Evaluation of the fracture strength of porcelain sectional veneers made from different sintered feldspathic porcelains: An in vitro study

Ocena wytrzymałości na złamanie częściowych licówek porcelanowych otrzymanych z różnych spiekanych ceramik skaleniowych – badanie in vitro

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Abstract

Background. Porcelain sectional veneers with no preparation (no-prep) are an ultra-conservative choice for the esthetic treatment of the anterior teeth. They can be made from a sintered feldspathic porcelain, which gives a great appearance with small thickness, but there are still concerns about the fracture strength of this material.

Objectives. The aim of this study was to evaluate the fracture strength of porcelain sectional veneers made from 2 different sintered feldspathic porcelains.

Material and methods. Twenty recently extracted human incisors were randomly divided into 2 groups according to the porcelain material ($n = 10$). The 1st group was applied the IPS Style® Ceram feldspathic porcelain and the 2nd group – GC Initial™ MC. The porcelain sectional veneers were fabricated following the manufacturers' instructions. After the veneers bonded with resin cement (Variolink® N), the fracture strength was measured using a universal testing machine (Instron®1195) at 1 mm/min until failure occurred. Failure modes were determined under a stereomicroscope.

Results. The mean fracture strength for group IPS Style Ceram was higher than that for group GC Initial MC (182.7 N and 155.7 N, respectively). The lowest value was observed in group IPS Style Ceram (78 N) and the highest value – also in the group IPS Style Ceram (294 N). Student's *t*-test demonstrated no statistically significant differences between the 2 groups ($p > 0.05$).

Conclusions. There was no difference in the fracture strength of the porcelain sectional veneers for the 2 types of sintered porcelain used in this study. Cohesive failure within the porcelain sectional veneer was the most common mode of failure.

Key words: fracture strength, porcelain sectional veneers, no-prep, feldspathic porcelain, ultra-thin veneers

Słowa kluczowe: wytrzymałość na złamanie, częściowe licówki porcelanowe, no-prep, ceramika skaleniowa, ultracienkie licówki

Introduction

Demands for esthetic and conservative treatment are increasing nowadays, especially with regard to the anterior region for malpositioned teeth and diastema.^{1,2} Progress in adhesive technologies has led to a variety of more conservative restoration techniques. For example, ultra-thin veneers with minimal or no preparation (no-prep),^{3–7} and recently porcelain sectional veneers, which are ultra-thin pieces that partially cover the teeth, and can be etched and adhered to the enamel to restore only the defected area while being ultra-conservative. These restorations can have biologically healthy and optically beautiful margins and emergence profiles if properly selected and managed to avoid overcontouring.⁸ Sectional veneers were an acceptable solution for patients, with high survival rates in several case reports.^{9–11}

Composite resin can be used to restore the defects in the anterior teeth. It has the advantage of direct placement at 1 appointment. It is also easily modified and repaired as well as inexpensive. However, low wear resistance and durability, discoloration, surface staining, and polymerization shrinkage are still the disadvantages of this material.^{12,13}

Dental porcelain is usually characterized by color stability, clinical longevity, esthetic appearance, and compatibility with periodontal tissues¹⁴; these characteristics make porcelain a good choice for such treatment. In addition, it can be thinned to less than 0.3 mm, which distinguishes sectional veneers from traditional 0.3–1-millimeter-thick laminate veneers.^{3,15,16}

Porcelain sectional veneers can be made from hot-pressed ceramic, but it does not yield the same esthetic results as build-up feldspathic porcelain, which closely resembles the natural tooth, and due to the presence of fluoroapatite crystals, this kind of porcelain gains a polychromatic appearance and high translucency.^{14,17,18} Many in-vivo studies revealed good survival rates for veneers made from feldspathic porcelain.^{18–20} The main limitation of sintered feldspathic porcelain is its fragile nature, especially in the case of low thicknesses as in sectional veneers,¹⁴ so there are still concerns about the fracture strength of this material and its ability to be used for fabricating sectional veneers. In addition, in vitro studies on sectional veneers are not available, so the aim of this study was to evaluate the fracture strength of porcelain sectional veneers made from 2 different sintered feldspathic porcelains.

Material and methods

Twenty recently extracted caries-free human incisors of similar dimensions were randomly selected for this study, and adhering soft tissues and calculus deposits were removed with a hand scaler. The teeth were stored

in 0.5% chloramine-T solution for a week and then in distilled water. Chloramine-T solution was chosen to store the extracted teeth according to the ISO recommendations.²¹

The teeth were divided into 2 groups (n = 10) according to the type of feldspathic porcelain used: the 1st group was applied sectional veneers made from the IPS Style[®] Ceram (Ivoclar Vivadent, Schaan, Liechtenstein) porcelain and the 2nd group – the GC Initial[™] MC (GC Nordic AB, Stockholm, Sweden) porcelain. Then, the teeth were embedded perpendicularly in self-cure acrylic resin blocks (18 mm × 18 mm × 18 mm), 2 mm below the cemento-enamel junction, using a dental surveyor so that during the loading test, the load could be applied parallel to the long axis of the tooth.

Fabrication of the porcelain sectional veneers

No preparation was made for the teeth. Customized trays were used for making the impressions with a polyvinyl siloxane impression material (Elite[®] HD+; Zhermack SpA, Badia Polesine, Italy).

The veneers were fabricated from a sintered feldspathic porcelain material using the conventional refractory die technique according to the manufacturer's recommendations. The sectional veneers extended gingivally to the cemento-enamel junction, buccally to the bucco-proximal line angle and lingually to the lingual-proximal line angle; the incisal edge was extended by 1 mm with a sectional veneer following the same natural incisal thickness of the tooth without covering it. The bucco-lingual thickness of the tooth was measured before and after bonding the sectional veneers. The difference between the 2 measurements resembled the sectional veneer thickness and was limited to 0.1 mm.

The impressions were cast in an investment material (G-Cera[®] Orbit Vest; GC America Inc., Alsip, USA) using a dental vibrator. After an hour, the cast dies were carefully separated from the impressions. A degassing process was performed for the dies in 2 stages; firstly, the temperature was gradually raised to 700°C over 1 h in a heating furnace, secondly, the dies were placed in a porcelain furnace with the temperature being raised from 700°C to 1,050°C and maintained for 5 min at this temperature. A thin layer of connector paste was applied on the dies using a brush. Then, the dies were placed again in a porcelain furnace, heated up to 950°C, removed, and cooled to room temperature. The porcelain sectional veneers were built up on refractory dies using the conventional technique (powder/liquid), shade A1 for GC Initial MC and A3.5 for IPS Style Ceram. Then, the veneers were fired in a furnace according to the manufacturers' instructions. The veneers were gently sandblasted to remove the residual investment material using aluminous oxide 50 µm from a distance of 10 mm at a pressure of 1 bar.

Bonding of the porcelain sectional veneers

The enamel was etched for 30 s using a 37% phosphoric acid etching gel (Total Etch®; Ivoclar Vivadent). Then, the tooth surface was rinsed with water for 20 s and gently air-dried. One layer of a bonding agent (Tetric® N-Bond Universal; Ivoclar Vivadent) was applied and light-cured for 20 s. The inner surface of the sectional veneer was etched with 5% hydrofluoric acid (IPS® Ceramic Etching Gel; Ivoclar Vivadent) for 60 s, rinsed thoroughly and air-dried. One thin layer of a silane coupling agent (Monobond® S; Ivoclar Vivadent) was applied for 60 s.

The porcelain sectional veneers were bonded using light-cure translucent resin cement (Variolink® N; Ivoclar Vivadent). The veneers were positioned on the teeth, held in place with finger pressure and light-cured with LED curing light (Guilin Woodpecker Medical Instrument Co., Ltd., Guilin, China) for 5 s at light intensity of 800 mW/cm². The excess cement was removed with blade 12. Then, the veneer was light-cured from the lingual, facial and incisal sides for 40 s. The margins were finished with a diamond bur and rubber disks. Figure 1 shows the final sectional veneers after bonding. The specimens were stored in distilled water at room temperature for 24 h before being subjected to mechanical tests.

Fig. 1. Final sectional veneers

On the left – IPS Style Ceram porcelain; on the right – GC Initial MC porcelain.

Fracture strength test

A fracture strength test was performed by applying progressive load to the specimen until fracture occurred. A universal testing machine (Instron® 1195; Instron, High Wycombe, UK) was used (Fig. 2). The load was applied at a crosshead with a speed of 1 mm/min at the incisal edge of the porcelain sectional veneer parallel to the long axis of the tooth. The maximum force that produced failure was recorded in newtons. The failure mode was categorized as cohesive (failure within the porcelain sectional

veneers or teeth), adhesive (failure between the porcelain sectional veneer and the tooth) or mixed. The failure mode was examined under a stereomicroscope at ×20 magnification.

Fig. 2. Load applied at the incisal edge using the Instron testing machine

Statistical analysis

The data was analyzed statistically using SPSS Statistics for Windows v. 17 (SPSS Inc., Chicago, USA). Student's *t*-test was used to compare the mean values of fracture strength between the 2 groups at a significance level of 95% ($p < 0.05$).

Results

Figure 3 and Table 1 show the mean values of fracture load and standard deviations (*SD*) for each group. Although the IPS Style Ceram group presented higher fracture strength, Student's *t*-test showed no significant differences between the sectional veneers made from GC Initial MC and IPS Style Ceram porcelain. The use of different sintered feldspathic materials did not affect the fracture strength at the significance level ($p > 0.05$) (Table 2).

Figure 4 shows the failure modes for the 2 groups. Cohesive failure of the porcelain sectional veneer occurred in most specimens, whereas a tooth fractured in only 3 specimens. There was no adhesive failure.

Fig. 3. Means of fracture strength [N] for the materials tested

Table 1. Descriptive data for the fracture strength values [N] for the test groups

Group	SD	SEM	Minimum	Maximum
IPS Style Ceram (n = 10)	76.4	28.9	78	294
GC Initial MC (n = 10)	86.7	28.9	78.4	284.2

SD – standard deviation; SEM – standard error of the mean.

Table 2. Results of paired comparisons using Student's *t*-test

Statistical data	Value
<i>t</i>	0.6499
<i>df</i>	18
difference between the means	27
<i>SE</i> of the difference	41.5
<i>p</i> -value	0.5263*

df – degrees of freedom; *SE* – standard error;

* statistically non-significant ($p > 0.05$).

Fig. 4. Incidence of fracture modes

Discussion

The present study investigated the difference in fracture strength of 2 types of sintered feldspathic porcelain used to fabricate porcelain sectional veneers. This type of restorations is an esthetic and conservative option that requires no tooth preparation and is ultra-thin, which makes the bonding remain on the enamel, consequently ensuring the best adhesion possible. Sectional veneers have many advantages, such as the needlessness of provisional restorations, no post-operative sensitivity and a simplified impression technique. The advantages of using sintered feldspathic porcelain include esthetics, low laboratory cost and excellent mechanical retention after bonding with resin cement.

Fracture is an important clinical problem. The most frequent kinds of failure associated with feldspathic porcelain veneers are fracture, debonding and microleakage,²² so the fracture strength of these materials must be taken into consideration.

In the present study, natural anterior teeth were used instead of acrylic or metallic dies, because they differ in elasticity and strength compared to the teeth. Besides, the study aimed to mimic the clinical situation as much as possible with respect to the adhesive bonding protocol.

In the present investigation, the teeth were embedded in acrylic resin blocks to facilitate testing procedures, such as preparing the impressions and bonding, and the specimens were later put into a testing machine. All specimens were embedded in acrylic resin without a simulated periodontal ligament that is usually used as a shock-absorbing layer. Currently, there is no consensus in the dental literature whether or not to use it; it may be of no importance in the case of progressive load like in this study.^{23–25} This research was conducted with regard to exact laboratory and clinical procedures, such as preparing impressions, casting with investment, sandblasting, and bonding to the teeth with resin cement, which make the results more clinically relevant.

Different load direction and placement were observed in the literature. In some studies, the teeth were loaded at the palatal surface,^{23,26,27} whereas in most other studies, the force was applied at the incisal edge parallel to the long axis of the tooth.^{24,28–33} Loading the force at the palatal surface would lead to the failure of the tooth structure itself. This angle might also cause the Instron crosshead to slide along the palatal surface of the tooth. Therefore, in the present study the load was applied at the incisal edge and according to the longitudinal axis of the specimens.

The sample size involved 10 teeth in each group like in many previous studies.^{23,27,29,31,32} When dividing *SD* by the mean (which is called the coefficient of variation), the result is <1 . Such a large deviation can be considered low variance and statistically correct.

There were no statistically significant differences in the fracture strength of the porcelain sectional veneers between the 2 studied materials.

No previous *in vitro* or *in vivo* studies on sectional veneers were found in the literature except for a few case reports. However, 1 study found that minimally invasive tooth preparation (0.2 mm) allowed higher fracture resistance in the case of restorations with lithium disilicate ceramic veneers.³⁴ Another study compared the fracture strength and other properties of the veneers fabricated using different techniques and materials, and concluded that there were fewer marginal discrepancies with feldspathic porcelain and that the fracture strength decreased when more covering to the dental tissue was applied.²⁴ Yet another study showed that more preparation for the dental tissue could be associated with a decreased shear strength of lithium disilicate laminate veneers.³⁵

The results of this study showed that the mean fracture strength of the IPS Style Ceram porcelain was 182.7 N and in the case of the GC Initial MC porcelain, it was 155.7 N. This result is close to that obtained by Alghazzawi et al., who found that the mean fracture strength was 161 N,³⁶ whereas Zarone et al. found that it was 220 N.³⁷ In the study conducted by Lin et al., laminate veneers fractured at 450 N.²⁴ They investigated the fracture load of feldspathic porcelain veneers using standardized composite resin dies, which may have affected their results.²⁴ However, Turkaslan et al. reported higher results (800 N),³¹

Fig. 5. Different modes for fractured sectional veneers

Fig. 6. Cohesive failure of the tooth

which might be due to the use of full veneers as well as the differences in the thickness of porcelain and the fabrication technique (computer-aided design and computer-aided manufacturing (CAD CAM)).

This study showed no adhesive failure; the main failure mode was the cohesive failure of the porcelain veneers (Fig. 5) followed by the tooth fracture. This finding may imply that the bond strength was high enough to withstand loading and eventually failure would occur cohesively within the veneer or the tooth itself. This result coincides with previous studies.^{24,32,36,38–40} However, different failure modes were reported by other researchers,^{29,30,37} which could be explained by the differences in the load direction, type of ceramic, adhesive cement, and bonding procedure. Three specimens showed cohesive failure in the tooth structure (Fig. 6). A possible reason for this could be that the load was high enough to exceed the proportional limit of the tooth,^{33–39} especially in the teeth with thin roots. In general, extracted human teeth vary in quality and standardizing this factor is difficult.

The average masticatory force reaches 130 N in the anterior teeth and the mean value of fracture strength in the present study was higher than the average masticatory force.⁴¹

Some limitations of this study need to be mentioned. Extracted human teeth greatly vary in size, shape and quality, which may influence the results, so it is better to use a larger sample size. Further studies involving other types of ceramic should be performed. This study was conducted under dry and static conditions, therefore not exactly mimicking the wet and cyclic nature of the oral environment. Apart from that, porcelain in the oral environment is subjected to thermal and chemical factors, which is why *in vivo* studies are needed.

Conclusions

Within the limitations of this in vitro study, it can be concluded that sintered feldspathic porcelain used for sectional veneers did not affect the fracture strength. The fracture of the porcelain sectional veneer was the most common failure mode.

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