The influence of cavity design for cusp coverage on fracture strength of weakened maxillary first premolars using two esthetic restorative systems (CAD/CAM hybrid ceramic and nanohybrid composite) (An in vitro study)

Zainab Salman Jawad, B.D.S., H.D.D. [(1)]
Abdul Karim J. Al-Azzawi, B.D.S., M.Sc. [(2)]

ABSTRACT

Background: Maxillary first premolar with wide MOD cavity more susceptible to fracture. The aim of this study was to assess the influence of cavity design for cusp coverage on the fracture resistance of weakened maxillary first premolar restored with CAD/CAM hybrid ceramic versus nanohybide composite.
Materials and Methods: Fifty six intact maxillary first premolars of approximately comparable sizes were divided into seven groups eight for each: Group A: Intact teeth (control group); Group B: teeth prepared for MOD inlay; Group C: teeth prepared for MOD onlay covering the lingual cusp; Group D: teeth prepared for MOD covering buccal and lingual cusps ,the previous three groups indirectly restored with nanohybrid composite (3M ESPE Z 250 XT); Group E,F,G prepared with the same design as group B, C, D respectively and restored with CAD/CAM hybrid ceramic (VITA ENAMIC).
Results: An axial compression test was used to measure the fracture strength of experimented teeth. The readings were analyzed statistically by t-test, one way ANOVA and LSD, then the mode of fracture had been examined. The results showed that sound teeth in group (A) had more fracture resistance values than all experimental groups and the difference were highly significant with group (B, E, F, G).When the influence of cavity design tested among composite groups it showed highly significant difference between group (B) and (C)and the highest fracture resistance value was for group(C), whereas the influence of cavity design among Enamic groups showed highly significant difference between group (E) and (G) the highest fracture resistance value was for group(E).T-test between similar designs showed non-significant difference between MOD groups and highly difference between other groups.
Conclusions: Cusp coverage increased the fracture resistance of composite groups but result in non-restorable fracture, while Enamic total onlay presented promising fracture resistance with favorable mode of fracture.
Key words: Fracture resistance, CAD/CAM, hybrid ceramic, VITA ENAMIC, nanohybrid composite, cusp coverage. (J Bagh Coll Dentistry 2015; 27(1):1-10).

INTRODUCTION

During cavity preparation the removal of marginal ridges, occlusal enamel and cusps weakness result in a progressive decrease in fracture resistance in teeth [(1)].

Indirect metallic restorations or amalgam restorations with occlusal recovering were first indicated to reduce the chance of fracture and increase teeth strength [(2)]. The use of ceramic and resin composite materials for posterior tooth restorations as alternative materials to metallic restorations had been increased in the past decades [(3, 16)].

Dental ceramics are considered to be esthetic restorative materials with desirable characteristics, such as translucency, fluorescence, and chemical stability. They are also biocompatible, have high compressive strength, and their thermal expansion coefficient is similar to that of the tooth structure. Since ceramics are fragile, cavity preparation design for posterior teeth restored with ceramic restorations should increase their resistance to fracture [(4,5)]. Tooth preparation designs advocated for posterior ceramic restorations have been based on traditional cast metal restoration designs, but with more occlusal tooth reduction and a slightly increased taper reduced chance of restoration failure and increase thier longevity [(6)].

In spite of their many advantages, direct composite resins are technically sensitive and have polymerization shrinkage, postoperative sensitivity and low wear resistance [(5,7)].

Indirect inlays/ onlays fabricated with composite resins provide excellent esthetic results that may also reinforce tooth structure. This is because a more conservative preparation design can be used since the bonding procedures strengthen the cusps and provide additional support for the dentition. Additional clinical benefits include precise marginal integrity, wear resistance similar to enamel, wear compatibility with opposing natural dentition, ideal proximal contacts, and excellent anatomic morphology [(8)].

Clinical CAD/CAM machines have stimulated dentists to provide more conservative restorations than in the past [(9)]. VITA ENAMIC, the first

(1)Master Student, Department of Conservative Dentistry, College of Dentistry, University of Baghdad.
(2) Professor, Department of Conservative Dentistry, College of Dentistry, University of Baghdad.

dental hybrid ceramic for CAD/CAM restorations in the world, has dominant ceramic network reinforced by a polymer network for that it combines the positive characteristics of a ceramic and a composite so it is important to study their effect on fracture resistant of weakened teeth and the suitable design prepared to receive this material [10].

MATERIALS AND METHODS

Samples selection and preparation

Fifty six sound human maxillary first premolar freshly extracted for orthodontic reasons were collected from patients of ages range between 16-20 years. The teeth had two fused roots and stored in 0.2% thymol solution for seven days [11]. Calculus and soft-tissue deposits were removed with a hand scaler and ultrasonic scaler. The teeth were cleaned using a rubber cup and fine pumice water slurry and then stored in 0.9% saline physiological solution at room temperature for 24 hr [12]. The teeth were also free of cracks while viewed under magnification observation (10x) and optic transillumination. To be included in the study, the premolars were required to have the following crown dimensions: 9.0–9.5 mm bucco-lingual distance; 7.0–7.4 mm mesio-distal distance and 8–8.5 mm cervico-occlusal distance.

The roots of each tooth was inserted in corresponding elastic root coping that had 0.3mm thickness similar to the width of periodontal ligament made by pressing elastic foil (Biostar copyplast, Germany) of 0.5 mm thickness on roots models in Biostar machine, then the roots with their elastic coping embedded in the self cure acrylic (Vertex, Netherlands) using dental surveyor, up to 2 mm below cemento-enamel junction to simulate the alveolar bone. The space created by root elastic coping was occupied by polyvinylpolysiloxane light body impression material (Chromaclone PVC, ULTRADENT, South Jordan, USA) to simulate the periodontal ligament [13]. An impression of each tooth crown was taken with a polyvinylsiloxane addition silicone material (elite P&P, Zhermack, Italy) and poured after 1 hour with type 4 die stone(elite Stone, navy blue, Zhermack, Italy) to make tooth model that was used as an anatomic guide during the study [14] .

The teeth were randomly divided into 7 experimental groups of 8 teeth each and subjected to the following procedures:

Group A: Eight Intact teeth (control group).

Group B: Eight teeth prepared for MOD inlay with extensive isthmus, indirectly restored with nanohybrid composite **(**Filtek Z250 XT, 3M ESPE).

Group C: Eight teeth prepared for MOD onlay with extensive isthmus covering the lingual cusp, indirectly restored with nanohybrid composite **(**Filtek Z250 XT, 3M ESPE).

Group D: Eight teeth prepared for MOD onlay with extensive isthmus covering buccal and lingual cusps, indirectly restored with nanohybrid composite **(**Filtek Z250 XT, 3M ESPE).

Group E: Eight teeth prepared as in group B and indirectly restored with CAD/CAM hybrid ceramic (VITA ENAMIC).

Group F: Eight teeth prepared as in group C and indirectly restored withCAD/CAM hybrid ceramic (VITA ENAMIC).

Group G: Eight teeth prepared as in group D and indirectly restored with CAD/CAM hybrid ceramic (VITA ENAMIC).

Cavity preparation for Mesio-occluso-distal inlay with extensive isthmus

The standard sizes for inlay MOD cavity preparation included: occlusal box with 1/2 of the intercuspal distance and the pulpal floor was prepared to a depth of 2 mm from the central groove. The buccolingual widths on mesial and distal boxes were 1/2 of the buccal-lingual distance. Each box had a gingival floor depth of 1.5 mm mesiodistally and the axial wall hight range between 2-2.5mm. The gingival floor located 1 mm above the cement-enamel junction (CEJ). Gingival floor were prepared with 90-degree cavosurface angles [15] Fig. (1, A),(3, A).

The outline dimensions were marked on the teeth by 0.4 mm marker**.** A modified tapered shoulder bur had depth marking at 2 and 4 mm (REF 6847KRD 314. 016, Komet, Germany), was used to prepare depth orientation groove (2mm in depth) following the central groove mesiodistally to the outer surface. Round-ended tapered diamond bur with 3° taper (REF 8845KR. 314.018, Komet, Germany) was used for cavity preparation to the determined depth and drown out line.

The depth of gingival floor (1.5mm) determined by the width of the end of the bur and checked by periodontal prob. All internal line angles were round taking the shape of round ended bur. The teeth were prepared by high speed air-water cooling turbine (Sirona, T3 Racer, Germany) that adapted in modified CENDRES & METAUX dental surveyor (BIENNE, SWISS) that has two arms with wide range of movements Fig.(2). The burs were replaced after every four teeth preparation to ensure high cutting efficiency. To finish the preparations the same bur was used at low speed handpiece .The dimensions of the cavity were measured with the digital caliper and periodontal probe.

Mesio-occluso-distal onlay with extensive isthmus covering the palatal cusp (partial onlay) cavity preparation

For partial onlay (PO) cavity preparation, MOD cavities with the same dimensions as that of previous design were prepared, then 2 mm occlusal reduction of the functional cusp [16] by using wheel bur (REF 909.314.065, Komet , Germany) to the mark made at the floor of depth orientation groove (DOG) prepared using bur with marks (then a circular reduction as in crown preparation was prepared at the palatal surface extended 2 mm in the cervical direction using diamond bur with guide pin (REF 8372P 341 023, Komet, Germany). The guide pin, was not diamond coated, ensure a controlled and safe preparation so a defined finishing line created. To place the prepared finishing line deeper to 1mm, previous round-ended tapered diamond bur was used. Again the preparations finished and the margin of reduced cusps beveled using the same bur with low speed hand piece Fig. (1, B), (3, B).

Mesio-occluso-distal onlay with extensive isthmus covering buccal and palatal cusps (Total Onlay) cavity preparation.

The preparation of total onlay (TO) was similar to that of the partial onlay with additional 1.5mm occlusal reduction in the buccal cusp [14] Fig. (1, C), (3, C).

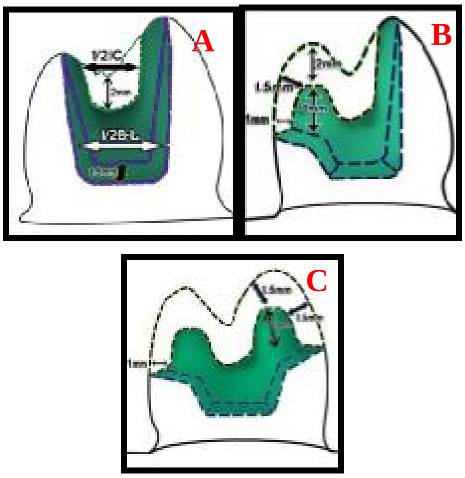

Figure 1: Cavity designs. (A) MOD inlay cavity design.(B)Partial onlay cavity design.(C) Total onlay cavity design.

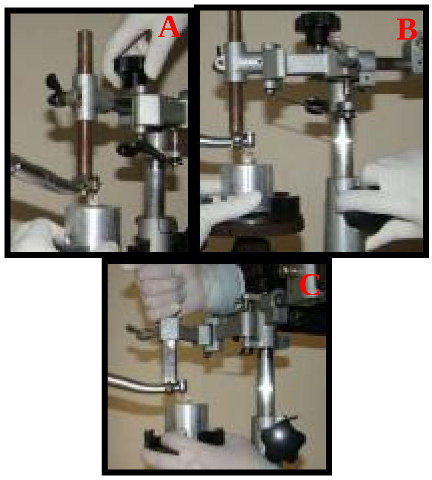

Fig. (2): Cavity preparation. (A) MOD inlay cavity design prepared using modified dental surveyor. (B) Partial onlay cavity design preparation, cusp reduction with diamond disk. (C) Finishing line preparation using the movable arm that had two joints.

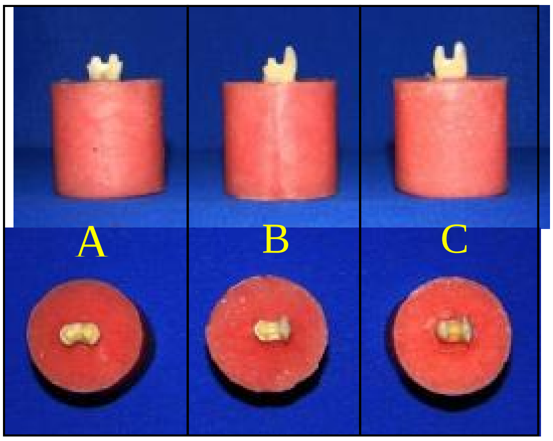

Figure 3:. Latral and occlusal view of the three designs of cavity preparations on the teeth (A) MOD inlay. (B) Partial onlay.(C) Total onlay.

Indirect composite restorations for groups (B),(C)and(D) using Filtek XT Z 250

An impression of each preparation was taken using double viscosity polyvinylsiloxane (addition silicone). Two stone models (master model and working model) were obtained from this impression.

The coping template of teeth before preparation was set on the model of preparation and the cusps height determined by reamer and endo-ruler for partial and total onlay. The margin of preparation marked on template by fine marker (0.4mm) then the crown template had been cut by scissor away from the drown margin.

The stone model of the preparation coated with three layers of die spacer till 0.5 mm from the margin then two glycerine layer [17] applied by a brush as a separating media and each layer allowed to dry for 2 minutes by inverting the model. The composite (Filtek Z250 XT, shade A2, , 3M ESPE, USA) added to the model in three layrs. The first third of composite added to the floor of the preparation using ash 49 and light cured for 20 second for each surface, then the second third added and cured allowing for the last third to be fitted by coping template of intact teeth to restore the original size, shape and anatomy [18, 19], then cured for 20 second for each surface using LED curing light unite with energy between 850 mW/cm²–1000 mW/cm² (WOODPECKER, China).

The working model broken down carefully to remove the restoration, then the restoration cleaned and checked on master model, finished and polished using soflex discs after checking the dimensions with metal gauge. The interior surface of restoration was roughened with aluminum oxide blast (50 µm) from a distance of 5cm at a pressure of 2 bars for 10 sec. [20] Fig. (4).

The restoration cemented to the prepared tooth with (RelyX U200 RF, shade A2, 3M ESPE, USA) under 1 Kg load for 2 minutes to be fully seated [14] using modified dental surveyor. Each surface of the cemented restoration cured for 20 seconds using LED curing light unite. All samples stored in distilled water at room temperature before test.

Figure 4: Restorations of the three designs ready for cementation.

Indirect hybrid ceramic restorations fabrication for groups (E), (F) and (G) using VITA ENAMIC blocks

Sirona CAD/CAM system (scanner, computer with version 4.0 software, milling machine) was used to fabricate indirect ceramic restorations. All steps of fabrication were the same for the three designs as the following:

Computer software which was provided by the manufacturers was used for designing the restorations. The stone model of the prepared teeth sprayed with cerec optispry to remove optical highlights from the surface of the preparation and to enhance the precision of the optical impressions acquired by creating a uniformly reflective surface, then scanned with inEos Blue scanner.

On computer screen 3D model was created, margins drown and the path of insertion determined preparing for restoration editing

To restore the tooth to its original dimensions, the depth from central groove to the floor of cavity, the boccolingual and mesiodistal dimensions, cusps height and restoration outline all of these criteria adjusted on design window.

The block (VITA ENAMIC blocks of hybrid ceramic, shade 1M2-T EM-14 translucent, LOT 34910, VITA Zahnfabrik, Bad Sackingen, Germany) inserted and fixed into milling machine (**Sirona CEREC inLab MC XL,** Germany)**.**The restoration separated from the block at the end of milling finished and polished with VITA ENAMIC polishing set (technical) and checked on stone model to be ready for cementation .

The restoration inner surface etched with hydrofluoric acid gel (5%) (VITA Ceramic etch, Zahnfabrik, Bad Sackingen, Germany) that applied with brush for 60 sec. then the restoration cleaned with water for 60 sec. and dried for 20 sec. producing white opaque surface.

VITASIL silane coupling agent (Zahnfabrik, Bad Sackingen, Germany) applied with needle to the etched surface and leaved for 5 min to dry, then a coat of A.R.T. adhesive (Zahnfabrik, Bad Sackingen, Germany) spread by brush on the inner surface of restoration to be cured by light with cement [21]. ENAMIC restorations cemented to the tooth (after tooth conditioning) by VITA DUO Universal shade cement (Zahnfabrik, Bad Sackingen, Germany) with VITA A.R.T. bond.

The restoration inserted and one kg load was applied on the occlusal surface as in cementation procedure of indirect composite groups. Each side cured for 40 seconds using LED curing light unite, then the restoration finished and polished using soflex discs. All restored samples stored in distilled water at room temperature before test.

Figure 4: VITA ENAMIC block inserted in Sirona CEREC in Lab MC XL

Axial compression test

The fracture resistance for each sample assessed under axial compressive loading with 3-mm metal sphere (Comparing it to small resistant foods that increase the risk of restoration fracture during mastication) in computer control electronic universal testing machine WDW-100 (Layree, china) at a cross-head speed of 0.5 mm/min until the specimen fractured [13].

On the computer screen the maximum load at the time of fracture recorded and displayed in (KN). The fractured specimens were evaluated to determine fracture patterns using a modified classification system based on the classification system proposed by **Burke et al.** [21] :

Type I: isolated fracture of the restoration.

Type II: restoration fracture involving a small tooth portion.

Type III: fracture involving more than half of the tooth, without periodontal involvement.

Type IV: fracture with periodontal involvement.

RESULTS

The means and standard deviations of fracture strength with minimum and maximum values which were calculated in (KN) for each group is shown in (Table 1).

Table 1: Descriptive statistics of fracture resistance values (KN) for all groups.

Groups		N	Mean	±S.D.	Min.	Max.
A	Control	8	0.88	±0.07	0.80	0.99
B	MOD Composite	8	0.64	±0.10	0.51	0.75
C	PO Composite	8	0.84	±0.13	0.70	0.99
D	TO Composite	8	0.75	±0.14	0.60	0.98
E	MOD Enamic	8	0.68	±0.09	0.56	0.84
F	PO Enamic	8	0.59	±0.10	0.45	0.76
G	TO Enamic	8	0.54	±0.09	0.43	0.71

Fracture strength analysis

In the following tests, P values considered as:

Non-significant (NS) P > 0.05

Significant (S) 0.05 ≥ P > 0.01

Highly significant (HS) P ≤ 0.01

The values showed that intact sound teeth (Group A) presented the highest mean value (0.88 KN), whereas teeth restored with Enamic total onlay (Group G) showed the least fracture resistance (0.54 KN) Fig.(4).

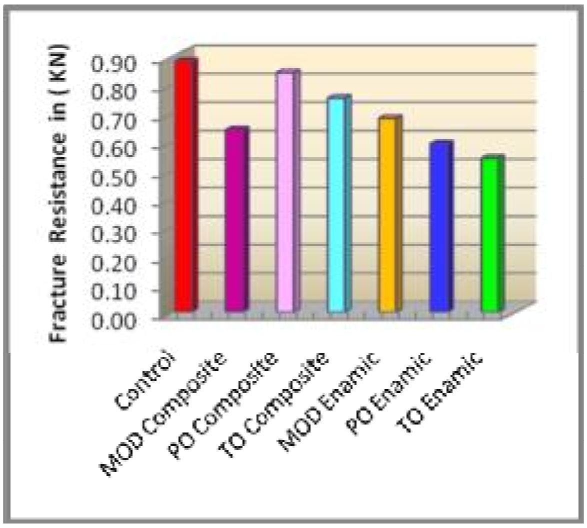

Figure 4: Bar-chart showing the mean values of the Mean values of the fracture resistance in (KN) for all groups.

By using Student's t-test, a comparison between group (A) and other groups had been done. It had been found that highly statistical significance was located between group A (sound teeth) and groups B, E, F and G while non-significant difference was noticed between group A and C. ANOVA test was used to make a comparison among the three designs restored with composite. The influence of difference designs on fracture resistance of teeth restored with composite was significant (Table 2). Further analysis was done by using LSD test to compare between each two groups with different designs that restored with composite. The difference between group B and group C statistically was highly significant but between group B and D and between Group C and D was non- significant (Table 3).

Table 2: Comparison among different designs restored with Composite by ANOVA test.

ANOVA	Sum of Squares	d.f.	Mean Square	F-test	p-value
Between Groups	0.165	2	0.082	5.54	0.012 (S)
Within Groups	0.312	21	0.015		
Total	0.477	23			

Table 3: LSD test after ANOVA test for different designs restored with composite.

Groups		Mean Difference	p-value
B	C	-0.20	0.003 (HS)
	D	-0.11	0.084 (NS)
C	D	0.09	0.146 (NS)

ANOVA test was used to make a comparison among the three designs restored with Enamic. The influence of difference designs on fracture resistance of teeth restored with Enamic was significant (Table 4).Further analysis was done by using LSD test to compare between each two groups with different designs that restored with Enamic. The difference between group E and F and between group F and G was non-significant while the difference between group E and G was highly significant (Table 5).

Table 4: Comparison among different designs restored with Enamic by ANOVA test.

ANOVA	Sum of Squares	d.f	Mean Square	F-test	p-value
Between Groups	0.082	2	0.041	4.612	0.022 (S)
Within Groups	0.186	21	0.009		
Total	0.268	23			

Table 5: LSD test after ANOVA test for different designs restored with Enamic.

Groups		Mean Difference	p-value
E	F	0.089	0.072 (NS)
	G	0.141	0.007 (HS)
F	G	0.052	0.282 (NS)

Student's t-test was used between each two groups that had the same design but different materials.MOD Enamic had higher fracture resistance mean value than MOD composite but the difference statistically was non-significant. PO composite had higher fracture resistance mean value than PO Enamic and the difference statistically was highly significant. TO composite had higher fracture resistance mean value than TO Enamic and the difference statistically was highly significant (Table 6).

Mode of fracture analysis

Type I, Type II and Type III of fracture considered as restorable while Type IV regarded as non restorable (Table 7).

DISCUSSION

All fracture resistant values of restored teeth can be considered to exceed reported maximum biting force in the premolar region (300 N) [22]. The difference between each of restored group and control group was obtained using t –test, the only non significant difference was found between PO composite group and sound teeth regarding fracture resistance mean value this result illustrated the influence of functional cusp coverage on fracture resistance of MOD cavity since the stress concentration areas on cusp tip was removed and as a sequence the stress on cusp base reduced too, so no tooth structure in this area deflected outward and the force transmitted from the thick restoration to the underlying dentin structure and distributed over a larger area of dentin, this coincide with the result of **Burke et al.,** [21]**, ElAyouti et al.** [23]**.**

Table 6: Inferential statistics of fracture resistance (KN) and materials comparison by t-test

Groups		Descriptive statistics		Group difference		
		Mean	±S.D.	t-test	d.f.	p-value
B	MOD Composite	0.64	±0.10	-0.802	14	0.436 (NS)
E	MOD Enamic	0.68	±0.09			
C	PO Composite	0.84	±0.13	4.461	14	0.001 (HS)
F	PO Enamic	0.59	±0.10			
D	TO Composite	0.75	±0.14	3.703	14	0.002 (HS)
G	TO Enamic	0.54	±0.09			

Table 7: Frequency of the type of failure and comparison among all groups

Groups		Type I	Type II	Type III	Type IV	Total
A	Control	0	0	6	2	8
B	MOD Composite	0	0	3	5	8
C	PO Composite	0	1	0	7	8
D	TO Composite	0	2	0	6	8
E	MOD Enamic	1	1	2	4	8
F	PO Enamic	3	1	0	4	8
G	TO Enamic	2	4	0	2	8

All Enamic designs showed high significant difference when compared to sound teeth and the designs that results in greater loss of tooth structure appear to decrease the resistance to fracture of restored teeth, this coincide with **St-Georges et al.** [24] who studied ceramic inlay and also coincide with **Soares et al.**[13]**; Habekost et al.** [14] these studies compare feldspathic ceramic, feldspathic ceramic reinforced with 10% aluminum oxide and leucite-reinforced ceramics used in different cusps coverage designs and concluded that ceramics used did not provide resistance to fracture similar to that achieved for the sound teeth, this is because ceramics has low elastic modulus and cannot absorb stresses even in the presence of resin cement. Since ceramics are not capable of undergoing elastic deformation at the same rate as tooth structure and resins. Stress will remain inside ceramic restoration itself inducing cracks propagations which lead to fracture**.**

Comparison among different designs of composite restorations showed that group C which restored with composite with palatal cusp coverage resisted fracture more than group B which restored with MOD composite and the difference was highly significant, this agree with **Burke et al.**[21], **Casselli et al.**[25], **yamanel et al.**[26], **ElAyouti et al.** [23] whose found that coverage of the at-risk palatal cusp may provide sufficient protection from fracture, this can be explained by: the composite resin characterized by lower modulus of elasticity that promoted a greater distribution of stress than the enamel. In contrast, the enamel has high elastic modulus, low strain capacity and friability, so the stress generated during the compressive load is concentrated and could initiate crack resulting in lower fracture resistance. Stress concentration areas located at palatal cusp tip, for cavities without cusp reduction, were wider than for teeth with cusp coverage, further, cusp reduction relocated stress concentration areas from the remaining tooth structures to the restoration [27, 28]**.**

Group TO composite had higher mean values of fracture resistance than MOD composite group but the difference was non-significant, this outcome coincide with **Yamada et al.** [29]. Even with non-significant difference total onlay is more promising solution because it exhibit compressive type of stresses that provide protection against debonding while MOD inlay show tensile interfacial stresses that cause adhesive [30].

There was no significant difference between PO composite and TO composite groups this agree with **Burke et al.** [21]**, Soares et al.** [31]**, Kantardžić et al.** [28] whose stated that cusp coverage produce lower stress values in dental tissues and restorative material. Palatal cusp reduction may provide sufficient fracture resistance, while it allows a more conservative preparation than that required for full coverage and permit keeping buccal enamel if esthetically not compromised. These finding conflict with that of **Panahandeh et al.**[32] who's found teeth with total onlay had significantly higher fracture resistance than those with palatal cusp coverage only. The difference with the results of previous studies may attributed to different dimensions (pulpal floor depth is 3mm, gingival floor width and depth is1 mm and 1.5 mm buccal and palatal cusp reduction) and cusp reduction done in inclined way without extension of finishing margin.

Comparison among different designs of Enamic restorations illustrated that both partial onlay and total onlay show lower resistance to fracture than MOD design this indicating that cusp coverage with this materials was not a benefit, non significant differences found between group E and F and between group F and G while the highly significant difference found between group G and group E this agree with **Edelhoff and Sorensen**[1], **Krejci et al.**[33] **, Habekost et al.** [14]**, Soares et al.** [13]**.**

Ceramics are not capable of undergoing elastic deformation at the same rate as tooth structure and resins because they present a high elastic modulus and low strain capacity. In addition, the resin luting agent under a ceramic restoration may act as a soft layer and could reduce the effects of stress concentration. Here the resin cement did not seem to be sufficient to absorb the stresses and the stresses remain inside the ceramic restoration and demand deformation, with the onlay design all stresses were located on the restorative material, since deformation did not occur and the stresses failed to be transferred to the tooth; fracture was the end result of restoration.

Although Enamic material hybridized by polymer network that reduce its modulus of elasticity but still behave like ceramic that used in previous studies regarding fracture resistance.

When comparison between the two materials within the same design had been done in this study the group of teeth restored with Filtek Z250 XT composite and that restored with Enamic in MOD cavity design have a close fracture resistance mean value of (0.64 KN) and (0.68 KN) respectively and statistically the difference was non-significant this indicating that polymer network that decrease the modulus of elasticity make the material behave just like composite in MOD cavity ,this come in agreement with **Shor et al.**[34]**, da Silva et al.** [35]**, Santos and Bezerra**[36]**, Abdallah and Alrawi** [37] who studied the fracture resistance of composite and ceramic in MOD cavity and it was found that these two materials restored lost fracture resistance to an acceptable level and the difference statistically was non significant.

The reinforcement of remaining tooth structure is related to the use of polymer containing materials that have low elastic modulus in addition to resin cement and adhesive boning that offered support for enamel and dentin, which was altered by cavity preparations, and increasing their stiffness.

At the same time the result disagree with **Soares et al.** [38], in this study it had been found that there is significant difference between fracture resistance of ceramic group and composite groups and the latest had the highest mean value. These dissimilar findings may related to the use of feldspathic ceramic (Duceram LFC) which is, unlike composite, a brittle restorative material characterized by high rigidity [15]. While Enamic contain dominant ceramic network and polymer network that penetrate each other ensuring strength and elasticity and preventing crack propagation [25]. Another important point that explains the close results is may be the synergism of behavior between the polymer network of Enamic, resin cement and adhesive system, which show similar compositions and high bond capacity among them resulting in increased fracture resistance in conservative cavity [38]. In addition, the prefabricated blocks are industrially conceived and highly homogeny, which should improve the mechanical properties of the restoration over time [39].

High significant difference in fracture resistance between Enamic and composite in both PO and TO designs, with the highest value found in composite groups. This come in accordance with **Magne and Belser** [30]**, Soares et al.** [38] who concluded that the fracture resistance values obtained for teeth restored with composite confirm the theory that polymer materials have greater capacity to distribute tensions in a more homogeneous way than ceramics.Total onlay designs restored with composite and Enamic differences agree with that of **Brunton et al.** [40] who found teeth restored with composite onlay restorations (SR Isosit) demonstrated a higher fracture resistance than onlay restorations produced from a ceramic material (Empress).

Although, Enamic contain polymer network that increase the elasticity (the elastic modulus about 30 GPa) but still has inferior resistance to fracture than composite in such cavity designs, this may be related to the dominant ceramic network. Large onlays were characterized by preferable stress pattern. Low elastic modulus of most composite can never fully compensate for the loss of strong proximal margin especially in large CL II, so ceramic onlay seems to be best indication. Another cause make onlay the restoration of choice is that the occlusal contact not established on tooth-restoration interface due to the difference in the mechanical behavior of the two materials. Stiffness of thick and bulky ceramic restoration allows for 100% recovery of crown rigidity [30,41], so increasing the thickness of Enamic restoration may improve their fracture resistance.

Based on the findings of this study, six of the samples in the intact control group (Group A) presented favorable fracture type. These findings may be due to the presence of the palatal and buccal cusps with intact mesial and distal marginal ridges in the control group [42]. In tooth restoration complex, the mode of fracture is probably the result of the mechanical properties provided by the materials, techniques employed for the restoration and cavity design, which influence the fracture pattern more than does the quantity of remaining tooth structure [25].

Investigations of the fracture patterns showed that, samples with higher fracture resistance produced the most catastrophic failures involving the fracture of restoration together with tooth structure [24, 14].

In this study, high frequency of non-restorable (type IV) fracture seen in all composites designs than in ceramic groups ,with highest frequency found in (group C) that had the uppermost fracture resistance value. It can be explained by the low elastic modulus of composite (approximately 16–20 GPa) and resin cement (approximately 8.30 GPa) which are similar to that of tooth. Because of this flexibility, these materials require to reinforcement from the remaining tooth structure for rigidity, as a result more occlusal force was transferred to the remaining tooth structure, which resulted in greater risk of tooth fracture**.** In addition to flexibility of restorative materials, good bond strength to enamel and dentin make them to behave as one unite. Filtek Z250 XT, Nano Hybrid composite characterized by higher filler content, resulting in better mechanical properties, therefore a larger number of catastrophic failures had been found in this groups, which leads to indication of tooth extraction [7,25,31,38].

Unlike composite, Enamic restorations presented isolated fractures of restorations (Type I pattern). Ceramics considered as a rigid materials with a high elastic modulus (approximately 65–95 GPa), showing little deformation and tend to reinforce the remaining tooth structure. The risk of tooth fracture may be minimized because the restorative material is likely to fracture before the tooth [7,38].

Type I fracture is more preferable in the clinical situation, because the restoration could be replaced, while tooth failure may impair the prognosis [2,43]. In this study Enamic restorations shows less frequency in type VI fracture than that in composite group and in total onlay the mode of this pattern was equivalent to that seen in intact teeth.Type I fracture appear in Enamic in addition to type II and III which are considered restorable type of fracture and their frequency was similar to that of type IV in group E and F ,this come in agreement with **St-Georges et al.**[24]**, Ragausk et al.**[7]**, Soares et al.**[31] but disagree with **Soares et al.** [13] whose found type I fracture in all ceramic restorations this may be because they tested ceramic restoration on molars not premolars with thicker walls that had higher fracture strength and Enamic has special polymer network that transmit occlusal load and allow deformation of restoration before fracture.

REFERENCES

1. Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designs for posterior teeth The International Journal of Periodontics & Restorative Dentistry 2002; 22(3):241-9.
2. Mondelli RF, Barbosa WF, Mondelli J, Franco EB, Carvalho RM. Fracture strength of weakened human premolars restored with amalgam with and without cusp coverage. Am J Dentistry 1998; 11(4): 181-4.
3. Bortolotto T, Onisor I, Krejci I. Proximal direct composite restorations and chairside CAD/CAM inlays: Marginal adaptation of a two-step self-etch adhesive with and without selective enamel conditioning Clinical Oral Investigations 2007, 11(1) 35-43.
4. Borges GA, Sophr AM, de Goes MF, Sobrinho LC, Chan DC. Effect of etching and airborne particle abrasion on the microstructure of different dental ceramics. J Prosthet Dent 2003; 89:479-88.
5. Anusavice KJ,Shen C, Rawles HR. Phillips' Science of dental materials.12th ed. Saunders: Elsevier Inc; 2013;Ch13:275,Ch18 : 418.
6. Etemadi S, Smales RJ, Drummond PW, Goodhart JR. Assessment of tooth preparation designs for posterior resin-bonded porcelain restorations. J Oral Rehabil 1999; 26:691-7.
7. Ragauska A, Apse P, Kasjanovs V, Cimdina LB. Influence of ceramic inlays and composite fillings on fracture resistance of premolars in vitro. Baltic Dental and Maxillofacial Journal, 2008; 10 (4), 121-126.
8. Howard NY. Advanced use of an esthetic indirect posterior resin system. Compend Contin Educ Dent 1997; 18: 1044-54.
9. Christensen JG. Considering tooth-colored inlays and onlays versus crowns. JADA 2008; 139(5):617-20.
10. VITA Dental product: ENAMIC; technical product profile: 2013.
11. Santana FR,Pereira JC ,Pereira CA ,Fernandes Neto AJ ,Soares CJ. Influence of method and period of storage on the microtensile bondstrength of indirect composite resin restorations to dentine. Braz Oral Res 2008; 22(4):352-7.
12. Willershausen B, Schulz-dobrick B. In vitro study on dental erosion provoked by various beverages using electron probe microanalysis. Eur j med res 2004; 9: 432-8.
13. Soares CJ, Martins LR, Fonseca RB, Sobrinho LC, Neto AJ. Influence of cavity preparation design on fracture resistance of posterior Leucite-reinforced ceramic restorations. J Prosthet Dent 2006; 95:421-9.
14. Habekost LV, Camacho GB, Pinto MB, Demarco FF. Fracture resistance of premolars restored with partial ceramic restorations and submitted to two different loading stresses. Operative Dentistry 2006; 31(2): 204-11.
15. Dalpino PH, Francischone CE, Ishikiriama A, Franco EB. Fracture resistance of teeth directly and indirectly restored with composite resin and indirectly restored with ceramic material. Am J Dent 2002; 15(6): 389–94.
16. Ritter AV, Baratieri LN. Ceramic restorations for posterior teeth: Guidelines for the clinician Journal of Esthetic Dentistry 1999; 11(2) 72-86.
17. Roulet J F, Wilson NH, Fuzzi M. Advances in operative dentistry. 4th ed. Quintessence Publishing Co, Inc; 2001, Ch13: P 167.
18. Salameh Z, Rani F, Aboushelib M, Al·Hamdan R, Sadig W, Ferrari M. Effect of different onlay systems on fracture resistance and failure pattern of endodontically treated mandibular molars restored with and without glass fiber posts. Am J Dent 2010; 23:81-86.
19. Al-Taii ZS. The influence of recent adhesive onlay fabrication techniques on the fracture resistance of endodontically treated premolars in vitro study. A master thesis, College of Dentistry, University of Baghdad, 2013.
20. D'Arcangelo C, Vanini L. Effect of three surface treatments on the adhesive properties of indirect composite restorations. J Adhes Dent. 2007; 9(3):319-26.
21. Burke FJ, Wilson NH,Watts DC. The effect of cavity wall taper on fracture resistance of teeth restored with resin composite inlays. Oper Dent 1993; 18:230-6.
22. Sakaguchi Rl, Powers Jm. Craig's Restorative Dental Materials.13th ed. Mosby Inc, 2012; Ch9: P 162-5.
23. ElAyouti A, Serry MI, Geis-Gerstorfer J, Lost C. Influence of cusp coverage on the fracture resistance of premolars with endodontic access cavities. Inter Endod J 2011; 44: 543–9.
24. St-Georges AJ, Sturdevant JR, Swift EJ Jr, Thompson JY. Fracture resistance of prepared teeth restored with bonded inlay restorations. J Prosthet Dent 2003; 89: 551-74.
25. Casselli DS, Silva AL, Casselli H, Martins LR. Effect of cavity preparation design on the fracture resistance of directly and indirectly restored premolars. Braz J Oral Sci 2008; 7(27):1636-40.
26. Yamanel K, Çağlar A, Gülşahi K, Özden UA. Effects of different ceramic and composite materials on stress distribution in inlay and onlay cavities: 3-D finite element analysis. Dental Materials Journal 2009; 28(6): 661–70.
27. Baldassarri M, Margolis HC, Beniash E. Compositional determinants of mechanical properties of enamel. J Dent Res 2008; 87: 645-9.

28. Kantardžić I, Vasiljević D, Blažić L, Lužanin O. Influence of cavity design preparation on stress values in maxillary premolar: a finite element analysis. Croat Med J 2012; 53:568-76.
30. Magne P, Belser UC. Porcelain versus composite inlays/inlays: effects of mechanical loads on stress distribution, adhesion and crown flexure. Int J Periodontics Restorative Dent 2003; 23(6):543-55.
31. Soares PV, Santos-Filho PCF, Martins LRM, Soares CJ. Influence of restorative technique on the biomechanical behaivior of endodontically treated maxillary premolars. Part I: fracture resistance and fracturemode. J ProsthetDent 2008; 99: 30-7.
32. Panahandeh N, Johar N. Effect of Different Cusp Coverage Patterns on Fracture Resistance of Maxillary Premolar Teeth in MOD Composite Restorations. JIDA 2014; 25(4): 228-232.
33. Krejci I, Duc O, Dietschi D, de Campos E. Marginal adaptation, retention and fracture resistance of adhesive composite restorations on devital teeth with and without posts. Operative Dentistry 2003; 28: 127–35.
34. Shor A, Nicholls JI, Phillips KM, Libman WJ. Fatigue load of teeth restored with bonded direct composite and indirect ceramic inlays in MOD class II cavity preparations. Int J Prosthodont 2003; 16: 64-69.
35. da Silva SB, Hilgert LA, Busato AL. Fracture resistance of resin-based composite and ceramic inlays luted to sound human teeth. Am J Dent 2004; 17: 404-6.
29. Yamada Y, Tsubota Y, Fukushima S. Effect of restoration method on fracture resistance of endodontically treated maxillary premolars. Int J Prosth 2004; 17:94-8.
36. Santos MJ, Bezerra RB. Fracture resistance of maxillary premolars restored with direct and indirect adhesive techniques. J Can Dent Assoc 2005; 71:585.
37. Abdullah HA, Alrawi II. The influence of CAD/CAM ceramic and heat processed composite Inlays on the fracture resistance of Premolars. J Bagh College Dentistry 2012; 24(4):14-18.
38. Soares CJ, Martins LR, Pfeifer JM, Giannini .Fracture resistance of teeth restored with indirect-composite and ceramic inlay systems. Quintessence International 2004; 35(4): 281-6.
39. Rusin R. Properties and applications of a new composite block for CAD/CAM. Compendium 2001; 22:35–41.
40. Brunton PA, Cattell P, Burke FJ, Wilson NH. Fracture resistance of teeth restored with onlays of three contemporary tooth-colored resin-bonded restorative materials. J Prosthet Dent 1999; 82:167-71.
41. Magne P, Knezevic A. Thickness of CAD-CAM composite resin overlays influences fatigue resistance of endodontically treated premolars. Dent Mater 2009; 25:1264-8.
42. Sagsen B, Aslan B. Effect of bonded restorations on the fracture resistance of endodontically filled teeth. Int Endod J 2006; 39:900–4.
43. Watts DC, Wilson NH, Burke FJ. Indirect composite preparation width and depth and tooth fracture resistance. Am Dentistry1995; 8(1):15-19.