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Comparison of Fracture Strength of Endocrowns and Glass Fiber Post-Retained Conventional Crowns

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Clinical Relevance

Restorations of the endocrown type are options for restoring endodontically treated molar teeth with extensive loss of coronal structure. The endocrown has advantages over the conventional crown because its mechanical performance is better, it costs less, and it takes less clinical time to complete.

SUMMARY

The aim of this in vitro study was to compare the fracture strength of full ceramic crowns using two techniques—indirect conventional crowns retained by glass fiber posts, and endocrowns with an "anchorage" in the pulp chamber—and analyze the failure mode. For this purpose, 20 healthy mandibular molars were divided into two groups (n=10): Group GC contained teeth with indirect conventional crowns, filling cores, and glass fiber posts; Group GE contained teeth with restorations of the endocrown type. Teeth were endodontically treated and prepared for ceramic restorations fabricated by the injection technique (IPS e.max Press, Ivoclar-Vivadent), forming the GC and GE groups. Specimens were mounted in a universal test machine (EMIC) and were submitted to an oblique compression load, at an angle of 135 degrees to the long axis of the tooth, until failure. Statistical evaluation performed by the Mann-Whitney nonparametric test showed significant differences between the two groups (*p*=0.002), with Group GE shown to be more resistant to compressive forces than Group GC. The predominant failure pattern in both groups was fracture of the tooth on the side of force application and/or consequent displacement of the restoration on the opposite side.

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DOI: 10.2341/11-105-L

INTRODUCTION

Restoration of endodontically treated teeth with extensive coronal loss has always followed a strict protocol, with the fabrication of total crowns supported on metal cores and/or glass fiber posts.[1-4] Initially, it was believed that this procedure would provide better reinforcement of the remaining dental structure.[5,6] However, it has been observed that the use of intracanal retainers only promoted retention of the prosthetic crown. As a result of removing a healthy dental structure to enable the placement of rigid elements devoid of mechanical behaviors similar to those of the tooth,[7-10] the remaining tooth could be weakened.

With the advent of adhesive dentistry, the need for using posts and filling cores has become less evident. Moreover, the appearance of ceramics that had high mechanical strength and were capable of being acid etched (such as those reinforced with leucite or lithium disilicate), allied with the adhesive capacity of adhesive systems and resinous cements, made it possible to restore posterior teeth, especially molars, without cores and intraradicular posts.[11] Thus, it became feasible to restore posterior teeth with extensive coronal destruction by means of onlay and/or overlay restorations and, more recently, with endocrowns, without the use of radicular posts and while using the entire extension of the pulp chamber as a retentive resource.[12-14]

Pissis[12] was the forerunner of the endocrown technique, describing it as the "mono-block porcelain technique." The nomenclature *endocrown* was described for the first time by Bindl and Mörmann[13] in 1999 as adhesive endodontic crowns, and was characterized as total porcelain crowns fixed to depulped posterior teeth. These crowns would be anchored to the internal portion of the pulp chamber and on the cavity margins, thus obtaining macromechanical retention provided by the pulpal walls, and microretention would be attained with the use of adhesive cementation. It is a method particularly indicated in cases in which there is excessive loss of hard tissues of the crown, interproximal space is limited, and traditional rehabilitation with post and crown is not possible because of inadequate ceramic thickness.[15] This technique is easily performed, demands less clinical time when compared with conventional crowns, costs less because of the fewer number of steps involved, overcomes the patient's lack of available time, and has good esthetic acceptance because it is made of ceramic.[2]

In a clinical study, Bindl and Mörmann[16] evaluated the performance of 208 endocrowns cemented to premolars and molars and observed that the premolars presented more failures than the molars. It is suggested that this occurs because premolars have a smaller adhesion surface when compared with molars. Additionally, premolars have greater crown height, which, consequently, compromises the mechanical properties of the endocrown. It is also suggested that endocrowns should be made only with reinforced ceramics. This has been shown to be an advantageous technique because the procedure is easy.[11]

Nevertheless, because of the absence of information about the biomechanical behavior of endocrowns and the expectation that this type of restoration would behave similarly or superiorly to conventional crowns (because of the potential to be retained in the pulp chamber by micromechanical retention given by the adhesive system and resin cement), the present study has endeavored to evaluate the fracture strength of endodontically treated molars with extensive coronal loss, restored by the conventional technique (glass fiber post and ceramic crown) and by endocrowns, in addition to observing the failure mode when they are submitted to an oblique compressive force.

METHODS AND MATERIALS

This study was approved by the Human Research Ethics Committee of the School of Dentistry and Dental Research, São Leopoldo Mandic (Process Number 2010/0240).

Specimen Preparation

Thirty mandibular molars with complete root formation were collected from the Tooth Bank of the School of Dentistry of the Health Science Center, Federal University of Santa Maria, and were cleaned and stored in 1.0% thymol. They were sectioned in the enamel 1 mm above the cementoenamel junction (CEJ). Twenty teeth were selected according to the following inclusion criteria: presence of enamel on the crown margins, wide pulp chamber, and similar mesiodistal and vestibulolingual diameters.

The teeth were individually fixed with acrylic resin (VIPI Flash, Pirassununga, SP, Brazil) in polyvinyl chloride (PVC) rings (Tigre SA, Joinville, SC, Brazil), leaving the CEJ 1 mm above and parallel to the acrylic resin. Then, teeth were randomly distributed into two groups (n=10): the endocrown group (GE) and the conventional crown and intraradicular post group (GC).

Endocrown Preparation

Preparations for endocrowns and for conventional crowns were made by using a preparation standard-

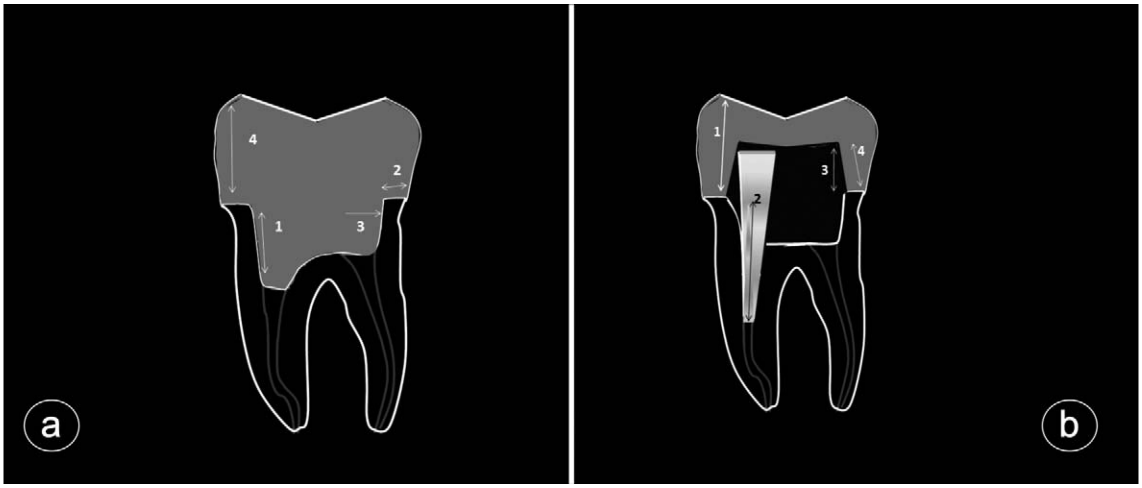

Figure 1. *Schematic representation of the preparation. a) Endocrown: 1) height between 5 and 3.70 mm from the cervical margin up to the distal canal entrance; 2) preparation margins between 2.2 and 2.7 mm; 3) expulsive degree of approximately 8 to 10 degrees; and 4) crown height of 7 mm from the gingival margin. b) Conventional crown: 1) crown height of 6 mm; 2) post height of 9 mm to the cervical margin; 3) core height of 3 mm; and 4) expulsive degree of approximately 6 to 8 degrees.*

ization device adapted from an optical microscope. Preparations were limited to removal of the pulp chamber roof, excessively retentive areas, and alignment of the pulpal walls, which was done up to the limit of the anatomic configuration of the chamber itself with an internal taper of 8 to 10 degrees. Entrances and undercuts of mesial and distal canals (1 and 3 mm depth, respectively) were protected using an adhesive system (Adper Single, Bond 2, 3M ESPE, St Paul, MN, USA) and a flowable resin (Natural Flow, DFL, Rio de Janeiro, RJ, Brazil). Preparations were finalized, allowing a path of draw without interferences. The distal canal was deepened between 3.7 and 5 mm from the cervical margin, limited by the canal anatomy. The procedure of smoothing and rounding the internal angles of the margins began with the use of the same diamond tip and ended with polishing of the margins and internal angles with an abrasive rubber tip.

Conventional Crown Preparation

Roots of Group GC received glass fiber posts #1 (White Post, FGM, Joinvile, SC, Brazil) and a resin composite filling core (Tetric N-Ceram, Ivoclar-Vivadent AG, Schaan, Liechtenstein), in which the gutta percha was removed from the distal canal up to the limit of 9 mm and was measured from the preparation margins. After this, the root canal was widened and enlarged with the bur included in the post system with the cursors duly positioned. The post was cut 3 mm above the gingival margin and was cemented using an adhesive system (Adper Single Bond, 3M ESPE) and dual resin cement (RelyX ARC, 3M ESPE).

After post cementation, the filling core was made with increments of resin composite (Tetric N-Ceram, Ivoclar-Vivadent AG). A transparent addition silicone mold (Transil, Ivoclar-Vivadent AG), which allowed for standardizing the core height, was filled and with the mold sitting on the tooth was light activated for 60 seconds.

Each tooth with a prefabricated core was taken to the standardizing device for adjustment of the preparation margins to a final width of 1.7 mm. Small adjustments were also made in cases in which the core exceeded the height of 3 mm. Final characteristics of endocrown and conventional crown preparations and their schematic representations may be seen in Figure 1.

Laboratory Phase

Endocrowns and conventional crowns were shaped with the use of light and heavy polyvinyl siloxane impression (Hidroxtreme, Coltène/Whaledent, Altstätten, Switzerland). The process of die-casting with special type IV stone plaster (Durone, Dentsply, Petrópolis, RJ, Brazil) began, and metal cylinders were used to make the dies and to facilitate manipulation afterward.

Laboratory procedures began by making the crowns in wax (Pro-mod VKS, Horgensell, Germany) on the dies of conventional crowns and endocrowns, maintaining the same proportion in height. Crowns

Table 1: *Classification of the Pattern and Failure Mode*

Failure Pattern	Description
1. Fracture of the *endocrown* or conventional crown	Fracture of the ceramic restoration
2. Fracture of the tooth	Fracture of the tooth or root
3. Fracture with displacement	Fracture of the tooth or restoration with displacement (loss of adhesion) of the endocrown or conventional crown
4. Displacement without fracture	Displacement (loss of adhesion) of the endocrown or conventional crown without fracture of the restoration or tooth

were made of IPS e.max Press (Ivoclar-Vivadent AG) by the injection technique as per the manufacturer's materials and instructions.

After polishing, the crowns were prepared with 10% hydrofluoric acid (Condac Porcelana, FGM), silane agent (Prosil, FGM), and adhesive agent (Adper Scotchbond Multi-Purpose, 3M ESPE). This was followed by a light jet of air and then light activation for 20 seconds. They were cemented after the teeth adhesive system (Adper Scotchbond Multi-Purpose, 3M ESPE) and dual resin cement (RelyX ARC, 3M ESPE) were applied. Specimens were kept in a humid environment for 72 hours before they were submitted to the compressive strength test.

Compressive Strength Test

To perform the compression test, each specimen was put into a fixation device and placed obliquely on the base of a universal testing machine (EMIC, São José dos Pinhais, PR, Brazil). A compressive load was applied at a 135-degree angle to the long axis of the tooth, on the internal and central face of the vestibular cuspid of all ceramic restorations. This was done by means of a metal rod 6 mm in diameter at a speed of 1 mm/min until failure occurred, represented by fracturing and/or debonding of the tooth and/or crown. All values involving displacement of the metal rod and the load exerted on the tooth restoration set were recorded by a software program. The value of the force required to cause failure was recorded for each specimen in N.

Failure pattern characteristics of each specimen were defined by observation under a stereoscopic loupe at 40× magnification (EK3ST, Eiconal, São Paulo, SP, Brazil) and were classified according to the four failure modes shown in Table 1.

Values obtained in the compressive strength test and data on the fracture pattern of each group were submitted for statistical evaluation by Mann-Whitney tests to detect significant variations between groups.

RESULTS

Mean fracture strength values for the different groups, standard deviations, and results of the Mann-Whitney test are presented in Table 2. The results of the Mann-Whitney test showed higher fracture strength values for Group GE than for Group GC ($p=0.002$). Results of the fracture pattern are presented in Table 3.

A high prevalence of fracture of the tooth or restoration with displacement (loss of adhesion) was noted for both groups (Figure 2), as was a low prevalence of three types of fracture: 1) fracture of one conventional crown (10%), which occurred in Group GC; 2) fracture of the tooth (10%), which occurred in Group GE; and 3) displacement without fracture (10%), which occurred in Group GC. It was observed that fractures in the teeth occurred on the

Table 2: *Median Fracture Strength Values**†

Group	Median (±SD)	Minimum Value-Maximum Value
Endocrown	674.75^{A} (158.85)	543.00–1095.64
Conventional crown	469.90^{B} (129.83)	316.26–787.62

* *Values expressed in Newtons (N), standard deviations (SD), minimum and maximum values, and results of the Mann-Whitney test.*
† *Different superscript capital letters indicate significant differences by the Mann-Whitney test (p=0.002).*

Table 3: *Failure Mode for the Groups Under Study in Percentages, %*

Group	Fracture of the Endocrown or Conventional Crown	Fracture of the Tooth	Fracture With Displacement	Displacement Without Fracture
Endocrown	0	10	90	0
Conventional	10	0	80	10

side on which the test force was applied, and displacement occurred on the opposite side. Only one specimen, which belonged to Group GE, presented root fracture (apical third), and only one, which belonged to Group GC, presented fracture of the cusp of the porcelain crown.

DISCUSSION

The restorative procedure performed with the conventional crown, the resin composite filling core, and the glass fiber post attempts to reproduce the biomechanical behavior and the esthetic of the enamel and the resilience of the dentin.[17,18]

An Endocrown preserves root tissue and limits internal preparation of the pulp chamber to its anatomic shape. It uses ceramic throughout the entire extension of the cavity[13,14] and, because of its rigidity, does not mimic dentinal tissue mechanically. Nevertheless, under oblique compression forces, higher strength values were detected in Group GE. The thickness and quantity of ceramic used in the restoration of Group GE were significantly greater than those used in Group GC. The high bonding capacity of lithium disilicate ceramics to the dental structure and the smaller number of bond interfaces probably make the dentin/enamel/ceramic group more resistant when compared with the dentin/enamel/post/resin/ceramic group.

For the endocrowns, 90% of failures were of the tooth fracture type associated with displacement of the restoration on the opposite side of the incidence of force. Only 10% presented fracture of the tooth (in the apical third of the root portion). On the other hand, in the group of ceramic crowns, 80% of test specimens fractured and displaced the restoration on the opposite side of the incidence of force. Nevertheless, with the exception of one specimen from Group GC, no "debonding" of restorations from the teeth occurred, even after fracture. This adequate resistance to displacement is due to the adhesive property of lithium disilicate–based ceramics, which can be acid etched, and promotes micromechanical interlocking with the resinous cement and with the adhesion between resin cement and tooth surface.[19] In cases of endocrowns, lithium disilicate can be considered one of the best restorative materials.

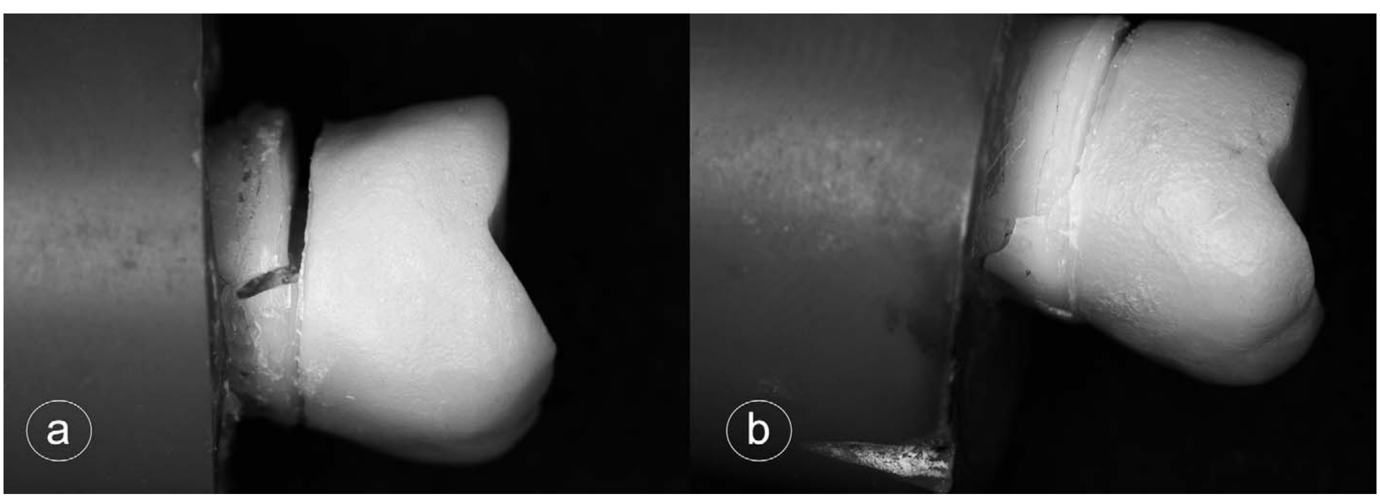

Figure 2. *Type of fracture. a) Fracture of the tooth with displacement (loss of adhesion) of the endocrown; and b) fracture of the tooth with displacement (loss of adhesion) of the conventional crown.*

Results showed significantly higher fracture strength for endocrowns when compared with conventional crowns; this is consistent with the findings of other *in vitro* studies.[15] *In vivo* studies have also demonstrated the favorable performance of endocrown restorations.[11,14,16] Moreover, it should be taken into account that these restorations are easy to perform but must be made only with reinforced ceramics.[11,14,16]

When the finite element method was used, the favorable performance of endocrown restorations was observed,[20] even in premolars.[21] However, *in vivo* and *in vitro* studies contradict each other concerning the possibility of using restorations of the endocrown type for premolar teeth.[16,22] This is a result of the smaller bond surface and greater crown height of premolars when compared with molars.

Thus, it should be considered that restorations of the endocrown type present advantages for depulped molar teeth, in that they promote adequate function and esthetics, in addition to the biomechanical integrity of the compromised structure of nonvital posterior teeth.[23] Moreover, they appear to be a solution for teeth with a short clinical crown and atresic, calcified, curved, or short root canals that make it impossible to use posts. They are made easily by the dentist, demand less clinical time when compared with conventional crowns, and have good esthetic acceptance because they are made of ceramics. Through elimination of the post and filling core, the number of bond interfaces is reduced, thus making the restoration less susceptible to the adverse effects of degradation of the hybrid layer.[24]

It is worth remembering that the restorative approaches studied simulate extreme situations with extensive loss of dental tissue, which do not allow the use of a ferrule. Knowing that the ferrule increases fracture strength and loss of bond of prosthetic restorations,[3] one understands that with ferulization, in both Group GE and Group GC, responses of greater resistance to oblique compression forces might have been observed.

Results obtained by the present study reinforce the advantages that have been presented in the clinical experiences of various authors. Given the two parameters evaluated—strength and failure mode—the mechanical superiority of restorations of the endocrown type was observed. It is known that *in vitro* tests have limitations in attempts to produce the mechanisms responsible for the occurrence of clinical failure. Therefore, although the method used endeavored to simulate the clinical situation in all stages, difficulties are inherent to the *in vitro* nature of the study. The results of the present study do not necessarily reflect the clinical performance of the restorative approaches tested. Therefore, from the results obtained, it may be concluded that restorations of the endocrown type are restorative options for endodontically treated molar teeth with extensive loss of coronal structure. They are able to replace conventional crowns supported on posts and filling cores and provide advantages in terms of mechanical performance, cost, and clinical time.

CONCLUSION

Endocrown restorations presented greater fracture strength than indirect conventional crowns associated with glass fiber posts and resin composite filling cores. For both groups, the failure pattern was characterized by fracture of the tooth associated with displacement of the restoration on the opposite side.

Conflict of Interest Declaration

The Authors of this manuscript certify that they have no proprietary, financial or other personal interest of any nature or kind in any product, service and/or company that is presented in this article.

(Accepted 16 August 2011)

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