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"Fracture resistance of endodontically treated maxillary incisors restored by two designed endocrowns using two materials"

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Abstract:

This study is conducted to evaluate the fracture resistance of endodontically treated maxillary incisors restored by endocrowns using two ceramic materials; lithium disilicate and polymer infiltrated ceramic in comparison to conventional fiber posts, core and full coverage crown. A total of thirty sound, carious free human maxillary incisors were freshly extracted due to periodontal disease. Teeth were divided into two groups; (I) to receive endocrowns and (II) to receive full coverage crowns. each group was further divided into two subgroups; (L) for lithium disilicate and (V) for Vita Enamic. Teeth were endodontically treated and then mounted into acrylic resins blocks using A.M.D dental surveyor. Computer numerical control machine (CNC) was used to standardize the preparation in all teeth. All teeth were scanned using an omnicam scanner and then the designed was established to receive the purposed restorations for each group. Wet milling technique of the CAD blocks was used. Restorations were glazed, finished and polished and cemented. The restorations were tested for fracture resistance using universal testing machine. E.max restorations showed higher fracture resistance in comparison to Vita Enamic. Different designs showed no significant difference.

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Introduction:

The coronal tooth structure can be compromised by multifactorial causative agents; defective restorations, large carious lesions, severe attrition, erosion or even wear and occlusal trauma. In these cases endodontic treatment propose the ultimate solution to remove the infected tissue and microorganisms to control the pain and radicular inflammatory response in the root canal system.[1]

Nevertheless, endodontic treatment show many problems due to coronal destruction and root dentin preparation which further weakens the tooth structure

integrity.2 This will result in reduction in the biomechanics of the tooth intraorally under normal occlusal forces and becomes at higher risk of failure.3

For long time dentists restored endodontically treated teeth by placing post, core with subsequent placement of full coverage crowns.4 However, they have some disadvantages, such as fracture of roots, corrosion and even loss of post retention. It requires removal of a large amount of root dentin for preparation for post placement particularly for cast post and cores. An alternative solution was proposed to use a glass fiber post system.

Glass fiber posts have the advantages of having same modulus of elasticity of dentin, using an all adhesive system and esthetically appealing in areas of high esthetic demands which all contributes to reinforcement of the remaining tooth structure, enhancing the esthetic outcome and reduce the mode of failure in comparison to regular metal posts.3

Endocrowns are ceramic restorations that are mechanically anchored and adhesively strongly bonded to hard dental tissues using resin cements.[5 – 7] These restorations are fitted into the internal part of the pulp cavity chamber and margins.8 The advantages of endocrowns are limiting the technical steps during fabrication, being a conservative technique, decreasing the treatment costs and being less time consuming.9

Materials and Methods:

1. Teeth Selection:

In this study, thirty sound, carious free human maxillary incisors were freshly extracted due to periodontal disease. The teeth were selected with average coronal and radicular morphological dimensions irrespective to age, sex and side of the arch. The teeth were examined with a magnifying lens for any coronal or root cracks. Teeth were meticulously scaled by ultrasonic scaler to remove any remnant calculus and debris from roots. The teeth were preserved in a saline solution.

2. Teeth Grouping:

Samples were divided into 2 groups according to design as follow:

1. Group (I): 20 endodontically-treated maxillary incisors restored by endocrowns.
2. Group (II): 10 endodontically-treated maxillary incisors restored by fiber post, core and full coverage crowns.

Each group was further divided according to material into two subgroups:

Subgroup (L): Lithium disilicate (E.max)

Subgroup (V): Polymer infiltrated ceramic network (Vita Enamic)

3. Teeth Endodontic preparation and mounting:

A hybrid technique was used in this study; where a step back and crown down techniques were performed. Pulpal extirpation was carried out using manual Nitiflex files sizes (#15, #20 and #25), (Dentsply, Germany) using the step back technique. Radicular and coronal shaping and flaring of canals were performed using rotary system (Root ZX II) with crown back technique. Irrigation was performed using 5.25% sodium hypochlorite solution in between each filing size. The canals were dried using paper points size #45, polymeric resin sealer ADseal was mixed and coated to the walls of the canals. A color coded (meta-biomed gutta percha 0.6 taper, size F5) was used in all canals. Endodontic finger spreader of size #30 was used to condense the gutta percha points (size #25) using lateral condensation technique.

After endodontic treatment, all samples were individually mounted vertically in polymethyl methacrylate (PMMA) resin blocks to a depth of 2 mm apical to the CEJ using A.M.D dental surveyor 102.

4. Teeth Preparation:

i. *Post space preparation and core build up:*

All group II maxillary incisors are prepared to receive fiber post and core. A Glassix fiber post was used in all teeth (Nordin, Switzerland). First, a penetrating color coded drill was used to remove gutta percha. A standardized (5 mm) gutta percha were left to maintain the apical seal of all teeth, measured by a periodontal probe and a stopper.

Second, a color coded matching calibrating drill was used to shape all canals to receive the fiber post. After drilling, the canal was irrigated and dried with paper points in preparation for post cementation.

Bifix QM resin cement was used. The two liquids (1 and 2) of the Futura Bond ® DC were mixed and used to massage the internal walls of the canals. The bonding layer was dried using oil-free air for 5 seconds. The bonding layer was not light-cured as recommended by the manufacturer. The resin cement was applied directly to the root canal using fine intra-oral canal tips that are provided with the kit. The Glassix fiber posts were silanated and luted by the resin cement and then seated into the root canals. Excess material was removed using cotton pellet. The resin cement was light-cured using LED light for 40 seconds according to the manufacturer to allow for post fixation in place.

Filtek Z250 composite resin was used for core build up. Futura Bond ® DC was used following the bonding system protocol provided by the manufacturer. The two liquids of the bond were mixed properly and applied over the incisal and palatal surfaces of the teeth, dried by oil free air for 5 seconds and then light cured for 40 seconds using LED light.

A standardized incremental composite build-up technique was established, by light curing the resin composite at 2mm increments.

ii. *Coronal preparation designs:*

All teeth preparations were done using CNC machine (Computer Numerical Control). Two designs were established for this study.

The first design, (Group I) is to receive endocrown restoration. Incisal butt margin was made using diamond disc such that the height of the remaining coronal tooth structure is 4 mm till labial C.E.J and the access cavity was made with 3 mm depth and 6 degree divergence. (Fig.1) The depth of the central retention cavity in Group I was 3mm measured from the cavosurface margin. The standardized depth was verified using periodontal probe.

The second design (Group II) is a conventional extracoronal axial wall preparation with circumferential deep chamfer finish line (1.0 mm) wide to receive full coverage crown. (Fig.2). Abrasive stone was attached to the stylus of the CNC machine to prepare both the axial walls and the central cavity extension with a 6 degree taper.

The height of the prepared axial walls of all teeth was standardized to an average of (5.0 mm) above the CEJ to simulate the remaining tooth structure after caries removal.

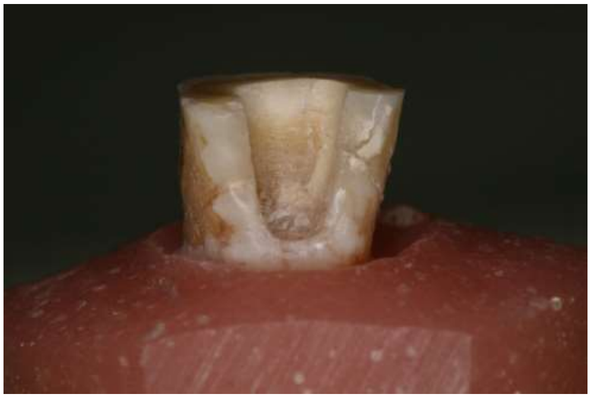

Figure 1: Group I – Endocrowns

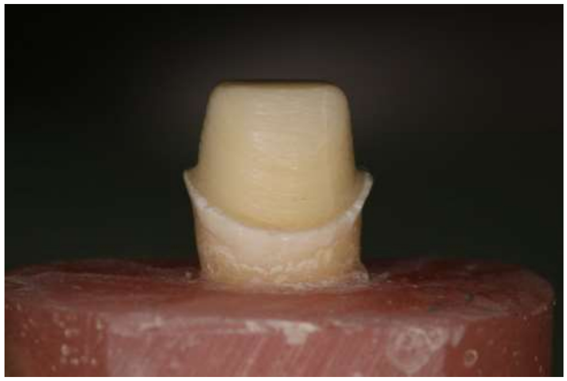

Figure 2: Group II – Full coverage

Preparation crown preparation (labial view)

6. CAD/CAM Restorations Fabrication:

All the specimens including the crowns and endocrowns were fabricated with CEREC system.

A. Scanning:

- Omnicam scanner was used to scan the specimens and produce STL files for the virtual 3D models of the prepared teeth (Fig. 5).

- A window for a new restoration was opened after starting the CEREC 4.4 3D software and a dialog box appeared to enter data regarding new restoration.

- The omnicam scanner was used to scan them in several directions to create a 3D virtual abutment.

values in °C			B	S	t	T	H	V1	V2	L
			Standby temp. [°C]	Closing time [mm:ss]	Temperature increase [°C]	Holding temp. [°C]	Holding time [hh:mm:ss]	Vacuum on [°C]	Vakuum off [°C]	Longterm cooling [°C]
	MIN		100	00:18	10	100	00:00:00	0	0	0
	MAX		700	30:00	140	1200	01:00:00	1200	1201	1200
P.Nr.										
161	Crystallization LT/MT/HT	m.V.	403	06:00	90 / 30	830 / 850	00:10 / 07:00	550 / 830	830 / 850	710
162	Corrective /Stain firing	m.V.	403	06:00	90 / 30	830 / 850	00:10 / 03:00	550 / 830	830 / 850	710
163	Fusion/Crystallization firing CAD-on	m.V.	403	02:00	30 / 30	830 / 850	02:00 / 07:00	550 / 830	830 / 850	610
164	Corrective/Glaze firing CAD-on	m.V.	403	06:00	60 / 30	830 / 850	00:10 / 03:00	550 / 830	830 / 850	610
165	Speed Crystallization	m.V.	403	00:30	120 / 70	850 / 870	00:00 / 03:30	690 / 850	850 / 870	705
166	Crystallization MO/Imp./LT/MT/HT	m.V.	403	06:00	60 / 30	780 / 860	00:10 / 10:00	550 / 780	780 / 860	710

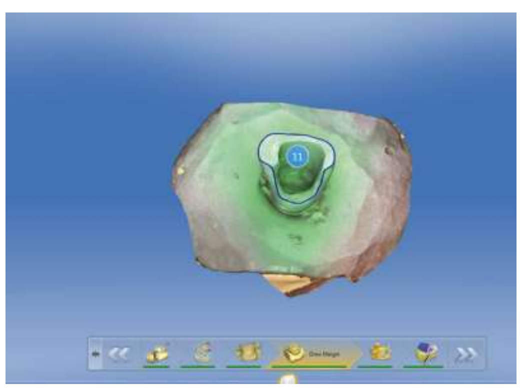

Figure 5: 3D virtual abutment of proposed modified endocrown design

B. Designing:

- Designing the restoration was done using Cerec premium 4.4 software (Fig.6).
- Standardized parameters were set like margin placement, insertion axis, occlusal, wall thickness and cement space.

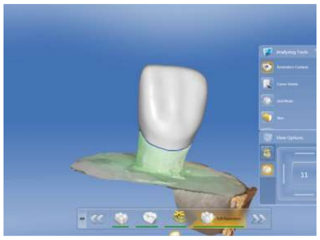

Figure 6: Showing proposed full coverage design – Group II

C. Milling:

- After inspection of the abutment on the screen and setting the cement space to be 60 microns, the designed restorations were exported to the CAM software to mill the crowns and endocrowns. The block size was C14 for the E-max and EM 14 for Vita Enamic. Once the milling process was done, a diamond bur was used to separate the restoration and smoothen the surface.

- Then ultrasonic cleaner filled with fresh distilled water was used to remove residual dust from restorations.

D. Crystallization of E-max restorations:

A brush was used to apply Crystall/glaze paste evenly on the entire restorations. The combination (crystallization/ glaze) was conducted in a compatible ceramic furnace (P3010 Ivoclar Viva Dent furnace) Crystallization\glazing program was then run following predetermined parameters for each material as shown in table (1).

E. Polishing of Vita Enamic Restorations:

The VITA ENAMIC polishing sets were developed for reliable, efficient and material-specific surface treatment of hybrid ceramic restorations in dental practices and laboratories. The sets include various polishing instruments for pre- and high-gloss polishing. These instruments are suitable for careful and gentle polishing of occlusal surfaces, cusps, fissures and contact points of the restoration and produce surfaces with exceptional gloss.

7. Cementation of the restorations:

Etching the restorations:

E-max restorations were etched by hydrofluoric acid for 10 seconds, while Vita Enamic restorations were etched for 30 seconds, according to the manufacturer instructions. Then restorations were rinsed thoroughly with water for 15 seconds and dried with air stream.

B. Silane application:

Ceramic bond (silane) was placed in a mixing dish. Disposable applicators were used to apply the ceramic bond to the inside of the restoration and allow it to take effect for 60s. Afterwards, dryness was done for 5 seconds with oil-free air.

C. Teeth conditioning:

Teeth were rinsed thoroughly with water. Excess moisture was removed with air-jet such that the surface of the teeth was kept slightly moist. Futurabond DC is dual-cured bond and therefore it was applied immediately after mixing. 1 drop of liquid 1 and 1 drop of liquid 2 were mixed on a mixing dish for approximately 2 seconds (produced a self-etching adhesive). The adhesive was applied in a layer of medium thickness to the enamel/ dentine and rubbed into the tooth surface for 20 seconds. The adhesive layer was dried for 5 seconds with an air syringe. The bonding layer was polymerized with light cure for 10 seconds.

D. Cementation of restoration:

A mixing tip was attached to the luting cement syringe. The material was automatically mixed in the mixing tip and was directly applied to the prepared contact areas and fitting surface of restorations. The material then was light cured with applied finger pressure.

E. Finishing and Polishing Post-cementation: All E-max restorations were finished and polished post cementation using Kenda Set, for Lithium Disilicate material while Vita Enamic restorations with their standardized manufacture polishing ket.

8. Testing of restorations (fracture resistance):

All samples were individually mounted onto the lower fixed compartment of a computer controlled testing machine (Lloyd LR 5k, Lloyd instruments Ltd, Hampshire, UK). The sample underwent static loading by means of metallic attachment until failure occurred, which was attached to the upper movable compartment of the machine. The load was applied at inclined 120 degrees angle just above the cingulum on the palatal surface. An aluminum sheet was placed between the needle tip and the cingulum surface to allow for stress distribution. A constant compressive load was applied at a crosshead speed of 1mm/min until failure occurred. The force at failure was measured in newton.

Results:

Numerical data were explored for normality by checking the data distribution, calculating the mean and median values and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data showed parametric distribution so; it was represented by mean and standard deviation (SD) values. Two-way ANOVA was used to study the effect of different tested variables and their interaction on fracture resistance. Comparison of main and simple effects was done utilizing bonferroni correction.

1-Effect of restoration: between the fracture resistance of different types of restorations (p=0.245). Samples restored with endocrowns (1264.07 ± 156.01), while the lowest value was found with full coverage crowns (1225.43 ± 162.59).

Table 2: Mean ± standard deviation (SD) of fracture resistance (N) of different restorations

Restoration (mean±SD)		p-value
Conventional endocrown	Full coverage	
1264.07 ± 156.01^{A}	1225.4 3± 162.59^{A}	**0.245ns**

Different superscript letters indicate a statistically significant difference within the same horizontal row*; significant (p ≤ 0.05) ns; non-significant (p>0.05)

2-Effect of ceramic material:

Vita Enamic samples (1374.76 ± 94.08) had a significantly higher value of fracture resistance than Vitaenamic samples (1181.06 ± 134.40) (p=0.004).

Table 1: Mean ± standard deviation (SD) of fracture resistance (N) of different ceramic materials.

Ceramic materials (mean±SD)		p-value
Vita Enamic	E.max	
1374.76 ± 94.08^{A}	1181.06 ± 134.40^{B}	0.004*

Different superscript letters indicate a statistically significant difference within the same horizontal row*; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

Discussion:

Human natural teeth have been selected in this study. Artificial abutments might provide similar standardized preparations and identical physical qualities of materials used in comparison to natural teeth, however the later ensure more simulation to clinical conditions 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 and clinically reliable than on artificial teeth [10] . Maxillary incisors were used in this study to evaluate the success of endocrowns with different designs restoring such teeth with special morphology together with their unique anatomy which is susceptible to cusp deflection and fracture under occlusal loads. [12, 13] Endodontic treatment was done by a single operator following standardized approach. Computerized Numerical Control (CNC) milling machine was used to prepare the teeth in a standardized method in order to minimize any possible variations. Fabrication endocrown restorations were standardized by adjusting the parameters in CEREC premium software (V4.4). 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. [11] Polymer infiltrated ceramic material (Vita Enamic) and Lithuim disilicate glass ceramics (emax CAD) Vita Enamic has mechanical properties close to the natural dentine and combines the properties of ceramic and polymer. The advantages of this material such as the reasonable brittleness index and proper fracture toughness in addition to modulus of elasticity similar to that of the natural tooth structure (enamic: 30GPa VS dentin: 13.3GPa) favors its further trial [14]as a material for endocrowns construction. Lithium disilicate – reinforced- glass ceramic (IPS e-max CAD) was the material of choice for the endocrowns and the conventional crown because of its adhesive properties [15] 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 such as inlays, complete crowns, and endocrowns.[16] Comparing different CAD/CAM ceramic material used in fabrication of endocrown restoration in this study, Vita Enamic endocrowns showed statistically higher fracture resistance values in comparison to E.max CAD endocrowns (1030.2±292.5 and 881.1±189.9 respectively). Our explanation is that the polymer part in the Enamic microstructure acts as a stress distribution mean leading to more uniform stress distribution and aborption in addition to the close similarity in the modulus of elasticity of Vita enamic 30GPa to natural dentine structure 13.3GPa in contrast to the emax CAD will have 95 GPa, with a considerable difference in their modulus of elasticity. Substrates with different modulus of elasticity behave differently under stress application leading eventually to failure. [17] our results confirms the concept of stress absorption and distribution of hybrid ceramic materials with a polymer content.

Conclusions:

With limitation of this study:

1. The use of resilient material as polymer infilterated ceramic network Vita

Enamic yield better stress distribution upon loading hence higher fracture resistance.

2.3mm intrapulpal extension showed higher fracture resistance.

Recommendations:

1. Vita Enamic can be safely used in thin 2mm incisal thicknesses as an endocrown for maxillary incisors.

2. More clinical studies need to be conducted to test the pulp chamber extension effect clinically and to test the mode of failure

and the fracture pattern of both

intrapulpal extensions.

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