9]. Another study on the fracture strength of restorations, 0.5 mm core thickness was used for all samples [10]. Benetti et al. [11] evaluated the effect of different zirconia thicknesses and application of a surface liner on the flexural strength of a ceramic system and showed that zirconia thickness affected the mean flexural strength, but the surface liner had no significant effect on the flexural strength or the mode of failure of the ceramic system examined. Kim et al. [12] compared the fracture load of zirconia crowns based on their coping thickness. They concluded that the thicker coping group (0.7 mm) had the highest fracture strength. Bakeman et al. [13] evaluated the effect of ceramic thickness and ceramic materials on fracture strength of posterior partial coverage ceramic restorations. The thickness of ceramic (1 mm or 2 mm) and the ceramic materials (a lithium disilicate glass-ceramic [IPS e.max] or leucite-reinforced glass ceramic [IPS Empress]) were examined. All ceramic restorations were luted with resin cement (Variolink II) on the prepared teeth. They concluded that the thickness of ceramic had no significant effect on fracture strength when the ceramics were bonded to the underlying tooth structure.

Clinicians are still concerned about the mechanical properties of all-ceramic restorations. Several studies have investigated the mechanical properties of ceramics. IPS e. max restorations have gained popularity due to their excellent esthetics and biocompatibility. E. max core supports ceramic veneers; thus, the core thickness may affect the gross fracture of restorations. To date, no consensus has been reached regarding the ideal IPS e. max CAD core thickness to well resist masticatory forces while providing optimal esthetics. The aim of this study was to evaluate the effect of 0.4 and 0.7 mm thicknesses of lithium disilicate glass ceramic core on the fracture strength of all-ceramic restorations. The results may be useful in selecting a core thickness to provide maximum strength with favorable esthetics. The null hypothesis was that the fracture strength of otherwise equal 0.4 mm and 0.7 mm core thicknesses of IPS e.max CAD would not be significantly different.

2. MATERIALS AND METHODS

In this *in vitro*, experimental study, one standard brass die was prepared with classic chamfer finish line design (0.8 mm depth). The axial walls had 10° taper (14) (Fig. 1).

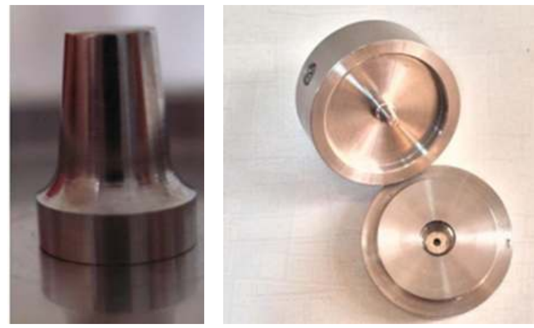

Fig. 1. Standard brass die

According to the manufacturer's instructions, condensation silicon (Speedex, Coltène/ Whaledent AG, Altstätten, Switzerland) was used to make an impression from the standard die (Fig. 2).

The impressions were inspected to ensure absence of voids or deformity. The impressions were then poured with epoxy resin according to the manufacturer's instructions. After completion of setting time, epoxy dies were inspected using a magnifier and those with bubbles were excluded (Fig. 3).

Epoxy resin dies were scanned by a scanner (Sirona in Eos scanner, Sirona Dental Systems Inc., Bensheim, Germany) and three-dimensional images were obtained. Images were processed by the respective software (Sirona in Lab MC XL software, Sirona Dental Systems Inc., Bensheim, Germany) and reconstructed. Twenty specimens (10 samples of each thickness of 0.4 mm and 0.7 mm) were tested. The die cement space of 35 microns was provided. Ceramic copings were fabricated from presintered lithium disilicate glass ceramic blocks (IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein) and milled

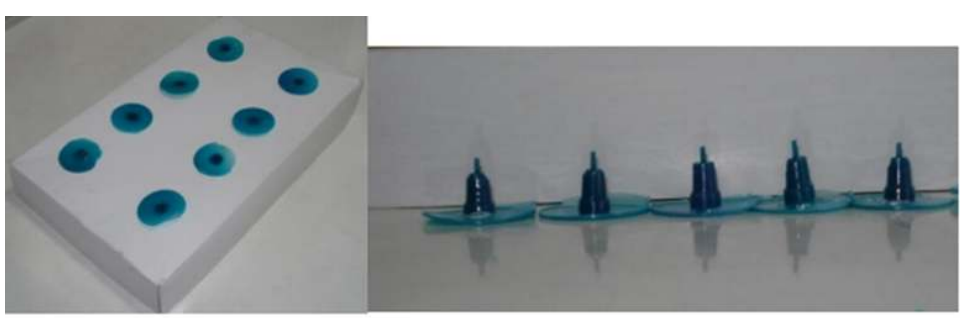

Fig. 2. Standard die impressions

a) b)

Fig. 3. (a) Milling machine (Cerec in Lab, Sirona Dental Systems Inc., Bensheim, Germany) (b) Ceramic core

(Cerec in Lab Sirona Dental Systems Inc., Bensheim, Germany). After milling, the thickness of samples was controlled (Fig. 4).

Fig. 4. The veneered core

The 0.4 mm and 0.7 mm copings were stained with A1 and A3 shades, respectively. Then the samples were fully sintered for seven minutes at a temperature of 820-840℃ (Sintramat, Ivoclar Vivadent, Schaan, Liechtenstein). Liner (ZirLiner, Ivoclar Vivadent, Schaan, Liechtenstein) was applied on the cores before porcelain veneering. Then, the veneer (Ivoclar Vivadent, Schaan, Liechtenstein) was applied to the cores according to the manufacturer's instructions. The veneering porcelain thickness was 1 mm for all samples. Crowns were placed on the dies and were randomly coded. The crowns were cemented to the dies using resin cement (Panavia F2, Kuraray, Tokyo, Japan). During cementation, 5 N load was applied to the crowns in a press machine for 10 minutes [15]. The samples were stored in saline for 24 hours at room temperature for the purpose of standardization. Mechanical test was carried out using a universal testing machine (Zwick Roell AG, Ulm, Germany). Occlusal loads were applied to the central fossa along the longitudinal axis of the crown at 90° with a crosshead speed of 1 mm/min until fracture. The data were statistically analyzed using t-test to compare the fracture strength between the two groups.

3. RESULTS

The Kolmogorov-Smirnov test showed that the data had a normal distribution (Figs. 5 and 6). Therefore, the data were analyzed by parametric t-test. The fracture strength values in the two groups are shown in Table 1.

The mean fracture strength of all samples irrespective of their thickness was 1413 N. The mean (±SD) fracture strength of 0.7 mm and 0.4 mm cores was 1754±313.47 N and 1073±202.81 N, respectively. The highest mean fracture strength was measured in 0.7 mm core thickness group (2257 N) and the lowest mean fracture strength was measured in 0.4 mm group (823 N). The mean fracture strength of 0.4mm cores was 39% (682 N) lower than that of 0.7 mm cores. The t-test analysis showed that the fracture strength of 0.7 mm cores was significantly higher than that of 0.4 mm cores ($P < 0.001$). The coefficient of variation of 0.4 mm and 0.7 mm cores were found to be almost similar (17.9% and 18.7%, respectively).

4. DISCUSSION

Durability and long-term clinical service of all-ceramic restorations is still a matter of concern for many dental clinicians [1]. Maximum fracture strength of restorations is often measured using a universal testing machine. Higher fracture strength increases the longevity of restoration and its resistance to fracture. Core material and its thickness are the main factors affecting the fracture strength of restorations [2]. Lithium disilicate glass ceramic block is composed of lithium disilicate glass ceramic. Presintered blocks are fabricated using the glass technology via a continuous casting process. Lithium disilicate crystals form following a complete crystallization process and confer high strength to ceramics.

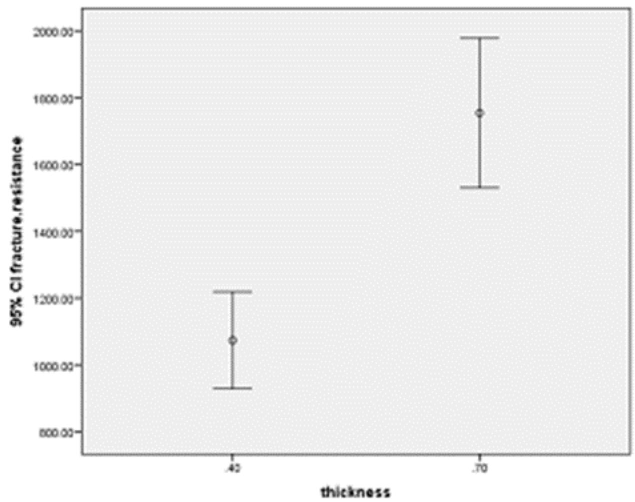

Fig. 5. Error bar of the mean and 95% confidence interval of the fracture strength of 0.4 and 0.7 mm core thicknesses

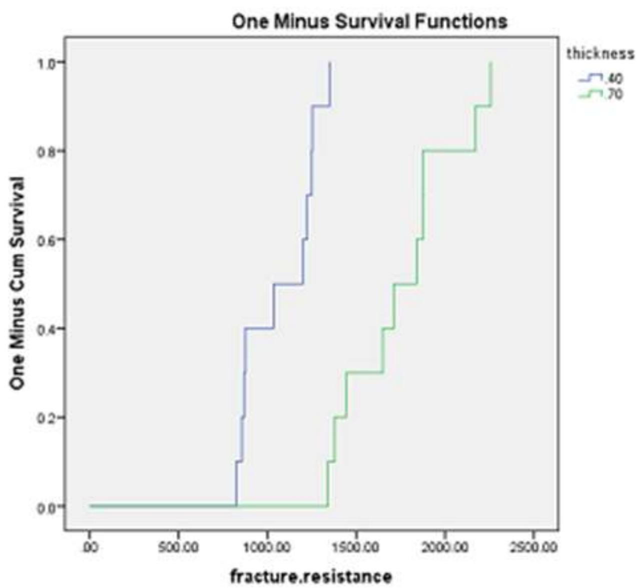

Fig. 6. The kaplan–meier plot

Table 1. The mean and standard deviation of fracture strength of 0.4 and 0.7 mm core thicknesses

Core thickness	Number	Mean	Standard deviation	Minimum	Maximum	Coefficient of variation
0.7 mm	10	1745	313.47	1341	2257	17.9
0.4 mm	10	1073	202.81	854	1350	18.68
Sum	20	1413	432.9	854	2257	30.63

Ceramic discs have been used in many previous studies to evaluate the fracture strength of all-ceramic restorations; in some others, only the fracture strength of the core has been measured. Kelly [14] used a standard die. All-ceramic crowns used in his study were similar to their original size in the clinical setting and loaded until fracture. Use of natural teeth instead of standard dies has some disadvantages. The major disadvantage is difficult standardization with regard to tooth preparation. Therefore, Kelly's method [14] was used in the current study.

Epoxy resin dies were used in the current study since epoxy resin and dentin have similar modulus of elasticity and well bond to resin cements; also, selection of epoxy resin dies in the current study was based on previous studies by Zahran et al. [15] and Volt von Steyern and Ebbesson [16].

Jalalian et al. [17] evaluated the effect of chamfer and radial shoulder finish lines on the marginal adaptation of all-ceramic restorations and stated that chamfer design provided better marginal adaptation. Moreover, in another study Jalalian et al. [18] assessed the effect of chamfer and shoulder design on the fracture strength of zirconia copings and concluded that the fracture strength was significantly higher when chamfer finish line was applied. The internal angle of chamfer margin is rounded to better contribute to force distribution with a more conservative tooth preparation. Therefore, chamfer finish line design with 0.8 mm depth was prepared on the dies.

Type of luting cement is another important factor affecting the fracture strength of all-ceramic restorations [19]. Controversy exists regarding the selection of adhesive resin cements versus the conventional cements. Omori et al. [20] showed that the fracture strength of all-ceramic crowns depended on the type of cement used. Bindl et al. [21] stated that when adhesive resin cements were used, loads were applied more directly to the underlying structure as compared with the use of conventional cements in all-ceramic crowns. Mahasti and Sattari [22] reported that the cytotoxicity of Panavia F2 cement decreased over time in comparison with other cements. Most previous studies have recommended the use of 10-methacryloyloxydecyl dihydrogen phosphate cements with active monomers such as Panavia for all-ceramic crowns.

Lawn et al. [23] reported that the fracture strength of all-ceramic restorations depended more on the thickness of the crown rather than the core /veneer ratio. According to Webber et al. [19] the thickness of the veneering porcelain had no significant effect on porcelain fracture. Reich et al. [24] indicated that by a reduction in zirconia coping thickness from 0.5 mm to 0.3 mm, 35% reduction occurred in forces required for fracture. Veneering porcelain was not used by Reich et al. [24]. In the current study, 1 mm uniform veneering porcelain was applied to all the cores.

Bindl et al. [21] measured the fracture strength of 0.4 mm zirconia core to be 697-1607 N. In their study, composite dies were used. In the current study, fracture strength of 0.4 mm lithium disilicate glass ceramic core was measured to be 845-1350 N.

In a study by Jalalian et al. [25] the fracture strength of 0.7 mm IPS e.max Press and IPS Empress 2 cores was reported to be 380 N, while in the current study, the fracture strength of lithium disilicate glass ceramic core with the same thickness was found to be 1754 N. Yu et al. [26] assessed the fracture strength of lithium disilicate glass ceramic crowns and onlays with two resin cements on premolar teeth and proposed IPS e.max CAD mesio-occluso-distal onlay to be an efficient restoration for endodontically treated premolar teeth. Nawaflen et al. [27] in 2015 reviewed laboratory studies that investigated fatigue resistance of lithium disilicate crowns and fixed dental prostheses to elucidate study designs and testing parameters. They demonstrated that different setting of the testing parameters and absence of testing standardization probably led to inconsistency in the reported results. The obvious heterogeneity in the setting of testing variables-especially the magnitude of load and number of cycles applied-made it impractical to run direct comparisons between the reviewed studies.

The current study had some limitations. First, compressive vertical loads (which are frequently applied to the posterior teeth) were only applied to measure the fracture strength of the restorations, and fatigue resistance and cyclic loads were not taken into account. All forces applied to crowns in the clinical setting and intraoral conditions such as saliva and pH were not simulated in the current study, which was another limitation of this study.

5. CONCLUSIONS

Based on the results of this *in vitro* study, both 0.4 and 0.7 mm lithium disilicate glass ceramic core thicknesses were able to withstand maximum forces during mastication. Since lithium disilicate glass ceramic copings are opaque, minimum core thickness can be used in the esthetic zones. Due to the presence of significant differences between the two thicknesses of the lithium disilicate glass ceramic cores, it can be concluded that the fracture strength improves by an increase in core thickness.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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