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FRACTURE RESISTANCE OF DIFFERENT CAD/CAM CERAMIC INLAYS (IN VITRO STUDY)

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ABSTRACT

INTRODUCTION: Ceramic inlays have picked up prominence due to their superior esthetic characteristics and work-ability. In addition, they allow chair-side restorations to be completed in one appointment.

OBJECTIVE: The aim of this study was to assess the in-vitro fracture resistance of three CAD/CAM ceramic materials.

MATERIALS AND METHOD: Mesio-occluso-distal (MOD) inlays (n=33) were fabricated from three CAD/CAM materials: Lithium disilicate glass ceramic (IPS-EMAX CAD), Zirconia-reinforced lithuim silicate (CELTRA-DUO) and hybrid composite filled with zirconium silicate particles (SHOFU HC BLOCK). Digital impressions of the inlay cavities prepared in the maxillary first premolar teeth were taken by CEREC scanner then the restorations were milled using CEREC MCXL milling machine.

Samples were cemented to MOD inlay cavities with resin cement (RelyX U200, 3M ESPE) and then fracture resistance test was performed by the Universal Testing Machine.

RESULTS: The fracture resistance values of inlays fabricated from lithium disilicate EMAX CAD (1104.627) was higher than those from CELTRA DUO (937.024) followed by those of SHOFU (724.417). There was a statistical significance between group A (EMAX) and group C (SHOFU) p=0.005. The mode of failure of the restorations presented mixed types of failure (cohesive and catastrophic).

CONCLUSION: Strengthening with zirconia particles did not have a positive influence on the fracture resistance of neither the glass ceramic nor the composite resin materials tested.

KEYWORD: Ceramics, CAD/CAM, Inlays, Fracture resistance.

RUNNING TITLE: Fracture resistance of different CAD/CAM ceramic inlays

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INTRODUCTION

Computer-aided design and computer-aided manufacturing (CAD/CAM) technology has become an important adjunct to fixed prosthodontics (1). CAD/CAM or ‘‘digital’’ dentistry had developed following two main streams. The digital procedure can be carried out by the technicians in their laboratories or, it can be performed entirely in dental offices. In the alleged chair side method, one single restoration can be created in the dental office and conveyed in the same meeting appointment (2).

Computerized impressions are getting higher significance in the dental office, prompting an expansion in the quantity of intraoral scanners availability. The main advantages are the comfort to the patient, time proficiency, the diminished expenses and furthermore the 3-dimentional models (3,4).

Indirect esthetic restorations, for example, ceramic inlays, onlays, veneers and full coverage crowns might be a minimal invasive treatment for large cavities (5,6) and have gained prevalence because of their superior esthetic properties, however their delicate nature restricted their use (7) .

The fracture resistance of porcelain inlay is a critical factor influencing their durability (8). Clinical fracture failure of ceramic restorations are influenced by multiple factors, for example, cavity geometry, mechanical properties of the restoration, thickness of the restoration, type of cement, occlusion load, and conceivable interior deformities in ceramics (9,10).

The essential method of breakdown of porcelain is simply the break of the substance (11) causing early failure of ceramics, so modifications have been made to improve the material’s mechanical properties (12).

Glass ceramics strengthened with lithium disilicate (13), zirconia strengthened by lithium silicate and hybrid porcelain material have recently been developed (14). The principal motivation behind these improvements is to produce restorations that are durable and resistant to forces in oral cavity without affecting esthetic outcomes (15).

Fracture tests of ceramic materials are performed with shear tests, three or four point bending tests by planning geometric examples. In these test strategies, estimations may not actually speak to the clinical conditions. Ceramic restorations can also be tested in terms of their fracture resistance in the anatomic form they are used in clinic such as inlays fractured under load. This methodology can be

more helpful for deciding the clinical performance of the material (16).
The aim of this study was to assess the fracture resistance of CAD/CAM ceramic materials in vitro.
The null hypothesis of this study was that the fracture resistance would not vary among different types of ceramics.

MATERIALS AND METHODS

Materials used in this study are shown in table (1).

Laboratory procedures

- The teeth selected for this study will be collected using the following criteria.

Inclusion criteria

- Maxillary first premolar teeth.
- Similar normal morphology seen by naked eye (free from any tooth anomalies; dens evaginatus and dens invaginatus).
- Free of caries.

Exclusion criteria

- Cracks.
- Endodontic treatment.
- Previous restorations.

Table 1: Showing materials utilized in this research

Name	Type	Composition	Manufacturer
1- IPS E-max CAD	Lithium disilicate glass ceramic	SiO_2 57-80, Li_2O 11-19, K_2O 0-13, P_2O_5 0-11, ZrO_2 0-8, ZnO 0-8, Al_2O_3 0-5, MgO 0-5	Ivoclar Vivadent AG, USA
2-CELTRA-DUO	Zirconia-reinforced lithuim silicate	SiO_2 58, P_2O_5 5, Al_2O_3 1.9, Li_2O 18.5, ZrO 10.1, TbO 1 , CeO_2 2	DENTSPLY DeguDent GmbH, USA
3-SHOFU-HC BLOCK	Hybrid composite filled with zirconium silicate	**Monomer:** Urethane dimethacrylate and triethylene glycol dimethacrylate **Filler:** Silica,silicate, zirconium silicate	SHOFU GmbH, Japan
4- Resin cement	Relyx U 200	**Base paste:** Methacrylate monomers containing phosphoric acid groups, Methacrylate monomers, Silanated fillers Initiator, Stabilizers rheological additives. **Catalyst paste:** Methacrylate monomers, Alkaline fibers, Silanated fillers Initiator, Stabilizers rheological additives	3M ESPE; Seefeld, Germany

Thirty-three extracted human maxillary first premolar teeth were collected and cleaned with a hand scaler to remove calculus and soft tissues. They were stored in 0.1% thymol solution at room temperature for about 1 month before planning, then were embedded in copper rings filled with autopolymerizing resin up to 2 mm beneath the cementoenamel junction (10).

- **Inlay Cavity preparation**

Mesio-occluso-distal inlay cavities were prepared in the 33 maxillary first premolar teeth using a round end tapered diamond bur TR-13 (ÖKODENT, Germany). The preparation design was as follows; a 2 mm-deep occlusal box, an isthmus width of 3.5 mm, and an overall divergence angle of approximately 6^0 degrees. The proximal gingival margin was located 1 mm above the cemento-enamel junction. The width of the proximal box was 3 mm (Figure 1). All internal angles were rounded. All these measurements were surveyed using a periodontal probe (10).
Subsequent to completing the cavity preparations, computerized impressions of the preparations were taken with CEREC camera (CEREC AC Omnicam software version 4.5, Dentsply Sirona).
The software (version 4.5) was used to design the inlay restorations. The cement thickness was set to be (0.75 µm). The preparation margins and insertion axis were determined and the virtual data was then sent to a milling machine CEREC MCXL (CEREC MC XL, Dentsply Sirona) where the dental restorations were milled of the selected blocks (Figure 2).

Figure 1: Inlay cavity preparation "proximal view"

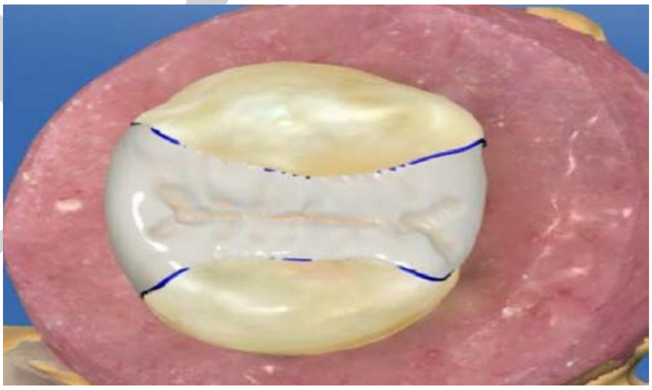

Figure 2: Design of the inlay cavity

The inlay specimens were classified into three main groups A, B and C (n=11) according to the type of materials used IPS-EMAX CAD, CELTRA-DUO and SHOFU HC respectively.
The adaptation of the inlays was checked after milling, then the IPS-EMAX CAD and the CELTRA-DUO ceramic inlays were glazed and sintered following manufacturer's instructions.
The inlays were then cemented on the teeth with self adhesive dual cure resin cement (RelyX U 200; 3M ESPE).
The IPS-EMAX ceramic inlays were etched with 5% Hydroflouric acid (ULTRADENT) for 20 seconds then the specimens were rinsed with water and dried with air and then silanated for 60 seconds. Self adhesive dual cure resin

cement (RelyX U 200; 3M ESPE) was applied in the cavity surface of the tooth, then the restoration is seated in place and light cured for 2 seconds with LED curing unit then excess cement was removed with probe, finally light cured for 20 seconds per surface. Final polishing was carried out with a rubber cup wheel and polishing paste.

The CELTRA-DUO ceramic inlays were etched with 9% Hydroflouric acid (ULTRADENT) for 120 seconds then the specimens were rinsed with water and dried with air and then silanated for 60 seconds. Self adhesive dual cure resin cement (RelyX U 200; 3M ESPE) was applied in the cavity surface of the tooth, then the restoration is seated in place and light cured for 2 seconds with LED curing unit then excess cement was removed with probe, finally light cured for 20 seconds per surface. Final polishing was carried out with a rubber cup wheel and polishing paste.

The SHOFU HC ceramic inlays had surface treatment with air particle abrasion with 50 μ Al_2O_3 at 0.2 - 0.3 bar for 10 seconds and then silanated for 60 seconds. Self adhesive dual cure resin cement (RelyX U 200; 3M ESPE) was applied in the cavity surface of the tooth , then the restoration is seated in place and light cured for 2 seconds with LED curing unit then excess cement was removed with probe, finally light cured for 20 seconds per surface. Final polishing was carried out with a rubber cup wheel and polishing paste.

- **Fracture resistance test**

All specimens were stored in distilled water at room temperature for 24 hours preceding testing. They were loaded until crack in a Universal Testing Machine (MarSurf PS1, Mahr, Germany) and the fracture loads (N) were recorded (Figures 3,4). The compressive load was applied at the central fissure of the premolars with a 4mm steel wedge at a 0.1 mm/min crosshead speed until fracture (10).

Figure 3: Inlay restorations under load in the Universal Testing Machine

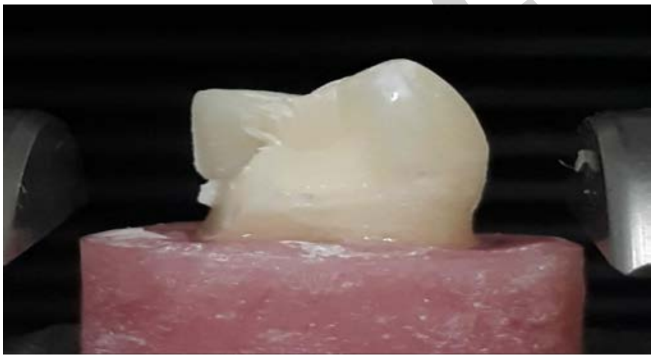

Figure 4: Fractured inlay restoration from group A showing catastrophic failure

- **Statistical analysis**

The obtained data were statistically analyzed using IBM SPSS software package version 20.0. Quantitative data were described using range (minimum and maximum), mean and standard deviation for normally distributed data. For normally distributed data, independent t-test was used for a comparison between two independent population while F-test (ANOVA) used to analyze more than two population. Significance of the obtained results was judged at the 5% level.

RESULTS

Table (2) showed the mean fracture resistance of the data obtained from the study.

Table 2: Showing results of fracture resistance test

Fracture resistance	Group			ANOVA Test
	Group A (EMAX)	Group B (CELTRA DUO)	Group C (SHOFU)	
- n -Min-Max -Mean±Std. Deviation - 95%CI for mean	11 601.069-1574.873 1104.627± 322.801 887.7668-1321.4886	11 649.473-1276.402 937.024± 183.283 813.8930-1060.1556	11 284.818-1085.419 724.417± 255.154 553.0019-895.8326	F=5.905 *p*=0.007*
Multiple Comparisons				
CELTRA DUO	Diff=167.603 *p*=0.423 NS		Diff =212.607 *p*=0.194 NS	
EMAX			Diff =380.210 *p*=0.005*	
SHOFU				

n: Number of samples
Min-Max: Minimum - Maximum
CI: Confidence interval
*: Statistically significant ($p<0.05$)
NS: Statistically not significant ($p\geq0.05$)

The mean fracture resistance was the highest in group A (IPS-Emax CAD)(1104.627±322.801) followed by group B (Celtra-Duo)(937.024±183.283) and then followed by group C (Shofu HC)(724.417±255.154) respectively.

There was a statistical significance in the fracture resistance among the three studied groups ANOVA TEST (F=5.905, p=0.007).

Pairwise comparison revealed that, there was no statistical significance between group A and group B (*p*=0.423) also there was no statistical significance between group B and group C (*p*=0.194). However, there was a statistical significance between group A and group C (*p*=0.005).

The mode of failure of the restorations presented mixed types of failure (cohesive and catastrophic).

DISCUSSION

According to the results obtained from the study, the null hypothesis suggested for this study should be rejected.

Soares CJ in 2004 stated that, in vitro experiments utilized for the failure evaluation are strategies that make huge commitments to the advancement of restorative procedures (17). Experimental fracture assessments are used to convert the fracture resistance of the restorative materials to numeric records. In these tests, commonly fracture forces exceeding chewing forces that occur in the oral cavity (levels ranging from 50 to 300 N) (18). Moreover, high forces that happen eventually of the test can be related with the power focused on one tooth while an individual is biting a strong substance (19).

Distinctive test machines were utilized so as to obtain fractures similar to fractures in vivo. In literature, metal antagonists in diameter of 24 mm and looking like a circle or a round cusp were utilized to quantify the fracture resistance of the premolar teeth (4). However, in this investigation, a metal antagonist cusp in diameter of 4 mm, reproducing a premolar tooth cusp, this was distinct with the investigation of Yoon et al 2019 (10).

The distinction in fracture resistance esteems among the three CAD/CAM materials tested might be because of their different compositions and microstructures as was expressed by Lin WS in 2012. The chemical composition is different among ceramic and composite inlays which clarifies the greater part of their in-vitro behavior. Ceramic inlays are essentially made out of glass with crystals incorporation to be strengthened (20).

Composite inlays are made of a resinous network and inclusions of various structures (21). The glass ceramics are more fragile and more inclined to break than composites (22). Both glass ceramic materials (IPS e.max CAD and Celtra Duo) in their crystallized/fired states had the most noteworthy mean fracture resistance esteems (23).

Lithium disilicate (IPS-emax CAD) has a high glass like content of up to 70 vol.% in glassy framework and 30 vol% silicate glass stage (24,25). The increase in fracture resistance obtained after the crystallization of the IPS e.max samples is most likely because of advancement of an exceptionally interconnected microstructure of lithium-disilicate crystals. As lithium disilicates contain randomly-oriented small plate-like interlocking crystals and particle size (from 0.5 to 4μm), so the crack deflection occurs (26). In that case more energy is needed to propagate cracks through the material (27). More over because of its glassy stage, lithium disilicate can be etched, permitting solid micro-mechanical clinging to tooth substrate which prompts an increase in its trademark strength (28).

The ability of lithium disilicate restorations to adhesively bond to tooth structure had played an integral part in the success of this ceramic as was shown in this study, this comes in accordance with Sulaiman TA et al who stated the same in 2020 (29).

Shofu is a nanoceramic resin composite (NCRC) which include BisGMA, UDMA, Bis-EMA and TEGDMA monomers shaping its polymer grid and 61% zirconium silicate (30). Na ZHANG et al in 2020 showed that, microcracks occurring within these nanoceramic clusters may coalesce to form larger cracks that further propagate, and in turn have a weakening effect on the nanoceramic material as was the case in this study (31).

All restorations were cemented using a self adhesive, dual-cure luting resin composite for cementation (32). Although only one resin cement type was used in this study, Yildiz C in 2013 clamed that etch-and-rinse, self-etch, and self-adhesive bonding systems were all have the same effectiveness in bonding of ceramic inlays to enamel and dentin surfaces (33). Although, the increased stress by external compressive loads could not be absorbed only by the cushioning effect of the adhesive resin cement, this leads to cohesive fracture of ceramic restorations (5,34).

As concluded by Hikita et al at 2007 and Yildiz C et al at 2013, it was expected that Lithium Disilicate would show lower fracture resistance than the lithium silicate fortified by zirconia because of the extra hardening mechanism identified with the presence of zirconia incorporations in the microstructure. In any case, truth be told, the expansion of ZrO_2 to lithium disilicate neither lead to an increment in strength nor show higher protection from crack propagation when contrasted and Lithium Disilicate (32,33). The results of these investigations were in accordance with the results shown in this study.

Resin composites are known for their reduced mechanical properties compared to dental ceramics which are known to frequently crack during milling. With an end goal to join the upsides of ceramics and polymers, materials known as nanoceramic resin composites had evolved (35). But Sagsoz O et al in 2018, reported that fracture strength of lithium disilicate inlays was found to be higher than other ceramic inlays and the lowest was in resin nano ceramic samples as was the case in this study (36).

CONCLUSION

Strengthening with zirconia particles did not have a positive influence on the fracture resistance of neither the glass ceramic nor the composite resin materials tested.

CONFLICT OF INTEREST

The authors proclaim that they have no conflicts of interest

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