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IMPACT OF INTEGRATING CRACK BRIDGING PHENOMENON ON THE FRACTURE RESISTANCE AND FRACTURE MODE OF THREE DIFFERENT ENDOCROWN RESTORATIONS IN ENDODONTICALLY TREATED POSTERIOR TEETH (AN IN-VITRO STUDY)

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ABSTRACT

Aim of study: Compare three endocrown restorations using crack bridging material beneath them on the fracture resistance and fracture mode in endodontically treated posterior teeth.

Material and methods: Fifty mature mandibular molars were selected. The samples were divided to five equal groups(n=10). Group (CN) 10 samples were kept untreated, Group (CP) 10 samples were endodontically treated only, the three test groups were subjected to root canal treatment and a standard butt joint endocrown preparation was done followed by application of 2mm Ever-X flow flowable composite to cover the floor of the pulp chamber. Group (EEC) 10 samples restored with Ever- X posterior composite endocrown, Group (EIM) 10 samples restored with IPS E-max CAD endocrown and Group (ECS) 10 samples restored with Cerasmart CAD/CAM endocrown. Following thermocycling fracture resistance and mode were assessed.

Results: The experimental groups (EEC, EIM, and ECS) showed comparable fracture resistance values of 1085.3±99.5, 1126.3±92.9, and 1111.4±90.8 respectively. There were no significant differences between the experimental groups (EEC vs EIM p=0.376, EEC vs ECS p=0.571, EIM vs ECS p=0.747), suggesting similar performance among these treatments. Type III fractures were most prevalent in all groups. Type IV fractures were less common, with EIM showing the highest occurrence (20%). While there are some variations in fracture modes between groups, these differences are not statistically significant.

Conclusion: Placing short fiber reinforced composite base beneath endocrown restorations not only produced near to intact tooth fracture resistance values but also yielded favorable modes of fracture.

KEYWORDS: Crack bridging, Endocrown, Endodontically treated teeth, Short fiber reinforced composite, Fracture resistance, Fracture mode.

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INTRODUCTION

Dental pain is a debilitating condition that often drives patients to inquire emergency dental treatment. Previous study by **Sindent etal** [(1)] has shown that 66% of dental pain need root canal treatment. Meticulous systematic reviews have shown that endodontic treatment help the preserve teeth that suffer from pulpal or periradicular disease and prevent extraction. [(2, 3)]

Endodontically treated teeth (ETT) usually have lost a large volume of the coronal structure either due to caries or previous restorations or traumatic injury prior to the actual treatment. An additional loss of tooth structure happens during endodontic treatment during access cavity preparation; where pulp chamber roof is removed; followed by root canal mechanical preparation; which also removes root canal structure from within the inner walls of the root canals. [(4, 5)] Therefore, favoring the tooth fracture under occlusal forces. [(6, 7)]

Many endodontically treated teeth (ETTs) are extracted; as previously stated by **Fuss et al** [(8)]; due to endodontic failure with a 21.1%, catastrophic (irreparable) crown fracture with a 43.5%, and with a 10.9% for vertical root fractures. Therefore, the long-term survival of ETT is a collective result of the quality of the endodontic treatment and the meticulous selection of the optimum coronal restoration that provides protection of the vulnerable remaining tooth structure from fracture**.** [(9-11)]

To do so and for many decades; researchers have meticulously studied the alterations that occur in ETT to underline the causes why these dental structures are more prone to fracture than vital teeth. Loss of tooth structure, alteration of physical properties, changes in collagen intermolecular cross-links and decreased moisture content of collagen all have been demonstrated as causes of reduction in strength and structural integrity [(12, 13, 14)]

Thus, the wise choice of restoration designs and materials in case of ETT should be fulfill replacement of lost dental tissue and at the same time ensure recovery of aesthetics, marginal seal, and biomechanical characteristics. [(15)]

Post- cores and full-coverage restorations have been employed to restore badly broken down teeth following endodontic treatment [(16, 17)] However, recently this treatment modality is looked upon as an aggressive means of restoration due to the loss of weakening of radicular dentin as post space is prepared and more dental tissue loss during the axial coronal preparation for traditional crowns all of which impair the biomechanical properties of the remaining dental tissue. [(18, 19)]

Recent ongoing development and implementation of adhesion and biomaterials, have suggested endocrowns as a more conservative means of restoration modality to replace the traditional post and full coverage crown restoration as they provide preservation of peripheral enamel and the pericervical dentin (PCD). [(20)]

Clark and Khademi [(21)] described (PCD); as the dentin extending 4mm coronal and apical to adjacent to crestal bone. This crucial region (PCD) plays an essential role biomechanically as it is the transitional structure transferring occlusal stress in to the radicular structure, consequently it is a determinant factor in tooth fracture. Therefore, the more thicker the dentin at that particular area the more the tooth can resist fracture especially catastrophic fractures that involve the root and it would be safe to assume that the quantity of this PCD impact the survival of ETT. Thus the concept of applying flowable short reinforced fiber composite as an intermediate layer beneath endocrowns not only will strengthen the PCD area but also due to the fact that it possesses similar modulus of elasticity it would mimic dentin's stress absorption capacity.

Short fiber reinforced composites (SFRCs) are resin based composite that have random discontinuous short fiber-reinforcement[(22)]. Tsujimoto et al.

reported that this innovative composition enhances the biomechanical behavior principally by acting as crack blocker, preventing crack initiation and propagation [23].

This unique composite possesses fiber strengthening mechanisms where the fibers are capable of not only stopping crack initiation but also inhibit its propagation, in addition to its stretching and crack bridging. The first mechanism; is that these short fibers redirect cracks to pass through a longer track. The crack moves beside the fiber as it reaches its terminus crack disruption occurs which blocks crack propagation. [24]

The second mechanism; is that it possesses closure ability of the crack itself. Owing to the fibers' stretchiness, crack bridging phenomenon occurs. Subsequently; stress concentration at the tip of the crack declines, which in turn slows or prevents crack progress. Moreover, when a SFRC fails, the fibers break at varying points along the span of the material, which allows it to absorb more load there for this random orientation of fibers with in the matrix provides reinforcement. [25]

As the crack is driven away from high occlusal stress regions the crack bends decreasing the stress propagation which help join the particle and allowing the bridge mechanism to take place. This bridge toughening phenomenon; was also explained by **Yasa etal** [26] who found that the twisting of these fibers aids in elastic spanning and friction within the fibers through a de-bonding mechanism which has also been described as frictional bridging.

Using such unique material as a stress breaking barrier beneath large restorations for badly destructed endodontically treated posterior teeth would improve the final coronal restoration. Long-term survival of ETTs can only be provided by the clinician when an optimum design and material have been achieved to maximize function and esthetics and at the same time minimize fractures. [27, 28]

Computer-aided design and computer-aided manufacturing (CAD/CAM) materials; with remarkable optical properties superior biomechanical characters; have provide exceptional revolution in the field of restoring ETTs. [29] Although ceramic restorations; IPS E-max CAD; have gained wide spread approval among dentists due to their esthetics, biocompatibility, and durability. However; they have a significant drawback, high brittleness which leads to catastrophic tooth fractures. [30, 31]

Resin nanoceramic (RNC) CAD/CAM materials have been presented as an alternative for ceramic materials; combining the benefits of nonbrittle polymers yet still preserving the favorable esthetics of ceramics. [32, 33] They possess close to dentin modulus of elasticity which has encouraged many researchers to recommend it for fabrication of endocrowns. This outstanding property allows it to act as stress absorbers under occlusal loads, reducing stress spikes within the radicular dentin and/ or the tooth -restoration interface. [34, 35]

Another innovative material that has been recently suggested for badly broken down teeth as ETT is short fiber-reinforced composite (SFRC); Ever-X posterior; as a bulk fill for posterior teeth that have been badly destructed. It is composed of e-glass fibers, and inorganic fillers. [36] This special design was proposed to simulate dentin's stress absorption capacity. Manufactured with the intention of restoring dental coronal structure in high-stress bearing areas as it acts in a unique way when subjected to pressure preventing crack formation and propagation subsequently; fracture risks decline. [37]

Thus the null hypothesis is that there is no difference in fracture resistance and fracture mode between the three tested endocrown material in restoring endodontically treated posterior teeth when using flowable SFRC as a stress breaking barrier beneath them.

AIM OF THE STUDY

Compare three endocrown restorations using crack bridging material beneath them on the fracture resistance and fracture mode in endodontically treated posterior teeth.

MATERIAL AND METHODS:

Study design and size sample calculation:

The study design follows comparative/control in-vitro study design. Prior to commencing the study an ethics committee approval was established. The study steps were in accordance with the Declaration of Helsinki. A sample size was achieved utilizing G*Power according to the null hypothesis and on the bases of a previous study [38] and found that the sample size required was 50 samples (10 samples for each group)

Sample selection and preparation:

Fifty mature mandibular first and second molars with intact coronal structure that were extracted for periodontal reasons were collected from the outpatient clinic. All samples were examined using 2.5x magnification eye-mag smart loupes to exclude samples showing fractures, cracks or external root resorption then pre-operative radiographs were also obtained to rule out any internal root resorption or calcifications within the root canals and to ensure presence of two mesial and one distal root canal; according to predetermined criteria. Dimensions of the samples were recorded at CEJ from the bucco-lingual and mesio-distal direction to only include statistically similar dimensions. Every excluded sample was replaced with new sample abiding with the inclusion criteria.

All samples were cleaned removing any soft tissue attachments and/ or calculus then immersed in 2.5% sodium hypochlorite solution for disinfection, washed and stored in 0.1% thymol solution (Aqua Solution; Deep Park, USA); for a period not more than one month.

Regarding groups (CP, EEC, EIM and ECS); a standard butt joint endocrown preparation was performed using diamond wheel with round edge (WR-13, Dia bur, Mani) to intra-coronal height of 3mm a tapered diamond coated bur with safe end (851/ 016, Strauss-Diamond, USA) was used to finalize the access cavity and provide an internal taper of 8 to 10 degree. Intra-coronal height was confirmed by placing a periodontal touching the floor of the pulp chamber to the internal coronal margin of the access cavity.

Grouping of the sample

The samples were divided into five equal groups(n=10). Group (CN) 10 samples were kept untreated serving as a negative control group, Group (CP) 10 samples were endodontically treated and the floor of the pulp chamber was only covered with 2mm of resin reinforced glass ionomer (Riva ,SDI, Germany) serving as a positive control group, the three test groups were subjected to root canal treatment and a standard butt joint endocrown preparation was done followed by application of 2mm Ever-X flow flowable composite (GC, Tokyo, Japan) to cover the floor of the pulp chamber. The scan of the preparations was taken for restoration to be prepared; for Group (EEC) 10 samples restored with Ever- X composite short fiber reinforced composite endocrown, Group (EIM) 10 samples restored with IPS E-max CAD lithium disilicate glass ceramic CAD/CAM endocrown and Group (ECS) 10 samples restored with Cerasmart Resin nano-ceramic (RNC) CAD/CAM endocrown. standard predetermined occlusal contour

Endodontic treatment of the root canals:

Root canal treatment was established by one experienced endodontist. All three canals for each sample were located and working length determined by passing size 10 K- file till visible at the apical foramen and length was recorded 1 mm short of that. Following conformation of apical patency, shaping was performed using rotary nickel-titanium files (Protaper Universal, Dentsply, Maillefer, Ballaigues, Switzerland), mesial canals were enlarged up to size F2 while distal canal was prepared to F3. In between files canals were irrigated with 3ml of 2.5 % sodium hypochlorite in between files, once shaping was finalized 2 ml of 17% EDTA then 20ml of distilled water was used as a final irrigation and a paper point of the corresponding instrument size was used to dry out the root canal. A single cone technique was used for obturation with AH Plus sealer (AH-Plus, Dentsply, Maillefer, Ballaigues, Switzerland). Excess gutta-percha was seared off with hot instrument then 1mm was removed apical to the orifice and filled with resin reinforced glass ionomer (Riva, SDI, Germany).

Mounting of the samples:

All specimens were embedded vertically up to 2mm away from the CEJ in an acrylic self-polymerizing resin (cold cure acrylic resin, Acrostone, Egypt) with 0.2mm polyether impression material (Soft-Monophase, 3M ESPE, Germany) covering the root surface as a periodontal ligament simulation in a standard cylindrical plastic ring in an upright position using a centralizing device. Fig. (1)

Fig. (1) Standard butt joint endocrown preparation embedded vertically up to 2mm below the CEJ in an acrylic self-polymerizing resin

Application of the flowable composite intermediate layer (stress braking base):

On completion of the root canal procedure; for groups (EEC, EIM, ECS); the pulp chamber was thoroughly cleaned then the interior dentin cavity walls and floor were covered with Single Bond Universal (3M ESPE) scrubbed with micro brush for 20 seconds then light-cured for 10 seconds at 1000 mW/cm^2 using Blue-phase N Cure (Ivoclar Vivadent, India). A standardized layering technique was applied each increment 1 mm thick followed by polymerization for 20s at the same parameter. A thickness of 2mm layer Ever-X flow dentin shade (GC; Tokyo; Japan) was applied then cured for 20 seconds.

(Ever X composite) endocrown construction (Group EEC)

Ever- X posterior (GC; Tokyo; Japan) was applied in a standard layering technique; 2mm / layer; similarly, light cured for 20 second at 1000 mW/cm^2. The procedure was repeated up to 1 mm shy of the complete occlusal anatomy which was restored using Filtek Z350XT composite (3M ESPE; Germany) which was cured with the same parameters. The occlusal anatomy was built up to a standard predetermined contour imitating the same contour of the CAD/ CAM constructed endocrowns. Finally, a thorough polishing and finishing of all restoration surfaces were performed.

CAD/CAM endocrown construction (group EIM & ECS)

For specimens of group EIM & ECS; were fixed on the scanning tray, scanned utilizing (CEREC, Omnicam 444, DENTSPLY, Sirona). A digital impression was acquired followed by a CAD/ CAM software (Ceramil, Mind, DENTSPLY, Sirona) endocrown design then the milling procedure was performed on the tested ceramic blocks with a computer controlled milling unit (Ceramill motion 2 (5 ×) according manufacturer's instructions

Regarding the IPS E-Max CAD endocrowns a final crystallization procedure was performed by applying crystal/ glaze paste evenly over the entire restoration surfaces and further processed in a ceramic furnace (Ivoclar; Viva Dent furnace / P3010).

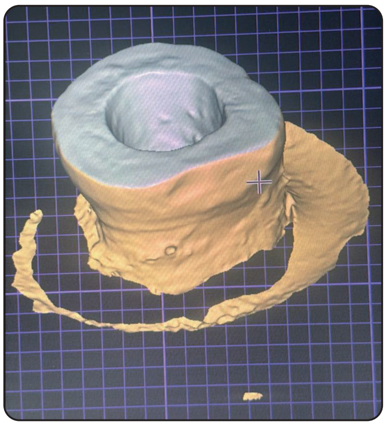

Fig. (2) Scanning of endocrown preparation.

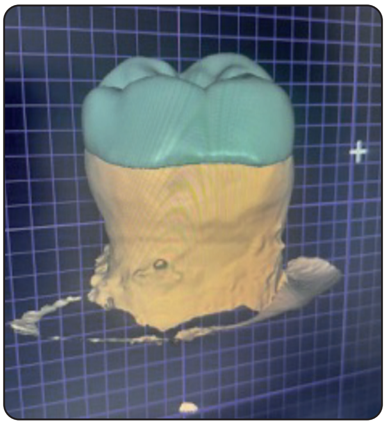

Fig. (3) Designing of endocrown

Fig. (4) Final IPS E-max CAD endocrown ready for cementation.

Endocrown cementation

For the tooth surface: A 20 second acid etch for the enamel margins with 37% phosphoric acid gel (Meta Etchant, Meta Biomed, Korea) was established followed by a 60 second careful rinse then samples were gently air dried. Two separate coats of adhesive (All-Bond Universal, DUO–LINK UNIVERSAL, Bisco, schaumburg. USA) were applied to the prepared dentin surface followed by 5 seconds of air dryness then finalized with 10 seconds of light curing.

For the fitting surface of the IPS E-max CAD ceramic endocrowns; a 4% hydrofluoric acid gel (Porcelain Etchant; Buffered Hydrofluoric, Bisco Inc, USA) was applied to etch the surface for 20 seconds followed by 60 seconds of rinsing under running water then 30 seconds of air drying. A silane coupling agent (Porcelain Primer/Bis-Silane™, Bisco Inc, USA) was applied to the fitting surfaces and left to dry for 60 seconds.

For the fitting surface of the Cerasmart Resin nano-ceramic (RNC) CAD/CAM endocrown; it was subjected to the same previously mentioned sandblasting with 50 μm aluminum oxide particles for 10 seconds with a pressure 2.5 bars from a distance 10 mm was performed followed by decontamination in an ultrasonic cleaner (Model WUC-D06H, Wisd, Korea) with ethanol solution then rinsed thoroughly with distilled water and gently air dried. A single coat of primer (Zprime Plus, duo–link Universal, USA) was painted on to the fitting surfaces of the endocrowns, air dried for 5 seconds over which an even layer of a dual-cure resin cement (duo–link Universal, Bisco, Schaumburg, USA) was applied. all endocrowns were seated in place; each to the corresponding prepared specimen; with light finger pressure. Excess cement was eliminated with scalpel after 15 seconds of application to preserve restoration marginal integrity. The resin cement was finally light activated from all four directions for 40 seconds each.

Thermocycling and cyclic loading process

All the specimens were subjected to thermocycling at 5 ºC and 55 ºC in water for 30 seconds for each temperature following a 5000 cycle which represents a six months clinical functioning followed by an additional cyclic loading of 50,000 times, which represents approximately twelve months of clinical service,19 in an Electro-Mechanical Fatigue Machine- MSFM (Elquip, São José dos Pinhais, Brazil). The loading parameters were set at frequency of 2 Hz per minute with a load ranging between 0 to 100 N. All specimens were kept in distilled water at 37 °C throughout the cyclic loading procedure. [39]

Fracture resistance assessment

Computer-controlled universal material testing machine was used for fracture resistance assessment (Model 3345; Instron/ Ind Products, Norwood, MA, USA) parameters were set at a load/cell of 5 kN using a metallic rod with round tip (5 mm diameter) attached to the upper movable compartment of testing machine moving at speed of 1mm/min. To provide homogenous stress distribution and minimize local force transmission peaks a tin foil sheet was placed in-between. The load that produced fracture was recorded in Newton (N) [40]

Fracture Mode assessment

To determine the fracture mode, the specimens' fragments were observed. One of the four fracture modes were recorded for each specimen: Mode of fracture was categorized according to **El-Damanhoury et al, 2015** [41] Type I: Complete or partial de-bonding of the endocrown without fracture, Type II: Fracture of only the endocrown, Type III: Fracture of both endocrown and tooth above bone level simulation and Type IV: Fracture of both endocrown and tooth complex below the bone level stimulation. The first three modes of fracture were considered favorable acceptable modes of fractures while type IV was regarded as catastrophic failure.

Statistical analysis

The data were recorded, tabulated and analyzed using the IBM SPSS Statistics 22 program. Data normality was established with the Shapiro-Wilk test. One -way ANOVA was used to evaluate and compare fracture strength results. Significance was set at p value < (0.001).

RESULTS

Fracture resistance

For fracture resistance was presented as mean and standard deviation. One-way ANOVA comparison across five groups (CN, CP, EEC, EIM, and ECS) for fracture resistance values, each with 10 samples. The analysis was set to have statistically significant differences between groups at p value < (0.001). The control negative (CN) group; intact samples having no treatment; showed the highest mean fracture resistance (1172.9±155.5), while the control positive (CP) group demonstrated significantly lowest values (348.3±38.7). The experimental groups (EEC, EIM, and ECS) showed comparable fracture resistance values of 1085.3±99.5, 1126.3±92.9, and 1111.4±90.8 respectively. Post-hoc LSD analysis revealed significant differences between CP and all other groups at a p value < (0.001), while comparisons between CN and the experimental groups (EEC, EIM, and ECS) showed no statistically significant differences at p value > (0.05). Further, no significant differences between the different endocrowns (EEC vs EIM p=0.376, EEC vs ECS p=0.571, EIM vs ECS p=0.747), suggesting similar performance among these treatments. **Tab (1), Fig (1)**

Fracture Mode

Examination of the distribution of fracture modes (Types I through IV) across three experimental groups (EEC, EIM, and ECS). Chi-square analysis showed no statistically significant differences in fracture mode distribution between groups

TABLE (1) Fracture resistance comparison between all five study groups

	CN	CP	EEC	EIM	ECS	P value
	N=10	N=10	N=10	N=10	N=10	
Fracture resistance	1172.9±155.5	348.3±38.7	1085.3±99.5	1126.3±92.9	1111.4±90.8	***<0.001****
P value						
CN		***<0.001****	*0.062*	*0.314*	*0.186*	
CP			***<0.001****	***<0.001****	***<0.001****	
EEC				*0.376*	*0.571*	
EIM					*0.747*	

One Way ANOVA test for comparison of quantitative data between the five group
Analysis between each two groups with Post Hoc LSD
****: Significant level at P value < 0.05***

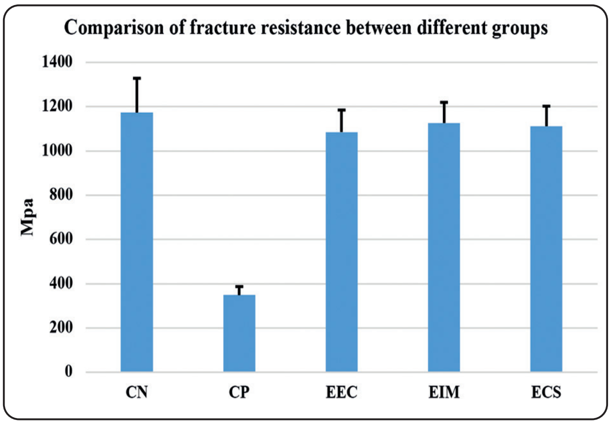

Fig. (5) Bar chart showing comparison of fracture resistance between different groups

TABLE (2) Fracture mode comparison between different endocrowns.

	EEC	EIM	ECS	P value
	N=10	N=10	N=10	
Fracture mode				
Type I	0(0%)	1(10%)	1(10%)	0.623
Type II	3(30%)	3(30%)	4(40%)	
Type III	7(70%)	4(40%)	4(40%)	
Type IV	0(0%)	2(20%)	1(10%)	

Comparison of qualitative data between the groups with Chi square test

Significant level set at P value < 0.05

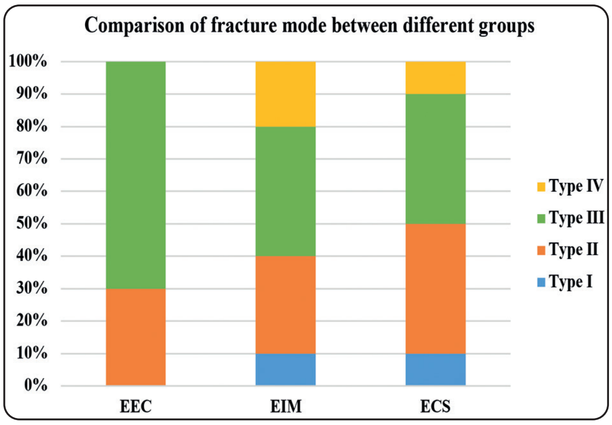

Fig. (6) Bar chart comparison of fracture mode between different groups

(p=0.623). Type III fractures were most prevalent in all groups, with EEC showing the highest percentage (70%), while both EIM and ECS showed 40%. Type II fractures occurred in similar proportions across groups (EEC: 30%, EIM: 30%, ECS: 40%). Type IV fractures were less common, with EIM showing the highest occurrence (20%), followed by ECS (10%), while EEC showed no Type IV fractures. Type I fractures were absent in EEC, while both EIM and ECS showed equal occurrence (10%). This distribution pattern suggests that while there are some variations in fracture modes between groups, these differences are not statistically significant. **Tab (2), Fig (2)**

DISCUSSION

It is the essence of biomimetic restorative dentistry to mimic tooth structure; giving that the main bulk of dental structure is dentin it is logic that the more the restorative materials behave biomechanically as dentin the more the fracture resistance of a tooth is restored. [22-26] The main predicament in endodontically treated teeth is the pretreatment tooth loss due to caries or trauma and the post treatment accumulative loss of dental structure due to access cavity preparation and shaping of the root canal; not to mention more destructive techniques required in complicated cases that need more tooth removal as during treatment of many mishaps. [4-7] One of the most critical areas of the dental tissues is the pericervical dentin area; where destructive occlusal forces and cyclic loading accumulate; the transfer of these loads down in to this particular area may not only cause the fracture of the restoration and / or tooth but also can cause the tooth to fracture in an unrepairable mode. [21]

It would then be safe to predict that utilizing a material at this critical pericervical area as a base beneath final restorations; that not only mimics the modulus of elasticity, biomechanical behavior and the fracture resistance of the dentin structure but also similar in composition of the distribute collagen fibers with in the dentin architecture; would ultimately reinforce and support the weak residual tooth structure and help act as a stress breaker (load bearing barrier). [24-26]

In the present study three different materials were utilized to restore endodontically treated posterior teeth. This invitro study design; an indispensable method to evaluate performance; allowed for high level of standardization for all procedures as the tooth, preparation, restoration dimensions, loading direction and magnitude were all controlled and standardized. Moreover, allowed the comparison with intact and endodontically treated teeth. The tooth preparation for all the test groups followed a standard butt joint endocrown preparation as a scenario mimicking a severely damaged (ETT) mandibular molar. The three tested endocrowns all showed excellent fracture resistance values that were extremely superior to physiological masticatory loading in mandibular molars. [43, 44]

Regarding the fracture resistance analysis, the results revealed significant differences between positive control group which had only endodontic procedure with no restoration and all three test groups at p value <0.001, this comes in accordance with many researches that have demonstrated the significant decline in fracture resistance of ETT [4, 5]

This was explained by the primary loss of tooth structure to cries and traumatic injuries, and secondary loss of tooth structure to endodontic treatment procedure. Moreover, the alteration of physical properties, changes in collagen intermolecular cross-links and decreased moisture content of collagen all have been demonstrated as causes of reduction in strength, toughness and structural integrity[6,7] on the other hand, comparisons between CN (intact tooth specimens) and the experimental restorative groups (EEC, EIM, and ECS) showed no statistically significant differences ($p>0.05$) which is in agreement with many previous studies [45-50]

This high fracture resistance values; for EEC (Ever-X posterior endocrown) comes in accordance with **Garoushi etal** [51] whom demonstrated that SFRC has superior strength and fracture toughness than conventional composite restorations, by which it is capable to support the residual tooth structure, and prevent fractures.[41]This may be due to the unique short E-glass fibers that are randomly oriented, minimizing polymerization shrinkage which prevents the buildup of internal stresses with in the material, in addition to the random organization of fibers which offers stress distribution in a uniform manner, essentially boosting up reinforcement of the remaining tooth structure . Furthermore, SFRC are able to prevent crack initiation, dispersion and act as a load-bearing barrier under high occlusal forces. [52]

Tsuujimoto etal [23], Shah etal [24], and Kim etal [25] all pointed out the fact that SFRC has similar modulus of elasticity as dentin which allows the material to undergo the same biomechanical behavior in regards to plastic deformation especially which in turn provide high capacity to with stand loads in high occlusal forces

As for EIM group (IPS E-Max CAD endocrown); although the results demonstrated also high fracture resistance; as previous studies by **Lawson etal [30] and Zhi etal [31]**; the biomechanical behavior is different this lithium disilicate CAD blocks possess extremely higher elastic modulus which is much higher than dentin. This allows the endocrown manufactured from these blocks to endure the majority of the occlusal load leaving minimum remaining load transferred to the underlining tooth structure specially to the PCD. This phenomenon known as stress shielding effect has been descried by **Nguyen etal [53] and Klingebiel etal [54]** who explained that the stress with the dentin is much lesser than that in the endocrown. Further describing that the more the mass of this glass ceramic the less the transferred stresses.

While for ECS (Resin nanoceramic (RNC) CAD/CAM endocrown) which are now used as an alternative for ceramic materials; combines the benefits of resilient polymers yet still preserving the favorable esthetics of ceramics. Unlike other ceramics RNC is composed of 80% nanoceramic particles with in a highly cured resin matrix which allows for more uniform stress distribution there for provides the high fracture resistance [32, 33]

Gresnigt etal [34] and Rocca et al [35] evaluated the biomechanical behavior for RNC endocrowns. They concluded that due to the dentin matching modulus of elasticity it acts as a cushion absorbing load and reducing stress spikes within the root dentin and the restoration-tooth interface.

Although each of the three tested endocrowns; had different mechanisms of action under occlusal loads there were no significant differences between the three different restoration groups, suggesting similar performance among these treatments. Study by **Acar and Kalyoncuoglu [55]** found no significant difference between IPS E-max CAD and Cerasmart endocrowns in regard of fracture resistance which comes in accordance with our study. Moreover, our results are in agreement with **Kaya Büyükbayram etal [38]** whom found that no statistical significance was shown between samples restored with Ever-X posterior and Cerasmart endocrowns.

Providing (PCD); this vulnerable area with a supportive dentin like material that will act under stress as the original dentin structure leading to outstanding modulation and even stress distribution specially in the transition zone from the coronal to the root structure. Many investigations have shown that teeth restored with SFRC as a base under composite restorations had increase stress-bearing capacity and preventing catastrophic failure**.** [56, 57] Many studies have investigated the load bearing capacity of SFRCs under different composite restorations of ETTs, while limited number of studies have investigated their efficacy beneath CAD/CAM materials. [26, 58]

In contrast to our results **Rocca et al [59]** compared restoring endodontically treated molars with resin nanoceramic CAD/CAM material (Lava Ultimate) either with or without fiber reinforcement regarding the fracture resistance and mode. It was found that using SFRC reinforcement did not statistically improve fracture resistance, moreover, all samples fractured catastrophically apical to the CEJ in a non-repairable manner. A study by **Kaya Büyükbayram etal [38]** also found no statistically significant between groups in terms of fracture resistance with and without short fiber reinforcement under different endocrown restorations.

On the contrary to our study **Garoushi et al [60]** investigated the effect of the thickness ratio of the SFRC on the fracture behavior of different posterior restorations. Direct and indirect restorations were constructed with a 2-mm layer of SFRC-or with out this layer. The results demonstrated no statistically significant difference.

On the other hand, **Huda et al** [61] stated that endocrowns provided superior fracture resistance than did inlay and onlay restorations the results further demonstrated that fracture resistance was higher in samples where Ever-X Posterior (SFRC) was used as a base material compared to samples without SFRC which comes in accordance with the present study. Variations may be due to the differences within each methodology as type of tooth, cavity design and material used to manufacture the endocrown

Regarding the fracture mode in the present study, the most prevalent type of fracture with in all three restorations was type (II, III); Type II: Fracture of the endocrown without fracture of the tooth (favorable failure), Type III: Fracture of the endocrown/tooth complex above CEJ (acceptable failure) which indicates the prevalence of favorable mode of fracture. This is in agreement with previous studies [62, 63]

This may be attributed to the application of a stress breaking barrier of SFRC of 2mm beneath all three restorations which acted in similar manner as dentin allowing for reinforcement at the vulnerable area of the PCD (the area joining coronal to radicular structure). Moreover, its unique a characteristic of preventing crack initiation/ propagation and crack bridging all allowed for favorable mode of failure.

No catastrophic fractures occurred in EEC group, while only 10% ECS showed catastrophic failure and EIM had the highest percentage of fracture apical to the CEJ at 20%. This comes in line with **Soares etal** [64] **and Magne etal** [42] whom found SFRC and RC to have no catastrophic fracture mode. This may be owed to the similar modulus of elasticity of both materials to dentin allowing more even distribution of stresses and low concentration of strain at the CEJ.

While in IPS E- Max ceramic restoration had the highest prevalence of catastrophic fracture mode which may be a result of high modulus of elasticity. This rigidity though it can with stand high loads, at certain limits it starts to concentrate strain in weak areas and ultimately results in more irreparable fracture. This comes in agreement with **El-Damanhoury etal** [41] **and El Ghoul etal** [65] whom found that most failures in root canal treated teeth that have been restored with ceramic rigid endocrown restoration are catastrophic irreparable modes of failure.

Though each of the tested endocrown materials function in a different biomechanical behavior. They all managed to ultimately provide fracture resistance which was close to fracture resistance of an intact tooth. Further, when failure occurred the facture mode mostly was more on the reparable side. Hence the null hypothesis was accepted.

CONCLUSION

This new (stress breaking barrier) approach of Placing short fiber reinforced composite base beneath endocrowns; of various materials for restoring posterior ETT; not only had near to intact tooth fracture resistance values but also yielded favorable and reparable modes of fracture.

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