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Comparative Study between Resin Nano Ceramic and CAD/CAM Ceramic Regarding Their Fracture Resistance, Microtensile Bond Strength and Fatigue Resistance

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ABSTRACT

Purpose: In an attempt to improve the mechanical properties, industrially CAD/CAM ceramics blocks have been introduced to dentistry. This study was directed to investigate the influence of the material thickness on the fracture resistance of CAD/CAM Resin Ceramic and CAD/CAM Ceramic and asses the fatigue resistance of class II mesio-occlusal-distal (MOD) inlays of both materials and compare their micro-tensile bond strength (μTBS) after cementation by two different adhesive resin cements. **Materials and Methods:** A total of 70 specimens were fabricated. The specimens were divided according to the material used into two main groups (n= 35). Group 1 specimens were fabricated from CAD/CAM Resin Ceramic (Vita Enamic), whereas Group 2 specimens were fabricated from Lithium disilicate glass ceramic (IPS e-max CAD). Specimens of each group were further subdivided into 3 subgroups according to type of testing (microtensile bond strength test, fracture resistance and fatigue resistance tests). Specimens of subgroup of microtensile bond strength test (n=40) were further subdivided into 2 divisions (n=20) according to type of surface treatment (control and sandblasting). Then each division was further subdivided into 2 subdivisions (n=10) according to type of cement used (Rely X Ultimate and multilink N). Furthermore, subgroup of fracture resistance test (n=20) was further divided into 2 division (n=10) according to thickness (0.5 mm and 3 mm). Two-way analysis of variance ANOVA test and three-way analysis of variance ANOVA test of significance were done for comparing variables. **Results:** For microtensile bond strength, it was found that the highest μ-tensile bond strength value was recorded for Multilink N control subgroup (54.07±7.9 MPa), while the lowest μ-tensile bond strength mean values was for Rely X Ultimate sandblasted subgroup (37.12±2.5 MPa) and IPS e-max CAD. Results revealed that the highest μ-tensile bond strength mean value was recorded for Rely X Ultimate

KEYWORDS

CAD/CAM ceramic, microtensile bond strength, fracture resistance, fatigue resistance

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sandblasted subgroup (63.78±9.4 MPa while the lowest μ-tensile bond strength mean value was for Rely X Ultimate control subgroup (22.94±1.6 MPa). For fracture resistance test, both groups (Vita Enamic and IPS e-max CAD), 3 mm thickness recorded higher fracture resistance mean values (1164.56±50.1, 2217.37±107.2 respectively), than 0.5 mm thickness (243.41±35.1, 131.35±32.3 respectively). For fatigue resistance, Vita Enamic recorded statistically significant higher fracture resistance mean values (888.89±43.05) than IPS e-max CAD (638.86±29.54) after chewing simulation. **Conclusions:** Sandblasting, influenced positively the microtensile bond strength of IPS e-max CAD and had a negative impact on Vita Enamic. When ultra-thin restorations were applied, the resin ceramic seemed to have a better fracture resistance than the ceramic.

INTRODUCTION

Ceramics are widely used clinically as indirect restorations because of their proved long lasting physical and mechanical properties.[1] However, because of the recent demand from patients for esthetics and biosafety, metal-free prostheses have been desired. Both new dental materials and new processing technologies are required to meet these demands. [2]

Along with the fast innovation in digital dental devices, new CAD-CAM blocks in different sorts of ceramics have been developed. [3] Ceramic dental restorations can be milled from a solid ceramic block instead of being made with conventional multiple firings of feldspathic porcelain. Because the millable ceramic material has minimal defects or flaws compared with conventional feldspathic porcelain, its mechanical properties are superior. [4]

CAD/CAM technology allows dentists to provide the same-visit indirect restorations that are accurate and esthetically satisfied. Digital impression taking create accurate models which is used for fabrication of either traditional or CAD/CAM restorations and needs less chair-side time.[5]

The existing classification of ceramic materials does not include resin-matrix materials that are highly filled with ceramics. These materials recently have been coded as ceramics by the American Dental Association (ADA) because they have ceramic-like properties and should not be ignored in any classification system. CAD/CAM ceramics are classified according to their composition into three types; CAD/CAM glass ceramics, CAD/CAM polycrystalline ceramics and Resin-matrix ceramics. [6]

A lithium disilicate CAD/CAM ceramic (IPS e-max CAD) was introduced in 2006.This lithium disilicate is glass ceramic that is composed of quartz lithium dioxide, phosphor oxide, alumina, potassium oxide and other components. [7] IPS e-max CAD possess flexure strength between 350 MPa and 450 MPa and has high fracture toughness which is higher than that of leucite-reinforced dental ceramics. [8]

Vita Enamic material is claimed to be a hybrid ceramic material comprising a structure sintered ceramic matrix with space in between ceramic substrates filled with resin material to form a so called double network hybrid. Its ceramic matrix contains a major leucite-based phase of feldspar and a minor zirconia phase as a strengthening component while its polymer component is composed of PMMA. [9] The mass percentage of the inorganic ceramic part is (75 vol%, 86 wt %) of ceramic matrix with the remaining (25 vol%,14wt%) filled with a polymer. The ceramic network provides resistance to deformation and wear, but it is brittle and susceptible to fracture. The ductile polymer network is capable of undergoing plastic deformation and yields resistance to fracture. [10]

The aim of this study was to investigate the influence of the material thickness on the fracture resistance of CAD/CAM Resin Ceramic and CAD/CAM Ceramic and asses the fatigue resistance of class II mesio-occlusal-distal (MOD) inlays of both materials and compare their micro-tensile bond strength (μTBS) after cementation by two different adhesive resin cements.

MATERIALS AND METHODS

Materials:

The materials used in the present study were CAD /CAM ceramic IPS e-max CAD (Ivoclar Vivadent) and Vita Enamic (Vita Zahnfabrik).Two types of resin cement were selected with different bonding strategies. Total etch RelyX Ultimate Clicker (3M ESPE) and self-etch Multilink N automix (Ivoclar Vivadent).

Methods:

Microtensile bond strength:

1. ***Preparation of dentin specimens & CAD/CAM blocks:***

Total of sixteen freshly extracted human non-carious first molars were selected. For each tooth, a flat dentin surface was prepared using diamond disk in cutting machine. Then the teeth were embedded in epoxy resin blocks below cemento-enamel junction by 1mm. The Vita Enamic and IPS e-max CAD, were sectioned longitudinally using Isomet 4000 precision saw (*Buehler Ltd., Lake Bluff, IL, USA)* under water coolant into two equal blocks, then sectioned horizontally into 6 smaller blocks with 3mm thickness. For IPS e-max CAD, each block was placed in Vita vacumat 6000 MP furnace (Vita Zahnfabrik) according to the manufacturer's instructions to complete the crystallization process. All the tested blocks (Vita Enamic, IPS e-max CAD) were then divided into two divisions, control group and sandblasted group by aluminiumoxide 50μm for 5 second with distance 10 mm and air pressure of 0.4 MPa. The adhesive was then applied according to the manufacturers' instructions for the two types of resin cements used.

2. ***Micro-tensile bond strength testing sample preparation:***

Serial sectioning was done in bucco-lingual direction then rotated 90° clockwise and sectioned in mesio-distal. A final horizontal cut at the cemento-enamel junction was done to obtain beams. Resultant beams were 1±0.1 mm in thickness and 6± 0.5 mm in length.

3. ***Microtensile bond testing (µTBS):***

Each sample was fixed with its ends to Ciucchi's jig. The final assembly was then mounted on a universal testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) (**Figure1**). A tensile load was applied at a crosshead speed of 0.5 mm/min until failure. The data were recorded using computer software (Instron Bluehill Lite Software).

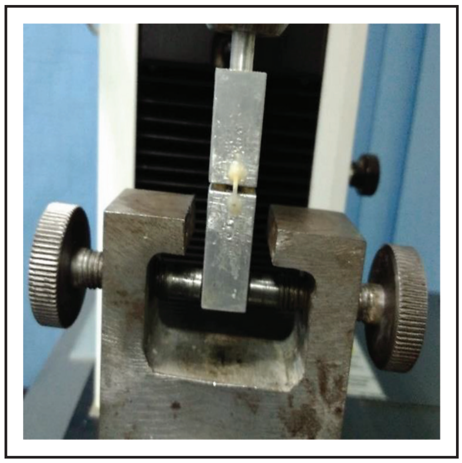

Fig. (1) µTBS sample mounted on the universal testing machine.

Fracture resistance:

The testing disc which represent the occlusal restoration, was 10 mm in diameter to mimic the average dimension of molars, then cemented to the substrate epoxy disc (simulating dentin) with an equal diameter. The bonded two-layer disc had a final thickness of 3.5 mm. Then the two-layer disc was bonded to a steel ring with an inner diameter of 5.5 mm, an outer diameter of 10 mm and a thickness of 2 mm mimicking the pulp chamber.

1. ***Preparation of specimens:***

The testing specimen were divided into two groups according to the testing material. Each group was further divided into two subgroups according to the thickness of the testing disc. The thickness of the testing discs were 0.5 mm and 3.0 mm; the thicknesses of their corresponding epoxy discs were 3.0 and 0.5 mm, respectively, achieving a final thickness of 3.5 mm. For Vita Enamic and IPS e-max CAD blocks were rounded into cylinders with an inner diameter of 10 mm. The cylinders were further cut into 20 discs by an *Isomet 4000* precision saw machine. Surface treatment was done with hydrofluoric acid gel 5% to the CAD/CAM discs, epoxy discs and metal ring with etching time: 60 sec. and cemented by multilink N resin cement self-etch resin according to the manufacturers' instructions.

2. Fracture resistance test:

All specimens were individually mounted on a computer controlled universal testing machine with a load cell of compressive load 5 kN at cross-head speed of 1mm/min. Data were recorded using computer software.

Fatigue resistance

1. Specimen preparation:

Ten human non-carious premolars were selected. Standardized MOD cavities were prepared, the occlusal and proximal boxes of groups were standardized in all cavities to a width of 3 mm and a depth of 2 mm using a diamond bur under water coolant spray. A special mold was fabricated (35mm in length and 29.5 in width) into which the teeth were embedded into acrylic resin 1 mm below the cemento-enamel junction (CEJ).

2. Inlay fabrication:

Ten inlays were fabricated from Ceramill motion 2(Austria, Amann Girbach) CAD/CAM system. The software was used to design the desired inlay contours. The IPS e- max CAD was fired as discussed before. Finally surface treatment of the inlay with hydrofluoric acid was done then cemented to the prepared cavity by Multilink N self-etch resin cement according to the manufacturers' instructions.

3. Fatigue testing:

Thermo-mechanical aging test was conducted using the newly developed four stations multimodal ROBOTA chewing simulator integrated with thermo-cyclic protocol.

Statistical analysis

Data were analyzed by SPSS 17 (Statistical Package for Scientific Studies) for Windows using Pair-wise student t-test, two-way analysis of variance ANOVA test of significance was done for comparing variables and three-way analysis of variance ANOVA test. *P*-value less than 0.05 were considered significant.

RESULTS

I. Results of Microtensile bond strength (MPa):

Regarding Vita Enamic group, Results showed that the highest μ-tensile bond strength value was recorded for ***Multilink N control subgroup*** (54.07±7.9 MPa), while the lowest μ- tensile bond strength mean value was for ***Rely X Ultimate sandblast subgroup*** (37.12±2.5 MPa).

Regarding IPS e-max CAD, Results revealed that the highest μ-tensile bond strength mean value was recorded for ***Rely X Ultimate sandblast subgroup*** (63.78±9.4 MPa while the lowest μ-tensile bond strength mean value was for ***Rely X Ultimate control subgroup*** (22.94±1.6 MPa). **(Table 1 and figure 2)**

The results revealed that Vita Enamic (48.36±4.49 MPa) showed higher μ-tensile bond strength mean value than IPS e-max CAD group (39.63±9.66 MPa). Moreover, there was a statistically non-significant difference (p>0.05) between Rely X Ultimate cement (44.38±3.68 MPa) and Multilink N cement (43.61±6.3 MPa).

Table (1): *μ-tensile bond strength of Vita Enamic and IPS e- max CAD with two types of surface treatments and two types of cements:*

		Vita Enamic (MPa)	IPS e-max CAD (MPa)	t-test
Rely X Ultimate	Control	53.67A±8.6	22.94C±1.6	<.0001*
	Sandblast	37.12B±2.5	63.78A±9.4	<.0001*
Multilink N	Control	54.07A±7.9	32.71B±3.9	0.0065*
	Sandblast	48.57A±6.2	39.07B±6.5	0.0308*
P value		0.0108*	<.0001*	

Different letter in the same column indicating statistically significant difference (p<0.05).

**; significant (p<0.05) ns; non-significant (p>0.05)*

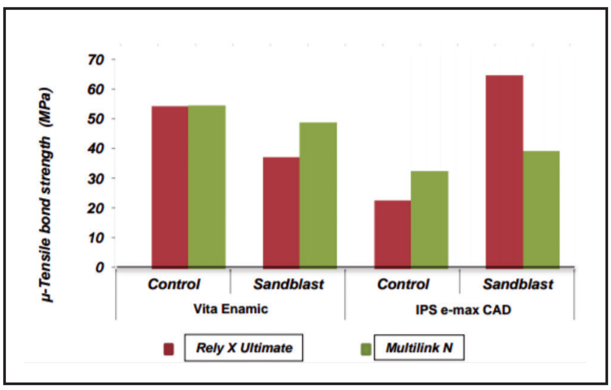

Fig. (2) Bar chart showing μ-tensile bond strength of Vita Enamic and IPS e-max CAD with two types of surface treatment and two types of cements.

II. Results of Fracture resistance (N):

Results revealed that there was a statistically significant difference between all tested subgroups. For both groups ***(Vita Enamic and IPS e-max CAD)***, 3 mm thickness recorded higher fracture resistance mean values (1164.56±50.1, 2217.37±107.2 respectively), than 0.5 mm thickness (243.41±35.1, 131.35±32.3 respectively) **(Table 2 and figure 3)**

Table (2): *The fracture resistance of Vita Enamic and IPS e-max CAD as function of thickness:*

Material / Thickness	Vita Enamic (N)	IPS e-max CAD (N)
3 mm	1164.56±50.1	2217.37±107.2
0.5 mm	243.41±35.1	131.35±32.3
P value	<.0001	

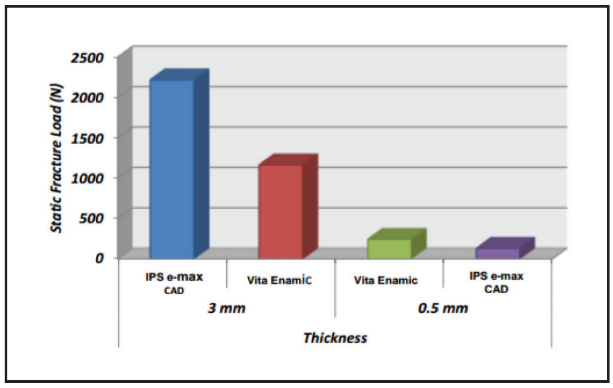

Fig. (3) Bar chart showing the fracture resistance results of Vita Enamic and IPS e-max CAD as function of thickness.

III. Fatigue resistance (N):

After chewing simulation there was a statistically significant difference between all tested groups as indicated by student t-test (t = 10.71, p value = <0.0001 < 0.05). Result showed that Vita Enamic recorded statistically significant higher fracture resistance mean values (888.89±43.05) than IPS e-max CAD (638.86±29.54). **(Table 3 and figure 4)**

Table (3): *Fracture resistance results for both ceramic groups after chewing simulation:*

	Vita Enamic	**IPS e-max CAD**
Mean±SD	888.89±43.05(N)	638.86±29.54(N)
P value	<0.0001*	
t-value	10.71	

**; significant (p>0.05) ns; non-significant (p<0.05)*

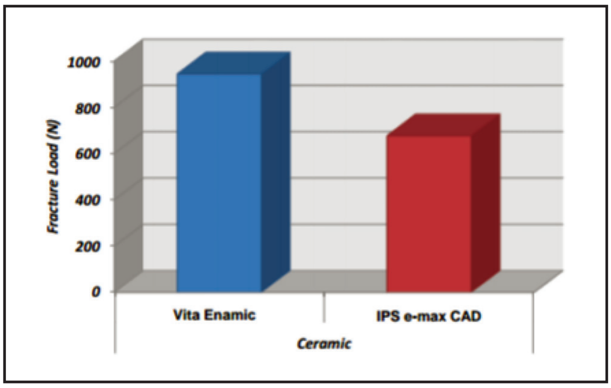

Fig. (4) Bar chart showing fracture resistance mean values between both ceramic groups after chewing simulation.

DISCUSSION

CAD/CAM ceramics became a popular restorative material in modern dental practice. The hybrid ceramic composed of dual interpenetrating networks having the modulus of elasticity similar to that of dentin, makes the stress distribution very different from that of feldspathic ceramic. The lower modulus of elasticity and hardness may represent better machinability leading to more accurate internal adaptation of the hybrid material when compared with ceramics. (9) IPS e-max CAD is categorized as a lithium disilicate glass-ceramic which has high mechanical properties compared with conventional feldspathic or leucite reinforced glass ceramics. (7)

Regarding Vita Enamic group, the results showed that the sandblasting subgroup of Vita Enamic had lower μTBS bond strength values than the control group in both bonding cements. This was attributed to the fact that sandblasting caused considerable de-bonding of the filler particles that play an important role in cementation. This result was in agreement with another study revealing that sandblasting can damage restorative surfaces and partially destroy the resin matrix and exposing filler particles in resin-based materials. (11) On the other side, this was in disagreement with the study that suggested that repair systems by sandblasting give higher bond strength than control and other surface treatments.(12)

In the current study the results showed that Multilink N cement had higher μTBS bond strength values than Rely X Ultimate in Vita Enamic group, this can be attributed to the silane coupling agent providing a chemical link between resin composite cement and silicate ceramic. Silane coupling agent contains a bifunctional molecule, which is able to bind covalently to silicon dioxide as well as to copolymerize with the organic matrix of resin composite cement. Furthermore, the presence of MDP in Rely X Ultimate cement that is slightly more hydrophilic led to less wetting of the resin matrix of the hybrid ceramic so decrease the bond strength. (13) This previous finding was in disagreement with a study which concluded that Multilink Automix silane containing adhesive system showed significantly higher bond strengths to lithium disilicate ceramic than the Rely X Ultimate with universal adhesive systems that do not contain silane. (14)

Regarding IPS e-max CAD, results showed that sandblasted subgroup of IPS e-max CAD had higher μTBS bond strength values than control group. This might be due to the fact that mechanical sandblasting caused an increase in the irregularity and the surface free energy so increased the bond strength. (15) These results were in consistent with another study which showed that the abrasion process removed contaminated layers and created a rough surface for mechanical retention by the luting agent. Additionally, surface roughening increased the surface area for efficient bonding and could lead to physicochemical changes such as an increase in surface energy and wettability. (16)

In the current study the results revealed that Vita Enamic showed higher μTBS values than IPS e-max CAD (Table 1 and Figure 2). This difference may be related to the mechanical differences between the hybrid ceramic and the lithium disilicate ceramic. The more brittle ceramic material tends to fracture at the adhesive interface at lower values than the more resilient resin ceramic. Also, differences in the elastic modulus between the two materials could play a role. [17] This was supported by a study which showed that the higher the elastic modulus of the material, the higher the stresses generated at the edge of the bonding interface.[18]

Furthermore, the higher microtensile bond strength values of Vita Enamic may be attributed to copolymerization process which occur between the 14% resin and methacrylate monomers with acidic group present in Rely X Ultimate and Multilink N cement. [19]

In the present study, RelyX Ultimate cement recorded the highest μTBS value this may be explained by the fact that the dual mode activation of the RelyX Ultimate cement enhanced the degree of conversion than the chemical Multilink N cement. [20] Moreover, the results of present study were in accordance with a study that compared the effect of three resin cement system on shear bond strength of ceramic. The results showed that Multilink N cement recorded the lowest shear bond strength values. This result could be explained by the relatively high viscosity of Multilink N cement so decreasing the flow. [21]

Results of the present study showed a significantly higher mean fracture resistance value for Vita Enamic when compared to IPS e-max CAD at 0.5mm thickness (Table 2 and Figure 3). This was attributed to the resin content in Vita Enamic which provide an elastic property and stress distribution of this material which was supposed to be different from that of the stiff ceramic. Whereas stiff ceramics seem to induce large internal stresses under loads, and transmit these stresses to marginal areas. [22] Another study showed a significantly higher mean fracture resistance value for resin ceramic block when compared to IPS e-max CAD. This may be due to the unique composition of resin ceramic block that allows the material to have a modulus of elasticity similar to that of dentin [23] and this finding was in agreement with the present study.

However, the results of current study were in disagreement with a study that investigated the fracture resistance of CAD/CAM monolithic ceramic and veneered zirconia molar crowns. They reported that when the veneer layer was milled from the high strength lithium disilicate material, fracture resistance was higher than feldspathic or resin-ceramic dual network veneer layers. This can be attributed to the superior mechanical properties of lithium disilicate.[24]

Results of the present study revealed a significantly higher fracture resistance values for IPS e-max CAD when compared to Vita Enamic at 3 mm thickness (Table 2 and Figure 3). This was attributed to the fact that reducing the dimensions of a restoration reduces its strength, the strength increased with increasing thickness. [25] These results were in agreement with a study that evaluated the fracture strength of high-translucent and low-translucent zirconia and glass-ceramic crowns. The results showed that the strength increased with increasing crown thickness for all groups. [26]

In the current study results of the fatigue resistance after chewing simulation showed that Vita Enamic inlay fracture at higher loads than IPS e-max CAD (Table 3 and Figure 4). This might be explained by the low stiffness of the resin ceramic blocks material acting to reduce the maximum stress level in two ways; the Vita Enamic more closely matches the dentine which led to less stress concentration and the CAD/CAM resin ceramic block would be expected to distribute loads over a large volume of the material. The results of the present study were in consistent with a study revealed that large ceramic restorations exhibited higher stress levels and that the use of materials with a lower elastic modulus like resin ceramic limits the stress intensity transmitted to the remaining tooth structure.[27] However, these results disagreed with a study which reported that significantly higher fracture resistance of occlusal veneers made from zirconia-reinforced lithium silicate than occlusal veneers made from the resin containing materials (Vita Enamic) after thermodynamic loading. There was no significant difference between lithium disilicate (IPS e-max CAD) and resin containing materials (Vita Enamic), the reason for that might be the inherent mechanical properties of the tested restorative materials. [28]

CONCLUSIONS

Within the limitations of the present study, the following conclusions can be drawn:

1. The bond of Vita Enamic was more resistant to microtensile stresses than IPS e-max CAD.
2. Sandblasting, influenced positively the microtensile bond strength of IPS e-max CAD and had a negative impact on Vita Enamic.
3. When ultra-thin restorations were applied, the resin ceramic seemed to have a better fracture resistance than the ceramic.
4. Vita Enamic demonstrated remarkable resistance to contact fatigue damage.

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