DOI: https://doi.org/ 10.32828/mdj.v19i2.892

MDJ

Fracture Resistance of Premolars Restored with Inlay/Onlay Composite and Lithium Disilicate CAD/CAM Block Restorations (An *In Vitro* Study)

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Abstract

Aim: To assess the fracture resistance of Premolars restored with inlay and onlay composite and E-max CAD/CAM block restoration.

Material and method: Randomly, fifty maxillary premolar teeth were separated into three major groups: The first group was left unaltered (control group), while the other two groups were prepared with inlay and onlay cavities and restored with lithium disilicate blocks (IPS E.max CAD) and ceramic composite blocks (Cerasmart). Restorations were bonded using adhesive resin cement (RelyX Ultimate). All samples were thermocycling 500 cycles, between 5 to 55°C and the cycle time was set at the 30s. The specimen was undergone compressive axial loading in a universal testing machine till the fracture occurred. The result was analyzed using one-way ANOVA, and LSD tests with a significance level set at 0.05.

Result: There were no significant differences in means between the control group and the inlay groups that were restored with Emax and Cerasmart (P >.05). However, the control group has significantly higher means than onlay groups restored with Emax and Cerasmart (P< .05). The two materials show comparable results in both designs.

Conclusion: The fracture resistance of inlay-prepared teeth showed comparable strength to the intact teeth. Conversely, the fracture resistance of onlay-prepared teeth is comparatively lower than intact teeth. The two materials show comparable results irrespective of cavity design.

Keywords: fracture-resistant, premolars, inlay/onlay restorations, E-max, Cerasmart.

Introduction

Restorative procedures induce enamel discontinuity and raise the susceptibility of teeth to fracture. As a consequence of the relationship between the efficacy of restorative materials as well as cavity preparation, numerous cavity design and preparation strategies have been developed. Significant carious lesions, unacceptable restorations, and tooth fractures have led to an argument regarding the most effective restorative approach (Soares et al,2006; Beier et al,2012). When an indirect restoration is most effective, the clinician must decide on the cavity preparation's geometric shape. Particularly regarding cusp coverage. It is imperative to think about the mechanical characteristics of restorative materials when selecting the cavity design (Frankenberger et al,2013).

The Inlay/Onlay technique was developed to restore posterior teeth that have been affected by decay or fractures. This technique addresses certain limitations related to direct filling techniques, including insufficient proximal or occlusal shapes, inadequate wear resistance, or insufficient mechanical characteristics of filling materials that are applied directly (Barone et al,2008). The adhesive technique in dentistry enables practitioners to effectively restore teeth' natural morphology, aesthetic attributes, and mechanical strength (Stappert et al,2006; Taschner et al,2012).

CAD/CAM lithium disilicate block is regarded as a standard gold material for all ceramic restorations owing to superior mechanical and esthetic properties. However, it has some drawbacks, including the material's brittle nature due to inherent cracks within the structure and the wearing of the opposing dentition.

To address these limitations, chair-side CAD-CAM material manufacturers have devised novel compositions that merge the benefits of ceramics, such as color stability and durability, combined with the advantageous characteristics of resin composites, like decreased abrasion and increased flexural strength (Awada & Nathanson,2015; Coldea et al,2013). The popularity of CAD-CAM composite blocks can be attributed to their undeniable advantages, including dependable mechanical properties, aesthetic potential, and wear characteristics comparable to opposing dental enamel (Rosentritt et al,2017). The utilization of digital chairside techniques and production procedures has enabled the implementation of standardized processing of restorative materials, leading to a reduction in fabrication times and an improvement in cost-effectiveness (Zarone et al, 2016; Vanoorbeek et al.2010).

In addition, it has been noted that CAD-CAM blocks composed of composites exhibit superior shock absorption properties compared to similar ceramic materials. However, these findings are still subject to some degree of controversy (Menini et al,2013).

The study aimed to assess the fracture resistance of maxillary Premolars restored with inlay and onlay composite and E-max CAD/CAM block restorationand to assess the fracture mode in each type.

The first null hypothesis states that there is no difference in fracture resistance

between the sound and restored groups or between the restored groups, regardless of the restorative material used. The second null hypothesis states that there is no relationship between cavity preparation and fracture strength and mode of fracture of both restorative materials.

2 Material and method:

The main materials utilized in the present research are mentioned in Table (1).

2.1 Samples and their Preparation

Ethical approval (No. MUOPR 9) was obtained to collect fifty human-sound maxillary first premolars extracted for orthodontic purposes, ages 18–25. Soft tissue and calculus deposits were eliminated from the teeth using an air scalar. Then the teeth were polished using free-from fluoride pumice with a rubber cup and rinsed with water (Hamouda and Shehata, 2011). All the teeth were examined by magnification loupes (3.5 X) under visible light trans-illumination utilizing the fiber optic light of the light curing unit (Diagnostic LED Attachment, SDI, Australia) to guarantee that there were no cracks, restorations, or caries lesions. Any teeth with defects were excluded from this study (Mortazavi et al, 2012). All the teeth utilized in this study had regular occlusal anatomy with completely formed apices. For each tooth, the maximum B.L. and M.D. dimensions were measured by a digital caliper (Soares et al, 2006; Taha et al, 2009). Teeth that were selected had bucco-palatal width varied between (8.5 - 9.5 mm), and miso-distal width varied between (6.5 - 7.5 mm). A one-way ANOVA test was done, and no significant difference was revealed for the 5 groups. The selected teeth were soaked for 48 hours in a 0.1% thymol solution. (Kikuti et al, 2012), following stored in distal water at room temperature until the time of the experiment to prevent the specimen's dehydration (Abdo et al, 2012). In order to resemble the periodontal ligament of the teeth, a wax layer was applied around all the teeth. Each tooth was first marked 2mm apical to the CEJ with an indelible pen, Then, the root surfaces were immersed into a molten wax at 70 °C using a dipping wax machine up to 2.0 mm apical to the CEJ for 5 sec. This resulted in a 0.2 to 0.3 mm thick layer of wax. All the teeth were embedded in a fabricated silicon mold with dimensions of 20 mm × 20 mm× 25 mm that is filled with self-cure acrylic resin (at the dough stage). They are positioned within their long axis utilizing a dental surveyor to the level of 2 mm beyond the CEJ (to simulate the alveolar bone). A rubber dam liquid was used to fix each tooth to the longitudinal arm of the surveyor before embedding it in the acrylic (Hegde and Sali, 2017; Hamad and Ali, 2017). After the initial indication of polymerization, the tooth (with the overlaying wax) is manually withdrawn from the resin block. then, the wax layer was substituted by a silicone light body impression material. First, the wax was removed using a probe and a spoon excavator from the root surfaces. The block of acrylic resin was filled with additional light silicone body impression material using a Garant™ dispenser and

auto-mixing tips. Then the tooth was back into the acrylic resin block.

The sample was randomly distributed into three major groups:

- Group 1: intact teeth (10) (control).
- Group 2: inlay cavity design (20) with subgroup:
  - 2A 10 restored with CAD/CAM E-max
  - 2B 10 restored with CAD/CAM composite block
- Group 3: onlay cavity design (20) with subgroup:
  - 3A 10 restored with CAD/CAM E-max
  - 3B 10 restored with CAD/CAM composite block

Standardized inlay and onlay cavities (MOD cavity) were prepared using a diamond fissure burs with a six-degree taper (Inlay Preparation Sets, Komet, Lemgo, Germany). The procedure was performed using a high-speed handpiece (NSK, Tokyo, Japan) and sufficient air-water cooling. A single operator carried out the preparation process following the prescribed order of particular diamond tools. To optimize cutting efficacy, it was deemed necessary to replace each utilized diamond instrument after completing four preparations. The process of standardized cavity preparation includes fixing the utilized handpiece within a specifically designed device, known as a modified dental surveyor. The utilization of this particular device facilitated precise movements of the handpiece, leading to the production of cavity walls with a consistent degree of divergence, as well as standard width and depth. The following describes the cavity preparation's dimensions: From the occlusal surface, the depth of the pulpal floor was 2.5 mm. and the buccolingual widths measured 3 mm. Each box's gingival floor was 1.5 mm deep, and an axial wall height of 1.5 mm (figure 1). The preparation of onlays involved the creation of MOD cavities with identical dimensions to those of MOD inlay cavities. Furthermore, 1.5 mm of reduction occurred in the palatal cusp, following the anatomical configuration of the occlusal surface. This outcome is associated with the butt joint preparation design, as shown in Figure (2). Using a digital caliper, the cavity's dimensions were determined (Saridag et al, 2013).

2.2 Construction of the indirect restorations

All the samples were scanned using an intraoral scanner (Medit i700, Seoul, South Korea). Exocad software (GmbH, Darmstadt, Germany) was utilized in the restorations' design. IPS E.max (HT block, A1 shade; Ivoclar Vivadent, Schaan, Liechtenstein) in addition to Cerasmart (HT block, A1 shade; Gc Corporation, Tokyo, Japan) were milled in approximately 10-12 minutes in the milling machine (ARUM Dentistry, Yuseong-gu Daejeon, South Korea). A diamond-cutting tool was used to separate the restoration from the block holder. The E-max block is then crystallized and fired in a single step, with the restoration placed in the center of the IPS E.max CAD crystallization tray in a furnace for burning ceramics (Programmed P310, Ivoclar Vivadent/technical, Schaan, Liechtenstein). For around a 25-minute firing cycle at 840 C, where the lithium disilicate crystals grow to reach their final

strength, shade, aesthetic, and physical properties, follow the manufacturer's recommendations. And for Cerasmart this material needs no further treatment after milling, rather than polishing the restorations were finished and polished using Diacomp plus Twist polishing, a two-step set mounted in a contra-angle handpiece (EVE, Germany). The polishing process was performed in two steps following the manufacturer's instructions: pre-polishing using the pink burs system and final polishing using grey burs.

2.3 The restorations' cementation

Following try-in of restoration, inlay, and onlay was bonded as described below:

For CAD/CAM E-max restoration:

Hydrofluoric acid 5% (IPS ceramic etching gel, Ivoclar Vivadent AG) use for the etching of restoration for 20 sec, followed by a thorough cleaning with a spray of water and drying with air free from oil. Then, a Single bond universal adhesive (3M ESPE, USA) was put on the entire fitting surface, and it was rubbed for 20 sec, followed by 5 sec of moderate air drying with humidity-free air, until the solvent evaporated and the adhesive stopped moving across the surface (Ewadh & Jasim ,2022).

For CAD/CAM composite block:

Etching with hydrofluoric acid (5%) for 60 sec (manufacturer instructions) then Clean with copioEus water. The entire fitting surface was coated with a single-bond universal adhesive (3M ESPE, USA). It was rubbed for 20 sec, then gently air dried with humidity-free air for 5 sec till the solvent was evaporated and the adhesive no longer moved over the surface following Manufacturer instructions (Ewadh & Jasim ,2022).

Surface Treatment of the Tooth

The phosphoric acid:37% phosphoric acid etchant was directly administered to the prepared tooth surfaces for 15 sec. Following the instructions of the manufacturer, the etchant was then entirely rinsed for 15 sec, and surplus water was removed using suction while ensuring that the preparation remained visibly moist. The single-bond universal adhesive was subsequently put on the etched surface using a disposable applicator. The adhesive was then rubbed for 20 sec, followed by a light stream of air for about 5 sec, till it ceased to move and the solvent had entirely dissipated.

Cementation utilizing an adhesive resin cement

The restoration was cemented with the dual-curing cement resin RelyXTM Ultimate Clicker (RelyXTM Ultimate, 3M ESPE, Germany). RelyX™ Ultimate adhesive resin cement was mixed with a plastic mixing spatula on the mixing pad (one click). And then carried by the spatula and placed over the whole tooth's prepared surface. Initially, restorations were seated on their respective teeth using finger pressing. Using a micro brush, any excessive cement was gently removed from the margin. To prevent rebounding, a custom loading apparatus was utilized to give a vertical static load of 5 kg (50 N) to the occlusal surface of each crown for 6 minutes (Guindy et al, 2016) Then light curing for 20 sec per surface in accordance to the manufacturer's instruction (De Kok et al, 2015).

2.4 Testing

The sample was kept in distilled water. Then was positioned in a incubator at 37°C in a laboratory for one week (Weyhrauch et al, 2016) then to attempt to simulate the oral cavity environment, artificial aging was performed. The specimens were thermocycler by using an automatic thermocycling device for 500 cycles between 5°C (± 2°C) to 55°C (± 2°C) using a dwell time of the 30s (Mohammadi et al, 2009; Hada & Panwar, 2019).

In a universal testing machine (LARYEE, Beijing, China), axial compression was applied to each specimen. utilizing a metal sphere of four mm diameter. A four mm rounded-end stainless-steel rod was attached to the test machine's loading arm, whereas the acrylic block of the tooth sample was attached to the test machine's base. A piece of 1 mm thick rubber was inserted between the restoration and the occluding rod to serve as stress breakers (Tsitrou et al, 2007) compressive axial loading is introduced to each Sample at a crosshead speed of 0.5 mm/min till fractures will take place (figure 3). The fracture-inducing force has been measured in Newtons (N). The modes of fractured of samples were categorized into the following: cohesive fracture of the tooth (CS), adhesive fracture at the interface (AD), cohesive failure of the restorative material (CM), and complete fracture of the specimen (CO) (Taha et al., 2011) (figure 4).

2.5 Statistical analysis

A one-way ANOVA test was utilized to verify the significance of the variance difference among groups. The level of significance was fixed at P.05. Using LSD multiple comparison tests, the significance of the difference between each group was determined.

3 Result

The mean force-producing tooth fracture for each group is shown in (figure 5). The one-way ANOVA demonstrated a statistically significant difference in the mean force between groups (Table 2).

The statistical analysis of the LSD test (Table 3) revealed no statistically significant differences observed in the means of the Intact tooth group and the groups that received restoration with E-max inlay (P=0.627) and Cerasmart composite block inlay restorations (P=0.268).

However, significant differences were observed between the means of the Intact tooth group and the groups restored with E-max onlays (P 0.016) and a significant difference between the Intact tooth group with Cerasmart composite block onlays group (P=0.004).

The study results indicate no statistically significant difference between the groups that received E-max inlay and Cerasmart composite block inlay restorations (P=0.530).

Statistically significant variations were noted in the mean values of the E-max inlay group compared to those treated with the E-max onlays group (P=0.049). Moreover, a significant difference was observed between the E-max inlays group and the group that received Cerasmart composite block onlays (P=0.014).

Concerning groups that were restored using inlay Cerasmart composite block restorations, the LSD test revealed no statistically significant difference between

the means of this group and those restored using E-max onlays (*P*=0.171) and Cerasmart onlays composite block (*P*=0.059).

Furthermore, no statistically significant difference was observed between the means of E-max onlays and the Cerasmart composite block onlays restoration group (*P*=0.588).

The fracture mode is listed in Table 4.

4 Discussion

Both null hypotheses were rejected due to there being a significant difference in fracture resistance between groups and the fracture strength and mode are dependent on the cavity design of prepared teeth.

The replication of the periodontal ligament simulation facilitates the adaptation of the tooth within the acrylic mold, thereby preventing the accumulation of stress in the cervical area of the tooth (Soares et al,2006). The teeth chosen for the study were inserted in acrylic resin cylinders at a depth of 2 mm below the CEJ to replicate the alveolar bone level. A cavity preparation with standardized dimensions was performed utilizing a six-degree taper fissure bur with a high-speed headpiece. The headpiece was connected to a specially designed to prevent potential biases or erroneous interpretations of the outcomes (Saridag et al,2013).

This study used all-ceramic restorative materials, widely regarded as superior for achieving aesthetically pleasing restorations (Montenegro et al,2010).

In this study, the same adhesive cementation technique was used for the cementation of onlay/onlay of both groups to have a standard cementation protocol that followed the manufacturer recommendations for all CAD / CAM materials utilized in this study utilizing a Dual-curing luting composite resin with a total-etch technique, considered a gold-standard cementation strategy (Piwowarczyk et al,2004).

For cementation, every restoration was placed on its respected prepared tooth under a constant load of five kilograms (approximately fifty Newtons). This was done to mimic the biting force that happened clinically during the cementation method (Anunmana et al, 2014). To ensure that the load is applied equally to the whole occlusal surface of restoration, a piece of rubber material placed at the end of the vertical arm of the holding device also has the advantage of simulation the Cushing effect applied by the cotton roll during the cementation clinically (Dimashkieh, 2010). Subsequently, all specimens underwent 500 thermal cycles utilizing a thermocycling apparatus to replicate the potential alterations in intraoral temperature resulting from exposure to extreme hot and cold temperatures.

The study found no significant difference between intact teeth and the tooth restored by inlay CAD/CAM glass ceramic (E.max) and composite block (Cerasmart) restoration. This is due to the minimal tooth structure removal during cavity preparation (Saridag et al., 2013). moreover, based on numerous in vitro studies, (Cubas et al.,.2011; Saridag et al.2013; Yu W et al.,.2014) Adhesive cementation of the

inlay restored the prepared tooth's rigidity. In addition, A higher elastic modulus of adhesive cement raises the fracture strength of inlay/onlay restorations (Cubas et al.,2011). These findings correspond to Harsha et al., Saridag et al., and Cubas et al. (Cubas et al,.2011; Saridag et al., 2013; Harsha et al.,2017). Also, agree with Stappert et al. Who claimed that bonded glass ceramic inlays provided effective stress distribution, reinforced the remaining tooth structure, and allowed the preparing teeth to approximate the fracture resistance of sound teeth (Stappert et al.,2006).

Disagree with Soares et al. Those claimed that independent of the cavity preparation design, The fracture resistance of natural teeth was larger than that of teeth restored with ceramic restorations (Soares et al.,2006).

The fracture resistance of the onlay preparation groups was significantly lower than the intact tooth and significantly lower than the inlay preparation group; as the quantity of preparation increased, the fracture resistance decreased. This may be attributable to the low elasticity of ceramics, which reduces their capacity to withstand shocks and undergo deformations (Dalpino et al.,2002). furthermore, Ceramic is a material that exhibits brittleness and possesses mild resistance to shear and tensile stresses in specific regions. (Dalpino et al.,2002) The occurrence and progression of cracks, particularly in ceramic restorations under repeated pressure, contribute to ceramic fracture (St-Georges AJet al.,2003).

These results coincided with the research of Saridag et al., where cusp coverage reduced fracture resistance of teeth restored with lithium-disilicate onlays. (Saridag et al.2013), and agreed with Habekost et al. who claimed that the fracture resistance of teeth with ceramic onlays was less than that of teeth with ceramic inlays (Habekost et al.,2006). In addition, the result is agreed with Cubas et al. Stappert et al., and Yoon et al. Cuspal coverage had no effect on enhancing fracture resistance according to the findings (Stappert et al.,2006; Cubas et al,.2011; Yoon et al.,2019).

This result disagreed with Yamanel, who stated When teeth were restored with a ceramic material, onlay cavities protected the tooth structure more efficiently than inlay cavities (Yamanel et al.,2009). And disagreed with Harsha et al. who stated that an increase in cuspal coverage significantly increased fracture resistance in comparison to intact teeth this may attribute to the use of monolithic partially sintered zirconia CAD restoration in his study (Harsha et al.,2017).

The findings of this study stated no significant difference in the fracture resistance of teeth restored by the two types of materials in both designs (inlay,onlay). Few studies are comparing these two materials in this design. However, fracture resistance of teeth restored by E-max is greater than those restored by Cerasmart in both designs.

This may coincide with Stona et al., who claimed that the I.P.S. Empress CAD crown and I.P.S. e.max CAD crown revealed greater fracture resistance than the Cerec Vita block Mark II crown (Stona et al,2015).

In addition, the outcome is disagreed with Mohammed and Majeed; they found the fracture resistance of premolars restored by overlay fabricated from Briliant Crios

recorded a higher fracture strength than that overlay fabricated from I.P.S E.max CAD This could be accounted for different designs and materials used in his study (Mohamed and Majeed,2021).

Furthermore, Al-Shribi et al. had different outcome,where these authors discovered that endo-crowns made of Cerasmart with a butt joint design had a statistically significantly greater mean value of fracture load than I.P.S. e.max CAD endo-crowns. This is attributable to the different designs used in her study, the bonding strength of Cerasmart to the tooth structure, and the thickness and size of materials may affect the result (Al-Shibri and Elguindy, 2017).

The study result shows no significant difference between the inlay group restored with Cerasmart and the onlays group restored Emax (although the means of inlays restored by Cerasmart are higher). This may be due to the mechanical properties of E-max with an elastic modulus of 95 Gpa and flexural strength of 262-360 Mpa, and fracture toughness of 2.0-2.5 MPa m1/2 (Awada and Nathanson,2015).

The current study results showed no significant difference between the teeth restored with Cerasmart inlay and onlay restoration. Yet, the present results also demonstrated that the fracture resistance of the inlays was greater than that of the onlays. This is agreed with (Abdel Ghany et al., 2022), And this could be attributable to the bonding strength of Cerasmart to the tooth structure, the stress-absorbing nature of its composition with a breaking energy of 2.2 MPa, and the low flexural modulus 7 Gpa (Awada and Nathanson,2015).

Regarding failure mode, the finding of this study demonstrates that a large proportion of inlay for both E-max and Cerasmart groups displayed severe restoration and tooth fractures (complete specimens' fracture, catastrophic failure). This might be related to the fracture test design used in this study, as the location of the loaded applicator and the inclination of the cusps have a major role in fracture behaviors. The crown of maxillary premolars has a sharp inclination between the buccal and palatal cusp so that under occlusal load, a vertical fracture with mesiodistal split was more susceptible (Sornsuwan et al., 2011).

Furthermore, this type of failure (catastrophic failure) supposes a highly adhesive bond between the inlays and their corresponding prepared teeth related to the protocol for adhesive cementing in this study. The high bonding strength between ceramic restoration and the tooth structure has been shown to minimize the chance of debonding in ceramic restoration (Lafuente et al., 2000).

Also, the adhesive types of cement with multiple steps were found to produce higher bond strength than self-adhesive cement types (de Menezes et al., 2006; Vaz et al., 2012). This fracture mode was also observed in previous studies done by (Bilkhair,2013; Sieper et al.,2017; Wafaie et al.,2018; Abdel Ghany, et al.,2021) who all stated that a static load until failure-induced crown broke through a central fossa in the abutment tooth mesiodistally bellow the C.E.J. (complete fracture of restoration).

In contrast, the most common failure mode revealed for the onlays group for both E-max and Cerasmart CAD/CAM block was a cohesive failure of onlay restoration (non-

catastrophic failure). This fracture mode was observed in Wafaie et al. and Yildiz et al. who proved that the most predominant mode of failure in glass ceramic onlay was a failure in the restoration itself (Yildiz et al.,2013; Wafaie, et al.,2018). And seen in Abdel Ghany et al. show the most failure mode of Vita Enamic and Lava Ultimate onlays is the failure of restoration itself (Abdel Ghany et al.,2021).

This in vitro study has limitations such as sample size, and parafunctional behaviors that could have altered the pattern distribution of force and time, hence the result cannot fully replicate oral condition and the study was based on administering a compressive load in a single direction until failure. further studies with different cavity dimensions or different designs are needed in addition to in vivo studies.

5 Conclusions

It can be concluded, within the limits of this in-vitro research, that:

1) The design of preparation has a major influence on tooth fracture resistance.

2) The study observed comparable fracture resistance between inlay restorations and intact teeth.

3) In spite of the proximity of the values, it was observed that the mean fracture resistance of onlays was inferior to that of inlays. Therefore, the coverage of cusps did not provide additional support to the structure of the tooth.

4) The E-max and Cerasmart CAD/CAM materials have demonstrated reliable use in the fabrication of inlays and onlays for the restoration of premolars. These materials have demonstrated comparable achievement in terms of fracture resistance, irrespective of the cavity design.

5) A significant proportion of E-max and Cerasmart onlays demonstrated a favorable fracture pattern limited to the restoration itself.

Acknowledgment:

The authors are grateful to Mustansiriya University, Baghdad, Iraq.

Conflict of Interest Statement:

The authors reported that they have no conflicts of interest.

Reference

1) Soares CJ, Martins LRM, Fonseca RB, et al. Influence of cavity preparation design on fracture resistance of posterior Leucite-reinforced ceramic restorations. J Prosthet Dent. 2006;95(6):421–429
2) Beier US, Kapferer I, & Dumfahrt H. Clinical long-term evaluation and failure characteristics of 1,335 all-ceramic restorations International Journal of Prosthodontics.2012; 25(1) 70-78.
3) Frankenberger R, Hehn J, Hajtó J, Krämer N, Naumann M, Koch A, & Roggendorf MJ. Effect of proximal box elevation with resin composite on marginal quality of ceramic inlays in vitro Clinical Oral Investigations.2013; 17(1) 177-183.
4) Barone A, Derchi G, Rossi A, et al. Longitudinal clinical evaluation of bonded composite inlays: a 3-year study. Quintessence Int. 2008;39: 65–71.

5) Stappert CF, Att W, Gerds T, Strub JR. Fracture resistance of different partial-coverage ceramic molar restorations: An in vitro investigation. J Am Dent Assoc 2006;137:514-22.
6) Taschner M, Krämer N, Lohbauer U, Pelka M, Breschi L, Petschelt A, & Frankenberger R . Leucite-reinforced glass ceramic inlays luted with self-adhesive resin cement: A 2-year in vivo study Dental Materials.2012; 28(5) 535-540.
7) Awada A., Nathanson D., Mechanical properties of resin-ceramic CAD/CAM restorative materials. J Prosthet Dent. 2015; 114(4): 587-593.
8) Coldea A, Swain MV, Thiel N : Mechanical properties of polymer-infiltrated- ceramic-network materials. Dent Mater.2013;(29): 419-426.
9) Rosentritt M, Hahnel S, Engelhardt F, Behr M :In vitro performance and fracture resistance of CAD/CAM-fabricated implant supported molar crowns. Clin Oral Invest.2017(21): 1213-1219.
10) Zarone F, Ferrari M, Mangano FG, Leone R, Sorrentino R :"Digitally Oriented Materials": Focus on Lithium Disilicate Ceramics. Int J Dent.2016 (18): 9840594.
11) Vanoorbeek S, Vandamme K, Lijnen I, Naert I.Computer- aided designed/computer-assisted manufactured composite resin versus ceramic single-tooth restorations: a 3-year clinical study. IntJ Prosthodont.2010; 23: 223-230.
12) Menini M, Conserva E, Tealdo T, Bevilacqua M, Pera F, et al.,: Shock absorption capacity of restorative materials for dental implant prostheses: an in vitro study. Int J Prosthodont .2013(26): 549-556.
13) amouda IM., Shehata SH., Fracture resistance of posterior teeth restored with modern restorative materials. J Biomed Res. 2011; 25(6): 418-424.
14) ortazavi V., Fathi M., Katiraei N., Shahnaseri S., Badrian H., Khalighinejad N., Fracture resistance of structurally compromised and normal endodonticaly treated teeth restored with different post systems: An in vitro study. Dent Res J. 2012; 9(2):185-191.
15) Soares CJ, Martins LRM, Fonseca RB, et al. Influence of cavity preparation design on fracture resistance of posterior Leucite-reinforced ceramic restorations. J Prosthet Dent. 2006;95(6):421–429
16) Taha NA., Palamara JE., Messer HH., Cuspal deflection, strain and microleakage of endodontically treated premolar teeth restored with direct resin composites. J Dent. 2009; 37(9): 724-730
17) Kikuti WY., Chaves FO., Di Hipólito V., Rodrigues FP., D'Alpino PHP., Fracture resistance of teeth restored with different resin based restorative systems. Braz Oral Res. 2012; 26(3): 275-281.
18) Abdo SB., Masudi SM., Luddin N., Husien A., Khamis MF., Fracture resistance of overflared root canals filled with MTA and resin-based material: an in vitro study. Braz J Oral Sci. 2012; 11(4):451-457.
19) Hegde V., Sali AV., Fracture resistance of posterior teeth restored with high-viscosity bulkfill resin composites in comparison to the incremental placement technique. J Conserv Dent. 2017; 20(5): 360-364.
20) Hamad AF., Ali AA., Microleakage of different laminated veneer materials with different adhesive methods (a comparative in vitro study). A master thesis, University of Baghdad 2017.
21) Saridag S, Sevimay M, Pekkan G. Fracture resistance of teeth restored with

all-ceramic inlays and onlays: an in vitro study. Oper Dent. 2013;38(6):626–634.

22) wadh AM, Jasim HH. The influence of different CAD/CAM materials on the marginal fit of endocrown with different cavity depths (A comparative in-vitro study). Materials Today: Proceedings. 2022 1;61:695-9.

23) Guindy, J. E.,Sherif, R. E. & Aboul-Ezz, A. A. Evaluation of marginal discrepancy and microleakage of lava ultimate (Resin nano ceramic) versus lithium disilicate (Ips e. max cad) endocrowns. in vitro study. Indian Journal of Scientific Research. 2016;7, 27-34.

24) De Kok P, Kleverlaan CJ, de Jager N, Kuijs R, Feilzer AJ : Mechanical performance of implant-supported posterior crowns. J Prosthet Dent.2015 (114): 59-66.

25) Weyhrauch, M.,Igiel, C.,Scheller, H.,Weibrich, G. & Lehmann, K. M. Fracture Strength of Monolithic All-Ceramic Crowns on Titanium Implant Abutments. International Journal of Oral & Maxillofacial Implants. 2016;31.

26) Mohammadi N., Abed Kahnamoii M., Yeganeh P K., Navimipour E J., Effect of Fiber Post and Cusp Coverage on Fracture Resistance of Endodontically Treated Maxillary Premolars Directly Restored with Composite Resin. J Endod. 2009; 35(10): 1428-1432.

27) Hada YS., Panwar S., Comparison of the fracture resistance of three different recent composite systems in large Class II mesio-occlusal distal cavities: An in vitro study. J Conserv Dent. 2019; 22(3): 287-291.

28) Tsitrou, E. A.,Northeast, S. E. & Van Noort, R. Brittleness index of machinable dental materials and its relation to the marginal chipping factor. Journal of dentistry. 2007;35, 897-902.

29) Taha NA., Palamara JE., Messer HH., Fracture strength and fracture patterns of root filled teeth restored with direct resin restorations. J Dent. 2011;39(8): 527-535.

30) Saridag S, Sevimay M, Pekkan G. Fracture resistance of teeth restored with all-ceramic inlays and onlays: an in vitro study. Oper Dent. 2013;38(6):626–634.

31) Montenegro AC, do Couto CF, Ventura PR, et al. In vitro comparative analysis of resistance to compression of laboratory resin composites and a ceramic system. Indian J Dent Res. 2010; 0;21(1):68–71.

32) Piwowarczyk A, Lauer HC, Sorensen JA. In vitro shear bond strength of cementing agents to fixed prosthodontic restorative materials. J Prosthet Dent. 2004;92(3):265–273.

33) Anunmana, C., Charoenchitt, M. & Aavanund, C Gap comparison between single crown and three-unit bridge zirconia substructures. The journal of advanced prosthodontics. 2014; 6, 253.

34) Dimashkieh M. The Effect of Veneering Porcelain on the Marginal Fit of Cercon Zirconia Copings (Doctoral dissertation, Department of Prosthetic Dental Science Collage of Dentistry, King Saud University Riyadh, Saudi Arabia).2010.

35) Cubas GB, Habekost L, Camacho GB, Pereira-Cenci T. Fracture resistance of premolars restored with inlay and onlay ceramic restorations and luted with two different agents. J Prosthodont Res 2011;55:53-9.

36) Yu W, Guo K, Zhang B, Weng W. Fracture resistance of endodontically treated premolars restored with lithium disilicate CAD/CAM crowns or onlays

and luted with two luting agents. Dent Mater J 2014;33:349-54.
37) Harsha MS, Praffulla M, Babu MR, Leneena G, Krishna TS, Divya G. The effect of cavity design on fracture resistance and failure pattern in monolithic zirconia partial coverage restorations – An in vitro study. J Clin Diagn Res 2017;11:ZC45-8.
38) Stappert CF, Att W, Gerds T, Strub JR. Fracture resistance of different partial-coverage ceramic molar restorations: An in vitro investigation. J Am Dent Assoc 2006;137:514-22.
39) Dalpino PH, Francischone CE, Ishikiriama A, Franco EB. Fractureresistance of teeth directly and indirectly restored with compositeresin and indirectly with ceramic materials. Am J Dent. 2002;15:389–394.
40) 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(6):551.
41) Habekost LV, Camacho GB, Pinto MB, & Demarco FF . Fracture resistance of premolars restored with partial ceramic restoration and submitted to two different loading stresses Operative Dentistry.2006; 31(2) 204-211.
42) Yoon HI, Sohn PJ, Jin S, Elani H, Lee SJ. Fracture resistance of CAD/CAM-fabricated lithium disilicate MOD inlays and onlays with various cavity preparation designs. J Prosthodont 2019;28:e524-9.
43) Yamanel K, Caglar A, Gulsahi K, Ozden UA. Effects of different €ceramic and composite materials on stress distribution in inlay and onlay cavities: 3-D finite element analysis. Dent Mater J. 2009;28(6):661–670.
44) Stona D, Burnett LH, Mota EG, Spohr AM .Fracture resistance of computer-aided design and computer-aided manufacturing ceramic crowns cemented on solid abutments. J Am Dent Assoc .2015; 146: 501-507. 53.
45) Mohamed, Z.H. & Majeed ,M.A. Effect of Cementation Protocol on the Marginal Adaptation and Fracture Strength of Indirect Overlay Restorations Fabricated from Two Different All-Ceramic CAD/CAM Materials (A comparative in vitro study).A master thesis .University of Baghdad.2021.
46) Al-Shibri S, Elguindy J. Fracture resistance of endodontically treated teeth restored with lithium disilicate crowns retained. J Dent. 2017;7:464.
47) Abdel Ghany, S., Kehela, H., Abdel-Fattah, W. evaluation of fracture resistance of maxillary premolar teeth restored with CAD/CAM inlays and onlays(in-vitro study). Alexandria Dental Journal, 2022; 47(2): 155-161. doi: 10.21608/adjalexu.2021.62472.1160
48) Sornsuwan T, Ellakwa A, Swain MV. Occlusal geometrical considerations in all-ceramic pre-molar crown failure testing. Dental Materials. 2011 ;1;27(11):1127-34.
49) Lafuente JD, Chaves A, Carmiol R. Bond Strength of Dual-Cured Resin Cements to Human Teeth. Journal of Esthetic and Restorative Dentistry. 2000;12(2):105-10.
50) De Menezes MJ, Arrais CA, Giannini M. Influence of light-activated and auto-and dual-polymerizing adhesive systems on bond strength of indirect composite resin to dentin. The journal of prosthetic dentistry. 2006 ;1;96(2):115-21.
51) Vaz, R. R., Hipolito, V. D., Dalpino, P. H. P. & Goes, M. F. D. Bond strength and interfacial micromorphology of etch-and-rinse and self-adhesive resin cements to dentin. Journal of Prosthodontics: Implant, Esthetic and

Reconstructive Dentistry.2012 ;21, 101-111.

52) Bilkhair, Asma. Fatigue behaviour and failure modes of monolithic CAD/CAM hybrid-ceramic and all-ceramic posterior crown restorations. 2013. PhD Thesis. Dissertation, Universität Freiburg, 2014.
53) Sieper K, Wille S, Kern M. Fracture strength of lithium disilicate crowns compared to polymer-infiltrated ceramic-network and zirconia reinforced lithium silicate crowns. Journal of the mechanical behavior of biomedical materials. 2017 ; 1;74:342-8.
54) Wafaie RA, Ibrahim Ali A, Mahmoud SH. Fracture resistance of prepared premolars restored with bonded new lab composite and all-ceramic inlay/onlay restorations: Laboratory study. J Esthet Restor Dent. 2018;00:1–11.
55) Yildiz C, Vanlıoglu BA, Evren B, et al. Fracture resistance of manually an CAD/CAM manufactured ceramic onlays. J Prosthodont. 2013;22(7):537–542.

Table (1) The chemical composition of the main materials used in this study.

Material	Composition
IPS E.max CAD	Silicon dioxide, lithium oxide, potassium oxide, phosphorous oxide, zirconium oxide, zinc oxide, other and coloring oxides
Gc Cerasmart	Ceramic network: 71% Silica (20 nm) and barium glass (300 nm) nanoparticles, Resin matrix: 29% Bis-MEPP, UDMA and DMA polymers
RelyX Ultimate clicker	Base paste: Methacrylate monomers, radiopaque, silanated fillers, initiator components, stabilizers, rheological additives. Catalyst paste: Methacrylate monomers, radiopaque alkaline (basic) fillers, initiator components, stabilizers, pigments, rheological additives, fluorescence dye, dual-cure activator for single bond universal adhesive.

Table (2) ANOVA test between groups for Fracture resistance

Groups	Means	Std.	Min.	Max.	f-test	p-value
group1	1383.50	0.12	1130	1670		
group2A	1324	0.25	860	1850	3.429	0.016*
group3A	1077.50	0.27	635	1615		
group2B	1247	0.33	675	1910		
group3B	1011	0.14	760	1175		

Table (3) LSD between groups for fracture resistance

Group I	Group J	Mean Difference (I-J)	p-value
group1	group2A	59.50	0.627
	Group2B	136.50	0.268
	Group3A	306	0.016*
	group3B	372.50	0.004*
group2A	Group2B	77.0	0.530
	Group3A	246.5	0.049*
	group3B	313.0	0.014*
Group2B	Group3A	169.5	0.171
	group3B	236	0.059

Table (4): Mode of fracture in study groups

Subgroup	CS	AD	CM	CO	total
2A	2 (20%)			8(80%)	100%
2B	2(20%)			8(80%)	100%
3A	1(10%)		8(80%)	1(10%)	100%
3B	1(10%)		9(90%)		100%

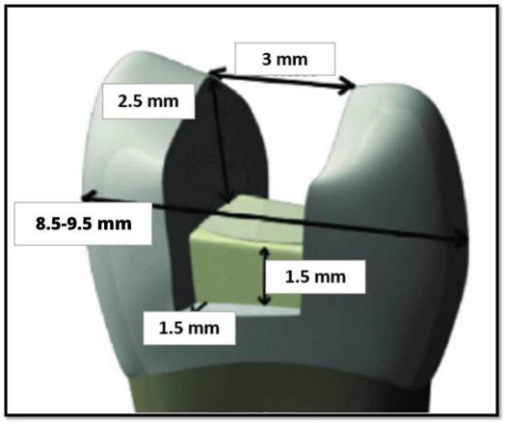

Figure (1): Diagram illustration of the dimensions of inlay cavity preparation.

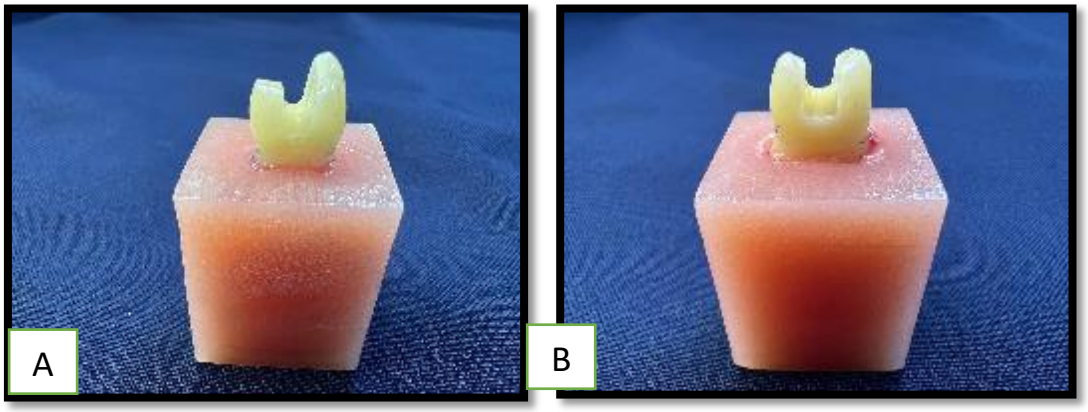

Figure (2): (A) MOD inlay cavity (B)MOD onlay cavity (proximal views)

Figure (3): The computer-controlled universal testing machine used in the study (Rod application used for axial compression test).

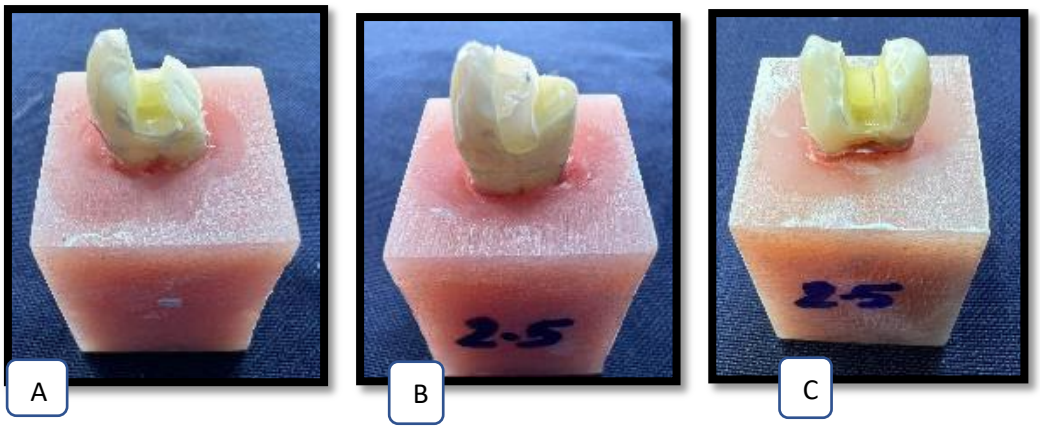

Figure (4) ; (A) Cohesive fracture of the tooth (B) Cohesive failure of inlay/onlay restoration (C) Complete fracture of the specimen involving the buccal cusp and inlay/onlay restoration.

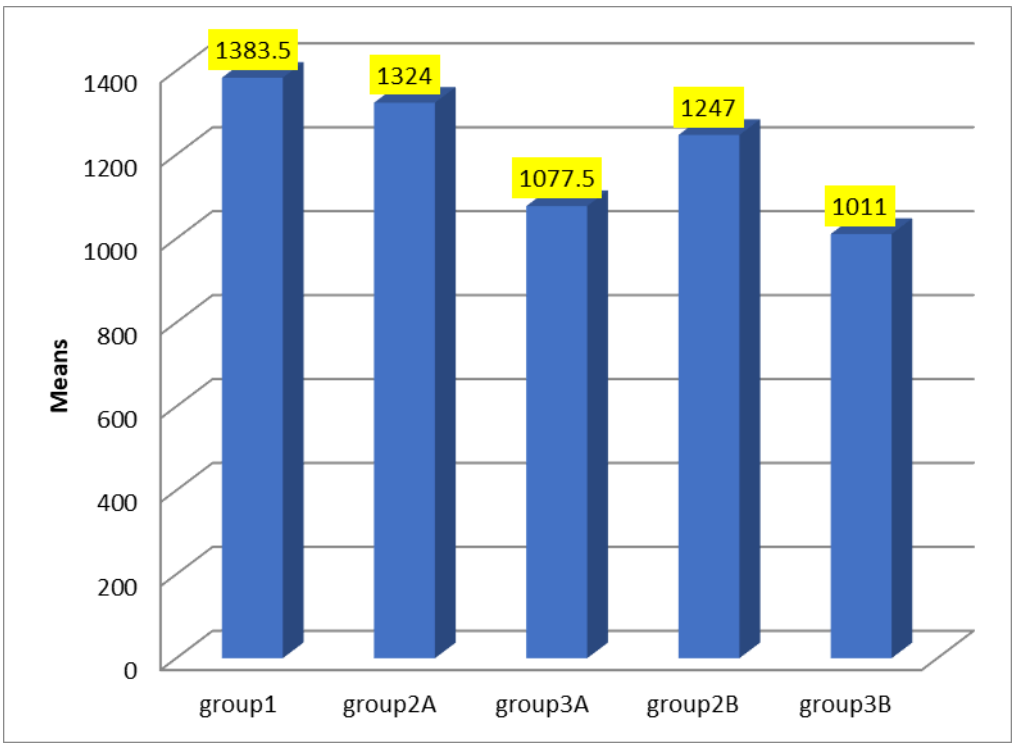

Figure (5): Means of fracture strength in study groups.