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EFFECT OF LASER DEBONDING ON FRACTURE STRENGTH AND STRUCTURE OF THREE TYPES OF CAD/CAM CERAMIC CROWNS

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ABSTRACT

Aim: To evaluate fracture strength and change in structure of three types of ceramic crowns after debonding with Er,Cr:YSGG laser. **Materials & Methods:** A maxillary premolar tooth was prepared to receive an all-ceramic crown then duplicated into thirty resin dies. Dies were scanned with Omnicam intraoral scanner, and thirty ceramic crowns were milled with Cerec MCXL milling machine. Crowns were divided into three main groups according to their material type (n=10); group A (E-Max CAD), group B (Vita Enamic) and group C (InCoris TZI). Crowns were bonded to their dies using TheraCem adhesive resin cement. Each group was subdivided into two subgroups (n=5); subgroup 1: crowns were not subjected to laser and subgroup 2: crowns were subjected to laser. Subgroups (A2, B2, and C2) were debonded using Er,Cr:YSGG laser irradiation then rebonded again. Crowns were loaded to fracture with the use of a universal testing machine at a crosshead speed of 1 mm/min. Six rectangular specimens were milled from the three materials blocks. One specimen from each material was subjected to laser irradiation then all specimens were scanned using x-ray diffraction. Data were analyzed by one way ANOVA and paired t-test. **Results:** There was a statistically significant difference in mean fracture resistance between subgroups of group A: A1 (770.19± 15.04 N) and A2 (725.10± 8.28 N) and subgroups of group B: B1 (519.45± 20.24 N) and B2 (337.01± 25.97 N). There was no significant statistical difference in mean fracture resistance between subgroups of group C: C2 (1747.38± 61.30 N) and C1 (1737.26± 28.58 N). **Conclusions:** Er,Cr:YSGG laser debonding had a significant effect on the fracture resistance of the rebonded E-max CAD and Vita Enamic crowns and a non-significant effect on the rebonded InCoris TZI crowns fracture resistance.

KEYWORDS: Er,Cr:YSGG laser, debonding, X-ray diffraction, all-ceramics, fracture resistance.

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INTRODUCTION

The tremendous increase of the use of all ceramic crowns into dentistry had challenged clinicians in terms of their removal. Removal of a dental crowns may be due to many reasons. In case of caries, gingival recession or fractures, the integrity preservation of the restoration is not essential. However, trying to remove the restoration shortly after cementation because of improper seating, periodontal defect or pulpal inflammation with maintaining the integrity of the restoration is a must to minimize restoration reconstruction. Using conventional techniques makes the removal of resin-bonded restorations in a single piece almost impossible.

Traditionally different crown removing systems were available, but these systems are not efficient to be used to debond resin-bonded restorations without affecting their integrity. [1]

Furthermore, trying to remove high-strength ceramic crowns by cutting procedure is assumed to be very difficult to be cut and removed because of their high strength.[2] So, their removal process consumes more time and diamond burs became dull quickly, with sparks occurrence due to the increase of contact time between the diamond burs and the crown**.** Also, it is not easy to differentiate between dentin of the tooth, resin cement and the crown during their cutting due to lack of difference in contrast between them with the risk of damaging of underlying tooth structure. On the other hand, rebonding of these restorations is not applicable after this destructive removal procedure. [3,4]

Use of lasers was introduced to be a more conservative crown removal technique and rebonding of these crowns could be possible.

Dental Lasers are used in the last years in many procedures hence they are beneficial in such cases where bonded crowns needed removal [5].

Laser debonding technique was employed for the first time for debonding of orthodontic brackets made from ceramics since early 1990s.[6]

Laser debonding of ceramic crowns is usually performed using Er: YAG (2940 nm) and Er: Cr YSGG (2780nm) laser. It was found that the debonding mechanism of ceramic bracket and laminate veneer using Er: YAG laser depends on thermal ablation and photoablation. This is more preferred than thermal softening that results when CO_2 or Nd: YAG lasers were employed for this purpose. In addition to laser type, laser debonding procedure is also affected by the ceramic type. It was found that monocrystalline ceramics were more suitable than polycrystalline-ceramics when subjected to laser debonding.[7]

The aim of the present in vitro study was to evaluate fracture resistance and change in structure of three different types of ceramic crowns after debonding with Er,Cr:YSGG laser.

MATERIALS AND METHODS

This study was approved by the research ethical committee of Faculty of Dentistry- Suez Canal University (n.177 /2019).

Samples preparation

An extracted sound human first premolar tooth was selected for this study. The tooth was mounted in epoxy acrylic resin. Tooth preparation was done under air water spray cooling using a 1mm tapered diamond stone with flat end. The preparation had (1 mm) shoulder finish line, 6 degrees convergence angle and 2mm occlusal reduction. The length of the prepared axial walls was 3 mm for the mesial and distal surface, 3.5 mm for the palatal surface and 4mm for the buccal surface.

Thirty epoxy resin dies were constructed by duplication of the prepared tooth using silicone duplicating material and poured in epoxy resin following the instructions of the manufacturer.

Crowns constructions

Dies were scanned using an intraoral scanner (Omnicam, Dentsply Sirona, USA).STL files were transferred to a computer software (CEREC SW extended 4.6, Dentsply Sirona, USA). A standard design was employed for construction of all the crowns.Crowns were milled using CEREC Inlab MC XL milling machine (Dentsply Sirona, USA). Crowns were equally grouped into three groups (n=10) according to the ceramic material used; group A: IPS E-max CAD (Ivoclar Vivadent, USA), group B: Vita Enamic (Vita Zahnfabrik, Germany) and group C: InCoris TZI (Sirona Dentsply, Germany).

E-max crowns were fired for crystallization and glazing, Vita Enamic crowns were finished and polished and InCoris TZI crowns were sintered and polished according to their manufacturer's instructions. All crowns were checked and seated on their corresponding dies.

Each group was subgrouped into two equal subgroups (n=5); subgroup 1: crowns not subjected to laser debonding and subgroup 2: crowns subjected to laser debonding.

Bonding of the crowns

All the crowns were bonded to their corresponding dies using TheraCem adhesive resin cement (Bisco Dental, USA) following the manufacturer's instructions. In order to standardize the pressure during bonding, a specially designed device was used to maintain a static load of three kg on the crown during bonding. Light curing was done using Elipar Deep Cure-L led curing unit (3M, USA) with 430–480 nm wavelength for 20 seconds for each crown surface.

Laser debonding of crowns

The crowns of subgroups (A2, B2, and C2) were debonded by the use of Er,Cr:YSGG (Biolase, USA) with a MZ8-6 zip tip Gold, 6.00 W and 20 Hz repetition rate, 2780 nm wavelength and beam diameter of 0.7 mm at the impact point. A non-contact type handpiece (Turbo) in H mode with 60 microseconds pulse duration was used under a 60% air and 80% water. After debonding of each crown, its corresponding die was evaluated for any damage using loupes with a magnification of 2.5×.

Rebonding of debonded crowns

The adhesive resin cement remnants on each die surfaces were removed using a finishing carbide bur then dies were polished using a 600-grid silicon carbide bur. The fitting surface of the debonded crowns was cleaned then crowns were rebonded on their corresponding dies using TheraCem adhesive resin cement according to the manufacturer's instructions.

Fracture resistance test

All the crowns of the three groups (A1,2), (B1,2) and (C1,2) were subjected to a load to fracture using a computer-controlled universal testing machine (TIRA test 2805, Tira GmbH, Germany) using stainless steel ball indenter with a diameter of 5 mm at crosshead speed of 1 mm/minute until failure and the readings were recorded in Newton and tabulated.

X-ray diffraction (XRD)

Six rectangular specimens (each with dimensions 1.5cm x 2cm x 2mm) were designed and milled from the three tested materials blocks using Cerec In-Lab MC XL milling machine (two specimens from each ceramic material). E-max specimens were fired for crystallization and glazing, Vita Enamic specimens were finished and polished and InCoris TZI specimens were sintered and polished. All specimens were conditioned for bonding following their manufacturer instructions. One specimen from each ceramic material was subjected to laser irradiation with the same time and manner of debonding method. All the specimens were scanned using XRD to detect the change in their structure with and without laser irradiation.

Statistical analysis

Data was analyzed with IBM SPSS Statistics Version 18 (SPSS Inc., USA). Numerical data was described as mean and standard deviation Data was explored for normality using Kolmogrov-Smirnov test and Shaprio-Wilk test. Comparisons within the same group (before and after laser debonding) for normally distributed numeric variables was done using the paired t-test, while ANOVA test was used for comparison between groups. A p-value ≤0.05 was considered statistically significant. All tests were two tailed.

RESULTS

Fracture resistance test results

The mean and standard deviation (SD) values of fracture resistance in Newton for the six subgroups are represented in table 1

There was a significant statistical difference in mean fracture resistance between both subgroups of group A and group B. Subgroup A1 had a higher mean fracture strength (770.19± 15.04 N) than that of subgroup A2 (725.10± 8.28 N) (P=0.002) while subgroup B1 had a higher mean fracture strength (519.45± 20.24 N) than that of subgroup B2 (337.01± 25.97 N) (P=0.004). However, there was no significant statistical difference in mean fracture resistance between both subgroups of group C where subgroup C2 had a higher mean fracture strength (1747.38± 61.30 N) than that of subgroup C1 (1737.26± 28.58 N) (P=0.06).

X-ray diffraction results

X-ray diffraction scan revealed a slight decrease in the crystalline size between the two subgroups A1 (5.21 nm) and A2 (4.51 nm) (Fig. 1, 2). Also, there was a dramatic increase in the crystalline size between the two subgroups C1 (3.41nm) and C2 (7.45nm) (Fig. 3, 4). However, it was difficult to investigate the change in the crystalline structure between the two subgroups B1 and B2.

TABLE (1): Mean and standard deviation (SD) values of the fracture resistance in Newton for the six subgroups.

	Group (A) E-Max CAD		Group (B) Vita Enamic		Group (C) InCoris TZI	
Subgroup	(A1) No laser debonding	(A2) laser debonding	(B1) No laser debonding	(B2) laser debonding	(C1) No laser debonding	(C2) laser debonding
Mean ± SD	770.19 ± 15.04	725.10 ± 8.28	519.45 ± 20.24	337.01 ± 25.97	1737.26 ± 28.58	1747.38 ± 61.30
p-value	0.002*		0.004*		0.67	

Significance level p ≤ 0.05 ****Statistically significant***

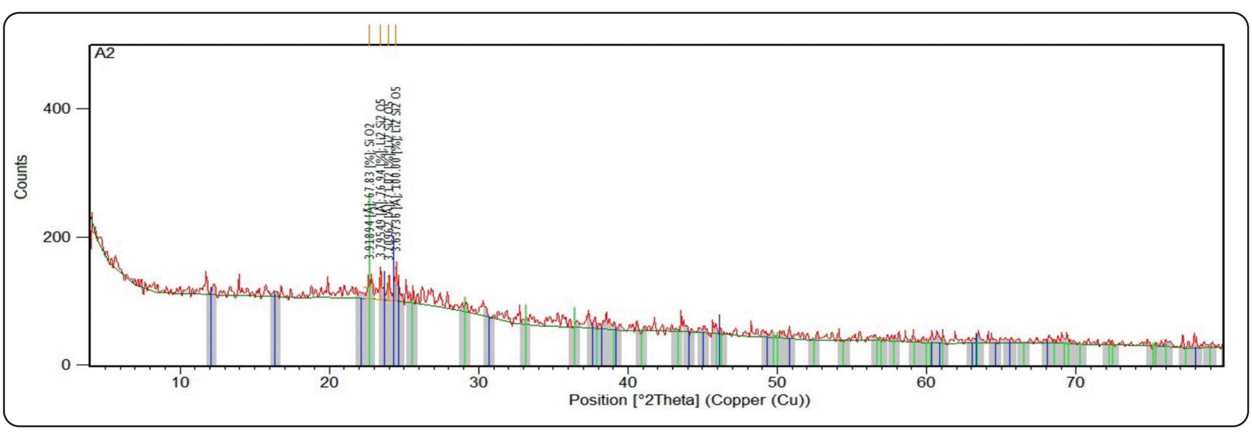

Fig. (1): XRD patterns of subgroup A1 specimen (no laser irradiation)

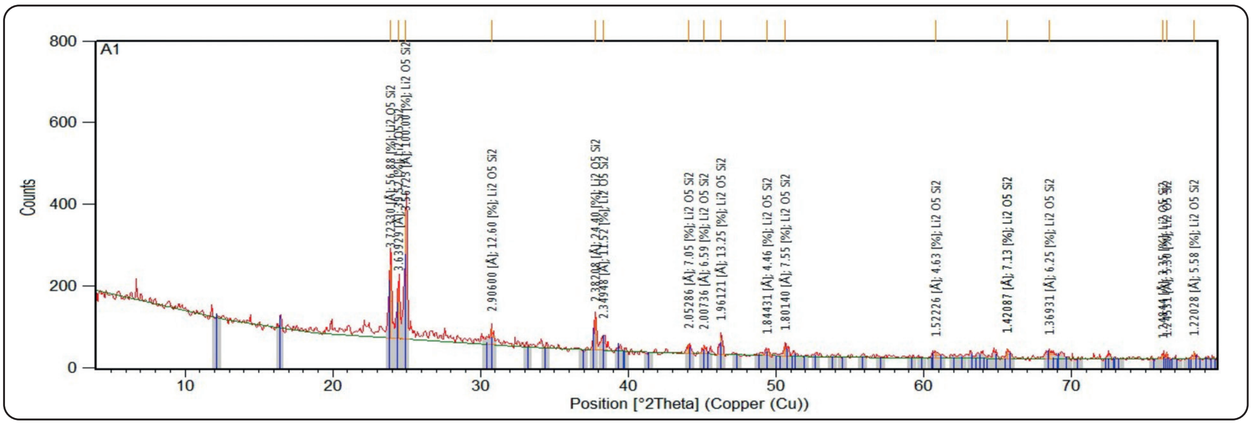

Fig. (2): XRD patterns of subgroup A2 specimen (with laser irradiation)

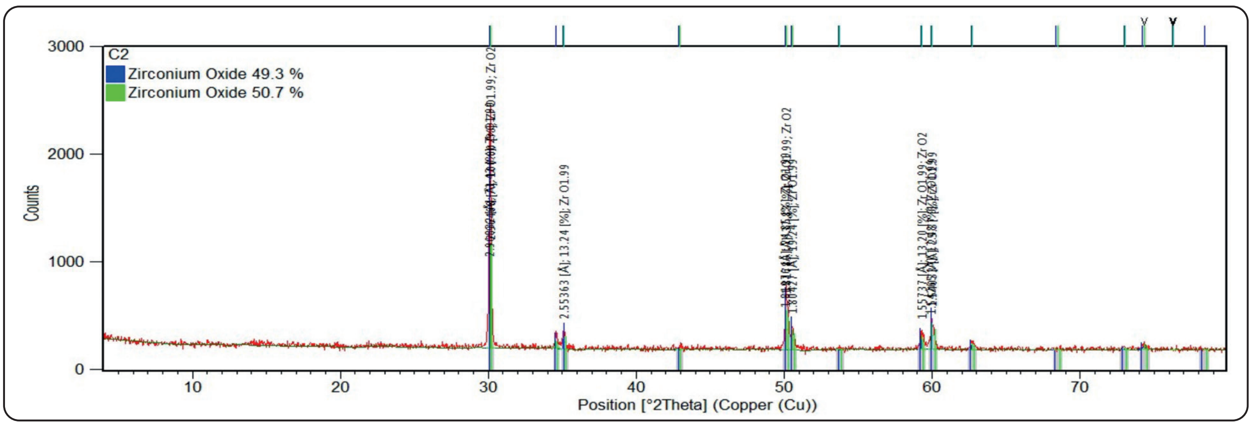

Fig. (3): XRD patterns of subgroup C1 specimen (no laser irradiation)

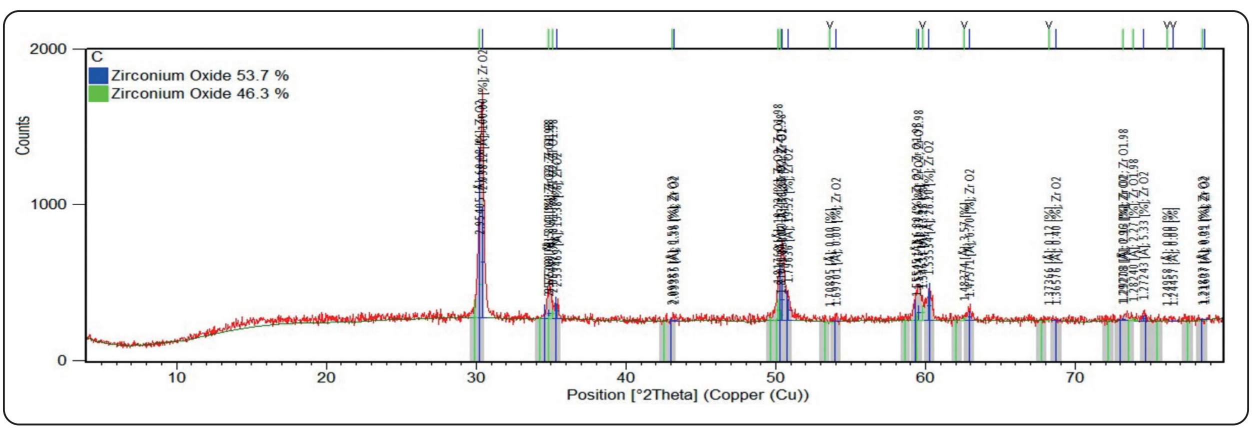

Fig. (4): XRD patterns of subgroup C2 specimen (with laser irradiation)

DISCUSSION

Over the years, many methods have been described and many devices and instruments have been designed for removal of crowns from the corresponding prepared teeth. However, these methods may have destructive effects on prosthetic restorations, prepared teeth, supporting bony, periodontal and gingival structures. Moreover, removing the restoration that is adhesively cemented in one piece is not always applicable [8].

Recently, several types of laser such as Nd: YAG and Er,Cr: YSGG laser were introduced for debonding of crowns from the prepared tooth without any destructions neither to the crown nor to its abutment [5].

Epoxy resin dies were used in this study because their modulus of elasticity, strength, and hardness are similar to natural tooth structure and also because of their dimensional accuracy[9]. Epoxy resin dies were duplicated using silicone duplicating material and poured in epoxy resin. Each die was duplicated in the same manner to produce identical replica from the same prepared tooth.

In the current study, three different CAD/CAM ceramic materials with different physical and mechanical properties covering a wide range of indications were chosen. The first is E-max CAD lithium disilicate which is one of the most esthetically dental ceramics in the market which has high thermal shock resistance and low thermal expansion [2]. The second is Vita Enamic hybrid ceramic which is composed of polymer and ceramic phases and that gives strength, stability, , hardness and elasticity similar to those of natural tooth [10,11]. The third one is InCoris TZI monolithic zirconia that has excellent mechanical properties, strength and hardness [12].

All the crowns had the same design using the same software and milled by using the same milling system. In order to standardize the bonding steps, all the crowns were bonded to the corresponding dies with TheraCem adhesive resin cement which contains 10-methacryloyloxydecyl dihydrogen phosphate (MDP) so there was no need for using a primer.

Erbium laser was chosen in the present study as it was concluded that mid-infrared erbium lasers are transmitted through ceramics and absorbed by resin cement and can debond the resin bonded restorations very easily in few seconds [13,14]. The type of erbium laser employed was an erbium, chromium:yttrium-scandium-gallium-garnet (Er,Cr:YSGG) of a wavelength of 2780 nm. This type of laser provides high ablation speed with minimal residual heat [15].

The MZ8-6 zip non-contact tip was used in the current study to eliminate the high thermal effect when using high power because when a noncontact handpiece is employed, it can be efficient in reducing the debonding time than a contact one [14]. Water cooling was used during laser application to allow proper heat diffusion and to minimize any possible thermal damage [4].

Universal testing machine was used in the current study to test fracture resistance of the crowns with a stainless steel ball indenter having 5 mm diameter at a crosshead speed of 1 mm/min. The fracture load was measured through application of a compressive load to the crowns' occlusal surface until failure. Catastrophic fracture failure was considered when there is a visible crack or sudden load drop or even acoustic events of fracture or chipping. Size of the stainless steel ball indenter ensured touching both the buccal and lingual cusps of the crowns to avoid stress concentration and to simulate the opposing functional cusp size and shape in the oral cavity [16].

X-ray diffraction was applied to examine any crystalline structure change that occurred in the ceramic materials after erbium laser debonding procedure to detect its effect on the crowns fracture strength. X-ray diffraction is a non-destructive analytical technique that is used to identify the crystalline structure, chemical composition and physical properties of some materials through detecting the scattered intensity of the X-ray beam upon hitting a sample through measuring of incident and scattered angles, wavelength or energy and polarization.

So, six rectangular specimens were designed and milled from the three tested materials to get a flat surface so the X-ray diffractometer can easily scan the tested materials.

In E-max group (A), XRD showed that the non-irradiated specimens' crystalline size was 5.21 mm while the irradiated specimens crystalline size decreased to 4.51 mm. This decrease in the crystalline size could be due to raising the temperature during erbium laser pulse. This multiple increase in surface temperature at heating values could affect the microstructure of lithium disilicate. It was also observed that the density of the lithium disilicate peaks decreased as the number of heating increased [17].

On the other hand, the crystalline phase of Vita Enamic group (B) stills unresolved partially. XRD through the patterns' bulging made it impossible to identify the crystalline phases. Just the low-intensity zirconia peaks could be detected related to the zirconia nanoparticles and high double bond conversion in the material' polymer phase [18].

For non-irradiated zirconia subgroup (C1), crystalline size was 3.41nm while that of the irradiated subgroup (C2) was 7.45nm with an increase of 4.04 nm and a transformation from tetragonal phase to a monoclinic one. This could be justified by the action of water during laser debonding procedure. The tetragonal to monoclinic transformation might be enhanced by the action of water molecules activated by erbium laser beam. It was reported that water molecules could penetrate into the zirconia lattice during exposure to make the atmosphere humid with aid of erbium laser beam during the laser debonding procedure and that might cause the outer tetragonal zirconia grains to transform into monoclinic grains [19,20].

Fracture strength test results showed that InCoris TZI crowns had a mean fracture strength of 1737.27 N before laser debonding with a non-significant increase to 1747.38 N after laser debonding. This increase in fracture strength after laser debonding could be attributed to the increase in the crystal size and the transformation from tetragonal to monoclinic phase as detected by x-ray diffraction. These results were in agreement with the studies conducted by Ozdogan and YesilDuymus (2020) [21] and Çağlarİ (2016) [22].

On the other hand, E-max crowns had a mean fracture strength of 770.19 N before laser debonding and 725.10 N after laser debonding. According to XRD, the crystalline size of E-max specimes decreased after laser irradiation in comparison to the non-irradiated ones. this could explain the decrease in the fracture strength after laser debonding. This was in agreement with the study conducted by Ozdogan and YesilDuymus (2020) [21].

However, Vita Enamic crowns had a mean fracture strength of 519.45 N before laser debonding and 337.01 N after laser debonding. The ablation process of Er,Cr:YSGG laser irradiation targets the resin matrix of hybrid ceramics and expose the filler particles. This might render the crowns more brittle and more liable to fracture. This could explain the statistically significant decrease in the fracture strength of the laser debonded Vita Enamic crowns. These results are in accordance with a study presented by Spitznagel et al., (2014) [23].

According to Bakke et al (1992) [24] who reported an average masticatory load of 441 N for females and 522 N for males in the posterior area of the mouth, and to Widmalm and Ericsson (1982) [25] who reported an average masticatory load of 445 N in the premolar area, the results of the present study could assume that Er,Cr:YSGG laser debonded Emax and InCoris TZI crowns can be rebonded and reused on the contrary to Vita Enamic ones.

CONCLUSIONS

Under the conditions of this in-vitro study, the following could be set as conclusions:

1. Er,Cr:YSGG laser debonding had a significant effect on fracture resistance of the rebonded E-max CAD and Vita Enamic crowns and a non-significant effect on the rebonded InCoris TZI crowns fracture resistance.

2. Er,Cr:YSGG laser debonded Emax CAD and InCoris TZI crowns can be rebonded and reused on the contrary to laser debonded Vita Enamic ones.

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