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Effect of restoration design and material on the fracture resistance and failure mode of endodontically treated premolars

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Abstract

To evaluate the effect of two different ceramic materials (IPS E-max and Vita Enamic) on fracture strength and failure mode of endodontically treated premolars restored with endocrowns, overlays, and occlusal veneers. A total number of 49 recently extracted intact maxillary first premolars were selected with standardized MOD cavities with endodontic treatment were selected for this study except for intact control group. Teeth were randomly divided according to type of restorations into four main groups: Group C: intact control (n=7), EN: endocrown group (n=14), OL: overlay group (n=14) and group OV occlusal veneer group (n=14). EN, OL and OV groups were further subdivided into two subgroups 1 & 2 (n=7) according to type of restorative material used lithium disilicate and polymer-infiltrated ceramic network. Restorations were fabricated by CAD/CAM technology and then bonded to their corresponding teeth. Fatigue survival was tested for all restorations using a cyclic loading machine until fracture occurred or 250,000 cycles were completed. Fracture resistance test was then performed using universal testing machine. The load needed for fracture of each specimen was registered automatically in Newtons (N) and mode of failure was also examined. Data were collected, tabulated, and statistically analyzed. Obtained data were analyzed using two-way ANOVA followed by Tukey's post hoc test. All samples survived after cyclic loading test, for fracture resistance test; no statistically significant difference was found among groups. In terms of failure modes, statistically significant differencewas found being more favorable for polymer-infiltrated ceramic network sub-groups than lithium disilicate subgroups. For restorative treatment of badly broken down endodontically treated premolars, minimal invasive occlusal veneer restorations made of LDC or PIC materials are successful alternatives. In failure mode polymer-infiltrated ceramic showed favorable fracture pattern than lithium disilicate.

Keywords: Endodontically treated teeth, endocrown, overlay, occlusal veneer, lithium-disilicate ceramic.

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1. Introduction

Restoration of endodontically treated teeth has been a controversial topic for many years in to resume full function and serve satisfactorily as an abutment for a partial dental prosthesis, so, special techniques are needed to restore teeth [1]. Usually, a considerable amount of tooth structure has been lost because of caries, trauma or endodontic treatment, and the placement of previous restorations. Moreover, and after endodontic treatment the proprioceptive response of teeth changes a lot [2]. The loss of tooth structure makes retention of subsequent restorations more problematic and increases the liability of fracture during functional loading, therefore different clinical techniques have been proposed to solve these problems and opinions vary about the most appropriate one [3]. Full crown and post insertion have been considered the gold standard therapeutic approach for large cavities in endondontically treated teeth for years [2]. However, full crown preparations tend to remove a large amount of healthy dental tissue from teeth that have already [4]. Also placing the post and removal of additional tooth structure to retain the post. Sometimes it may be difficult to restore the tooth later, when a complete crown is needed, because the cemented post may have failed to provide adequate retention for the core material. The post itself can complicate or prevent future endodontic re-treatment that may be needed; also, preparation of a post space may accidentally lead to root perforation [5,6]. During the last 30 years, adhesive philosophy in dentistry had dominated and gradually changed the belief that the endodontically treated tooth should be restored with post, core, and crown, instead, adhesion provides sufficient material retention without the need of aggressive macro-retentive technique [7,8]. Recently, studies have focused more on partial bonded restorations, which ensure higher sound tissue preservation than traditional fixed full crowns [9]. As a consequence of this paradigm shift, partial bonded restorations, such as inlays, onlays, overlays, occlusal veneers and endocrowns, have been proposed for the rehabilitation of endodontically treated teeth as alternatives to conventional post, core and crown [7,10]. Recent studies have reported that their longevity depends directly on the amount of remaining tooth structure and the efficacy of restorative procedures in replacing fracture structural integrity [11]. The partial coverage restorations are basically monolithic restorations, manufactured by computer-aided design/ computer-aided manufacturing technology (CAD/CAM) or by heat pressing technique. Currently, CAD/CAM technology has attracted attention from most health professionals, mainly dentists, due to its practicality and high-level results, allowing a more adequate adaptation of the prostheses in general [12]. Monolithic restorations offer high flexural strength, with no chipping of a porcelain veneer. They provide a balance of versatility and simplicity and are recommended for posterior restorations with limited space between maxillary and mandibular teeth and for patients exhibiting bruxism and clenching [13,14]. Partial coverage restorations can be constructed using an array of materials such as feldspathic ceramics, lithium disilicates, zirconia and hybrid ceramics [9,15]. With the intent of increasing the amount of information about the mechanical behavior of these materials and the performance of different minimally invasive restorations int restoring endodontaically treated teeth, the present study evaluated the fracture resistance and failure modes of three different partial coverage restorations using two types of CAD/ CAM materials when they were submitted to cyclic loading followed by axial compressive load to fracture. The null hypothesis of this study was that: neither the CAD/CAM material nor the preparation design would affect the fracture resistance and failure mode of endodontically treated premolars with MOD cavity.

2. Materials and methods

2.1. Tooth Collection and Preparation

A total number of forty-nine recently extracted intact, crack and caries-free human maxillary first premolars, extracted for periodontal or orthodontic reasons, were selected for this study. For standardization, the teeth were selected with approximate similarity in crown size, length, and shape. They were of average dimensions (7 ± 0.5 mm) mesio-distal width, and of bucco-lingual width (8mm ± 0.5mm). All dimensional measurements were taken at the proximal cementoenamel junction (C.E.J) level using a digital caliper. Any calculi and soft tissue deposits were removed with a hand scaler (Gracey currette; Hu-Friedy, Chicago, IL, USA) and pumice prophylaxis. Then the collected teeth were stored in distilled water at room temperature from the day of extraction until the time of testing, to keep them hydrated and prevent cracking during preparation. The teeth were randomly divided into four main groups: Group C: sound premolars without endodontic treatment or cavity preparation as control (n=7), group EN: sound premolars with endodontic treatment and the prepared cavity were restored with endocrown (n=14) , group OL: sound premolars with endodontic treatment and the prepared pulp chambers were restored with composite then the occlusal part was restored with ceramic overlay (n=14), group OV: sound premolars with endodontic treatment and the prepared pulp chambers were restored with composite then the occlusal part was restored with ceramic occlusal veneers (n=14).

The three groups EN, OL and OV were furtherly subdivided into 2 sub-groups:

- **Subgroup 1**: restorations made from E-max CAD (n=7).
- **Subgroup 2:** restorations made from Vita Enamic (n=7).

2.2. Endodontic Procedures

Endodontic treatment was performed for all groups except for the control group. A diamond round bur (Komet, Germany) was employed with a high-speed handpiece under copious air-water cooling to eliminate the roof of the pulp chamber. Size 10 K files (Dentsply, Germany) were placed into a canal after the pulp was removed till their tip could be seen at the apical foramen. By subtracting 1 mm from this length, the working length was calculated. NiTi rotary instruments were used for the endodontic procedure (ProTaper next; Dentsply Maillefer). The canals were enlarged using a crown-down technique with EDTA (MD-CHelCream, META®BIOMED, Korea) as a lubricant until master apical file X2. During endodontic procedures, 5.25 % NaOCl was used to irrigate the canal. All canals were dried with paper points and obturated with ProTaper next X2 gutta percha with sealer (Gutta Flow® 2, Coltene) and Extra gutta-percha was eliminated with a heated tool, and the coronal portion was compacted vertically with a plunger[4]. Walls of the pulp chamber were prepared to provide occlusal divergence with 10º using tapered abrasives with flat end(16). The access cavity was restored for only groups OL and OV. the etch-and-rinse adhesive approach was used, the access cavities were etched with 37% phosphoric acid for 20 sec., then rinsed with water for 10 seconds and dried with air for 5 seconds. Two thin coats of a universal bond were applied and polymerized using LED light-curing unit (Elipar S10, 3M ESPE, St Paul, MN, USA) operating in standard mode at light intensity 1200 mW/cm². Then the composite resin (Filtek Z350XT, 3M ESPE) was applied into two increments and the teeth were cured occlusally, mesially and distally for 20 sec. for each surface with the light curing unit. For group EN, A thin layer of flowable composite resins (Filtek Z350, 3M ESPE) was applied to seal the canals entrance and uniform depth of pulp chamber at 4 mm. For periodontium simulation, the roots of all teeth were dipped in melted blue inlay wax to a depth of 2mm away from cemento-enamel junction to form a uniform coat of about 0.3 mm around root [17]. Specially designed cylindrical Teflon mold formers having 2cm length and 2cm internal diameters were fabricated. Its cylindrical tube used for holding of the epoxy resin and the tooth inside it. Accurate centralization of the teeth in the epoxy resin was done using a specially designed centralizing metal device for standard placement. The teeth were removed from the casted epoxy block, wax spacer was removed and light body poly-vinyle siloxane material (Speedex, Coltene Whaldent AG, Attstatten, Switzerland) was injected in the space between mold and root and teeth were re-inserted in the mold. The specimens were stored in distilled water in 37°C.

2.3. Samples preparation

The teeth were prepared using a high-speed turbine hand piece that was secured and adapted to a modified dental surveyor to ensure a standardized degree of taper and uniform amount of reduction. Occlusal reduction was performed for all teeth in all groups except the control group, for groups EN

& OL the preparation included: planar occlusal reduction of 2 mm of the palatal cusps and 1.5 mm for the buccal cusps with butt joint, while for group OV the occlusal reduction was 1.5 mm of the palatal cusps and 1 mm for the buccal cusps with butt joint. Four depth grooves were made in the occlusal surface following tooth anatomy using Komet® PrepMarker cutting depth burs then then these depth grooves were connected by removing enamel portions between them with a flat-ended cylindrical diamond bur size #8113R Intensiv® for inlay preparation. For EN group, an MOD cavity was prepared using Intensiv® kit for inlay preparation diamond burs #8113R, #8113NR, #8117, #3113R, #3113NR, # 3117 at the former position of the central fossa of the occlusal surface to a depth of 2mm. Then the cavity was extended mesially and distally to the mesial and distal fossa. The preparation was extended 1.5mm beyond the central groove in the buccal direction and 1.5mm in the lingual direction so that buccolingual width corresponded to one-third of the bucco-lingual distance, with a flat floor proximal box 3mm cervically and 4mm occlusally. All internal line angles were rounded. The pulp chambers were prepared with 10º occlusal divergence and oval shape with a 4 mm depth from the cavosurface margin. A proximal box-shaped cavity with no proximal step was prepared with 6-degrees divergence and width of the gingival seat 1.5mm mesiodistally and the height of the axial wall was 2mm. The bucco-lingual width of the with smooth and rounded internal line angle (Fig. 1). For OL group, the MOD cavity was prepared with the same dimensions as the EN group except that the access cavity was sealed with composite with 2 mm deep pulpal floor from the occlusal surface, and 4 mm deep proximal boxes (Fig. 2). While for OV group, no MOD cavity was performed, only the proximal preparation was represented by slot design which had a rounded shoulder of about 1.5 mm depth, with bucco-lingual width was 1/2 of the buccal-lingual distance, and gingival floor was located 1 mm above the CEJ (Fig. 3).

2.4. Restoration design and bonding procedures

The samples were scanned by extraoral Scanner (T300 MEDIT) after being sprayed by sprayed by Renfert scanspray and STL files were produced to create a 3-D virtual abutment, designing the restoration was done using Exocad Galway 3.0 software. All the samples were designed to have similar occlusal anatomy by using the biogeneric reference option. After checking the design milling process was done using Mc XL milling machine. After checking the restorations on their corresponding teeth, then E-max restorations were etched by hydrofluoric acid (Porcelain Etchant Gel- 9.5% Buffered Hydrofluoric, Bisco Inc, USA)9.5%) for 20 seconds while Vita Enamic restorations were etched for 60 seconds, then rinsed thoroughly with water for 15 seconds and air dried. Silane coupling agent (Porcelain Primer/Bis-Silane™, Bisco Inc, USA) was then applied on the internal surface of restorations for 60s and air dried for 5 seconds. Surface treatment was done for teeth utilizing total etch technique by applying 37% phosphoric acid–etching gel (ETCH-37 w/BAC, Bisco Inc, USA) for 15 seconds, rinsed for 20 seconds, and air dried for another 5 seconds, then two separate coats of all-bond (Universal ALL-BOND UNIVERSAL, Bisco Inc, USA), were applied to the preparation with a microbrush, air dried for 3 seconds, then light cured for 20 seconds. The dual cure resin cement BisCem cement (BisCem, Bisco Inc, USA) was applied on the prepared surface of teeth. Then each restoration was bonded to its corresponding tooth with finger pressure, excess cement was removed immediately with a microbrush,.a loading device was then used to apply constant load of 1 Kg parallel to the long axis of each restoration, then light activated at each surface for 20 seconds according to manufacturer's instructions (fig 4).

2.5. Cyclic loading and fracture resistance

Mechanical aging was performed using a programmable logic-controlled equipment; the newly developed four stations multimodal ROBOTA chewing simulator (Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY), the specimens were embedded in Teflon housing in the lower sample holder. A weight of 5 kg, which is comparable to 49 N of chewing force was exerted at an angle of 90 degrees to the long axis of each sample. The test was repeated 250,000 times to clinically simulate the 1 year chewing condition according to previous studies (18) (19) (20). A single static compressive load application was applied along the long axis of the survived specimens and mounted on universal testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) with a loadcell of 5 KN and data were recorded using computer software (Instron® Bluehill Lite Software). Samples were secured to the lower fixed compartment of testing machine by tightening screws. Fracture test was done by compressive mode of load applied occlusally using a metallic rod with round tip (3.4 mm diameter) attached to the upper movable compartment of testing machine traveling at crosshead speed of 0.5 mm/min with two layers foil sheet in-between to achieve homogenous stress distribution and minimization of the transmission of local force peaks (fig 5). The load at failure was manifested by an audible crack and confirmed by a sharp drop at load-deflection curve recorded using computer software (Bluehill Lite Software Instron® Instruments). The load required to fracture was recorded in Newton. Data recorded were collected, tabulated, and statically analyzed. After fracture resistance test, specimens in all test groups were viewed using a USB digital-microscope (U500x Digital Microscope, Guangdong, China), magnification x35, and the images were captured and transferred to a personal computer equipped with the Image-tool software (Image J 1.43U, National Institute of Health, USA) to determine failure mode pattern (Fig 6).

2.6. Statistical analysis

Categorical data were presented as frequency and percentage values and were analyzed using chi-square test. Numerical data were represented as mean with 95% confidence interval (CI), standard deviation (SD), minimum (min) and maximum (max) values. Shapiro-Wilk's test was used to test for normality. Homogeneity of variances was tested using Levene's test. Data showed parametric distribution and variance homogeneity and were analyzed using two-way ANOVA followed by Tukey's post hoc test. Groups were compared to the control group using one-way ANOVA followed by Dunnett's post hoc test. The significance level was set at $p<0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.3.1 for Windows[1].

3. Results

Descriptive statistics for fracture resistance values are presented in table (1) and in figure (1). Results of two-way ANOVA presented in table (2) showed that the effect of both tested variables as well as their interaction on fracture resistance was not statistically significant (p>0.05). Results of intergroup comparisons showed all groups to be not significantly different from the control group (f=1.57, p=0.180). Results for intergroup comparisons for failure modes are presented in table (3) and in figures (2) and (3). Results showed that regardless of preparation design, significantly higher percentage of Vita Enamic samples had non catastrophic failures in comparison to Emax samples (p<0.05). While within both materials, results showed that there was no significant difference between failure modes in different designs (p>0.05).

4. Discussion

Rehabilitation of the endodontically treated teeth with severe crown damage represents a clinical challenge, in fact, tooth fracture's etiologies are multiple and uncontrollable by dentists [21]. While making a decision for treatment of endodontically treated teeth with extensive loss of coronal structure, it should be aimed at protecting and strengthening the remaining tooth structure. Therefore, the materials available in the market and the prosthetic treatment choices play an important role in the longevity of both the restoration and endodontically teeth [22]. The introduction of adhesive techniques has altered the restoration of endodontically treated teeth, since it is no longer necessary to take the mechanical retention into account, but instead rely on micromechanical retention provided by the adhesive procedure. Bearing this in mind, the more area between the tooth and the restoration (interface area), the higher probability of survival of the restoration [23,24]. It is reported in literature that the restoration of cavities with remaining palatal and buccal walls using onlay restorations with proximal boxes and cusp coverage is better than with Inlay restorations without cusp coverage [25,26]. In this study, maxillary endodontically treated premolars with MOD cavities were used as they present unfavorable anatomy in crown volume and crown-to-root proportion, making them more susceptible to cusp fractures compared to other posterior teeth when exposed to occlusal load, also cusp coverage becomes necessary when the width of the cavity isthmus is greater than two thirds of the inter-cuspal distance or one third of the buccolingual distance [7,27,28]. Moreover, endocrowns and various partial coverage restorations effectiveness to restore endodontically treated premolars still needs to be proved in such deteriorated clinical scenario [29,30]. The superior mechanical strength of lithium disilicate ceramics is credited to the interlocked microstructure and shape of crystals [9,23]. They are characterized by high crystallinity and high aspect ratio grains, which promote bridging and hinder crack propagation [31]. Additionally, lithium disilicate can bear high occlusal stresses due to its slightly higher elastic modulus than enamel (100 GPa versus 84 GPa respectively) that made it a reliable material for indirect restorations [32]. Another advantage of lithium disilicate ceramics is that it can be reduced to a certain thickness while still maintaining high strength [33] together with their esthetic properties [34]. Vita Enamic has mechanical properties close to the natural dentine and combines the properties of ceramic and polymer [33]. The advantages of this material such as the reasonable brittleness index and proper fracture toughness [35]. In addition to modulus of elasticity similar to that of the natural tooth structure (Vita Enamic: 30GPa VS dentin: 13.3GPa) and it's hardness value was lower compared to silica-based ceramics thus resulting in less wear than traditional ceramic, all of this reasons favors its trial as a material for various partial coverage restorations construction [16,35]. In this study all the specimens survived after being tested by the chewing simulator indicating that all designs and materials have the minimum requirements to withstand the intraoral conditions for at least 12 months of service without any detectable sign of early failure with a 100% survival rate. After that fracture resistance test was performed. Depending on age and facial morphology, the physiological maximum occlusal force will range from 100 to 500 N. According to the findings of several studies, the usual biting force in the premolar region ranged from 222 to 445 N (average 322.5 N). During clenching, the occlusal force could be as high as 520–780 N (average 660N) [23]. The mean fracture loads for the various tested groups are higher than the mean of maximum biting forces in this study. As a result, all the tested samples should be able to withstand the masticatory forces. According to the results of this study, the research null hypothesis was partially accepted, neither the CAD/CAM material nor the preparation design had affected the fracture resistance of endodontically treated premolars with MOD cavity. However, Vita Enamic restorations showed significantly more favorable mode of failure. Regarding the effect of the control group (1225.26±39.43) showed higher values than IPS E-max and Vita Enamic groups. IPS E-max (1031.95±334.53) had a higher value than Vita Enamic (973.18±210.08) yet the difference was not statistically significant (p=0.510). The higher fracture resistance of IPS E-max groups could be attributed to its superior bonding strength to natural structure and biomechanical properties [38]. The lower values of Vita Enamic groups could be attributed to the relatively low mechanical properties of this material including low flexural strength (150-160 MPa) and low fracture toughness (1.5 MPa) [39]. Another possible factor may be the hybrid nature of this material as it is composed of interconnected networks of ceramic and polymer, which leads to different rates of ablation for ceramic and polymer during the grinding and polishing processes, that may result in microcracks in the network boundaries, and this is assumed to decrease the mechanical properties of the material. Moreover, in a hybrid material, failure could be initiated from any weak point of the microstructure, like the polymer in a polymer-infiltrated ceramic [24].

[1]R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

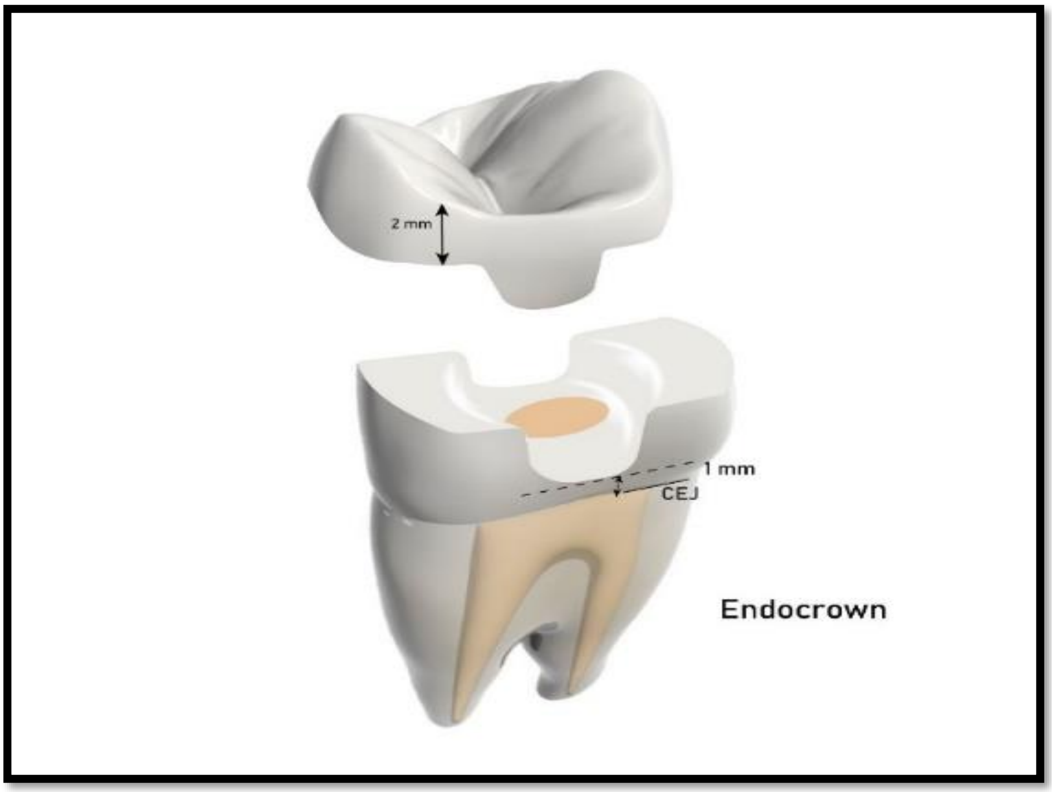

Figure 1: Schematic diagram of endocrown preparation

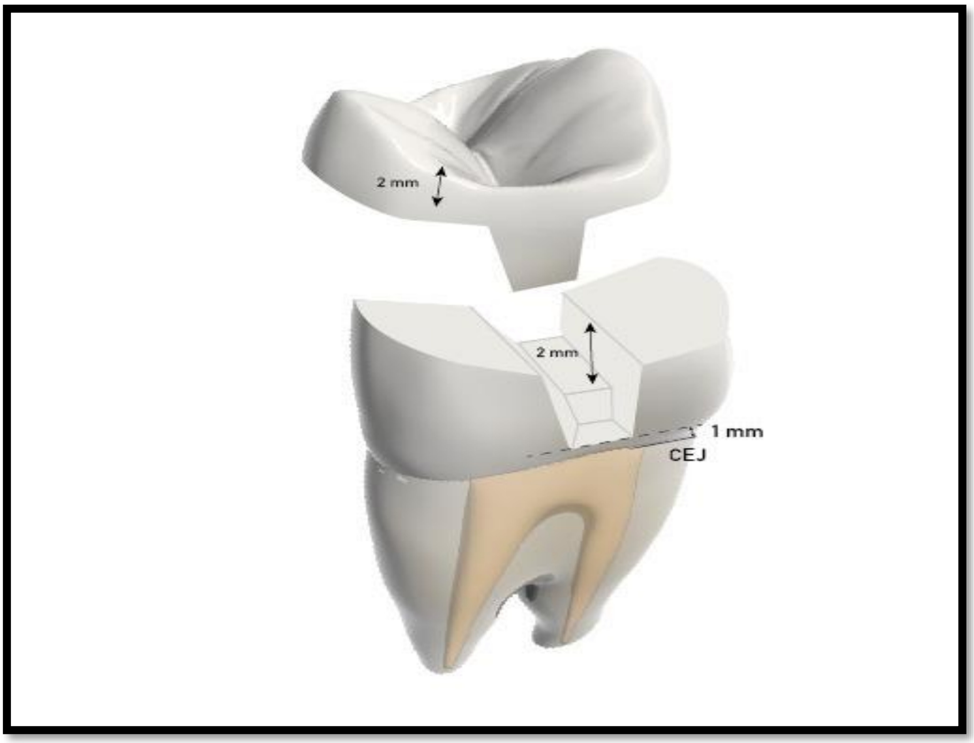

Figure 2: Schematic diagram of overlay preparation.

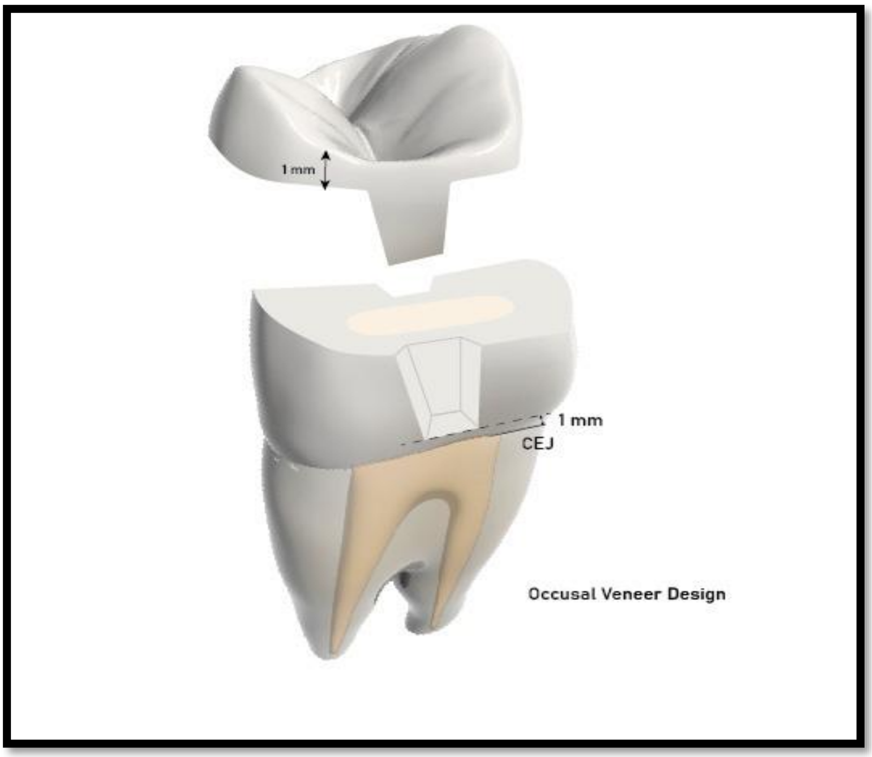

Figure 3: Schematic diagram of occlusal veneer.

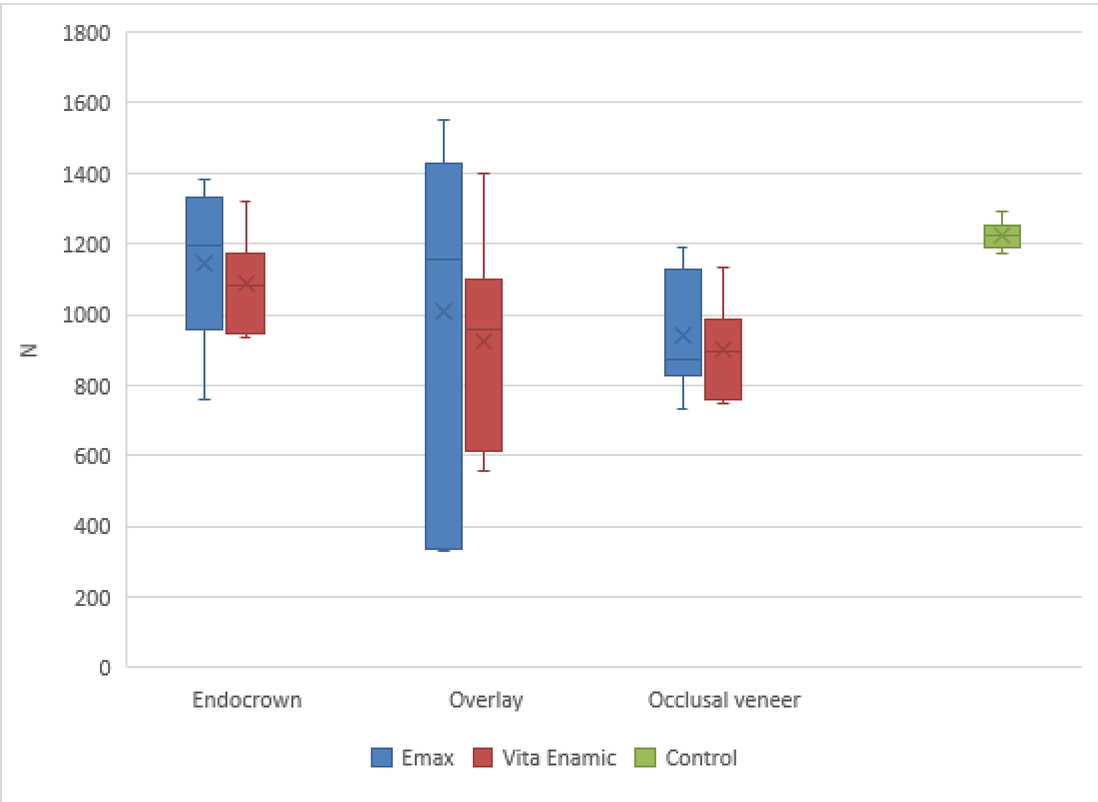

Figure 4: Box plot for fracture resistance (N) values

Table 1: Descriptive statistics

Material	*Preparation design*	*Mean*	*95% CI*		*SD*	*Min.*	*Max.*
			Lower	*Upper*			
Emax	*Endocrown*	1147.20	976.10	1318.31	230.97	758.23	1381.11
	Overlay	1007.47	625.93	1389.02	515.04	329.28	1552.99
	Occlusal veneer	941.16	815.88	1066.45	169.12	729.31	1189.41
Vita Enamic	*Endocrown*	1090.10	989.83	1190.38	135.36	933.63	1320.49
	Overlay	926.02	708.58	1143.45	293.51	557.34	1401.79
	Occlusal veneer	903.40	802.87	1003.94	135.71	746.52	1134.39
Control		1225.26	1196.05	1254.47	39.43	1171.95	1289.19

Table 2: Two-way ANOVA test results

Parameter	*Sum of squares*	*df*	*Mean square*	*f-value*	*p-value*
Material	36265.71	1	36265.71	0.46	**0.501**
Preparation design	296865.00	2	148432.50	1.89	**0.165**
*Material * design*	3356.21	2	1678.10	0.02	**0.979**

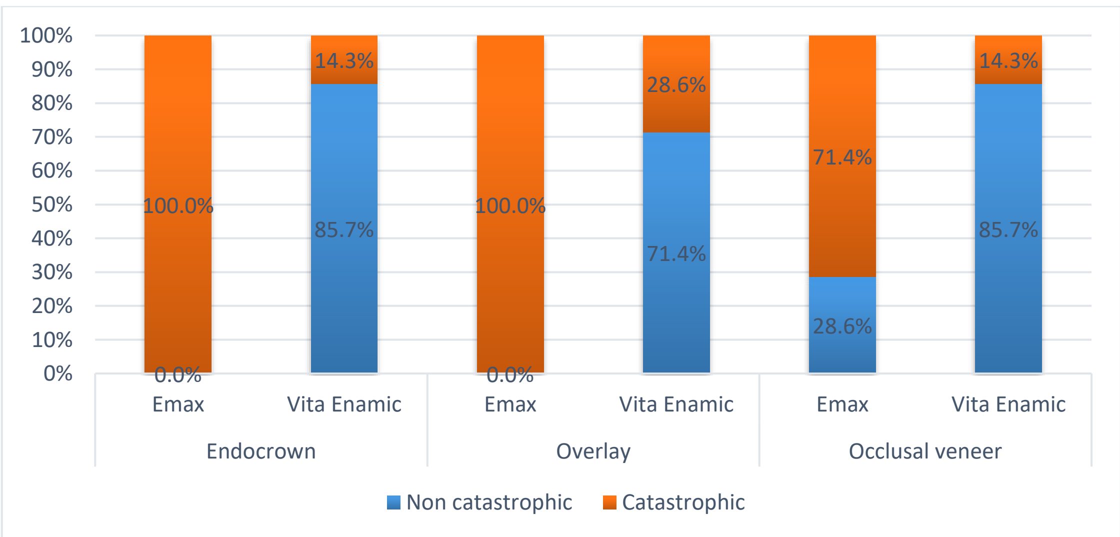

Figure 5: Stacked bar chart showing mode of fracture distribution (A)

Table 3: Intergroup comparisons of failure modes

Preparation design	***Failure mode***	***Material***		χ^2	***p-value***
		Emax	***Vita Enamic***		
Endocrown	***Non catastrophic***	0 (0.0%)	6 (85.7%)	**10.5**	**0.001***
	Catastrophic	7 (100.0%)	1 (14.3%)		
Overlay	***Non catastrophic***	0 (0.0%)	5 (71.4%)	**7.78**	**0.005***
	Catastrophic	7 (100.0%)	2 (28.6%)		
Occlusal veneer	***Non catastrophic***	2 (28.6%)	6 (85.7%)	**4.67**	**0.031***
	Catastrophic	5 (71.4%)	1 (14.3%)		
χ^2		**4.42**	**0.62**		
p-value		**0.110**	**0.734**		

*significant (p<0.05)

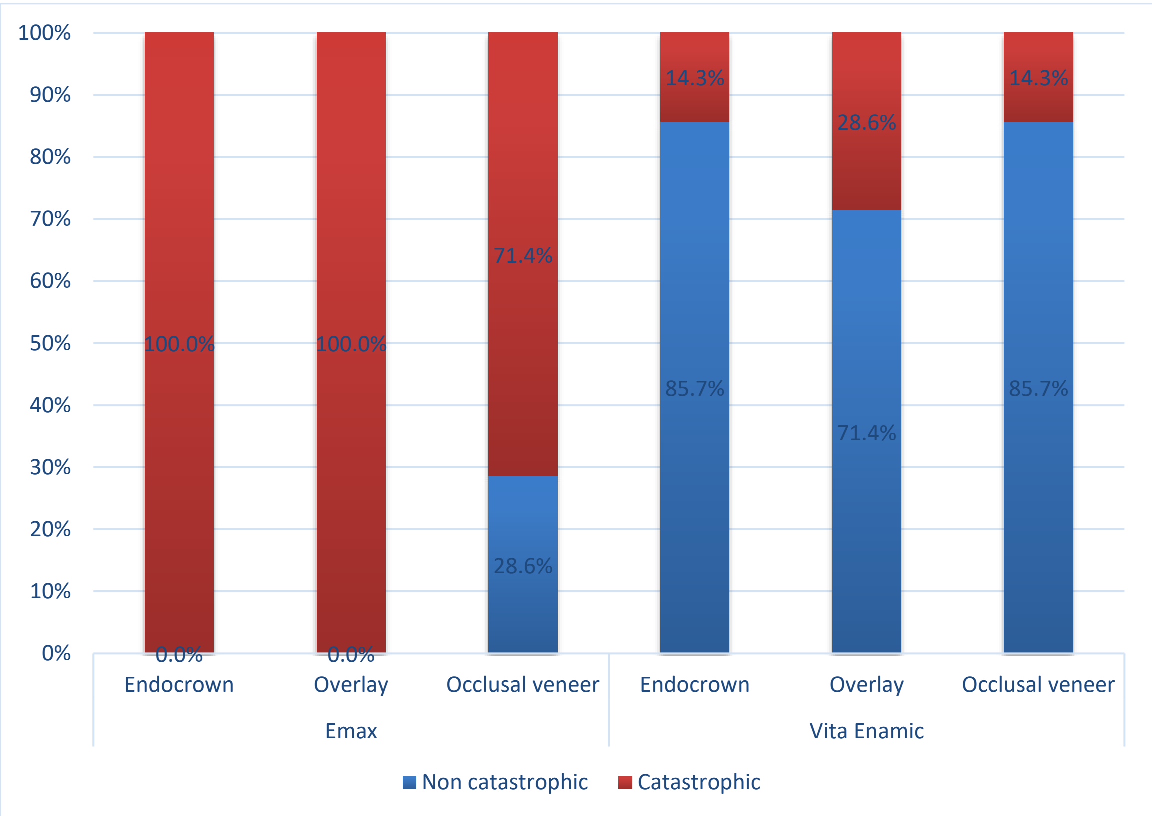

Figure 6: Stacked bar chart showing mode of fracture distribution (B)

These values were comparatively similar to other study conducted by Alshehri et al. who showed results similar to\ our study, they evaluated the influence of occlusal thickness and radicular extension on the fracture resistance of premolar endocrowns from different ceramic materials and concluded that fracture resistance of endocrowns fabricated from polymer infiltrated ceramics are lower than that of lithium disilcate ceramic with mean fracture resistance at 2 mm radicular extension [38]. On the other hand, the results of this study were opposed by that conducted by S. Al shibri et al. who compared the fracture resistance of endocrowns on endodontically treated premolars made of lithium disilicate and hybrid ceramics, in their study the higher mean value of fracture resistance was found in hybrid ceramic group followed by the lithium disilicate group. these differences in results may be attributed to the difference in the material used in their study since they used CERASMART. Blocks [40]. Concerning the effect of preparation design on fracture resistance of partial coverage restorations, this current study showed that there was no significant difference between different groups, (p=0.524). for both ceramic materials, the highest value was found in endocrowns, followed by overlays, while the lowest value was found in occlusal veneers, this could be due to the thicker the ceramic thickness from the occlusal surface of the restoration the more its fracture resistance [41]. These results are comparable to the results conducted by Mohamed S. et al who studied fracture resistance of molar teeth restored by endocrown and onlay CAD/CAM monolithic ceramic materials. Their results revealed that no statistically significant difference between endocrown and onlay with endocrown group showing slightly better results than onlay group [24]. However, our study was opposed by a study published by B. Gürpınar et al. who evaluated the fracture resistance of occlusal veneer and overlay CAD/CAM restorations made of polymer-infiltrated ceramic and lithium disilicate ceramic where they used occlusal veneers of 1mm occlusal thickness and MOD overlay of 2mm occlusal thickness, their results showed that no statistically significant differences were found in terms of fracture strength between the occlusal veneer and overlay groups with occlusal veneer group showing slightly higher results than overlay group. Though, in their study, sound mandibular molar teeth with no endodontic treatment were utilized and the samples were exposed to thermo-dynamic cyclic loading of 100,000 cycles. Also no MOD cavity design was applied to the occlusal veneer group [42]. Most IPS E-max restorations showed a catastrophic mode of fracture, which includes combined fracture of the restorations and the tooth structure. According to Yamanel et al., they suggested that the more stress is transferred to restorative material with the high elastic modulus, predisposing it for the early fracture [43]. Materials with more compatible elastic moduli tend to bend under load and distribute stresses more evenly, while rigid materials with different elastic moduli produce stress concentrations at critical areas that might cause catastrophic failures [44]. Furthermore, high bond strength that occurred between ceramic restorations and tooth surface by resin cement may have played a role in this [24]. This goes well with El-Damanhoury et al., in their study they evaluated the fracture resistance of endocrowns utilizing different CAD/CAM blocks and their results showed that more favorable failure mode of hybrid ceramics when compared to lithium disilicate ceramics when used to restore endodontically treated teeth with extensive loss of tooth structure [44]. Yet, the current results are not coinciding with Gurpinar et al., according to the results of their study, 29.1% of the Vita Enamic restorations and 20.8% of the E-max restorations exhibited catastrophic failures, with no statistically significant difference between materials in terms of failure mode, this could be due to the fact that they used sound mandibular molar teeth with no endodontic treatment were in their study, also the samples were exposed to thermo-dynamic cyclic loading of 100,000 cycles with no MOD cavity design applied to the occlusal veneer group [42]. It is important to point out that the present study does not accurately reflect the dynamic intraoral conditions. In contrast to clinical studies, the clinical load capability of root-filled teeth is predisposed by other factors like the number of adjacent teeth, occlusal contacts, tooth position in the dental arch and apical status. Exposure of combined thermal, chemical, and physical stresses may also have played role. In addition, the destructive fracture testing method used is not typical of the type of loading that occurs clinically. Therefore, long term clinical studies are recommended to verify in-vitro results.

5. Conclusions

Within the limitations of this in-vitro study, the following could be concluded:

- Endodontically treated teeth with severe crown damage can be restored by minimal invasive partial coverage restorations made of Lithium disilicate and Polymer infiltrated ceramics.
- Polymer infiltrated ceramics (Vita Enamic) restorations are as resistant as lithium disilicate (E-max) restorations, but they tend to have more favorable mode of failure.

Recommendations

- Endocrown, overlay & occlusal veneer provide good choices for endodontically treated premolars.
- Lithium disilicate restorations provide better mechanical properties.
- In cases of questionable prognosis, Vita Enamic restorations are recommended over lithium disilicate ones due to their more favorable mode of failure.
- MOD cavities in endodontically treated premolars can be utilized in restoration design as a minimally invasive therapeutic approach.

Conflict of intrest

The authors have no conflicts of interest related to this study.

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Nil.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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