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Effect of fiber post placement on the fracture resistance of overlay system for endodontically treated molars using two ceramic materials: (In vitro study)

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Abstract:
Objective: The aim of this research was to study the fracture resistance of overlay system for endodontically treated teeth with composite resin core and fiber post and composite resin core using two ceramic materials lithium disilicate (E. max CAD) and polymer infiltrated ceramic network PICN (Vita Enamic hybrid ceramic). **Material and methods:** 28 extracted human first molar teeth were selected with comparable dimensions. Access cavities were made and the molars were endodontically treated and received 1.5 mm occlusal reduction and were divided into two groups (N=14). The first group were filled with composite resin core (C group) ((N=14) and the second group received composite resin core with fiber post (F group) (N=14). Each group will further be subdivided into two subgroups (N=7) according to the material of fabrication of the overlay. Subgroup L (lithium disilicate) (N=7) and subgroup P (PICN) (N=7). **Results:** Two-way ANOVA showed that fiber post placement did not significantly affect the fracture resistance (p=0.751) even when two different materials were used (p=0.361). Moreover, the mode of failure of the majority of samples made from both materials was the fracture of the restoration only without tooth fracture (Mode of failure A) (p=0.453) with and without fiber post (p=0.169) and the difference was not statistically significant. **Conclusions:** Neither fiber post placement nor ceramic type influenced the fracture resistance of overlay system for endodontically treated teeth.
Keywords: Fiber post; Fracture resistance; Lithium disilicate; Overlay; Vita Enamic.

Introduction:

Endodontically treated teeth (ETT) are known to have increased risk of biomechanical failure due to the decreased dentin elasticity, water content and loss of structural integrity due to excessive removal of dentin or endodontic over-onstrumentation or prolonged use of sodium hypochlorite , which in terms makes them more liable to fracture than sound teeth[1]. The restoration of ETT remains clinically challenging. Multiple restoration designs were proposed including partial and complete coverage restorations with or without post and core build-up material were established with the aim to attain increased fracture resistance of the ETT. Post and core and crown, Endocrowns and the overlay system can be used to restore ETT [2]. There seems to be a direct relationship between the number of residual wall and the fracture resistance as by removing one marginal ridge 46% of the tooth rigidity is lost and by removal of two marginal ridges 63% of the rigidity is lost [3] .So , a key factor for the choice of the restorative material to be used is the residual coronal tooth structure [3] .Acceptable results can be achieved with crowns that are supported by post and core, however, it might lead to weakening of the mechanical resistance of the tooth structure [4].

Endocrowns are another valuable treatment option that is commonly used in the dental practice Pissis was the forerunner of endocrown technique and described it as the ‘mono-block technique[5]. Endocrowns are monolithic restorations defined as “bonded overlay restorations”, which enables both macromechanical and micromechanical retention to the tooth structure.

The increased emphasis on minimally invasive concepts as well as the advancement in adhesive dentistry enabling proper adhesion are of great importance for the success and longetivity of the restorations [6]. That is why the overlay system have gained a great popularity in the past few years as it is considered a more conservative modification of the endocrown without pulpal chamber extension [7]. Despite all these designs fracture of ETT remained a common clinical occurrence [8].

New treatment modalities have been suggested with the aim to increase the fracture resistance and avoiding failures. Several in vitro studies reported increased fracture resistance of ETT when restored with direct composite restorations reinforced with fiber posts (FRC) as pulpal cavity filling with different restorative systems [8]. Especially, FRC with overlay system, this might be due to the fact that using a composite core to fill the whole pulp cavity avoids removal of unnecessary sound tooth structure by eliminating the need for macro-mechanical retention and also enabling proper adhesion [9]. Moreover, adding glass fiber posts to the composite core is advocated by Jurema etal to increase the fracture resistance of the tooth through enabling better stress distribution [9]. Adding to that , cuspal coverage for ETT molars using overlay system leads to a more favorable stress distribution than non cuspal coverage leading to a higher fracture resistance [10] .

The overlay system is usually fabricated from a monolithic adhesive etchable materials [10]. It can be fabricated from feldspathic glass ceramic , llithium disilicate glass- ceramic (ingots by heat- press technique e.g E-max press or blocks e.g E-max CAD) , zirconia reinforced glass ceramic (suprinity) or hybrid ceramic (polymer infiltrated ceramic network ‘PICN’ and resins with dispersed fillers RNC) [11] . Lithium disilicate (E-max CAD) and Hybrid ceramic (Vita enamic PICN) both provide proper adhesion to the tooth structure enabling the biomimetic concept as well as favorable mechanical properties and aesthetic outcomes [11]. Rigid restorations such as lithium disilicate that adhere to the tooth structure offers the distribution of the stress uniformly and provides good support. However, some studies state that catastrophic failure might result if the tooth was over loaded [12,13].

Vita Enamic exhibits properties similar to those of natural teeth due to its hybrid component of ceramic and composites leading to being less brittle and having more elasticity than traditional dental ceramic [11]. Due to its elasticity it may bend under high loads leading to failure in the adhesive interface and not the tooth structure, which provides a damping effect. Moreover , it easier grinding by different milling tools and more ease of repair in case of shipping or fracture [13,14]. Foad et al stated that vita enamic had a higher fracture resistance than E-max [15]. On contrary, Nabih et al. stated that IPS e.max CAD produced more favorable stresses on the tooth structure than Vita Enamic [16].

To date, there is no agreement in literature about which material or preparation design can optimally restore ETT to ensure the best mechanical behavior. Thus, the aim of this study was to assess the effect of fiber post placement on the fracture resistance of overlay system suing two CAD/CAM ceramic materials: lithium disilicate (E-max) and polymer infiltrated ceramic network PICN (Vita Enamic hybrid ceramic). The null hypothesis is that neither fiber post placement nor ceramic type influence the fracture resistance of overlay system for endodontially treated teeth.

Materials and methods:

Sample size

A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there was no difference between different tested groups regarding fracture resistance. By adopting an alpha (α) level of (0.05), a beta (β) level of (0.2), (i.e., power=80%), and an effect size (f) of (0.719) calculated based on the results of a previous study; the total required sample size (n) was found to be (28) samples. Sample size calculation was performed using R statistical analysis software version 4.3.2 for Windows[1].

Sample preparation

28 extracted human first molar teeth were selected with comparable dimensions . They had average sizes and almost similar shapes with the mean mesio-distal dimension of 10.5 mm. ± 0.5 mm. and mean bucco-lingual dimensions of 9 mm. ± 0.5 mm. by measuring with a digital caliber. the samples were divided into two groups (N=14). The first group were filled with composite resin core (C group) ((N=14) and the second group received composite resin core with fiber post (F group) (N=14). Each group was further subdivided into two subgroups (N=7) according to the material of fabrication of the overlay. Subgroup L (lithium disilicate IPS emax CAD Ivoclar vivadent , switzarland) (N=7) and subgroup P

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(Hybrid ceramic Vita enamic PICN) (N=7).

Samples were mounted in epoxy resin molds through using a silicon ring with internal diameter of 15 mm that was nearly filled with liquid resin. A paralleling device was used to make sure that the teeth is upright position in the blocks then they were centralized in a level that cemento-enamel junction was 2mm above the epoxy resin margin.

Samples were stored and placed under distilled water in separate closed containers. All the samples received reduction of coronal portion of 1.5 mm using a large diamond rotary wheel instrument (Intensiv wheel 817, Swiss) mounted on high-speed headpiece leading to a flat occlusal butt joint margin. The Pulpal cavity preparation was established by using a tapered flat end diamond rotary instrument (Intensiv inlay kit, Swiss) mounted on high-speed headpiece leading to 5 degrees diverged axial walls with a total 10 degrees divergence. A 2mm circumferential occlusal band thickness was established and checked via periodontal probe. A paralleling device was used for standardizing both flat butt reduction and occlusal divergence between samples.

Both groups F and C received endodontic treatment was performed to all teeth, Cleaning and shaping was done using rotary files (Dentsply Rotary files) followed obturating them with gutta percha using the warm vertical condensation technique (Guttacore obturators , Dentsly Sirona). All the canals in Group F were obturated except the ones receiving the fiber post (Itena fiber post) , keeping at least 4 mm of root filling intact to maintain the apical seal. The canal receiving the fiber post was dried with paper point then self- adhesive resin cement (Breeze, Pentron , USA) was placed inside the canal then the fiber post was placed and light cured (diode light curing unit , bluephase Ivoclar vivadent) and was cemented . SE adhesive (ALL-bond universal ,Bisco , USA) was placed in the access cavity and light cured (diode light curing unit , bluephase Ivoclar vivadent) then a dual cure composite resin core (Charmcore) is placed to fill the whole access cavity and light cured. In group C , SE adhesive (ALL-bond universal ,Bisco , USA) was placed in the access cavity and light cured (diode light curing unit , bluephase Ivoclar vivadent) then dual cure composite resin core (Charmcore) was placed and light cured .

Digital scans of all samples were converted to STL format in order to create virtual dies using CAD system software (Exocad in-lab designing software) and designing of the restorations was done leading to manufacturing of a 2mm restoration with anatomical occlusal aspect .

Both restorations were milled (Imes -icore Gmbh Im Leibolzgraben 1636132 Eiterfield, Germany) and crystalized in a Furnace (programat EP3010, Ivoclar Vivadent) and glazed.

Surface treatment of the tooth structure by etching of the enamel rim by phosphoric acid etch (Spident Fine Etch) and the ceramic was done by etching of the fitting surface with hydrophloric acid etch (Bisco , USA) followed by silane application (Porcelain primer , Bisco , USA) and then the overlays were then cemented using dual cure resin cement (Breeze ,entron , USA) while being loaded with 1 kN pressure directed towards the central fossa of the occlusal surface of the restoration. Initial Light curing (diode light curing unit , bluephase Ivoclar vivadent) was made and the excess was removed with a brush followed by light curing for 20 seconds for each surface.

Thermocycling Aging (SD mechatronic thermocycler, Germany) was done through cold water bath immersion for 30 seconds at 5 degrees, hot waterbath immersion for 30 seconds at 55 degrees and dwell time 10 seconds. It was done for 5000 cycles to resemble the conditions of 6 months in the oral cavity.

Fracture resistance testing

All specimens were stored in distilled water in sealed containers at room temperature for a period of 48 hours before testing.

Each specimen was individually mounted on a computer-controlled testing machine (Introm model 3345 universal testing machine) with a load cell of 1 kN. The data were calculated and recorded using computer software (Instron® Bluehill universal instron, England). Fracture test was done by compressive mode of load applied occlusally into central fossa of each sample through the use of metallic rod with round tip (5.6 mm diameter) travelling at a cross-head speed of 1mm/min with tin foil Sheet.

The load at failure manifested by an audible crack and that was being confirmed by a sharp drop at the load detection curve recorded using computer soft-ware (Instron® Bluehill universal instron, England). The load needed to fracture was recorded in Newton.

SEM analysis to analyze failure modes

The fractured samples and fragments were collected and the mode of fracture was examined both visually and under microscope (Nikon SMZ745T Stereo microscope) to detect different fracture (failure) modes.

Mode of failure A: Represents fracture of restoration only without tooth fracture .

Mode of failure B: Represents fracture of restoration with tooth fracture above CEJ .

Mode of failure C: Represents Fracture of restoration with tooth fracture below CEJ .

Statistical analysis:

Categorical data were presented as frequency and percentage values and were analyzed using chi-square test. Numerical data are presented as mean and standard deviation values. They were checked for normality by viewing the data distribution and by using Shapiro-Wilk's test. They were found to be normally distributed and were analyzed using two-way ANOVA. Comparisons of simple effects were done utilizing Bonferroni correction with the pooled error term from the main ANOVA model. The significance level was set at $p<0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.3.2

for Windows[1].

Results

There was no statistically significant difference between the fracture resistance of the teeth restored with fiber post and those that did not. Also, there was no statistically significant difference between the two different materials used. Moreover, the mode of failure was not statistically significant in all groups.

A- Effect of Fiber post placement on the fracture resistance

Samples without fiber post had a higher fracture resistance value (1557.29±308.63) (N) than samples with fiber post (1524.66±227.28) (N). Yet the difference was not statistically significant (p=0.751). (Table 1, Table 2 and Figure 1)

B- Effect of using two different ceramic materials

Vita Enamic had a higher value (1588.32±332.63) (N) than Emax (1493.62±178.93) (N). Yet the difference was not statistically significant (p=0.361). (Table 1, Table 2 and Figure 1)

Table (1): Intergroup comparisons, mean and standard deviation values of fracture resistance (N) for different materials with and without fiber post.

Fiber post placement	Fracture resistance (N) (Mean±SD)		p-value
	Emax	Vita Enamic	
Without fiber post	1447.32±175.22	1667.25±384.01	0.193ns
With fiber post	1539.93±183.46	1509.38±278.78	0.813ns
p-value	0.353ns	0.396ns	

ns; non-significant (p>0.05)

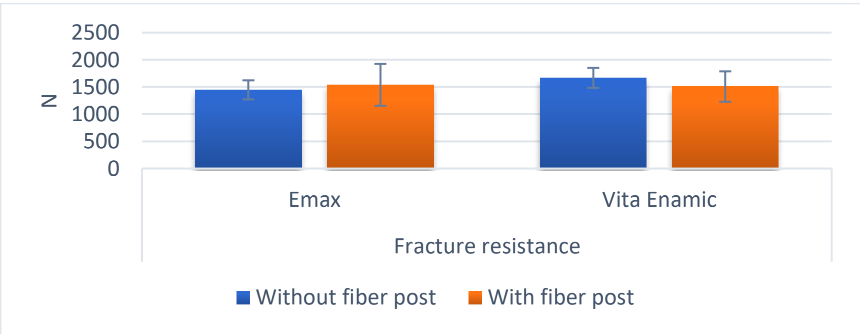


Figure (1): Bar chart showing mean and standard deviation (error bars) values for fracture resistance (N).

Table (2): Effect of different variables and their interactions on fracture resistance (N).

Variable	Sum of squares (II)	Df	Mean square	f-value	p-value
Material	62764.42	1	62764.42	0.87	0.361ns
Fiber post placement	7453.02	1	7453.02	0.10	0.751ns
Material * Fiber post placement	109810.33	1	109810.33	1.52	0.230ns

df; degree of freedom, ns; non-significant (p>0.05)

C- Effect of fiber post placement on the mode of failure

The majority of samples with and without fiber posts had failure mode (A) and the difference was not statistically significant (p=0.169). (Table 3 and Figure 2, 3 ,4 and 5).

D- Effect of different materials on the mode of failure

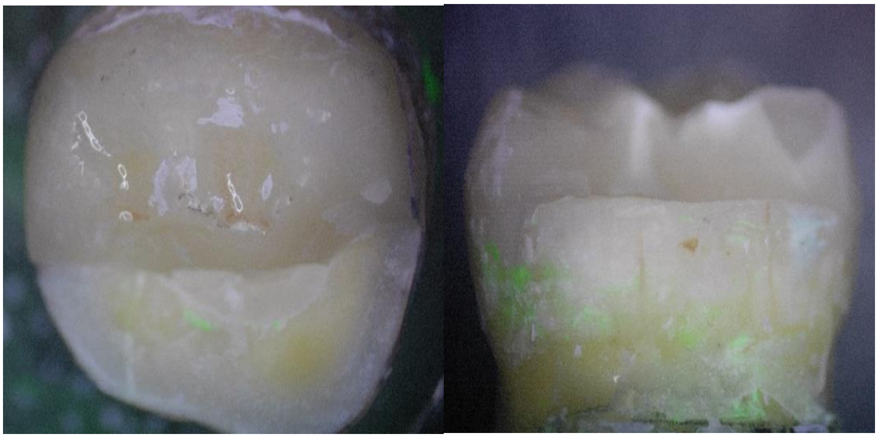
The majority of samples made from both materials had failure mode (A) and the difference was not statistically significant (p=0.453). (Table 3 and Figure 2, 3 ,4 and 5).

Table (3): Intergroup comparison, frequencies, and percentages values for mode of failure for different materials with and without fiber post placement

Fiber post placement	Failure mode	n (%)		p-value
		Emax	Vita Enamic	
Without fiber post	A	5 (71.43%)	6 (85.71%)	0.580ns
	B	1 (14.29%)	1 (14.29%)	
	C	1 (14.29%)	0 (0.00%)	
With fiber post	A	5 (71.43%)	2 (28.57%)	0.175ns
	B	0 (0.00%)	2 (28.57%)	

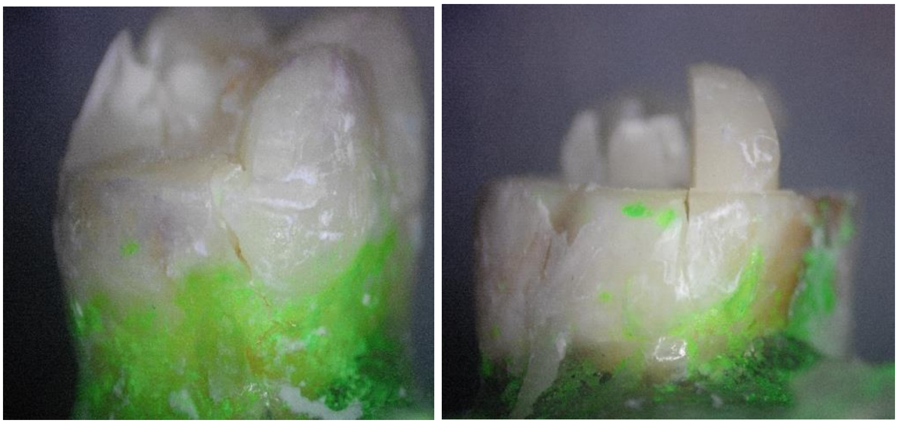
	C	2 (28.57%)	3 (42.86%)	
p-value		0.513ns	0.069ns	

ns; non-significant (p>0.05).



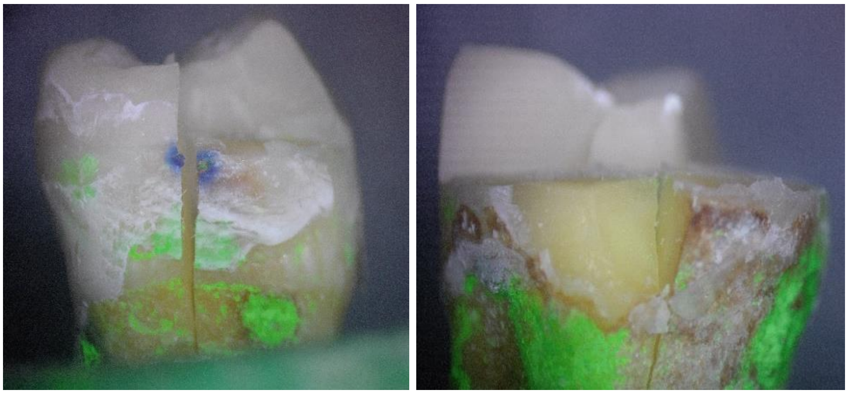
A B

Figure (2): Mode of failure A A) lithium dislicate with fiber post
B) lithium dislicate without fiber post



A B

Figure (3): Mode of failure B A) lithium dislicate without fiber post
B) Vita Enamic with fiber post



A B

Figure (4): Mode of failure type C A) Vita enamic with fiber post

B) Vita enamic without fiber post

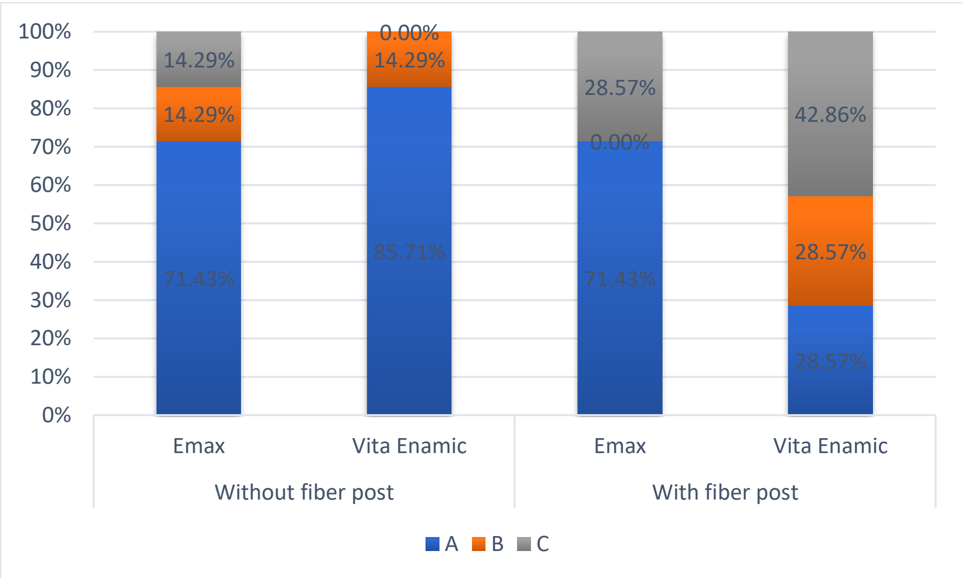


Figure (5): Stacked bar chart showing mode of failure distribution.

Discussion:

In order to approach the desired standardization and minimize the possible variations, selection of mandibular first molar human teeth of average sizes and almost similar shapes allowed maximum deviation of 10% from the determined mean [17,18].

The teeth were embedded into Epoxy resin, with the vertical distance between the cemento-enamel junction and the acrylic resin level set to 2 mm, to simulate the alveolar bone [19].

Preparation was done via individual partitioned clinician for purpose of standardization. The tooth preparation was done with diamond kit and a high-speed hand piece connected to paralleling holding device to ensure the standardization of the taper [20].

A loading device was used with 1kN to reduce the variation in pressure applied to restoration during cementation [20].

In order to simulate the clinical conditions to which the restorations will be subjected, Thermocycling aging was carried out to mimic six months of oral conditions according to ISO standards 13356 [21]. El Etreby et al. stated that Thermo-mechanical aging adversely affect the fracture resistance of IPS emax Press crowns [22].

The results of the current study stated that the first null hypothesis was accepted. The fiber post placement did not statistically affect the fracture resistance. Our results was in agreement with Büyükbayram et al. [23] .our results was not in agreement with Solanki et al. [24] who compared the fiber-reinforced composite and nanohybrid resin impregnated with glass fibers as a core restoration for ETT and concluded that there was a statically significant difference in terms of the fracture resistance .This can be explained by the better mechanical property of ever-X posteriors as they consist of short randomly organized E-glass Fibers embedded in resin matrix containing barium glass fillers which gives an isotropic reinforcement effect in multiple directions instead of just one or two directions [25,26].

The second null hypothesis was accepted as different materials (lithium disilicate and Vita enamic) did not affect the results statistically. Our results was consistent with the findings of Suksawat et al. [27] .

On the contrary, several studies which compared the fracture loads of glass-matrix ceramics (IPS e.max CAD) and polymer-infiltrated ceramic networks (Vita Enamic) and/or resin nanoceramics (Cerasmart) had conflicting results [28-33]. One of them was by Oguz et al. [29] who evaluated the fracture strength of lithium-disilicate and resin-matrix ceramic CAD-CAM crowns. and stated that Lithium disilicate had a significantly higher fracture strength than resin-matric ceramic restorations. However, in these studies different experimental designs and variable factors were used.

The Important factors affecting the fracture resistance of a restoration includes the types of the abutments being used (acrylic resin, composite resin, alloy, or natural human teeth). Also, the type or quality of the adhesive interface (adhesive or non-adhesive cementation). Moreover, the load direction (axial or non-axial loading). Added to that the material type or thickness and the preparation design, etc. [34]. In addition, the greater amount of tooth structure remaining the higher the fracture resistance [34].

The failure mode results were not statistically significant and most of them were repairable. Our results was in agreement with Rocca et al. [35]. Our results were not in agreement with Salameh et al. [36] who stated that the presence of a fiber post was associated with higher percentage of restorable fractures only with the gold onlays. The difference between this result and our result might be due to the presence of a variable that was not standardized such as the type of restoration.

A number of factors can interfere with the fracture resistance and the failure mode of ETT. Future clinical studies are required to enable the assessment of the long-term survival of ETT restored with FRC and overlay systems.

Conclusion:

Fiber post placement does not improve the fracture resistance of ETT when an overlay system is used and the fracture resistance of ETT restored with an overlay system was not significantly different when two different ceramic materials were used. Moreover, Fiber post placement does not improve the mode of failure of ETT restored with an overlay system using two ceramic materials.

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