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Fracture strength and failure load of CAD/CAM fabricated endocrowns performed with different designs

Fernanda Angeloni de Souza[1], Catarina Borges da Fonseca Cumerlato[1,*], Pedro Paulo Feltrin[2], Ricardo Tatsuo Inoue[2], Raquel Virginia Zanetti[2]

[1] Graduate Program in Dentistry, Department of Restorative Dentistry, Federal University of Pelotas, Pelotas, RS, Brazil. ORCID

[2] Graduate Program in Dentistry, São Leopoldo Mandic College, São Paulo, SP, Brazil.

Aim: Endocrown restorations are commonly used to rehabilitate endodontically treated posterior teeth and their use is well-founded in these cases. However, to date, there is little scientific evidence of their behavior in anterior teeth. The aim of this in vitro study was to evaluate the compressive strength of upper central incisors teeth, restored with glass-ceramic total crowns by the conventional anatomical core technique, and compare them to teeth restored with endocrowns with and without the presence of ferrule. **Methods:** Thirty teeth were randomly distributed into three groups: GE2 - endocrown group with 2 mm ferrule, GE0 - endocrown group without a ferrule, and GC - conventional crown with intraradicular post group. Crowns were cemented and teeth submitted to the 45º compression test until the fracture happened. Fractured specimens were analyzed to determine the fracture pattern. Descriptive analysis of the variables was performed and one-way analysis of variance was utilized to analyze the data for significant differences at $p < 0.05$. **Results:** The results of the control group (284.5 ± 201.05N) showed the highest fracture resistance value, followed by the 2mm group (274.54 ± 199.43N) and by the 0mm group (263.81 ± 80.05N). There was no statistically significant difference between all the groups ($p = 0.964$). **Conclusions:** The absence of a cervical enamel necklace favored a debonding of the pieces and endodontically treated anterior teeth could be restored with endocrown, which could be considered a conservative and viable treatment option.

Keywords: Endodontics. Computer-aided design. Crowns. Flexural strength.

Corresponding author:
catarinacumerlato@hotmail.com
Federal University of Pelotas,
Graduate Program in Dentistry
Rua Gonçalves Chaves 457.
96015-560, Pelotas-RS, Brazil
Tel./Fax: +55-53-3222.6690

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Introduction

Restoration of endodontically treated teeth (ETT) is often a clinical challenge because the ETT are frequently fragile and more susceptible to fracture than vital teeth due to loss of structural integrity, as a result of caries, trauma, previous restorations, and endodontic treatment[1-3].

With the development of adhesion methods, endocrowns can be used to restore supragingival structure of posterior demaged teeth. The advantages of using these restorations include fewer dental structures preparation compared with post and cores, as well as reduced intervention in the root canals[4,5]. This is an important advantage since it is know that the higher the ferrule of tooth, the higher the fracture resistance[6]. Moreover, compared to traditional methods they need less time to be made and fewer interfaces between each part of the restorations and the teeth. Five-year clinical observations reveal that 87.1% of endocrowns in posterior teeth functioned well, without fracture or debonding[7,8].

Considering all of these critical factors, endocrowns restorations are commonly used for restoring endodontically treated teeth[9-11]. Besides that, an in vitro study has investigated the fracture resistance of restorations from endodontically treated anterior teeth and promising results for endocrowns were found[12]. However, there is limited evidence about the endocrown's behaviour with and without ferrule component, compared to conventional crown technique. In addition, it is not possible to find, in the available literature, accurate information on the use of endocrowns for the rehabilitation of incisors.

In this sense, this study aimed to evaluate the fracture strength of teeth restored with glass-ceramic total crowns by the conventional anatomical core technique and compare them to teeth restored with endocrowns with and without the presence of ferrule.

Material and Methods

Ethical Issues

All stages of this study were approved by the Human Research Ethics Committee of the School of Dentistry and Dental Research, São Leopoldo Mandic (Process Number 2.604.244/18).

Specimen Preparation

Thirty maxillary central incisors with complete root formation were collected from the Tooth Bank of the School of Dentistry at the Health Science Center/Federal University of São Paulo. Teeth were examined under ×4 magnification and cleaned to remove all tissues and debris.

Then, specimens were randomly distributed into three groups (10 specimens for each): endocrown group with 2mm ferrule (GE2), endocrown group without ferrule (GE0) and conventional crown with intraradicular post group (GC) (Figure 1).

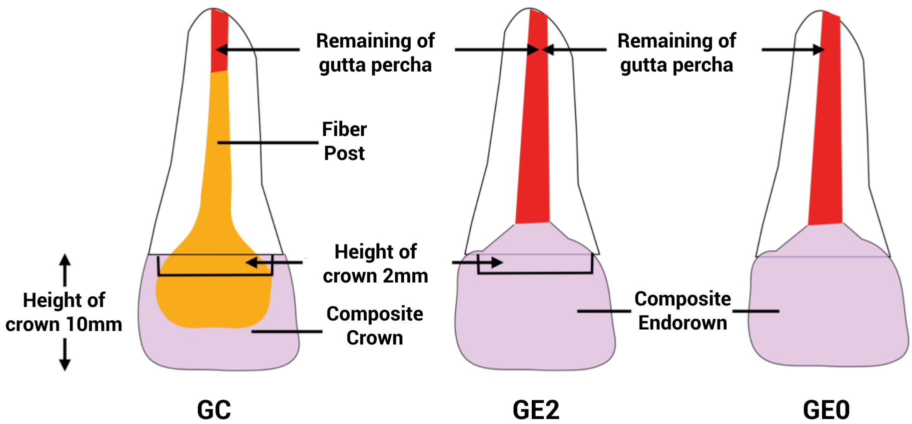

Figure 1. Image of the section type according to the amount of wear. GC - Control group; GE2 – endocrown with 2 mm ferrule group; GE0 – endocrown with 0 mm ferrule group.

All teeth received conventional endodontic treatment, where root canals were prepared up to no. 60 K file using manual instrumentation (Dentsply Sirona, Bensheim, Germany) and irrigation with 2% chlorhexidine. Each canal was then obturated using lateral condensation of the gutta-percha (Dentsply Sirona, Bensheim, Germany), and sealed with sealing cement (AH26, Dentsply Sirona, Bensheim, Germany). The anatomic crowns were reduced according to the predetermined height for the experimental groups. The cement enamel junction (CEJ) served as the circumferential reference for the linear measurement of the remaining coronal heights for each specimen.

Endocrown Preparation and Conventional Crown Preparation

Preparations for endocrowns were performed using a standardization device adapted from an optical microscope. Entrances and undercuts were made 2mm from the cervical margin, limited by the canal anatomy, and then, protected using an adhesive system (Ambar Universal, FGM, Joinville, Brazil) and a flowable resin (Opallis Flow, FGM, Joinville, Brazil).

Roots from Group GC received glass fiber post #1 (White Post, FGM, Joinvile, SC, Brazil) with was anatomized with composite resin (Vitra APS, FGM, Joinville, Brazil) and cemented using an adhesive system (Ambar Universal; FGM, Joinville, Brazil) and dual cure resin cement (Allcem Core – FGM, Joinville, Brazil). To standardize the core height a transparent addition silicone mold (Transil, Ivoclar-Vivadent AG, Schaan, Switzerland), was filled and with the mold sitting on the tooth was light activated for 60 seconds. It resulted in final margins with width of 1.7 mm. Small adjustments were also performed in cases in which the core exceeded the height of 7 mm.

Laboratory Phase

Specimens were scanned using a desktop scanner (Ceramil Mind, Amann Girrbach, Koblach, Austria), and the virtual planning of the standardized crowns was started using the CAD system from the software Total Ceramil Mind. And then, crowns were milled on a 3D printer (Amann Girrbach DNA Motion 2, Koblach, Austria) using blocks of glass-ceramic resin (BRAVA BLOCK, FGM, Joinville, Brazil). Marginal adaptation was checked with the aid of a 4x magnifying glass (EyeMag Smart, Zeiss, Jena, Germany) and samples that showed mismatch were excluded and a new crown milled.

Cimentation

Aluminum oxide blasting (CoeJet, 3M ESPE, Minnesota, USA) was carried out with a pressure of about 3 bar in the internal surface of the crown until it became matte, and then was rinsed for 180 seconds. Subsequently, the adhesive system was applied, waiting for 20 seconds, and a light jet of air was applied for 5 seconds.

The remaining coronary structure was cleaned with pumice and water prophylaxis and washed for 30 seconds to remove debris. Acid conditioning was performed on the enamel for 30 seconds and on the dentin for 15 seconds, and then ilhe structure was rinsed and blot-dried (Ultra-Etch Indispense 35% - Ultradent). Afterwards an adhesive system was applied actively for 20 seconds, and dried for 5 seconds. The cementation of the glass-ceramic pieces was carried out with dual cure resin cement (Allcem Core, FGM, Joinville, Brazil).

After reconstruction, the teeth were fixed in cylinders of a self-curing resin having a height of 30mm and 22mm in diameter and taken to the universal testing machine, model DL 2000 (EMIC, São José dos Pinhais, Brazil).

Fracture Strength Test

To perform the fracture strength test, each specimen in a fixation device was placed obliquely on the base of a universal testing machine (EMIC, São José dos Pinhais, Brazil). A compressive load was applied at a 135-degrees angle to the long axis of the tooth, on the internal and central face of the lingual cuspid of all ceramic crowns[5]. This was done by means of a metal rod 6 mm in diameter at a speed of 1.0 mm/min until failures occurred, represented by fracturing and/or debonding of the tooth and/or crown. The amount of force required to cause failure was recorded for each specimen in Newton (N)[5] (Figure 2).

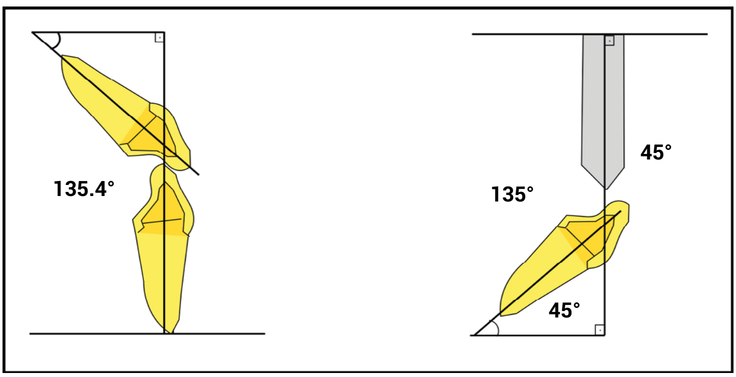

Figure 2. Schematic drawing of test specimens subjected to load at 45° in a universal testing machine. Pressure from the rod tip was applied at a crosshead speed of 1 mm/min (3 mm below the incisal edge) on the palatal surface of the crown.

Data analysis

Statistical analysis was conducted with SPSS 23.0 (SPSS INC., Chicago, USA). Descriptive analysis was performed, presenting the maximum, minimum, means and standard deviations of the variables. One-way analysis of variance (ANOVA) was utilized to analyze the data for significant differences at $p < 0.05$.

Results

Fracture resistance

Table 1 shows the descriptive analysis of the samples from each group tested. The results of the control group (284.5 ± 201.05N) showed the highest fracture resistance value, followed by the 2mm group (274.54 ± 199.43N) and by the 0mm group (263.81 ± 80.05N).

The analysis of variance (ANOVA) showed no statistically significant difference among the tested groups ($p = 0.964$).

Table 1. Descriptive analysis of the sample including the maximum, minimum, mean values of load failure with standard deviation for each tested group (Newton).

Group	N	Max.	Min.	Mean ± SD	P value
					0.964
GE0	10	763.77	93.2	263.81±80.05	
GE2	10	374.07	80.05	274.54±199.43	
GC	10	664.89	131.02	284.50±201.05	

Failure mode

Types of fractures were classified according to the position of the failure and the damage to the prosthetic crown and the dental remnant. The classification was developed by us based on the observation of flaws presented (Figure 3).

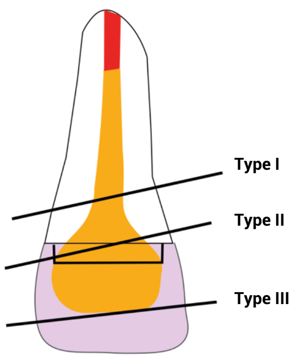

Figure 3. Failure pattern of the specimens according to the type of fracture (I- Catastrophic fracture of the crown and/or remnant (below CEJ); II- Fracture of the crown with remnant above or at CEJ; III- Debonding of the glass-ceramic crown).

The delimited groups were:

I - Catastrophic fracture of the crown and/or remnant (below CEJ);

II - Fracture of the crown with remnant above or at CEJ;

III - Debonding of the glass-ceramic crown.

In relation to the failure pattern, endocrowns with no ferrule (Group 0mm) obtained the highest rates of debonding without fracture of the part and/or dental remnant in 50% of the total sample (Type III), followed by catastrophic fracture of the dental remnant in 30% (Type I). And only 20% of the sample obtained a favorable fracture (Type II).

The endocrown group with 2mm of ferrule showed a catastrophic failure pattern (Type I) in 60% of the sample followed by 30% of the crown fracture with the dental remnant at gingival level (Type II).

Control group showed a higher fracture rate (50%) of the glass-ceramic piece without compromising the post or the dental remnant (Type II), followed by a fracture pattern involving the post and/or root remnant (Type I - 40%).

Discussion

The decision to restore a non-vital tooth with loss of coronary structure can be complex so aspects such as planning, selection of the restorative system and adequate cavity preparation must be carefully considered[13]. The classic alternative to rehabilitate endodontically treated teeth is through the use of intraradicular posts as retainers of total crowns[4,14]. However, with the placement of post and cores, there is a risk of root perforation and thinning of the canal walls due to excessive preparation[15].

The advantages of endocrown restorations include less preparation of dental structures compared to posts and cores, as well as reduced intervention in the root canals. Compared to traditional methods, they need less laboratory and clinical time for the treatment to be completed[16-18]. In addition, the masticatory stresses and forces received to the tooth are better dissipated when endocrows are placed[19]. Nevertheless, some studies show that the full crown is still more reliable than endocrown[4,20].

From the results of this study, we could observe that the group with no ferrule effect showed greater resistance to compression. However, when it was compared to the group with 2mm of ferrule, the group with no ferrule exhibited a higher rate of debonding. This may be attributed to the fact that the surface available for the adhesive joint is reduced, the cementation is only in dentin substrate and there is no ferrule for a better distribution of force, corroborating with another studies[2-5,7,10,11,18].

On the other hand, the group with 2mm of ferrule, showed lower rates of fracture resistance, and the worst results when assessing the fracture pattern of the pieces, since 60% of the samples had catastrophic fractures (Type I) corroborating with the findings from recent studies[8,21]. In contrast, some studies observed that the presence of ferrule increased fracture resistance[2,6]. Extrapolating to the clinical environment, this type of fracture are critically and normally irreparable leading to tooth extraction.

The control group has shown a higher fracture rate (50%) of the glass-ceramic piece without compromising the fiber post or the remnant (Type II), agreeing with several authors[4,18-23]. In relation to failure mode, it has been reported in literature a maximum incisal forces of almost always below 200N for restorations in anterior teeth[24,25.] Our research demonstrated the need of a greater force for fracturing the central incisors than the normal values of oblique loads described in the literature, corroborating with some recent studies[10,19,22,23].

Moreover, it is worth mentioning that this study applied only a static dynamic load, being a limitation that should be considered.

In conclusion, endodontically treated anterior teeth with a ferrule effect of at least 2 mm can be restored with endocrown, as well as using a glass fiber post with an adhesive crown/endocrown. No statistically significant difference was found in fracture resistance and failure mode in upper central incisors cemented with glass-ceramic resin comparing total crown with glass fiber post and endocrown with 0mm and 2mm of a template. In this sense, crowns and endocrowns fabricated from machinable glass-ceramic resin blocks are a viable alternative to the restoration of anterior endodontically treated teeth.

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Author Contribution

Conceptualization: Zanetti RV. Data curation: de Souza FA and Cumerlato CBF. Formal analysis: de Souza FA and Zanetti RV. Investigation: de Souza FA. Methodology: Feltrin PP, Inoue RT. Project administration: Zanetti RV. Resources: Souza FA and Zanetti RV. Software: de Souza FA. Supervision: Zanetti RV. Validation: de Souza FA. Visualization: Cumerlato CBF, Feltrin PP, Inoue RT. Writing - original draft: de Souza FA and Cumerlato CBF. Writing - review & editing: Zanetti RV, Feltrin PP, Inoue RT. All authors actively participated in the discussion of the manuscript's findings, revised, and approved the final version of the manuscript.

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