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Effect of Veneering Ceramic Thickness on Fracture Strength of All-Ceramic Lithium Disilicate Restorations

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ABSTRACT

Fracture strength is an important factor affecting the survival and clinical service of all-ceramic restorations. This study aimed to assess the effect of veneering ceramic thickness on fracture strength of all-ceramic restorations. Thirty lithium disilicate discs (IPS e.max Press) with 10 mm diameter and 0.5 mm thickness were fabricated to serve as restoration core. They were placed at the bottom of the mold and porcelain was applied on top of them in 0.5, 1 and 1.5 mm thickness. They were then subjected to thermocycling and cyclic loading to simulate stresses in the oral environment. Fracture strength was measured using a universal testing machine. Data were analyzed using one-way ANOVA and Tukey's test (0.05). Fracture strength increased from 157 to 912 N by an increase in ceramic thickness from 0.5 to 1.5 mm. One-way ANOVA showed a significant difference among the three groups in terms of fracture strength (P=0.000). Fracture strength in 1.5 mm thickness was significantly higher than that in the other two groups. The difference in fracture strength was significant in presence of 0.5 and 1 mm ceramic thicknesses. Within the limitations of this study, it may be concluded that increasing the veneering ceramic thickness increases the fracture strength of all-ceramic restorations.

Key words: CAD/CAM, Ceramic Thickness, Fracture Strength, Lithium Disilicate

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INTRODUCTION

Demand for tooth-colored restorations has increased during the past decade [1]. Inlays, onlays, ceramic veneers and all-ceramic restorations have excellent esthetics [2]. Dental ceramics are reliably used for the fabrication of frameworks of fixed partial dentures due to their optimal chemical stability, biocompatibility, physical properties, mechanical properties and esthetics. Although dental ceramics provide excellent esthetics, their brittleness is their main shortcoming [1, 3]. The structure of dental ceramics has greatly changed in the recent years and their durability has improved. Ceramics are currently used for the fabrication of crowns and fixed partial dentures using computer aided design computer aided manufacturing systems [1]. Porcelain fused to metal restorations has long been used in dentistry [3]. Due to higher esthetic demands of patients as well as health and environmental concerns with regard to the use of metal restorations [4], they have been gradually replaced with metal-free restorations. All-ceramic restorations have advantages such as optimal biocompatibility [5], color stability, excellent esthetics [3], high wear resistance, low thermal conductivity, no risk of allergy [6] and low plaque accumulation [7]. The color match and fracture strength of ceramic restorations are the main reasons for success of these restorations from the patients' perspective [8]. Core thickness, veneering thickness, porcelain type (in terms of the amount of crystals) and cement type affect the fracture strength of these restorations [9].

Limited studies have evaluated the effect of the veneering thickness on fracture strength of restorations and the existing ones have reported controversial results. Ge *et al*., showed that increasing the veneering thickness increased the fracture strength. However, this increase in thickness also increased the risk of crack initiation in the porcelain [10]. In a recent study (2016), an ideal ratio of core to the veneering thickness in lithium disilicate ceramic was reported to be 1:1 [11]. By an increase in veneering/core thickness, the risk of fracture increases [12]. Seydler *et al*., showed that reduction in porcelain thickness in posterior teeth increased the risk of fracture [13]. However, Bakeman *et al.,* (2015) reported that the strength of lithium disilicate ceramic was not influenced by its thickness [14].

Considering the existing controversy and the gap of information on this topic, this study aimed to assess the effect of the veneering ceramic thickness on fracture strength of IPS e.max all-ceramic restorations.

MATERIALS AND METHODS

This in vitro, experimental study was conducted on 30 lithium disilicate discs (IPS e.max Press; Ivoclar Vivadent) with 10 mm diameter and 0.5 mm thickness. These discs were fabricated using the Press system to serve as restoration core [15]. The discs were placed in a standard mold and veneered with 0.5, 1 and 1.5 mm thicknesses of lithium disilicate glass ceramic in all surfaces [16]. Considering the sample size in previous studies [17,18] (targeted sampling), 30 samples were included in this study (n=10 for each porcelain thickness).

For the purpose of standardization of thickness, disc-shaped metal molds measuring 10 mm in diameter and 1, 1.5 and 2 mm in thickness were used [16] (Figure 1).

After the fabrication of lithium disilicate discs and their placement at the bottom of each mold, porcelain was applied on the top according to the manufacturer's instructions. Porcelain was baked four times by the same technician according to the manufacturer's instructions. After porcelain application and baking, excess material was removed using silicon carbide discs [16]. Using a digital micrometer, dimensions of the specimens were measured again and the samples were glazed under standard conditions.

Figure 1: Metal molds for standardization of lithium disilicate core thickness

All samples were subjected to 5,500 thermal cycles between 5-55°C with a dwell time of five seconds and transfer time of 30 seconds to simulate thermal stresses in the oral environment [19]. Duration of each thermal cycle was 70 seconds [19].

To simulate mechanical stresses in the oral environment, samples were subjected to cyclic loading for 500,000 cycles with 49 N load and 1.6 Hz frequency applied vertically to the samples [19]. Fracture strength was measured using a universal testing machine (Z010.TN25; Zwick, Ulm, Germany) with a crosshead speed of 1 mm/minute. Load was applied to the center of samples by a spherical steel indenter with 4.9 mm diameter [15].

Statistical analysis

Data were analyzed using Xpert version 7.1 software (Zwick) [20]. Since the data were normally distributed, ANOVA was applied for statistical analysis, and pairwise comparisons were made using post-hoc Tukey's test.

RESULTS

Table 1 shows descriptive results regarding the fracture strength of samples based on porcelain thickness. The mean fracture strength increased from 190 to 775 N with an increase in the veneering porcelain thickness from 0.5 mm to 1.5 mm. The highest fracture strength was noted in 1.5 mm thickness of dentin porcelain (Figure 2).

One-way ANOVA was used to compare fracture strength among the three thicknesses of porcelain. This test showed a significant difference in fracture strength among the three groups (P=0.000). Using Tukey's HSD test, the fracture strength in use of 1.5 mm thickness of porcelain was significantly higher than that in the other two groups (P=0.000). Also, the fracture strength was significantly different in presence of 0.5 and 1 mm thicknesses of dentin porcelain (P=0.000).

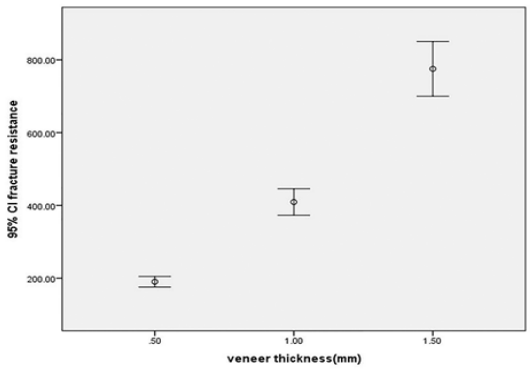

Figure 2: Mean fracture strength of samples based on the veneering ceramic thickness (0.5 to 1.5 mm)

Table 1: Mean and standard deviation of fracture strength in the three groups

Veneering Thickness (mm)	Fracture strength		P value
	Mean± standard deviation	Coefficient of variation	
0.5 mm	190.2±20.3	6.44	<0.001
1 mm	409.3±50.8	16.08	
1.5 mm	775.2±105.1	33.24	

DISCUSSION

Due to high demand for esthetic restorations, metal-free, tooth-colored restorations are becoming increasingly popular. Dental ceramics were introduced to the market to obviate this need. Ceramics are routinely used for dental restorations. However, they are susceptible to fracture particularly in the posterior region. Thus, aside from esthetics, fracture strength of restorations must be taken into account [1, 3]. Ceramic fracture has been reported in both monolithic and layered crowns [21]. This study assessed the effect of the veneering ceramic thickness on fracture strength of ceramic restorations. The results showed that increasing the veneering porcelain thickness increased the fracture strength of restoration.

Review of the literature revealed no study on the effect of thickness of lithium disilicate ceramic on fracture strength of restoration after controlling for other factors. However, many studies have evaluated the effect of total thickness or change in core/veneering thickness ratio on fracture strength of ceramic restorations. The results of some of these studies were in line with ours. Dhima *et al*., (2014) evaluated the fracture strength of lithium disilicate restorations and concluded that by an increase in thickness of the veneering ceramic, higher number of load cycles was required for crown fracture; 1.5 and 2 mm thicknesses of ceramic showed the highest fracture strength [22]. In another study, Chen *et al*., (2014) evaluated the effect of restoration thickness on fracture strength of Lava and IPS e.max computer aided design ceramic systems. They showed that by an increase in thickness of the veneering ceramic, fracture strength significantly increased [21]. Ge *et al*., (2014) showed that increasing the thickness of feldspathic porcelain increased the fracture strength of these restorations [10]. Seydler *et al*., (2014) evaluated the fracture strength of lithium disilicate porcelain restoration with an anatomy similar to that of molar tooth and showed that risk of fracture significantly increased in restorations with less than 0.5 mm porcelain thickness [13]. Shirakura *et al*., [19] and Wakabayashi *et al*., [23] demonstrated that by an increase in thickness of the veneering porcelain, fracture strength of restoration increased.

Our results were in line with those of previous studies. This study showed a significant linear correlation between the fracture strength and thickness of the veneering porcelain such that by an increase in porcelain thickness, the fracture strength significantly increased. The highest fracture strength was noted in presence of 1.5 mm thickness of the veneering porcelain. The mean fracture strength was 190, 409 and 775 N in presence of 0.5, 1 and 1.5 mm thicknesses of the veneering porcelain.

On the other hand, the results of our study were in contrast to the findings of some other studies. Guazzato *et al*., showed that after the application of thermal cycles, by an increase in the veneering thickness, risk of crack formation increased [24]. Nawafleh *et al*., (2018) indicated that increase in core thickness and reduction in the veneering thickness increased the strength of lithium disilicate ceramic restorations. This strength was not affected by cyclic loading [11]. Cattell *et al*., indicated that changing the thickness of IPS 2 restoration and its veneering had no significant effect on fracture strength [25]. According to Briony Webber, porcelain thickness does not significantly affect the fracture strength of restorations [26]. These controversies can be due to different methodology of studies.

An interesting finding of our study was tolerating load over 600 N by 1.5 mm thickness of the veneering ceramic. Since the masticatory and deglutition forces in posterior teeth are in the range of 500-600 N [26], 1.5 mm thickness of the veneering porcelain can well resist maximum masticatory forces in the oral cavity and can be a more appropriate choice for use in the clinical setting.

In previous studies, 250,000 cycles were applied to restorations corresponding to one year of clinical service. In the current study, 500,000 cycles were applied corresponding to two years of clinical service. Also, review articles have shown that most ceramic systems are composed of core ceramic with 0.5 to 1 mm thickness and 1-2 mm space for the veneering ceramic [14,21]. Thus, in the current study, 0.5 to 1.5 mm thicknesses of the veneering porcelain were tested.

It should be noted that several factors affect the fracture strength of ceramic restorations [9]. In the current study, we tried to control for these confounding factors. Wakabayashi *et al*., showed that fracture strength of restorations was correlated to the core/veneering ceramic thickness ratio [23]. Therefore, the thickness of core was considered constant in our study (0.5 mm) and the thickness of the veneering changed to assess its effect on fracture strength. Also, Bakeman *et al*., (2015) evaluated the effect of the veneering ceramic thickness and type of ceramic on fracture strength and revealed that fracture strength was affected by the type of ceramic [14]. In our study, fracture strength of one type of ceramic was evaluated.

Although our results showed the effect of the veneering ceramic thickness on fracture strength in vitro, these results cannot be directly generalized to the clinical setting. To better simulate the clinical conditions, we performed thermocycling and cyclic loading. Also, the designed samples simulated occlusal non-retentive preparation for veneering of posterior restorations and their dimensions were chosen based on the mean dimensions of molar teeth [21]. Moreover, it should be noted that although we tried our best to simulate biomechanical environment in this study, it had some limitations. Unilateral vertical loads applied to samples in cyclic loading only simulate vertical masticatory loads and cannot well simulate the biomechanical environment in the oral cavity.

CONCLUSION

Considering the significant difference in fracture strength of the three groups, it may be concluded that fracture strength increases by an increase in thickness of the veneering ceramic in all-ceramic restorations. Also, the load causing fracture in presence of 1.5 mm thickness of the veneering ceramic was higher than the maximum load applied to restorations in the oral cavity. Thus, 1.5 mm thickness of the veneering ceramic is recommended for use in the clinical setting.

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