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ORIGINAL RESEARCH

Overlays or Ceramic Fragments for Tooth Restoration: An Analysis of Fracture Resistance

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ABSTRACT

Purpose: The aim of this study was to evaluate the mode of fracture and resistance of partial ceramic restorations of posterior teeth.

Materials and methods: Thirty healthy upper premolars were selected and divided into three groups (n = 10): Group 1—control, healthy unrestored teeth, group 2—teeth restored with ceramic fragments; and group 3—teeth restored with ceramic overlays. The restorations were manufactured with feldspathic ceramic and cemented with RelyX ARC resin cement. After being stored in distilled water for 7 days, the teeth were subjected to axial compression mechanical testing with a universal testing machine. Force was applied to the long axis of the tooth at a speed of 0.5 mm/min until fracture. The data were analyzed with one-way ANOVA and Tukey's test (5%). The mode of fracture was scored according to the degree of involvement of the tooth structure and the type of restoration.

Results: A significant difference ($p < 0.05$) was showed between groups 2 (1155 N) and 3 (846.6 N), but there was no significant difference between group 1 and the other groups (1046 N), More extensive fractures were prevalent in the healthy teeth group (Group 1), which had no occlusal coverage; less severe fractures were found in groups 2 and 3.

Conclusion: We conclude that teeth restored with ceramic fragments may offer greater resistance to fractures compared to teeth that have overlay restorations.

Keywords: Ceramics, Compressive strength, Dental restoration.

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INTRODUCTION

Alterations or wear on the occlusal surface of teeth usually appear as a result of physiological wear or from the parafunctional habits of clenching or bruxism.[1] These alterations usually cause a loss of occlusal anatomy, which often must be recovered by restorations. When teeth show reduced height, they can be rehabilitated with prosthetic crowns. Alternatively, rehabilitation can be performed with restorations with partial preparations of the overlay type. When the coronal height is sufficient, these restorations can provide total coverage of the cusp.[2] In teeth with extensive coronal destruction and endodontic treatments, indirect restorations that increase fatigue resistance are recommended instead of direct restorations.[3]

Dental ceramics are one of the most prevalent dental materials for the partial or total restoration of teeth that are physiologically worn, worn from parafunctional habits, or destroyed by cavities or fractures. Full crowns, inlays, onlays, and overlays are routine procedures, and ceramics are the materials of choice for manufacturing indirect esthetic restorations. The mechanical properties of ceramics include high resistance to abrasion, compression, bending, and fracture; low thermal and electrical conductivity; chemical stability and good wear resistance.[4,5] In addition to the clinical longevity and satisfactory biomechanical properties of ceramics, the esthetic results of working with ceramics are predictable, and ceramics are increasingly biocompatible with periodontal structures.[5-7]

In posterior teeth, the removal of the tooth structure during the course of cavity preparation is directly related to a decrease in fracture resistance.[8,9] Occlusal cusp coverage should be considered, as increased coverage strengthens the remaining tooth structure.[10,11] In teeth that are physiologically worn or have been damaged by parafunctional habits, partial ceramic restorations are indicated to preserve the tooth structure and to restore esthetics and dental anatomy.

The manufacturing of restorations with little or no tooth preparation, which is known as ceramic fragments, has been suggested in the literature.[6,12] To preserve the healthy tooth structure, this conservative technique represents one of the primary advantages of using ceramic fragments and can be performed with minimal or no dental preparation.[12]

Combined with the favorable mechanical characteristics of ceramics and the possibility of using adhesive cement, partial ceramic restorations of posterior teeth have been increasingly used.

To improve the esthetic and functional levels, a variety of full-coverage and metal-free ceramic systems have been introduced to the market. Systems that are made from other materials, such as alumina, leucite, and lithium disilicate, also provide the appropriate esthetic, physical and mechanical properties.[13-15] A variety of ceramics are used to manufacture restorations. For example, feldspathic ceramics include crowns, veneers, inlays, onlays, overlays, and ceramic fragments. Feldspathic ceramics combine the desired esthetic properties with color stability, biocompatibility, and the possibility of being etched with hydrofluoric acid, which improves the efficiency of the bond to the dental structure.[16]

Combined with the proper planning, the intrinsic characteristics of ceramics ensure the success and longevity of oral rehabilitation treatment. However, the clinical failure of ceramic restorations is associated with parafunctional habits, such as bruxism/teeth clenching, and clinical failure can lead to secondary cavities, material fractures, marginal deficiencies and postoperative sensitivity.[7,17]

Therefore, the objective of this study was to conduct an *in vitro* evaluation of the fracture resistance of human maxillary premolar teeth that were restored with ceramic fragments and overlay restorations with a feldspathic ceramic, The null hypothesis was that there would be no significant differences among the studied treatment types.

MATERIALS AND METHODS

Thirty upper premolars with similar mesiodistal and vestibulolingual dimensions were extracted for orthodontic reasons were selected for the present study. Healthy teeth, free of cavities, cervical injuries, enamel or restoration cracked/defects were selected. This study was approved by the Ethics Committee at CEUMA University (n. 657/2007).

The teeth were cleaned, immersed in 0.1% thymol, and stored in distilled water at 37 ± 1°C. Using a delineater, the teeth were vertically positioned in the center of polyethylene tubes. The samples were embedded in cured acrylic resin (JET-Clássico Artigos Odontológicos LTDA, São Paulo, SP, Brazil) with 1 mm of exposed root.

The teeth were randomly divided into three experimental groups (n = 10) with the following treatments: G1-intact teeth without any preparation (positive control); G2-unprepared teeth restored with ceramic fragments with 1 mm thickness; and G3-teeth with extracoronal preparation restored with overlays measuring 1 mm in thickness.

To standardize the samples, no dental preparations were performed in G2, and only the retentive areas were eliminated with a fine-grain 4137F drill (KG-Sorense, Barueri, SP, Brazil). In G3, the following standardized dental preparations were performed for overlays: the occlusal box was established with a depth of 2 mm, one-third of the intercuspal distance, and had expulsive vestibular and lingual walls with a rounded axiopulpal angle; the proximal box was established with a depth of 1.5 mm, expulsive vestibular and lingual walls, and a gingival wall that was 2 mm from the pulpal wall. All preparation angles were rounded (Fig. 1).

To manufacture the ceramic fragments and overlay restorations, a kiss feldspathic ceramic was used (DUCERAM, Hanau-Wolfgang, Germany). The thicknesses of the fragments and ceramic overlay restorations were checked with a thickness gauge (BioArt Artigos Odontológicos LTDA, São Paulo, SP, Brazil) to obtain similar thicknesses for all of the samples. Internal adaptation of the indirect restorations was carefully verified on each tooth to obtain the minimum possible space. After the procedure was completed, restoration finishing and glazing were conducted.

Following the manufacturer's recommendations, the inside of the ceramic restorations was etched with 10% hydrofluoric acid (FGM, Joinville, SC, Brazil) for 1 minute, and silane (3M ESPE, St, Paul, MN, USA) was applied with a microbrush. Subsequently, one layer of Adper Scotchbond Multipurpose adhesive (3M ESPE, St. Paul, MN, USA) was applied.

After prophylaxis was performed and pumice was applied to the dental structure, the dental surface was treated with phosphoric acid at 37% (FGM, Joinville, SC, Brazil) for 15 seconds, and the surface was dried with absorbing paper. A layer of primer and Scotchbond Multipurpose adhesive were used.

RelayX^{TM} ARC (3M ESPE, St. Paul, Minnesota, USA) resin cement was used for the cementation of overlays and ceramic fragments. The base paste/catalyst proportion and the cement mixture were prepared following the manufacturer's recommendations. Resin cement was applied

Fig. 1: Fragment (G2) and ceramic overlay (G3) specimens

Fig. 2: Applying a static load to the sample with a universal testing machine

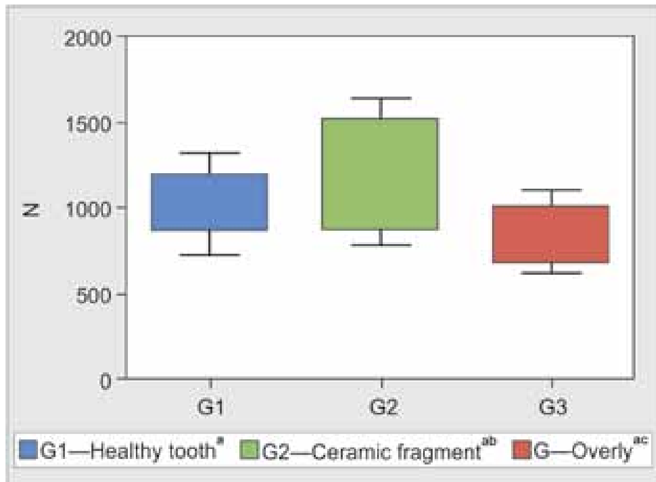

Fig. 3: Turkey's test. minimum and maximum values of fracture resistance for the three groups [Groups with different letters are significantly different from each other ($p < 0.05$)]

Table 1: Fracture resistance values (N) of the experimental groups

Groups	*Mean (standard deviation)*	*Minimum*	*Maximum*
G1–Healthy	1.046 (202.2)	723.8	1.309
G2–Fragment	1.155 (317.4)	773.3	1.643
G3–Overlay	846.5 (183.7)	615.3	1.098

on the inner surface of the ceramic fragment and overlay, which was positioned and set with an initial manual pressure that allowed the excess material to overflow. A constant pressure of 0.5 kg was then applied. After elimination of the excess cement photopolymerization was performed for 40 seconds on the vestibular and lingual phases of each tooth, The samples were stored in distilled water at 37 ± 1°C until the experimental tests were performed.

The fracture resistance test was performed in a universal testing machine (EMIC DL 2000, São José dos Pinhais, Brazil); a 2.5 mm rounded device was used to transmit the load on the occlusal surface of the teeth.[3] The samples were positioned on a base that was connected to the test machine so that the force was applied parallel to the long axis of the tooth.

A progressive static load was applied at a speed of 0.5 mm/min using a 2000 KGF cell until each sample fractured (Fig. 2). The area at the medial third of the occlusal tooth surface was standardized to ensure that the load distribution would be conducted in the same direction on all teeth.

After the fracture resistance test, the samples were analyzed to determine the mode of fracture. The mode of fracture was determined using the scores that were proposed by Burke[18] (1992): Type I: fractures involving a small portion of the coronal tooth surface; Type II: fractures involving a small portion of the coronal tooth structure and restoration cohesive failure; Type III: fractures involving the dental structure, restoration cohesive, and/or adhesive failure with root involvement that can be restored with periodontal surgery; and Type IV: severe fractures involving the root and crown and resulting in tooth extraction.

STATISTICAL ANALYSIS

A descriptive statistical analysis was performed and is reported in Table 1 and Figure 3. The Kolmogorov-Smirnov test was performed, which confirmed that the data followed a normal distribution. The data were subjected to a statistical model of variance analysis (one-way ANOVA) and a Tukey's test (5%). Statistical significance was set at 5%. To perform the statistical tests, the software programs PASW Statistics (version 17.0, release 17.0.2.2009) (Indianapolis, IN, USA) and GraphPad Prism (version 5.00.2007) (San Diego, CA, USA) were used.

RESULTS

The one-way ANOVA test showed significant differences among the groups ($F = 3.34$; $p < 0.05$). Means, minimum and maximum values, and the standard deviations of the fracture resistance during the axial compression test are represented in Table 1.

According to the post hoc Tukey's test (5%) (Fig. 3), the compression resistance was significantly different between G2 and G3, but G1 did not show a significant difference in relation to the other groups. A 95% confidence interval between the groups is represented in Table 2.

The distribution of the modes of fracture is shown in Table 3. The teeth that were restored with ceramic fragments (G2) and overlays (G3) predominantly presented with type II fractures that involved a small portion of the coronal tooth structure and cohesive failure. With no cusp coverage, the healthy teeth (G1) predominantly presented with more extensive fractures involving the root; these fractures could be restored with periodontal surgery.

Table 2: Confidence intervals for the studied groups

Comparison between groups	*Confidence interval (95%)*
G1–Healthy *vs* G2–Fragment	–413.5-196.3
G1–Healthy *vs* G3–Overlay	–105.2-504.6
G2–Fragment *vs* G3–Overlay	3.383-613.2

Table 3: Distribution of the modes of fracture (%) in three experimental groups

Groups	*Type of fracture (%)*			
	I	*II*	*III*	*IV*
G1–Healthy	25	25	50	0
G2–Fragment	0	75	0	25
G3–Overlay	0	87.5	0	12.5

DISCUSSION

Fracture resistance is an issue of great relevance for rehabilitation in patients with significant dental structure wear. This study evaluated the influence of feldspathic ceramic restorations on the fracture resistance of superior premolars. Because there were significant differences between teeth with conservative preparations that were restored with ceramic fragments and teeth with conventional preparations that were restored with overlay ceramic restorations. Thus the null hypothesis proposed was rejected.

Because premolars present an unfavorable anatomic shape with regard to crown volume and the root-crown proportion, premolars are more susceptible than other posterior teeth to cusp fracture from occlusal forces.[18,19] The results of this study found fracture toughness values in the upper premolars from 723.8-1309 N. The clinical literature suggests that the normal force for these teeth varies from 222-445 N,[20] but the occlusal force that is exerted during dental clenching ranges from 520 to 800 N.[21]

In the present study, conventional extracoronal preparations for overlays and conservative preparations for ceramic fragments were applied on superior premolars. There was no significant difference between healthy teeth and teeth with overlay restorations. Other studies[9] found no significant differences between teeth with partial onlay restorations and teeth with total onlay restorations, as ceramic inlay restorations showed greater axial compressive resistance and did not differ from the control premolars.[22] Moreover, no significant differences were observed when comparing the fracture resistance of healthy premolars and the ceramic inlay and onlay restorations cemented on these teeth.

By performing dental preparations for onlay and overlay restorations, the fracture resistance is expected to decrease because of greater wear to the tooth structure. Whenever possible, restorations should be performed to reduce wear to the dental structure.[8,15] The results of the present study corroborate this recommendation, as restorations involved a decrease in the fracture resistance of the dental structure compared to teeth that had undergone more conservative preparations. Several studies indicate the types of cavity preparation and cementing agents that influence the fracture resistance of teeth.[9,15]

In this study, indirect restorations were cemented with an adhesive technique that uses RelyX ARC resin cement, as etching and adhesive cementation of the onlay and overlay restorations are known to reinforce the dental and ceramic structures.[22,23]

Feldspathic ceramics are commonly used for fragment and overlay restorations. While feldspathic ceramics show fracture resistance and greater friability, they have the advantage of allowing etching and bonding, which allows for an effective resin cementation.[23-25] In the present study, the ceramic fragments were cemented to healthy premolar enamel, and only retentive areas were eliminated. This method allowed for the maximal dental structure preservation, effective bonding, and increased fracture resistance, all of which have been corroborated by other studies.[9] In a longitudinal clinical study,[6] satisfactory clinical results and the success of esthetic treatments with porcelain laminates were shown. After 10 years, the veneer porcelain demonstrated a probability of clinical success of 93.5% and treatment failures were associated with bruxism and loss of vitality.[7]

The mechanical properties of the materials that are used to restore a tooth can influence the behavior and progression to fracture between the tooth/restoration complex.[18] A review of the literature shows that the mode of fracture of teeth with ceramic restorations is similar to the modes of fracture of nonrestored healthy teeth.[22,26] In ceramic restorations, the fracture profile is less catastrophic than in teeth that have been restored with amalgam restorations or indirect restorations with composite resin.[12] We verified that 75% (G2) and 87.5% (G3) of the teeth had cohesive restoration fractures that involved a small portion of the coronal structure (Type II). These fractures were less catastrophic than the fractures that were observed in G1, where 50% of the fractures involved the radicular portion of the tooth and could only be restored with periodontal surgery (Type III).

Based on these results, ceramic fragments are a feasible and conservative option for clinical use, but more clinical and laboratory studies are needed to identify and correlate other factors, such as the longevity and clinical application of ceramic fragments.

CONCLUSION

Within the limitations of this *in vitro* study, we conclude that teeth that have been restored with feldspathic porcelain ceramic fragments can offer greater resistance to fractures compared to teeth that have been restored with overlays.

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