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Original Article

Effect of Access Cavity Preparation and Cement on the Fracture Load of Translucent Zirconia Crowns

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Abstract

Purpose: To evaluate the effect of endodontic access hole preparation and choice of luting cement on the fracture resistance of translucent zirconia (5Y) crowns.

Materials and Methods: Polymethylmethacrylate (PMMA) dies, representing a prepared maxillary molar tooth, were milled. Translucent zirconia crowns were milled from 5Y (Cercon XTML) zirconia discs and sintered. Forty crowns were divided into four groups (n = 10 per group) based on access hole preparation (accessed, non-accessed) and type of luting cement (resin cement, resin modified glass ionomer (RMGI) cement). Crowns were cemented on the PMMA dies with either resin cement (Panavia SA Cement Universal, Kuraray Noritake Dental Inc.) or RMGI cement (RelyX Luting Plus, 3M, US) under constant weight (500 g) and incubated (37°C) for twenty-four hours. In half of the samples, a uniform endodontic access hole was created using a diamond bur under water irrigation and restored immediately using resin composite (Filtek Supreme Ultra, 3M ESPE). The fracture resistance of the specimens was tested on an Instron 5566 universal testing machine with a stainless-steel ball indenter and the maximum load before failure was recorded as fracture load (N). Two-way ANOVA testing examined the effect of access hole preparation and luting cement on fracture load of the crowns. Statistical tests were two-sided and significance level was set at 95% ($\alpha = 0.05$).

Results: Fracture load was significantly affected by access hole preparation and choice of luting cement ($p < 0.001$). Pairwise comparisons revealed that access hole preparation significantly reduced the fracture load of all specimens, regardless of the type of cement used. When resin cement was used, the fracture load was increased in the accessed and non-accessed specimens.

Conclusion: Access hole preparation and type of luting cement had significant effects on the fracture load of translucent zirconia crowns.

Keywords: *Endodontic Access, Ceramic Crown, Zirconia, Fracture Load*

Introduction

Traditional zirconia (3Y) has become a popular material for single-unit crowns due to its toughness and high strength, wear compatibility against natural dentition, and low cost. However, a drawback of traditional zirconia is its opacity, which can yield less-than-desirable esthetic results. To overcome this drawback, five mol% yttria-stabilized zirconia (5Y) zirconia or third generation zirconia has been developed. This product has been titled “translucent” or “anterior” zirconia because of its greater translucency compared to traditional zirconia [1].

The difference in translucency of 3Y and 5Y zirconia can be attributed to the larger cubic phase present in 5Y zirconia that enhances translucency by preventing light scattering at grain boundaries and residual porosities [2,3]. When compared with traditional lithium disilicate glass ceramics, 5Y zirconia has similar translucency values, but significantly higher strength, making it an attractive option for cases requiring a strong, but aesthetic option [4,5]. Although translucent zirconia has the required flexural strength (type 2 class IV) to be suitable for both anterior and posterior restorations, the flexural strength is significantly lower than that of traditional (3Y) zirconia [1,5]. The chemical and crystallographic changes associated with translucent zirconia lead to a flexural strength that is approximately half that of traditional zirconia (approximately 1100 MPa in 3Y zirconia versus approximately 600 MPa in 5Y zirconia) [5]. In addition to a reduction in flexural strength, the high concentration of cubic phase in translucent zirconia makes it unlikely to undergo transformation toughening, which is a property of traditional zirconia that impedes propagation of an advancing crack by local transformation of tetragonal zirconia to monoclinic zirconia. This reduction in flexural strength and inability of the material to undergo transformation toughening must be considered when performing endodontic access on teeth restored with translucent (5Y) zirconia [1,5].

Another important factor that the clinician must consider when working with translucent zirconia is the selection of the appropriate luting cement. Although the treating endodontist will not ordinarily be involved in the selection of cement, it is an important consideration, as more definitive and widely accepted cementation protocols may influence the survival of translucent zirconia crowns following endodontic access. This is currently confounded by the fact that there is still no general consensus in the literature regarding the ideal zirconia cementation protocol [7,8]. Translucent zirconia shares physical characteristics with both traditional zirconia and lithium disilicate, which further confuses the cement and surface treatment selection process [1]. Modern cements can be categorized as either resin-based or ater-based acid-base cements such as RMGI or zinc phosphate cements. Use of a resin-based cement is termed 'bonding' a crown, as a hybrid layer is formed at the tooth-cement interface. Though an ionic bond forms between the polyacrylic acid of RGMI and the calcium ions in hydroxyapatite of enamel and dentin, use of RMGI cement is not termed 'bonding' a crown, and the strength of the bond formed is significantly lower than that formed between resin cements and tooth structure [9]. According to a recent survey, 71% of lithium disilicate crowns were luted with a resin cement as compared to only 30% of zirconia crowns luted with resin cement. However, in a recent study comparing fracture loads of all ceramic crowns with different luting cements, results showed that luting with resin cement, compared with RMGI, gave the highest fracture resistance in traditional zirconia (3Y), translucent zirconia (5Y), and lithium disilicate crowns, respectively [1].

According to the 3M product guidelines, during crown preparation for a translucent zirconia crown, a minimum of 0.5 mm of tooth structure must be removed in every dimension to retain sufficient mechanical properties [10]. Whitworth et al points out that most teeth are crowned due to damage or wear, and after many cycles of insult, crown preparation may elicit sufficient stress to the dental pulp for irreversible damage to occur [11]. High speed removal of hard tooth structure can cause pulpal damage by overheating, causing disruption to microcirculation and by opening of dentinal tubules, leaving the pulp vulnerable to chemical and microbial irritants [12,13]. If chronic pulpal inflammation and pulpal necrosis develops, endodontic therapy must be initiated. A realistic estimation of the occurrence of loss of pulp vitality in the ten years following crown preparation is between 4-8%, though this estimation assumes that a reasonable effort was made to identify and manage pulpal pathosis prior to treatment, and other estimations place that number as high as 13.3% [11,14]. In total, an estimated 20-50% of all nonsurgical endodontic therapy procedures are performed through full-coverage restorations [4] and surveys report that up to 72% of clinicians would choose to preserve the original crown following endodontic therapy and maintain it as the definitive restoration prosthesis [15,16]. In such situations, an endodontic access through the crown would be sufficient to perform root canal treatment. However, limited data is available on the effect of endodontic access preparation on translucent zirconia crowns.

With the knowledge that approximately 15% of teeth with crowns will eventually require non-surgical root canal therapy, it is crucial that the clinician have a strong understanding of how choice of luting agent and access during endodontic therapy affect the fracture resistance of translucent zirconia crowns. The purpose of this investigation is to determine the effect of access cavity preparation and luting cements on the fracture load of translucent zirconia crowns. The first hypothesis was that the endodontic access hole reduces the fracture load of 5Y zirconia crown significantly. The second hypothesis was that the fracture load of samples bonded with resin cement would be significantly higher than the samples luted with resin modified glass ionomer cement.

Materials and Methods

Sample preparation

In this study, tooth dies were milled out of VITA Enamic blanks (VITA North America) in a 5-axis milling machine (inLab MC X5, Dentsply Sirona) from a master model of a maxillary first molar. After fabrication of the tooth dies, crowns were designed in the CAD software (Exocad GmbH, Germany) and then milled using translucent zirconia (Cercon XTML, Dentsply Sirona) containing 5 mol% yttria (5Y). Crowns were sintered in the furnace (inLab Profire, Denstply Sirona) using the manufacturer's recommended sintering cycle.

Crowns were air-abraded using 50 um alumina particles (Kramer Industries, NJ) at 0.02 MPa pressure for 10 seconds at a distance of 10 mm. Crowns were placed in an ultrasonic bath with deionized water for 10 minutes to remove the remaining alumina particles. Crowns were then cemented on PMMA dies using a resin cement (Panavia SA Cement Universal, Kuraray Noritake Dental Inc.) in half the specimens and a RMGI cement (RelyX Luting Plus, 3M, US) in the remaining half. A 500 g weight was applied to each specimen for six minutes while removing excess cement and light-curing for five seconds from each side. The specimens were kept in an incubator (37°C) for 24 hours. In half of the specimens from each type of cement, an endodontic access was prepared under water irrigation using a diamond bur (ZR6850, Komet). A template was used during access to ensure uniform shape and depth. Access holes were immediately restored with composite resin (Filtek Supreme Ultra, 3M ESPE).

Study Groups:

Forty total crowns were fabricated and divided into four groups (n = 10 per group) based on endodontic access (accessed or non-accessed) and type of cement (RMGI or resin cement); G1, cemented with RMGI without endodontic access; G2, cemented with RMGI with endodontic access; G3, cemented with resin cement without endodontic access; G4, cemented with resin cement with endodontic access.

Fracture load measurement

In order to measure the fracture load of the crowns, specimens were mounted in the universal testing machine (Instron 5566, Norwood, MA) and load was applied through a stainless-steel ball indenter with a rubber coating with crosshead speed of 0.5 mm/min until failure. To improve the distribution of the forces, a 1-mm-thick rubber dam sheet was placed between the crown and the indenter. Fracture load was measured as the maximum load prior to fracture and reported in Newton (N).

Statistical analysis:

The measurements were tested for normality using Kolmogrov-Smirnov test. Descriptive statistics including mean and standard deviation used to report the fracture load of each group. In order to examine the effects of endodontic access preparation and cement type and possible interaction between the independent variables, a Two-way ANOVA test was performed. In addition, pairwise comparisons were performed using Tukey post hoc test and adjusted independent sample T-test. All of the statistical tests were two-sided and statistical analyses were performed in SPSS version 28.0 software (IBM SPSS Statistics, Armonk, NY).

Results

Descriptive statistics are presented in Table 1 and demonstrated in Figure 1. According to Two-way ANOVA test, both endodontic access and cement type had significant effect on the fracture of the tested crowns ($P<0.001$). No significant interaction was found between the two independent variables ($P = 0.813$). Based on the adjusted pairwise comparisons it was found that creating access hole resulted in significant reduction in the fracture load in both RMGI and Resin groups ($P<0.001$). In addition, it was found that that cementing the crowns with resin cement resulted in significant increase in fracture load in the groups received the endodontic access preparation ($P=0.004$). Cementing the crown without endodontic access increased the fracture values when resin cement was used in comparison to resin modified glass ionomer, ($P = 0.048$).

Table 1. Fracture Load (N) of the specimens according to the endodontic access preparation and cement type.

Cement	Endodontic Access		Decrease in Mean Fracture Load Following Access Preparation
	No	Yes	
	Mean ± SD	Mean ± SD	
RMGI	2381.24 ± 437.61	1102.38 ± 190.44	53.7%
Resin Cement	2646.35 ± 357.76	1417.03 ± 277.21	46.4%

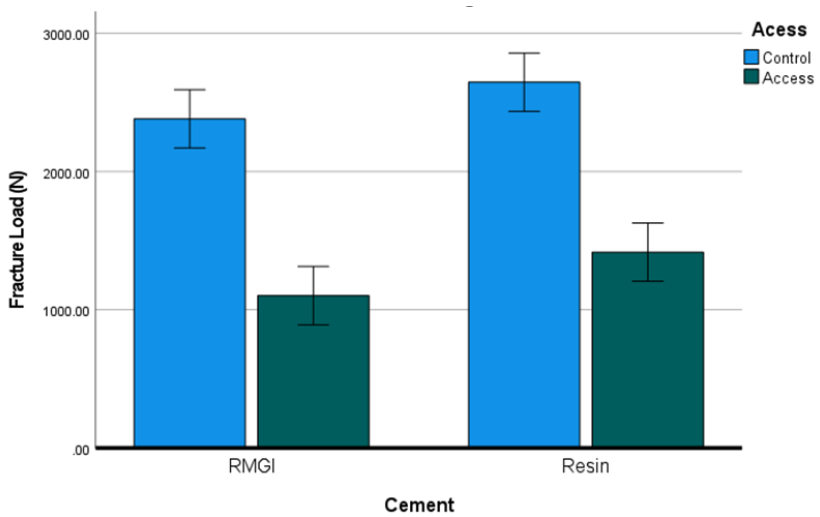

Figure 1. *Fracture Load (N) of the tested groups.*

Discussion

The purpose of this study was to determine the effect of access cavity preparation and luting cements on the fracture load of translucent zirconia crowns. Based on the results, the only hypothesis accepted was that the fracture load of endodontically accessed crowns would be significantly lower than that of non-accessed crowns. The second hypothesis was also accepted as fracture load of crowns bonded with resin cement was significantly higher than those luted with RMGI only in the accessed and non-accessed groups. Although bonding increased the fracture load in the non-accessed group.

In this study, it was found that access hole preparation reduced the fracture resistance of translucent zirconia crowns. There are several studies which have evaluated the effect of access cavity preparation on fracture resistance of various crown materials. Mallya et al. [17] found that endodontic access preparation through zirconia crowns luted on extracted molar teeth led to significantly lowered fractured load. Additionally, Nejat et al. [18] found that endodontic access through traditional zirconia (3Y) and translucent zirconia (5Y) crowns had a significant impact on fracture load when the specimen occlusal thickness was <1.0mm and <1.5mm respectively. In the present study, the occlusal thickness of the crowns varied based on the location on the occlusal table, but was always less than 1.5mm, making the results of this study consistent with previous findings [17]. A systematic review by Gorman et al [19] included eight *in vitro* studies which evaluated the effect of access cavity preparation on all-ceramic crowns. The authors found that failure load was influenced by the type of ceramic material used, the grit size of the diamond bur used during access, the luting agent, and the method of crown fabrication. The protocol used to repair the access cavity was the only factor that did not influence fracture load [19].

Panavia SA Cement Universal is a self-adhesive resin cement that partially demineralizes and forms a hybrid layer at the tooth-cement interface. This differs from the mechanism of action of RelyX Luting Plus Cement, an RMGI containing polyacrylic acid that creates an ionic bond with the calcium ions found in hydroxyapatite of dentin and enamel. Several studies have shown that the dentinal bond created when using resin cement is significantly stronger than that created with RMGI cement.

One such study by De Angelis et al. [6] showed that the shear bond strength of traditional (3Y) and translucent (5Y) zirconia was significantly higher when using Panavia SA Cement Universal compared to an RMGI cement (FujiCEM 2, GC America). Chen et al. [20] evaluated the effect of luting agents on the fracture resistance of translucent zirconia (5Y) crowns and found that bonding with resin yielded significantly higher fracture loads compared to luting with RMGI. Similarly, the present study found that bonding the samples with resin cemented increased the fracture resistance of the crowns in both non-accessed and accessed groups.

In this study, endodontic accesses were cut by an endodontic resident using a jig to facilitate standardized shape and depth. Each access was in the shape of an equilateral triangle, with each side measuring 3mm in length. The depth of the access cavity was consistently 8mm, measured from the buccal cusp tip to the pulp chamber floor. An endodontic microscope was used during access to aid in visualization. Limiting the size of the access cavity was important, as this can directly affect the fracture load of ceramic crowns and natural teeth [21]. Cutting through ceramic crowns can be challenging and it is imperative to choose a bur that will allow maximum cutting efficiency with minimal crown damage. Microcracks, chipping, and even catastrophic crown failure are all possible sequelae of endodontic access through ceramic crowns. Gorman et al [19] reported that accessing with a large diamond grit size (150-180μm) significantly lowered the fracture resistance of lithium disilicate crowns. Similarly, Qeblawi et al. [22] found that using a 126-μm grit size, compared to a larger grit size, led to decreased damage of the lithium disilicate specimens, and helped maintain integrity of the bonded interphase. Finally, Chen et al. [20] found that a small diamond grit size was more effective for endodontic access through ceramic crowns. In the present study, accesses were cut using a medium-grit (107μm) diamond round bur (1.4mm diameter), with a new bur used for each access. Copious water spray was used during access which acts as a coolant and a lubricant, reducing heat buildup that can lead to microcracks and improving cutting efficiency.

Several limitations exist in this study. The translucent zirconia crowns were luted onto PMMA dies which replicate the physical characteristics of natural dentin. However, to extrapolate the results of this study to the clinical setting, crowns would ideally be cemented onto natural teeth. The choice to use PMMA dies was made to allow standardization between samples and to control for confounding factors which would have been impossible to control if natural teeth were used. Another limitation of this study was that the occlusal anatomy of the crowns may have prohibited the even distribution of force during occlusal loading. Every effort was made to position each crown so that the pistol of the Instron machine had the same 3 points of contact for every sample. A rubber dam was also placed between the occlusal surface and the pistol to aid in load distribution. The points of contact produced in this experiment do not emulate the same points of contact that a human maxillary molar would have while in functioning occlusion. A final limitation was that the crowns did not undergo fatigue load cycling prior to fracture. Fatigue load cycling and aging are helpful ways to replicate the clinical function of crowns more accurately. Future studies would be recommended to address these limitations by using a protocol that more closely simulates the clinical environment.

Conclusion

Based on this study, endodontic access preparation and choice of luting cement have a significant impact on the fracture load of translucent zirconia crowns. Accessed crowns had significantly lower fracture load than non-accessed crowns, regardless of the type of luting cement used (resin or RMGI). When resin cement was used, fracture load was significantly increased in the accessed and non-accessed specimens.

Conflict of Interest

The authors declare no conflict of interest.

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