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EFFECT OF FILLING PULP CHAMBER ON MARGINAL ADAPTATION AND FRACTURE RESISTANCE OF ZIRCONIA REINFORCED GLASS CERAMIC ENDOCROWN RESTORATIONS

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ABSTRACT

Purpose: The purpose of this in vitro study was to evaluate the marginal adaptation and the fracture resistance of endodontically treated molars restored with zirconia reinforced glass ceramic endocrown restoration with or without incorporating a fiber-reinforced composite (FRC) layer into the pulp chamber.

Materials and methods: Mandibular first molars (n= 30) were prepared by computerized numerical control (CNC) in a standardized way to receive standardized CAD/CAM fabricated zirconia reinforced glass ceramic endocrowns after root canal treatments. The selected teeth were divided into two groups (n=15) according to the presence of fiber reinforced composite (FRC) in the pulp chamber. Group NF (Non filled) represented teeth with the pulp chamber without filling and Group F (Filled)represented teeth with the pulp chamber filled with FRCs. Marginal gaps (μm) were measured using stereomicroscope (32x) before cementation and after cementation. Thermal aging (3000 cycles) was performed then marginal gaps measurements were repeated. Then, fracture resistance test was performed. ANOVA test was used to study the interactions while Independent t-test was used to study the effect of using FRCs in the pulp on marginal adaptation in each stage and on the fracture resistance (N).

Results: The results of independent t test showed that there was no statistically significant effect of incorporating FRCs into the pulp chamber on the marginal adaptation during all stages before (p= 0.844) or after cementation (p=0.884) or after thermocycling (p=0.875). Regarding the fracture resistance, the test showed that Group NF had higher mean fracture load value than Group F and the difference was statistically significant (p=0.004)

Conclusions: Within the limitation of this study, the incorporation of FRCs into the pulp chamber of endodontically treated teeth restored with zirconia reinforced glass ceramic endocrowns had no influential effect on the marginal adaptation of the restoration before or after cementation or after thermocycling. However, the presence of the FRCs unexpectedly decreased the mean values of the fracture resistance of the restorations. Further investigations are needed to confirm these findings before clinical application.

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INTRODUCTION

The challenge of restoring endodontically treated teeth continues to be a problem in reconstructive dentistry. The most common protocol of restoring such teeth has been to build up the tooth with a post and core. However, it was reported in many clinical and laboratory studies that placing a post though contributing to the retention of the core portion of the restoration, it may cause weakening of the root. [1,2].

A shift in treatment options toward more conservative modalities has been observed recently with the increasing popularity of adhesive dentistry, questioning the need for conventional post and cores. Ceramic restorations including endocrowns have been introduced as alternative options for restoring endodontically treated teeth depending on the availability of remaining tooth structure [3] because a macro-retentive design is no longer a prerequisite if there are sufficient tooth surfaces for bonding. [4]

The endocrown is a one-piece ceramic construction comprises a circumferential butt margin and a central retention cavity inside the pulp chamber and constructs both the crown and core as a single unit. This approach utilizes the surface available in the pulp chamber to ensure the stability and retention of a restoration through adhesive bonding. [5] It also follows the concept of decay-orientated design leading to minimally invasive preparations. [6] Several in vitro studies showed significantly higher fracture strength for endocrowns when compared with conventional crowns. [7),8] The favorable performance of endocrown restorations was also demonstrated in several in- vivo studies. [9,10),11]

Endocrowns use ceramic material throughout the entire extension of the pulp cavity and because of the ceramic material rigidity; this doesn't mimic dentinal tissue mechanically. [7] According to some authors, the pulp chamber space can be managed differently and a composite build-up of this space was one of these suggested managements [12; 13] Regardless of its composition, this resin composite base fills pulp cavity undercuts, thus saving sound tooth structure. Moreover, it leads to the fabrication of endocrowns with shorter extensions into the pulp chamber, thus reducing the overall thickness of the endocrown. A better light penetration through the definitive restoration during light polymerization can therefore be achieved, allowing the use of light-cured luting resin composites for cementation in alternative to the chemical or dual cured resins. [14] Fiber reinforced composite (FRC) material was also used in some studies to help in standardizing the depth of the pulpal floor because sometimes if the pulp chamber was deep a blurred image of the central retention cavity of the endocrown preparation may result if adjacent teeth limit the position of the camera head. [8]

Recently, some in vitro studies showed that endocrowns demonstrated high risk of drastic failure below the CEJ. [11; 15] This led to the suggestion of using fiber reinforced composites (FRCs) to reinforce this kind of cusp-replacing restorations. It was suggested that besides improving the strength of the restoration, it usually leads to more favorable fracture patterns—above the CEJ—due to the fact that the fiber layer acts as a stress-breaker and deviates the crack propagation. [16; 17]

An important area of interest is the choice of the restorative material. Recently, a zirconia reinforced lithium silicate glass ceramic (Vita Suprinity; Vita Zahnfabrick, Bad Säckingen, Germany) for dental CAD/CAM applications for the fabrication of inlays, onlays, partial crowns, veneers, anterior and posterior crowns and anterior and posterior single tooth restorations on implant abutments has been introduced to the dental market. This new glass ceramic is enriched with zirconia (≈10% by weight). It is the first zirconia reinforced lithium silicate ceramic.[18]

The zirconia particles act as a second phase that is stiffer than the glass-ceramic matrix, allowing the load transfer reinforcing mechanism to occur from the matrix to the reinforcing phase.[19, 20]

It seems also that the main strengthening mechanism, as observed in the fracture morphologic aspects after wear tests, is the strengthening effect of zirconia particles promoted by a strong bonding between glass-ceramic matrix and zirconia particles and by the load transfer mechanisms occurring from glass-ceramic matrix to the zirconia particles.[20]

Little information have been available regarding whether incorporating a fiber-reinforced composite (FRC) layer into the pulp chamber of endodontically treated teeth will have an influence on their marginal adaptation and fracture resistance when restored with zirconia reinforced glass ceramic endocrown restorations.

The purpose of this in vitro study was to evaluate the marginal adaptation and the fracture resistance of endodontically treated molars restored with zirconia reinforced glass ceramic endocrown restoration with or without incorporating a fiber-reinforced composite (FRC) layer into the pulp chamber.

MATERIALS AND METHODS

Recently extracted human mandibular molars with completely formed apices, without caries or visible fracture lines were selected with similar bucco-lingual (BL) and mesio-distal (MD) dimensions, as determined with a digital caliper allowing a maximum deviation of 10% from the determined mean. [21] Afterwards teeth were cleaned with ultrasonic scaler (SUPRASSON™ P5 Booster ultrasonic scaler, S.A.T.A.L.C., France) then were stored in distilled water until required for experimentation. Protaper system (Dentsply-Maillefer; Ballai- gues, Switzerland) was used for root canals treatment for standardization.

The selected teeth were divided into two groups (n=15) according to the presence of FRCs in the pulp chamber. Group NF represented teeth with the pulp chamber without filling and Group F represented teeth with the pulp chamber filled with FRCs.

A surveyor was used to ensure upright position of teeth in moulds which were filled with non-shrink epoxy resin material placing the margin of the epoxy resin below the cemento-enamel junction by 3 mm. All the endodontically treated teeth were prepared using a Computerised Numerical Control (CNC) milling machine (C.N.C.Premium4820, i-mes, Germany) to standardize the preparation dimensions. (Figure 1) For all teeth, the CNC milling machine was adjusted to reduce the teeth to have 90˚ butt margin design, 2 mm reduction in the occlusal surface and the pulp chamber with a retention cavity extending 6 mm from the central groove with 8 degree divergence of the walls.

Total etch bonding system was used before application of the core material in the pulp chambers of Group F, following the manufacturer instructions. Phosphoric acid etch 37% (ScotchBond etchant 3MESPE , USA) was used for 15 seconds on the dentine surface. Each tooth was then rinsed for 30 seconds with air water syringe before using the bonding agent. The bonding agent(Adper single bond 3M ESPE, USA) was applied and light cured for 20 seconds, and then the core material (Build-It® FR™ Fiber Reinforced Core Material, Pentron, USA) was applied using auto mix tip then cured for 20 seconds. (figure 2)

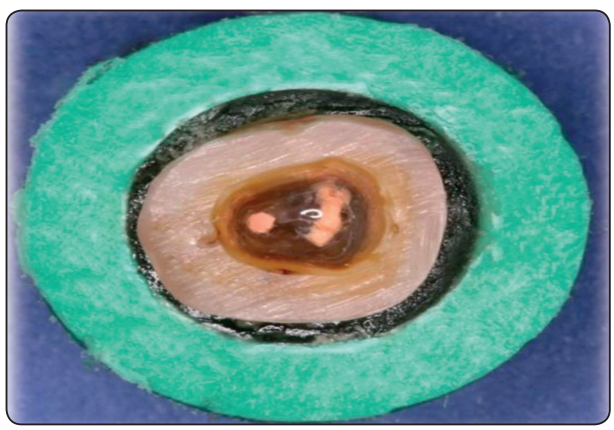

Fig. (1) Occlusal view of prepared tooth structure

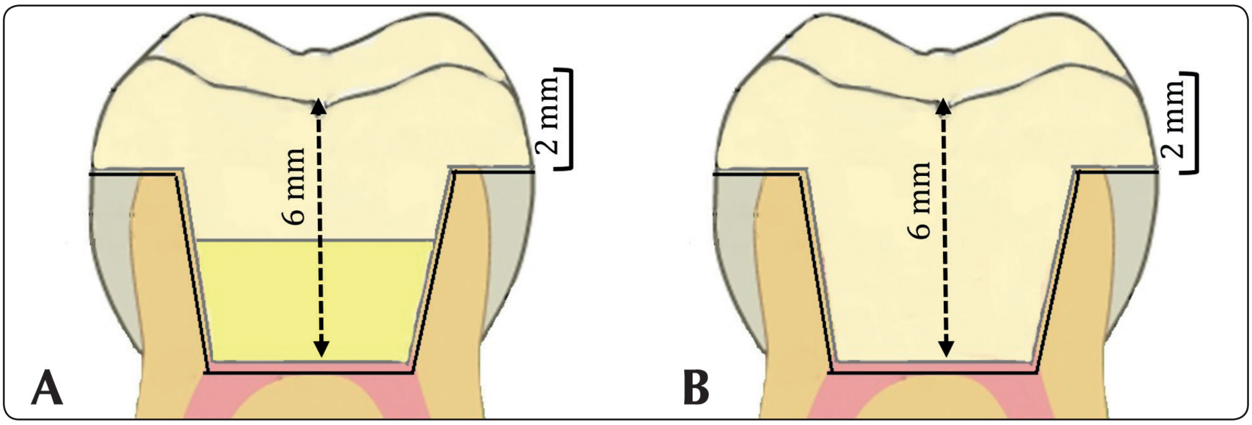

Fig. (2) Schematic presentation of butt margin preparation with 2 mm occlusal thickness endocrown restoration with the pulp chamber (A) Filled (F) (B) Not filled (NF)

Endocrown restorations were fabricated using The CEREC AC system (Sirona, Bensheim, Germany). Bluecam was used for scanning the preparations and the CEREC 3D Software (version 4.3) for designing the restorations. Standardized endocrowns were generated with the Cerec 3 CAD/CAM system. The occlusal surface was created using the software's set in Master Mode, with the average thickness required. To standardize the form and the anatomy, the design of the restoration was obtained by the sole use of the "position" tools (translation and rotation), with no editing of the original shape produced by the software. Then the restorations were milled from Vita Suprenity blocks (vita-zahnfabrik, Germany), crystallisation,polishing and glazing were performed according to manufacture instructions.

Precementation measurements of the cervical vertical marginal discrepancies were performed before cementation. Each endocrown was seated on its corresponding abutment tooth using specially designed metal jig to ensure complete seating. For each specimen, four stereomicrographs, at the four predetermined marks, were captured by a Stereomicroscope (Wild 400, Heerbrugg, Switzerland) at a magnification 32x. Images were then transferred to the computer system for analysis.

Etching of the bonding surfaces of the endocrowns was done using 9.5% hydrofluoric acid gel (Porcelain etch, Ultradent Products, United States) for 20 seconds. The endocrowns were then rinsed thoroughly for 20 seconds then dried with oil free air. The surfaces were then Silanized by a primer (Porcelain Silane, Ultradent Products, United States) and left to react for 60 seconds. The Enamel of all preparations were selectively etched for 30 seconds with 37.5% phosphoric acid (Ultra-Etch, Ultradent Products, United States), rinsed, and dried. Self- adhesive resin cement (RelyXTM Unicem 2 Automix, 3M ESPE, United States) was applied using the automix tip to the fitting surface of the endocrowns which were placed on their relevant preparations by static finger pressure then axially loaded with a 1kg load using a specially designed device. The endocrowns were left under the static load for 5 minutes then exposed to a brief light curing for only 2 seconds. The excess cement was removed with a scaler, and then light curing was done for 20 seconds for each side. Measurements of the cervical vertical marginal discrepancies were repeated after cementation. The teeth were stored in distilled water at 37 ºC for 24 hours prior to thermal cycling according to the ISO (International Organization for Standardization) recommendations. The specimens were submitted to 2500 thermocycles in a thermal cycling simulation machine (Haake W15, Karlsruhe, Germany) between 5°C and 55°C in water. Dwell time is 30 seconds and transfer time between baths is 5 seconds.

Measurements of the cervical vertical marginal discrepancies were repeated again after thermal cycling.

Using the image analysis software (Image Pro-plus V.6), vertical gaps between the cervical margin of the endocrown and the outer end of the finish line at 5 different points were measured in each stereomicrograph. Therefore, the measurements were carried out at 20 points for each endocrown. The collected data were tabulated and the mean vertical gap (in microns) for each specimen was then calculated and tabulated for statistical analysis. (Fig 3)

The fracture resistance test was performed, all samples were loaded vertically on the central fossa of their occlusal surfaces in a universal testing machine (Zwick Z010, Zwick,Ulm,Germany) until fracture occurred. The loading piston was centered along the long axis of the specimens with a 6mm in diameter steel ball and the thrust speed of the machine was 0.5 mm/min. The breaking load was recorded in Newton (N). (Fig 4)

The collected data were analyzed using Statistical package for Social Science (SPSS) version 22. Initially descriptive statistics for each group were held. Shapiro-Wilk test was used to assess data normality and data was assumed normally distributed. ANOVA test was used to study the interactions while Independent t-test was used to study the effect of using FRCs in the pulp on marginal adaptation in each stage and on the fracture resistance (N).P-value is the level of significance, if $P > 0.05$:

Non significant (NS), $P \leq 0.05$: Significant (S)

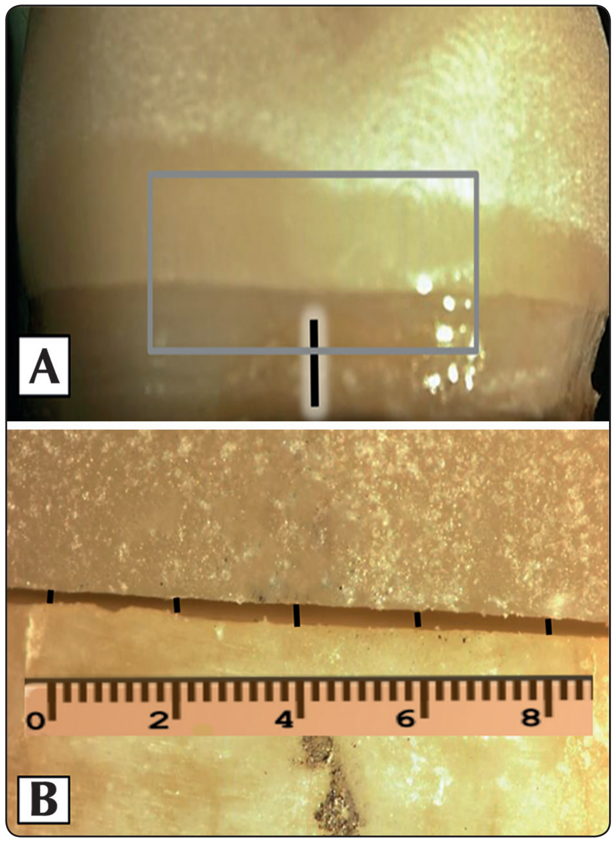

Fig. (3) Example on Marginal gap measurements A: area of stereomicrograph around virtual predetermined mark, B: five equidistant marks for measurements before cementation (with a virtual ruler)

Fig. (4) Universal testing machine

RESULTS

Regarding the marginal adaptation:

Table I: Descriptive statistics (Mean and standard deviations) of marginal gap results measured in (μu) for the tested groups in the three stages before cementation, after cementation and after thermocycling

	Filling the pulp chamber	Mean	Std. Deviation	P value
Before cementation	Filled	48.45	8.37	0.75 N.S
	not filled	46.22	7.3	
After cementation	Filled	76.7	11.6	0.88 N.S
	not filled	75.7	11.6	
After thermocycling	Filled	86.33	8.6	0.82 N.S
	not filled	84.6	10.3	

Descriptive statistics (Mean and standard deviations) of marginal gap results measured in (μu) for the tested groups in the three stages before cementation, after cementation and after thermocycling are presented in (table I). These values show that marginal gap increased after cementation, and increased further after thermocycling. The results of independent t test showed that there was no statistically significant effect of incorporating FRCs into the pulp chamber on the marginal adaptation during all stages before (p= 0.75) or after cementation (p=0.88) or after thermocycling (p=0.82)

Regarding the fracture resistance measurements

Table II: Descriptive statistics (Mean and standard deviations) of fracture resistance results measured in Newton (N) for the tested groups.

Filling the pulp chamber	Mean	Std. Deviation	P value
Not filled (NF)	1230.2	210.7	0.004 Sig
Filled (F)	782.4	98.6	

Descriptive statistics (Mean and standard deviations) of fracture resistance results measured in Newton (N) for the tested groups are presented in (table II). Independent t test showed that Group NF showed higher mean fracture load value than Group F and the difference is statistically significant (p=0.004)

DISCUSSION

Several in vitro studies showed significantly higher fracture strength for endocrowns when compared with conventional crowns.[7,8] The favorable performance of endocrown restorations was also demonstrated in several in- vivo studies.[9-11]

This study was performed on lower molar natural human extracted teeth. Various studies suggested extending the concept of restoring endodontically treated teeth with endocrowns to premolars and incisors. Whether the concept is similarly successful in anterior teeth and premolars as proved to be in molars is still controversial. This is because of the smaller bonding surface and greater crown height of premolars when compared with molars. [4; 22]

The use of human teeth in this study might have increased the variability of the fracture load when compared with artificial abutments which provides standardized preparation and identical physical qualities of the materials used. But this choice was based on the fact that it more closely approximates a clinical situation with respect to tooth architecture and morphology. The dentin and enamel surface for bonding, the contour of the pulp chamber and root canals, and the ratio between the crown and root are more accurate than on artificial teeth. [8] In addition, artificial replicas fail to reproduce the actual force distribution at the inner surface of the crown. [23] In order to minimize the possible variations and errors, selection of teeth of average sizes and almost similar shapes allowing a maximum deviation of 10% from the determined mean was performed before testing. [21]

Computerized Numerical Control (CNC) milling machine was used to prepare the teeth in a standardized method in order to minimize any possible variations. Endocrowns were standardized by adjusting the parameters in inlab software (V4.3). All endocrowns were crystallised and glazed in the same manner according to the manufacturer's recommendations. Full anatomic restorations were used, because it has been reported that these may allow the restorations to behave in a manner that potentially represents the clinical situation more closely than ceramic discs. [23]

Regarding marginal adaptation:

The assessment of the marginal adaptation of the endocrowns was performed using stereomicroscope; all measurements were made by the same operator to avoid errors as much as possible. Direct viewing with external measurements which was used in this study has the advantage of not being invasive and, therefore, applicable to clinical practice but it is difficult to repeat the measurements from an identical angle and to distinguish the actual marginal gap from its projection. [24] The vertical cervical marginal gap measurement was selected as the most frequently used to quantify the accuracy of fit of a restoration. [25]

The effect of using a base under indirect restorations on their marginal adaptation has been studied in several in vitro studies with the elastic modulus of the base as the main influential factor. [26; 27] Depending on the modulus of elasticity of the base, functional stresses transmitted to the luting interface and to the resting tissues can be decreased (in case of low E-modulus) or just passed on (in case of high E-modulus) with limited or no stress reduction. These transmitted stresses may result in debonding at the tooth-restoration interface followed by consequences of micro-leakage, post-operative sensitivity and secondary caries. [28]

The results of the current study showed that there was no statistically significant effect of incorporating FRCs into the pulp chamber on the marginal adaptation during all stages before or after cementation or after thermocyclying. That means that the presence of FRCs in the pulp chamber did not affect the restoration's external adaptation compared to non-reinforced group. These results are in agreement with those of Rocca et al (28)who evaluated the marginal adaptation of endodontically treated molars restored with CAD/CAM composite resin endocrowns either with or without reinforcement by fiber reinforced composites (FRCs) using different configurations of fibers. They concluded in their study that the use of FRCs to reinforce the pulp chamber of devitalized molars restored with CAD/CAM composite resin restorations did not significantly influence their marginal quality.

Regarding the fracture resistance

Knowing the fracture resistance of a ceramic material in vitro, prior to its clinical application is very important. Static loading to fracture is a test that is most commonly used to give an indication of a material and a type of restoration suitability as viable option for clinical situations. However, it can only show the strength of a restoration immediately after bonding and most likely it shows values of fracture resistance that are not indicative of the long-term success of the restoration. [29] The specimens in this study were subjected to thermal cycling before fracture testing in an attempt to closely simulate the clinical conditions under which the restorations function.

All specimens were tested using vertical loads, even though lateral forces are the most damaging, so clinical implications of the current study must be limited to that application. The data of fracture resistance in this study should be taken relatively not as absolute ones, and the extrapolation of this data to the clinical situation must be considered carefully. [30]

The results showed that endocrowns restoring teeth without incorporating FRCs showed higher mean fracture resistance values than endocrowns restoring teeth with FRCs reinforcement and the mean difference was statistically significant. It's assumed that after the adhesion has been established, the occlusal stresses that occur during function are transmitted to the walls of the pulp chamber. So the deeper the pulp cavity and the resulting intracoronal extension, the greater the surface area that can be utilized for adhesive retention and transmission of masticatory forces. [31]

In this study, FRCs was used to reinforce the cavity of endodontically treated teeth instead of the restoration. For classic lab-made indirect composite restorations, FRCs are commonly incorporated during the hand-made laboratory fabrication directly inside the work piece. Since FRCs cannot be incorporated into machine milled blocks, the alternative method will be the insertion of the FRC layer inside the direct resin composite build-up of the pulp chamber during the cavity preparation underneath the restoration, in a more "tensile" zone. This mean that any beneficial effect of fibers will appear only in case of a thin restoration. It is worth mentioning that in the current study, the high thickness of the CADCAM restorations could have contributed to the lack of the effect of the FRCs substructure on the fracture resistance. Further in vitro studies and clinical trials are needed to confirm these results. [28,32]

The assumption that the FRC layer has the ability to slow or stop the crack propagation through underlying tissues preventing irreversible fractures cannot be taken into consideration without further investigations. The orientation of the fibers, fibers volume fraction, fibers localization inside the restoration, the type of composite material, the application technique and the thickness of such layer are all factors which should be widely considered. [33]

Rocca et al [33] presented clinical technique using fiber-reinforced composite as a resin-coating layer for adhesive endocrown restorations in an attempt to reduce the risk of catastrophic fractures and thus improve the success rate of this type of restoration on non-vital teeth. Furthermore, this composite base reinforces cavity walls during the temporary phase. [11] Although all of the above mentioned benefits of FRC coating might seem rewarding, its effect on the fracture resistance of the endodontically treated teeth restored with endocrowns was not clearly investigated.

Adding FRC to fill the pulp chamber although meant to be of a certain purpose it added to the complexity of the structure. Being a complex multilayered restoration, several factors contribute to the mechanical behavior of the restoration/ tooth system. The intrinsic strength of each component of the system (tooth, adhesive system, luting cement layer, pulp chamber filling material and restoration), the thickness of the restorative material, the ratios of elastic moduli between the components, and finally the quality of the adhesive interface between these layers in terms of bond strength, all these factors play a role in the behavior of such restorations which may has affected the results of fracture resistance. [34,35]

The results of the current study are in agreement with those of a recent study (2015) by Rocca et al [32] who evaluated the fracture strength and the mode of failure of endodontically treated molars restored with CAD/CAM overlays with fiber reinforced composite build-up of the pulp chamber. Their study included the following groups: group 0 (control), no resin build-up; group 1, hybrid composite build-up (G-aenial Posterior, GC); group 2, as in group 1 but covered with 3 nets of bi-directional E-glass fibers (EverStickNET, Stick Tech ltd); group 3, a FRC resin (EverX Posterior, GC); group 4, as in group 3 but covered by the bi-directional fibers. It was concluded that for the restoration of endodontically treated molars, the incorporation of FRCs did not influence the load-bearing capacity of the tooth-restoration complex. The SEM analysis showed a low ability of the bi-directional fibers net in deviating the fracture but this effect was not sufficient to cause more favorable fracture patterns, over the CEJ.

CONCLUSIONS

Within the limitation of this study, the incorporation of FRCs into the pulp chamber of endodontically treated teeth restored with zirconia reinforced glass ceramic endocrowns had no influential effect on the marginal adaptation of the restoration before or after cementation or after thermocycling. However, the presence of the FRCs unexpectedly decreased the mean values of the fracture resistance of the restorations. Further investigations are needed to confirm these findings before clinical application.

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