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Effect of Different Preparation Designs on the Fracture Resistance of IPS Emax CAD Endo-Crowns

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Abstract

Purpose: The present study intended to evaluate the effect of different preparation design on fracture resistance of CAD/CAM endocrowns.

Materials and methods: twenty human mandibular molars were selected to the present study. All teeth were randomly divided into 2 groups (n=10 each) according to the preparation design of endocrown, Group (1): Endodontically treated teeth without ferrule (butt joint). Group (2): Endodontically treated teeth with 1.5 mm ferrule. All prepared teeth were restored using IPS emax CAD endocrowns. After cementation of endocrowns all specimens were subjected to thermal cycling in automated thermocycling machine in order to mimic the intra-oral condition. Then fracture resistance were measured using material testing machine. The recorded data were collected, tabulated and statistically analyzed.

Result: Endodontically treated molar with 1.5 mm ferrule show high fracture resistance than endodontically treated molar without ferrule.

Conclusions: All obtained fracture resistance morals lie within the clinically accepted ranges, endocrowns with 1.5mm ferrule have fracture resistance higher than endocrowns without ferrule (butt joint).

Key word: Endocrown, fracture resistance, IPS emax CAD, ferrule.

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Introduction:

Fractures are more common in pulpless teeth than teeth with vital pulp, as endodontically treated teeth are more brittle due to loss of structural integrity associated with access preparation or caries, or due to decrease moisture content , planning to restore this teeth will be associated to remaining tooth structure and functional demands[1]. Several studies have indicated that the strength of the tooth is directly related to the remaining bulk of dentin [2]

The loss of tooth structure following a conservative access cavity preparation affects tooth stiffness by only 5%. The influence of subsequent canal instrumentation and obturation lead only to a slight reduction in the resistance to fracture and ultimately have little effect on tooth biomechanics. In fact, the largest reduction in tooth stiffness results from additional preparation related to post preparation [3]

For many years, post and core systems have been used as foundational materials for final restoration of endodontically treated teeth that have lost most of their coronal tooth structure[4] but they need additional preparation in the root canal. vertical and deep root fractures have been associated with tapered cast posts and cores as it exhibit wedging effect within the root, [2] but fiber reinforced posts possess a number of advantages that include biocompatibility, high flexure and fatigue strength high resistance to corrosion modulus of elasticity similar to that of dentin of the teeth ,and the ability to form a single bonded (mono-block) complex within the root canal.[5]

Although the fiber reinforced option in restoring pulpless badly broken down teeth proved a clinical success however the true breakthrough in the restoration of endodontically treated teeth was the introduction of adhesion and development of effective dentin adhesives.[6]

With this approach the insertion of radicular post has become the exception rather than the rule in fact minimally invasive preparation with maximal tissue conservation are now considered the gold standard for restoring endodontically treated teeth [7]

The **Endocrown** firmly follow this rational: the preparation consists of a circular butt-joint margin and central retention cavity inside the pulp chamber and lacks intraradicular anchorage constructing both the crown and core as a single unit, i.e., a monoblock. [8]

The first propagated study [9] on ceramic endocrown was published in 1995. It was described as the technique of ceramic monoblock fabrication for restoration of endodontically treated teeth. However, this restorative procedure was named later as “endocrown” in 1999 [10].

Endocrown is a single monoblock that contains the entire crown and an intra-radicular extension that adapts into the “endo-preparation” [11] having macromechanical retention (obtained through fitting into the pulpal walls), and microretention (by utilizing adhesive cementation) [12].

Molars with short, calcified, severely curved and extra thin roots are specially indicated for endocrown restorations. Endocrowns may also be used in cases with sever loss of coronal dental tissue and reduced interocclusal space as there is no enough space for the ceramo-metal restoration or ceramic substructures [13] .

There is no specific or defined design for endocrown preparation, Some studies recommend endocrown preparation parameters to include; occlusal reduction of 2 to 3 mm, 90° butt margins, Smooth internal line angles, Six occluso-cervical internal taper of the pulpal walls, Flattened pulpal floor and Supragingival enamel finish line when possible [14].

Several studies suggest a 2 mm intraradicular retentive feature to afford the sufficient retention and resistance features,[15,16], while other studies highlighted the effect of the depth (shallow or deep depth) of this intaradicular retentive feature on the marginal and adaptation of the endocrown restorations [17,18].

Long term success of fixed restorations is highly related to adequate marginal adaptation of the restoration. Exposed luting material to the oral environment with increased marginal discrepancies, may lead to cement dissolution with subsequent microleakage. [19].

Therefore, the effect of different endocrown's preparation on fracture resistance and retention of endocrown has to be thoroughly investigated.

The null hypothesis of the present study was that variation in margin design will have no effect on fracture resistance of IPS emax CAD endocrowns constructed on endodontically treated molar.

Materials and methods:

Natural teeth Preparation:

Twenty (N=20) extracted human mandibular first molars, have no cracks, fractures or caries were selected in accordance with guidelines from research ethics committee approval of Faculty of Dental Medicine,Al-Azhar University. The teeth were selected according to the following criteria: presence of enamel on the crown margins, wide pulp chamber, and similar mesiodistal and vestibulolingual diameters. The teeth were cleaned and stored in 1.0% thymol. After that 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 using the dental surveyor. Then, teeth were were endodontically treated and then randomly distributed into two groups (n=10 each) according to the preparation design.

Grouping:

I. **Group (1)**: preparation design without ferrule (butt joint).
II. **Group (2)**: preparation design with 1.5 mm ferrule

Pulp chamber of all teeth were etched with etchant gel for 20 sec, then rinsed with water spray then universal adhesive bonding agent applied with a micro brush and cured for 30 sec, finally 3M flowable composite was applied and cured for 30 sec, to seal the orifice of the canal and to close any undercuts.

A special milling machine (Centroid CNC, Milling machine, USA) was used for standardized teeth preparations. The machine assembly incorporates a slow-speed hand-piece attached perpendicularly to the machine platform.

The endodontic access cavity was prepared with 10^{o} coronal divergence. The depth of the intraradticular retention cavity was standardized for all specimens with 2mm. Cavity depths were measured from decapitation level using the digital caliper.

Endocrowns Fabrication:

Exocad dental system was used for fabrication of all samples in the study to obtain a three dimensional image for each prepared tooth. The prepared tooth was sprayed using a Telescan light reflecting powder from Vita Zahnfabrik, Germany, to obtain optical impression of the sample. Samples were scanned using Identica blue for scanning then the captured picture was saved, an automatic margin finder was used for detection of preparation's margin. Restoration design parameters were standardized for all samples, with the aid of both exocad dental system and biogeneric copy option. The scanned prepared tooth was used to construct a 3D virtual endocrowns according to data gained during acquisition phase.

In milling procedure the IPS Emax blocks were attached to the spindle arm of the milling chamber of Roland milling machine. The milling process was fully automated without any interfere with two diamond burs acting together simultaneously in the shaping process ,with copious water cooling sprayed from both directions. After that, Programat Furnace was used for crystallization and glaze firing.

In firing process the endocrowns were supported by an object fix material and fired on their special firing tray according to the manufacturer's instruction. The starting temperature was 403c and increased at a rate of 90cmin until 840c and hold for 7 minutes to obtain final endocrown.

Each endocrown was then seated on its respective tooth and checked for complete seating using magnificent lens(x=15).

Cementation procedure:

Restorations' internal surface treatment using (Condac Porcelana, FGM), silane agent (Prosil, FGM), Tooth surface treatment using Scotchbond Universal Etchant and Single Bond Universal Adhesive(3M ESPE, St Paul, MN, USA), Bonding using RelyX Ultimate Clicker adhesive resin cement(3M ESPE, St Paul, MN, USA). Each sample was subjected to 5kg weight in a load applicator then the cement was light cured for 20 seconds for each surface. After that the Specimens were kept in a humid environment for 72 hours before they were submitted to the compressive strength test.

Thermal cycling:

In order to mimic the intra-oral condition the cemented specimens were subjected to thermal cycling, in automated thermocycling machine, for 2000 cycle between 5- 55 ^{0}c with a abide time 25 second.

Fracture resistance 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, Sa˜o Jose´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, with tin foil sheet in-between to achieve homogenous stress distribution and minimization of the transmission of local force peaks. The load at failure manifested by an audible crack and confirmed by a sharp drop at load-deflection curve was recorded using computer software. The load required to fracture was recorded in Newton.

Statistical analysis

All data showed a parametric distribution and were compared between groups using independent t test. Pearson correlation test was used to study correlation between fracture resistance and retention. The Pearson correlation coefficient is used to measure the strength of a

linear association between two variables. The level of significance was set at $P < 0.05$

Results

Fracture resistance

The higher mean failure load was recorded for endocrowns with 1.5 mm ferrule group (2), (4528.69N± 669.83) while endocrowns without ferrule group (1) recorded a mean failure load (3393.91±859.71) Independent t test revealed that the difference between two groups was statistically significant (p=0.03) (Table 1)

	Mean(N)	SD
Group(1) *(Without ferrule)*	3393.91	859.71
Group(2) *(With ferrule)*	4528.69	669.83

Table (1) :Comparison between groups (fracture resistance with and without ferrule)

N=Newton.
SE=Standard Error of Mean. SD=Standard Deviation
*Significance level P<0.05, * significant*

Fracture mode failure: Samples were examined to determine the type of fracture occurred in this study visually using magnification lens (x=15) to determine different fracture modes according to Burke's classification. [42, 22, 23] (Table 2 and figure 1)

TABLE (2): Distribution of the failed samples into three types as detected with the results.

Failure mode	*Group I*	*Group II*
Failure mode class II **(Less than half of the endocrowns fractured without fractured of the teeth)**	0%	10%
Failure mode class IV **(More than half of endocrown fracture without fractured of the teeth.)**	20%	20%
Failure mode Class V **(catastrophic fracture occurred for both endocrowns and teeth)**	80%	70%

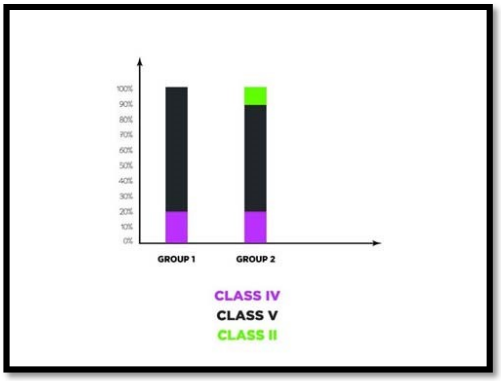

Figure (1) : chart show failure pattern distribution among two group

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 [24]. Therefore it is now possible to depart from the classical preparation to what is called ***Endo preparation technique*** and use endocrown in restoration of endodontically treated teeth [25]. Endocrown eliminate the need for posts and build up therefore they are less expensive, time saving and more practical [10]. Endocrowns were presented as a prosthetic option in restoration of endodontically treated incisors [27], premolars [28] and molars [29, 30] with excessive tissue loss. The endo-core improves the bonding surface of restorations inside the root as well as their macro-mechanical retention, hindering their displacement from the root cavity under lateral stresses [31].

There had been no demarcated preparation design for endocrown restorations, especially in terms of intracoronal cavity depth and marginal configuration. Some studies suggest a 2 mm central retentive cavity depth to afford the optimal retention and resistance features, [32, 33] other studies highlighted the effect of the depth (shallow or deep cavities) of this central retentive feature on the marginal and internal adaptation of the endocrown restorations [34]. So this study aimed to investigate the effect of the marginal design on the fracture resistance and retention of the endocrown as the prognosis of fixed restorations is directly related to its retention and fracture resistance.

Teeth were prepared according to clinically established preparation criteria for all ceramic endocrown using special milling machine to ensure standardization of the preparations [35]. Intracoronal height of the prepared walls was reduced to 2.0 mm, measured from the internal cavity margin to the floor of the pulp chamber as it demonstrated the highest fracture resistance [36].

For standardization of e.max CAD restoration, the endocrowns was designed to have similar occlusal anatomy by using the biogeneric reference option (Biogeneric copy mode in the exocad software used) as well as having the same occlusogingival height [37].

Although various machinable material are available for fabricating all ceramic crowns using CAD CAM systems, IPS Emax CAD blocks was selected because it has the advantage of long term clinical acceptability, good bonding characteristics, short laboratory steps, favorable esthetics and lack for veneering porcelain need [38] , in addition to high fracture load values for endocrowns fabricated from e.max CAD [39].

Indirect restorations are exposed to adverse conditions after cementation. Artificial in vitro aging can be performed to simulate in vivo conditions, namely temperature alterations and loading of the oral environment. Thermal cycling is among the aging methods that can be used. These procedures has been used to determine lifetime of restorative materials [40-42].

Regarding the preparation design the results obtained in this study showed that endocrowns with 1.5mm ferrule recorded a statistically significant higher mean fracture load than endocrown without ferrule. This result is was agreement with studies [43, 44], who observed higher fracture loads of endocrown with 1mm ferrule than without ferrule.

The results of the current study can be explained by the fact that the greater surface area for adhesive bonding for endocrown with 1.5 mm ferrule over those without ferrule (106mm^2 and 94 mm^2 respectively) increase fracture resistance of endocrown with ferrule than without ferrule, in addition to the presence of the ferrule effect. It has been reported that a ferrule with 1.5 mm vertical height duets the resistance to fracture versus teeth restored without a ferrule and provide a greater amount of dentin for redistribution and dissipation of force [45, 46].

In addition considered that dentin and crown ferrule influences the fracture resistance. Teeth without (dentin and crown) ferrule effect were fractured at a significantly lower load than teeth restored with an apical extended ferrule [47].

Alternative elucidation may related to stress distribution, Tooth without ferrule showed greater stresses concentration (16.3 MPa) than those with a ferrule (9.2 MPa). With a ferrule, stress was uniformly distributed along the abutment and the root, with no critical stress concentration. The Finite Element analysis confirmed a beneficial ferrule effect on stress distribution so affect mechanical behavior of the teeth and failure mode of restoration [48].

Additionally, another study approved that endocrowns, embracing both the crown and core as a single unite was suggested to provide a monoblock effect. When the monoblock system is subjected to occlusal loads, the whole system will deform uniformly and generated stresses will be distributed along the whole system decreasing the stresses transferred to the vulnerable tooth structure and increase fracture resistance [49], this suggestion is supported by study which reported that the stress values on the enamel, dentin, and luting cement for endocrown restorations exhibited the lowest values relative to conventional crown restorations supported with fiber posts and composite core. [50]

This was conflicting by a study which report that regarding adhesive technique creating a ferrule might cause the loss of sound tooth structure and compromising bonding strength, because enamel is preferred to dentine for bonding. This opposed finding might be related to difference in methodology between the studies, this study preformed on premolars but our study performed on molars [51].

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 attempted 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

Conclusions:

Within the limitations of this study, the following conclusions can be drawn:

1. All obtained fracture resistance values lie within the clinically accepted ranges.
2. Endocrown with 1.5 mm ferrule marginal configuration has superior fracture resistance than those without ferrule (butt joint) marginal configuration.
3. The null hypothesis that there would be no difference in fracture resistance with variation in margin design was rejected. Endocrowns margin design affected the fracture resistance.

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