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EFFECT OF LASER DEBONDING ON COLOR CHANGE OF THREE DIFFERENT CERAMIC MATERIALS

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ABSTRACT

Introduction: All ceramic restorations have become popular for their esthetics and durability. These restorations possess a unique biocompatibility, as well as favorable physical and mechanical properties. Debonding of ceramic restoration due to various clinical reasons may affect the shade of the restorations. **Aim:** This in vitro study aimed to evaluate the color change of three different all ceramic materials (Monolithic lithium disilicate material, hybrid ceramic material and monolithic translucent zirconium material) after debonding with an Erbium Chromium laser. **Material and methods:** Human first premolar tooth was selected for this study;. Tooth was prepared, an epoxy resin dies were duplicated from the prepared tooth, optical impression for each die, crowns were designed and Ten e-max CAD (shade A1), ten Vita Enamic (shade 1M2) and ten InCoris TZI (shade A1) crowns were milled, All the crowns were bonded to their corresponding dies;. Crowns were debonded using Er, Cr: YSGG. Shade was measured before and after debonding for each group. **Results:** There was a statistically significant difference in the mean ΔE in the three tested subgroups (P= 0.008) after laser debonding data was collected, tabulated and statically analyzed. **Conclusion:** (InCoris TZI) and (e-max CAD) crowns, can rebond and reuse after Erbium laser debonding, on the contrary of the (Vita Enamic) crowns without great change in shade.

INTRODUCTION

Ceramics are popular as a result of its availability in different shades and translucencies. Recent advances in mechanical and optical properties, techniques of fabrication of ceramic materials in addition to new adhesive systems aid in increasing the use of all ceramic restorations [(1)].

Based on their esthetics, conservative nature, strength, longevity and biocompatibility, ceramic crowns were considered esthetically pleasing restorative materials. This led to a continuous modification in their composition, microstructure and processing in order to achieve a satisfactory level of clinical performance [(2)].

The retention of these ceramic restorations is dependent almost completely on micromechanical and chemical adhesion among the luting resin cement and the tooth surface from one side and porcelain surface from the other side. This creates an intense bonding connection between the ceramic surfaces and the tooth, hence making it difficult to debond the ceramic restoration in a single piece [3].

Several factors like recurrent caries, ceramic fracture or chipping and patient-described problems with a restoration's shade, shape or position have caused the need to remove these restorations. Such clinical cases need intact removing of the restoration, without harming the underlying tooth structure and to allow rebonding after laboratory repair [4].

IPS e.max Press offered optimum homogeneity and high strength creating accurately fitting restorations. Even in non-vital teeth cases, it was possible to produce pressed all-ceramic restorations, as the IPS e.max Press range also included high opacity ingots. It can be used for anterior and posterior crowns, partial crowns, three-unit anterior bridges and veneers [5].

IPS e.max CAD was based on the same materials technically as IPS e.max Press. [4] It combined the benefits of CAD/CAM processing with a high performance lithium disilicate ceramic in a best manner. An innovative processing procedure allowed tooth-colored restorations to be produced from IPS e.max CAD blocks, which at the same time feature high final strength values [6].

The combination of polymer and ceramic phases gives stability, elasticity, strength, and hardness to these materials similar to the structure of natural tooth. The presence of a polymer network helps absorbing the masticatory forces more than glass ceramics. Polymer infiltrated ceramics have been reported to have a strength of approximately 150 MPa whereas Nano-ceramic resins have a strength of 200 MPa [7].

Vita Enamic® (VITA Zahnfabrik, vita-zahnfabrik.com) was launched in (**2013**) onto the market as an example for polymer infiltrated ceramic network (PICN). Its inorganic ceramic part of this block was 86% (by weight) and organic polymer matrix was 14% (by weight) with which the pores in the structure-sintered ceramic matrix were filled with a polymer material. This (PICN) was based on the initial sintering of a porcelain powder to 70% of its full density, and then it was infiltrated with a monomer mixture. The material was a resin ceramic composite material, consists of two interconnected networks: a dominant ceramic and a polymer [8,9].

A trend towards the use of monolithic hybrid ceramic restorations had changed the way clinicians produce all-ceramic dental prostheses, since the more aesthetic multilayered restorations unfortunately were more prone to chipping or delamination. Composite materials processed via CAD-CAM had become an interesting option, as they had intermediate properties between ceramics and polymers and were more easily milled and polished [10, 11].

Zirconium metal oxide (Zirconia) had been used in medical field as a prosthesis of hip bone head since 1980 as reported by *Boutin et al.* [12]. In 1990 *Kon et al.* [13], reported the first use of zirconium-dioxide in prosthetic dentistry when small amounts of aluminum-oxide (Al_2O_3), in glass-infiltrated ceramic (In Ceram, Zahnfabrik Vita, Germany), were replaced by zirconium-dioxide crystals (ZrO_2). Later on, the development of zirconium-dioxide was followed by the development and improvement of CAD/CAM technology, as the only commercial way for making restorations in fixed prosthodontics from this material.

Paradigm MZ100 (3M ESPE, Minnesota, USA) was launched onto the market in (**2000**). It was the first commercially available material considered a hybrid ceramic [14].

Recent resin cements were considered one of the biggest factors of the dental restoration's success and their durability due to their high compressive and tensile strengths, low solubility, and very favourable aesthetic qualities [15].

Their significant short comings were difficult excess removal, technique sensitive, a restoration which must be removed may have to be released in pieces rather than intact, and they were relatively expensive per unit dose [16].

The traditional removal method uses burs to grind the restorations into pieces. This may cause iatrogenic damage to the tooth tissue and patient discomfort, require excess time, and result in costly waste [17].

Laser treatment is a newly developing technique for ceramic removal. Among the lasers used for debonding, Erbium lasers (including Erbium-doped Yttrium Aluminum garnet; Er: YAG lasers and Erbium, Chromium-Yttrium Scandium Gallium Garnet; Er, Cr: YSGG lasers) are preferred for debonding ceramic restorations. Erbium laser energy is absorbed by the cement-containing water molecules, and residual monomers can break the bonding interface, causing decreased bond strength and enabling the removal of the restorations [18].

The final color of a ceramic restoration may be influenced by opalescence, translucency, surface texture, fluorescence, shape character and properties, the brand and batches of the porcelain used, the number of porcelain firings and the condensation technique, and also by the translucency, the color, and the thickness of the underlying resin luting agent [19].

The current study aimed to evaluate the colour change of three different all ceramic materials (Monolithic lithium disilicate material, hybrid ceramic material and monolithic translucent zirconium material) after debonding with Erbium Chromium laser.

MATERIAL AND METHODS

Sample size:

A total of thirty crowns were constructed and were divided into three main groups according to the type of the ceramic used:

Group A: Ten crowns were constructed from lithium disilicate material (E-max CAD).

Group B: Ten crowns were constructed from hybrid ceramic material (Vita Enamic).

Group C: Ten crowns were constructed from monolithic translucent zirconium material (InCorisTZI).

Each group was subdivided into two equal subgroups (№=5), subgroup 1 crowns were not subjected to laser and subgroup 2 crowns were subjected to laser.

Methods

An extracted sound human first premolar tooth for orthodontic treatment was selected for this study. Calculus and residual periodontal tissues were removed using ultrasonic scaler. The tooth was mounted in epoxy acrylic resin. Dental surveyor was used to allow accurate positioning of the tooth in the milling machine. A contra-angled hand piece was fixed to the upper arm of the milling machine to align the diamond stone parallel to the long axis of the tooth **(Figure 1A & 1B)**.

Construction of the working dies

Thirty epoxy resin dies were duplicated from the prepared tooth using silicone duplicating material **(Figure 2).**

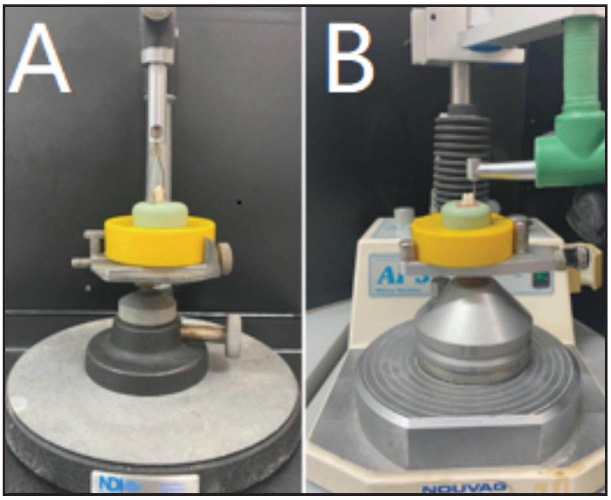

Fig. (1) (A) mounting of the tooth with the aid of dental surveyor, (B) The hand piece attached to the milling machine during tooth preparation

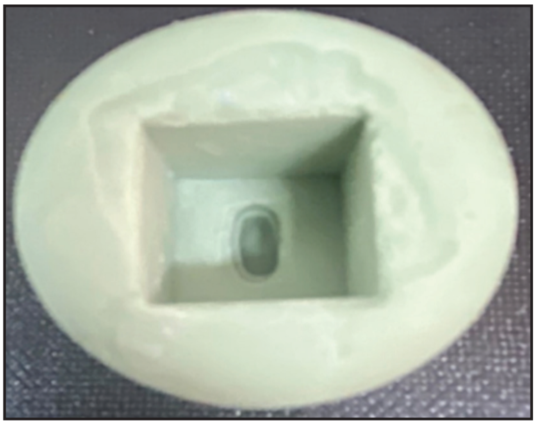

Fig. (2) A silicon impression of the prepared tooth

An optical impression was taken for each die using Sirona Omnicam® scanner with the aid of CEREC SW extended 4.6 software. A virtual model of the prepared die was made and the dental database design option was used by the software to design all of the crowns, a cement space of 60µ was selected on the software during design, Cerec MCXL fully automated milling machine used to mill the crowns **(Figure 3)**.

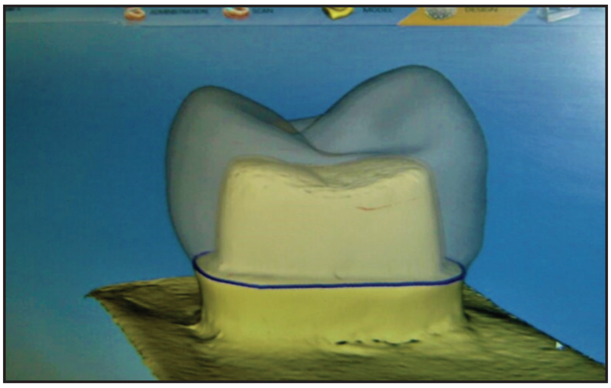

Fig. (3) Crown designing by CEREC software

Ten e-max CAD (shade A1), ten Vita Enamic (shade 1M2) and ten InCoris TZI (shade A1) crowns were milled using Sirona CEREC Inlab MC XL milling machine from the three different types of blocks.

Group A: (e-max CAD crowns)**:** The fitting surface of each crown was etched with hydrofluoric acid gel (9%) for 90 seconds then rinsed with a copious amount of water and placed in an ultrasonic cleaner for 5 minutes to remove salts and debris produced from hydrofluoric acid etching of the porcelain, then dried and silane was applied for 1 minute according to the manufacturer's instructions**. (Figure 4).**

Group B: (Vita Enamic crowns): The fitting surface of each crown was etched with hydrofluoric acid gel (5%) for 60 seconds then rinsed with a copious amount of water and placed in an ultrasonic cleaner for 5 minutes to remove salts and debris produced from the hydrofluoric acid etching of the porcelain, then dried and one coat of all bond universal light-cured dental adhesive was then applied to the fitting surface of restoration, air dried and then light cured for 10 seconds according to the manufacturer's instructions.

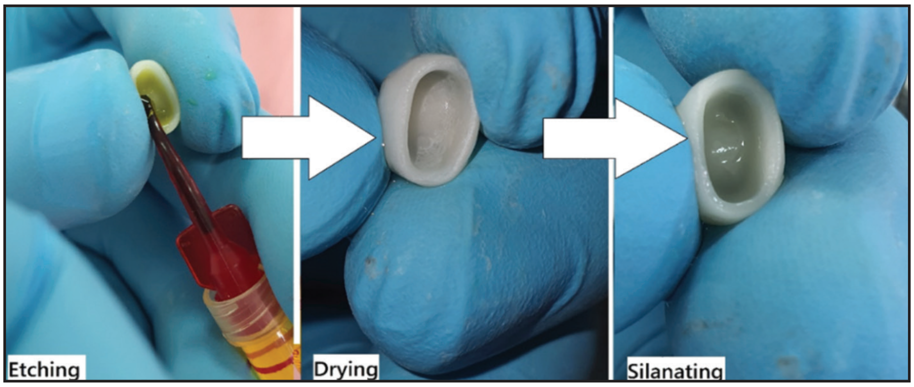

Fig. (4) Steps of e-max crown fitting surface conditioning

Group C: (InCoris TZI crowns): The fitting surface of each crown was sandblasted using 50 μm alumina oxide particles (Al_2O_3) under 2.5 bar pressure at a distance of 10 mm for 15 seconds. The fitting surface was ultrasonically cleaned to remove debris and oil free compressed air was used to clean the alumina dust off the zirconia fitting surface.

All the crowns were bonded to their corresponding dies using TheraCem adhesive resin cement, the crown was seated on its corresponding die. 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, excess cement was removed using a probe **(Figure 5).**

Shade of each crown in subgroup (A2, B2, and C2) of the three materials was recorded using a spectrophotometer (vita Easyshade®) to record the color shade of each crown after bonding **(Figure 6).**

The crowns of subgroup (A2, B2, and C2) were debonded using Er, Cr: YSGG of a 2780 nm wavelength (Waterlase MD, Biolase technology, Inc., Irvine, CA, USA) with a MZ8-6 zip tip gold, and with 6.00 W and 20 Hz repetition rate, and a 0.7 mm beam diameter at the impact point. A non-contact type hand-piece (Turbo) in H mode (60 microseconds pulse duration) was used under a 60% air and 80% water.

Starting with the "occlusal surface", the irradiation fiber tip was moved in direction from buccal to lingual in a back and forth while irradiating the area from one contact point to the other. When the tip reached contact point at the opposite aspect, the same irradiation pattern going from buccal to lingual was repeated until reaching the original contact point (painting the surface with imaginary 1 mm wide stripes). When the tip arrived at the original contact point the irradiation direction was changed from mesial to distal (and back) and the occlusal area was irradiated from contact point to contact point.

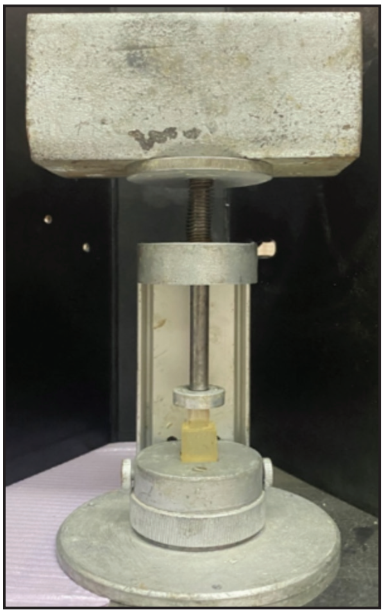
Fig. (5) A specially designed device used to standardize load during bonding

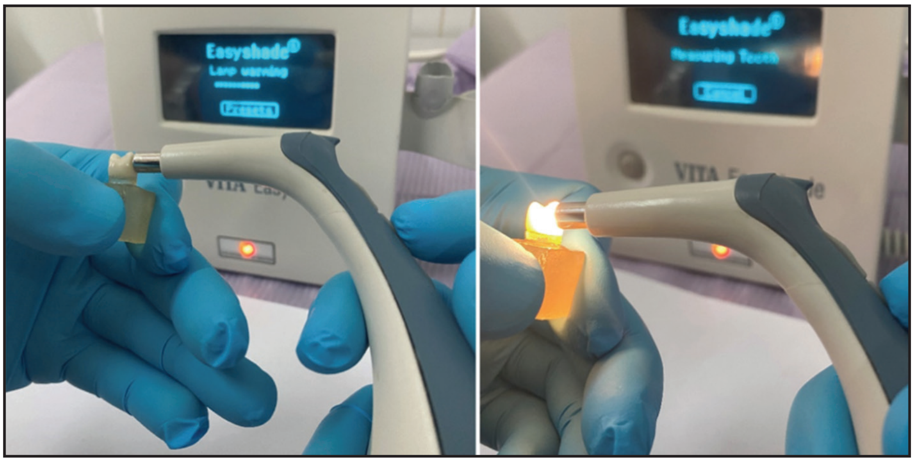

Fig. (6) Shade record using (Vita Easyshade®)

The next step was to irradiate the "occluso-buccal line angels/cusps" for another 30 seconds. The irradiation then continued down the "buccal surface" for a maximum of 30 seconds, hitting the cervical margins only once.

Next, the "occluso-lingual line angles/cusps" and "lingual surface" were irradiated in the same manner as the buccal surface (line angle/cusps first then down in to the cervical margin) for 30 seconds **(Figure 7 &8)**.

For re-bonding of the debonded crowns, the adhesive resin cement remnants on the die surfaces were removed by using a finishing carbide bur, the die surfaces were polished using a 600-grid silicon carbide bur to obtain a clean surface for subsequent rebonding procedures. The debonded E-max and InCoris TZI crowns were placed in the furnace and were heated to 454°C for 10 min to completely carbonize the remnant resin cement. On the other hand, the Vita Enamic crowns fitting surfaces were cleaned using the 30-blade tungsten carbide bur in high speed followed by etching with hydrofluoric acid gel (9%) for 90 seconds according to the manufacturer's instructions. Then the crowns' fitting surfaces were rinsed with a copious amount of water and placed in an ultrasonic cleaner for 5 minutes to remove salts and debris produced from hydrofluoric acid etching of the crown fitting surface.

Fig. (7) Laser application to the crown of mesial aspect

Fig. (8) Crown debonded from its corresponding die

The debonded crowns of the three groups were re-bonded on their corresponded dies using the same bonding steps done before debonding.

The shade of the re-bonded crowns was recorded using Vita Easyshade® (Intra oral spectrophotometer) to detect the change in colour change (ΔE) of each of the laser-debonded crowns using the following equation [86]:

$$\Delta E = \sqrt{(\Delta L)2 + (\Delta A) 2 + (\Delta B) 2}$$

Equation 1 delta E equation

All of the crowns were scanned using XRD (X-Ray Diffraction) to determine their crystalline structure, and examined using the scanning electron microscope to examine the outer surface changes after erbium laser irradiation in debonding procedure **(Figure 9&10)**.

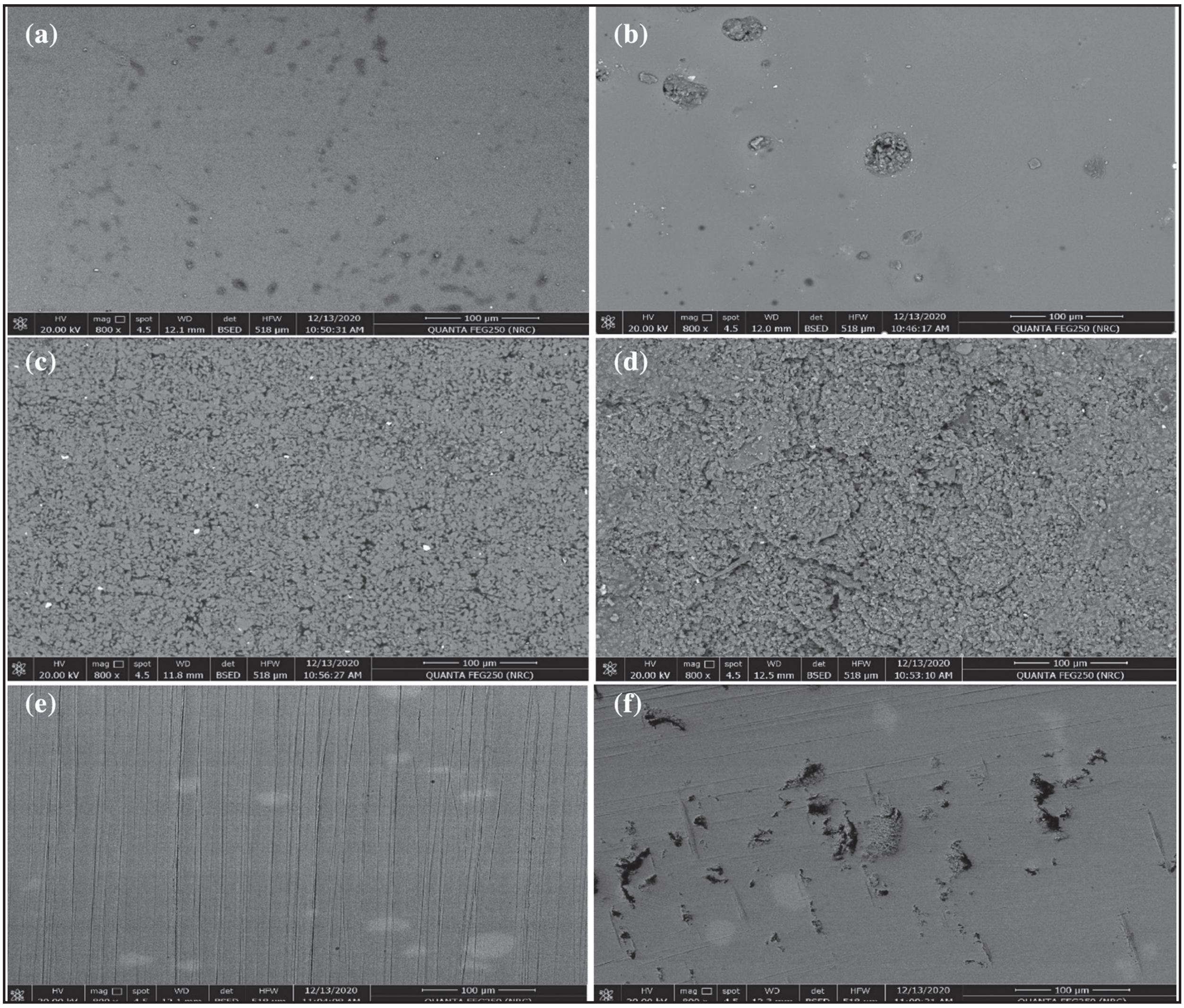

Fig. (9) SEM images of erbium chromium effect on (e-max CAD),(Vita Enamic) and (InCoris TZI). ***(a)*** SEM image of E-max CAD sample not exposed to laser irradiation (magnification × 800). ***(b)*** SEM image of E-max CAD sample after laser irradiation (magnification x 800). ***(c)*** SEM image of Vita Enamic sample not exposed to laser irradiation (magnification × 800). ***(d)*** SEM image of Vita Enamic sample after laser irradiation. (magnification × 800). ***(e)*** SEM image of InCoris TZI sample not exposed to laser irradiation (magnification × 800). ***(f)*** SEM image of InCoris TZI sample after laser irradiation (magnification × 800)

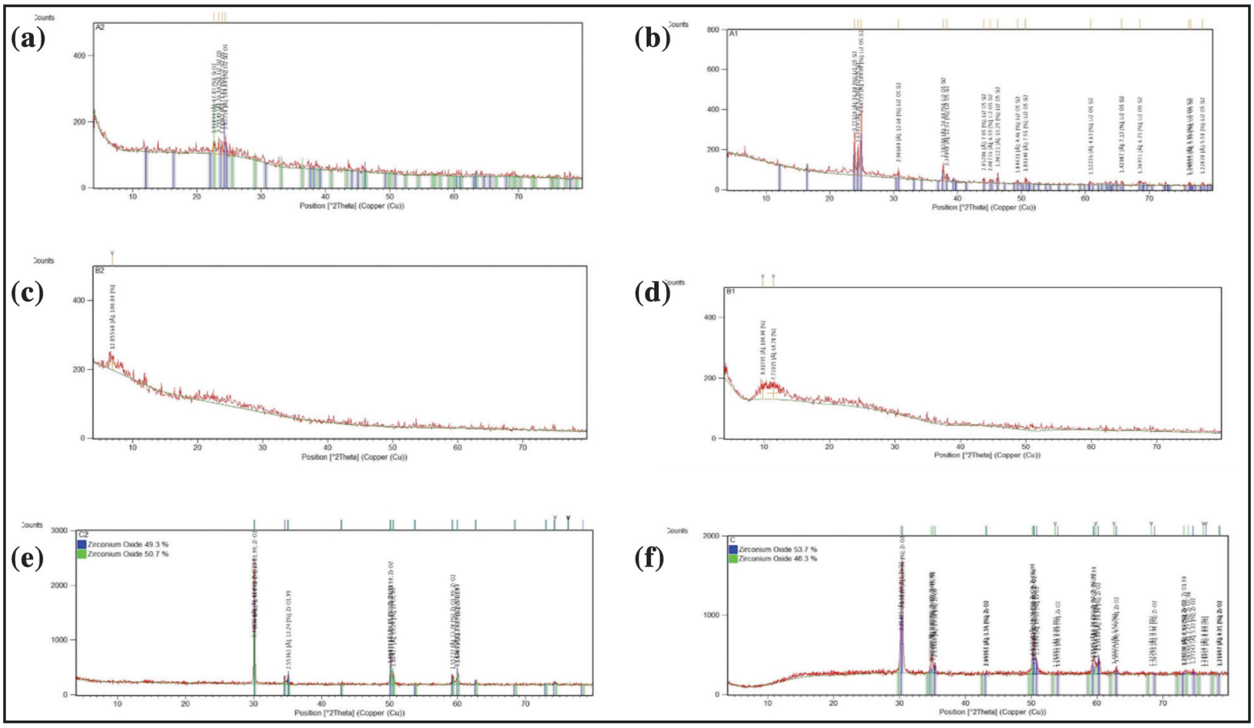

Fig. (10) XRD charts of erbium chromium effect on (e-max CAD), (Vita Enamic) and (InCoris TZI) crystalline structur. ***(a)*** XRD patterns of E-max CAD samples not exposed to laser irradiation. ***(b)*** XRD patterns of E-max CAD samples not exposed to laser irradiation. ***(c)*** XRD patterns of Vita Enamic samples not exposed to laser irradiation. ***(d)*** XRD patterns of Vita Enamic samples after laser irradiation. ***(e)*** XRD patterns of InCoris TZI samples after laser irradiation. ***(f)*** XRD patterns of InCoris TZI samples after laser irradiation.

The X-ray diffraction scan showed the crystalline structure of specimens before and after laser irradiation during debonding procedure and according to Scherrer equation the crystal sizes were calculated and recorded.

$$\beta(2\theta) = \frac{K\lambda}{L\cos\theta}$$

Equation 2 the Scherrer equation

When the wave length of the X-Ray Diffraction was (1.5406) the crystalline size was calculated

K = Scherrer Constant 0.9

L = Crystalline Size

β = Peak Width

θ = Peak Position And Angle

λ = Wave Length of XRD

For scanning electron microscope images with high magnification in 800x with high resolution were recorded.

RESULTS

There was a significant difference statistically in the mean ΔE in the three tested subgroups (P = 0.008) after laser debonding.

Samples of subgroup B2 (Vita Enamic) had the highest ΔE values (10.49±3.90), followed by the

Table (1) *Mean and standard deviation (SD) of (ΔE) values of the three groups after laser debonding*

Group	Subgroup A2 e-max CAD	Subgroup B2 Vita Enamic	Subgroup C2 InCoris TZI	p-value
Mean ± SD	1.46^{b}± .22	10.49^{b}± 3.90	1.06^{b}±.15	0.008*

Different super script letters indicate a statistically significant difference   **Significant at p≤0.05*

samples of subgroup A2 (e-max CAD) (1.46± .22) while the samples of subgroup C2 (InCoris TZI) had the lowest ΔE values (1.06±.15).

Tukey's post hoc test sowed statistically significant difference between ΔE values between subgroup A2 (e-max CAD) and subgroup C2 (InCoris TZI).

The mean and standard deviation (SD) values of (ΔE) of the three subgroups were presented in table 1.

DISCUSSION

Aesthetically pleasing restorative materials are launched every year to provide dentists with tools that offer ideal aesthetics to their patients. However, the incorporation of all ceramic crowns into dental practice had also challenged clinicians in terms of their removal. Removal of a dental crowns may be needed for many reasons such as the need for root canal treatment of the related prepared tooth and the need for gingival and periodontal treatment of the surrounding bone and gingival structure. Traditional methods are used to remove ceramic restoration but since 2011, laser irradiation has been tested for this purpose [(20)].

Over the years, many methods have been described and many devices and instruments have been designed for the removal of crowns from the corresponding prepared teeth. These may vary from simple instruments to specific coronal disassembly instruments [(21)].

Recently many types of lasers including Nd: YAG and Er, Cr: YSGG laser were introduced for debonding of crowns from the tooth structure without any destructions neither to the crown nor to its abutment [(22)].

In the current study, three CAD/CAM materials were chosen. The first was e-max CAD (Litium disilicate) which it is one of the most esthetically dental restoration in the market and has high thermal shock resistance and low thermal expansion. The second was Vita Enamic (hybrid ceramic) which is composed of ceramic and polymer phases that gives these material stability, strength, elasticity, and hardness similar to the natural tooth structure. The third material was InCoris TZI which is (monolithic zirconium) that has excellent mechanical properties, strength and hardness.

Epoxy resin dies were used in this study because of their modulus of elasticity, strength, and hardness similar to natural tooth structure and also because of its dimensional accuracy according to *Paquette et al*.[(23)].

In order to standardize the crowns employed in this study, one of the produced dies was sprayed with a uniform layer of opti-spray to enhance the precision of optical scanner, in agreement with *Dehurtevent et al*. [(24)].

Bonding of crowns to their corresponding resin dies was undertaken using TheraCem adhesive resin cement in the current study. It was provided by auto-mix dual-syringe which provided a consistent mix of the cement so avoiding human mixing errors. In order to standardize the pressure during bonding of the crowns, a specially designed device was used to maintain a static load of three kilo grams on the crown during bonding. This load was recommended by *Rinke et al.* (25), and *Groten* and *Probeste* (26) to avoid the risk of the ceramic crowns destruction.

Erbium lasers was used as a suitable method alternatively to conventional ceramic crowns removal techniques. The parameters Laser should be selected and adjusted according to the target character: the ceramic type, the type of bonded tooth surface, and the restoration thickness. Erbium laser was chosen in this study because it was found that mid-infrared lasers (Erbium Family) was transmitted through ceramics and absorbed in resin cement and can debond the resin bonded restorations very easily in a few seconds (28 ,29).

Shade of the crowns in subgroup 2 (A2, B2, C2) before subjecting to Erbium laser were evaluated directly after bonding and recorded by using an intra oral spectrophotometer (Vita Easyshade®) to eliminate the human variations. Many studies employed the Vita Easyshade® in extra oral measures. The readings were taken at the middle of the buccal surface to prevent the edge loss phenomenon which has an effect on the color measurements. Whenever the light within the sample is scattered near the edges without being absorbed which could lead to loss of accuracy in measurement of color, edge loss phenomenon occurs as mentioned by *Garrana* and *Elgabarouny* (30), *Pohjola et al.* (31).

In the present study, the non-irradiated e-max crowns showed a clear surface while the crowns that were subjected to laser showed some ablation spots and this could be due to the laser application on the outer surface of the crowns and this correlate positively with the difference of color (ΔE).

On the other hand, the non-irradiated crowns of Vita Enamic showed a smooth and polished surface. However, the irradiated crowns showed a markedly rough surface with multiple spots and fissures. This could explain the massive change in (ΔE).

The least affected ceramic type in the present study was the InCoris Tzi. The non-irradiated crowns showed a shiny glazed surface while the crowns subjected to laser showed a tiny black spot that cannot be seen without a magnification of more than 1000x. This tiny black spot might be the cause of the slight change of (ΔE) of these crowns.

The change of color of the crowns (ΔE) was recorded by comparing the results of shade measuring of the crowns in (A2, B2, C2) before and after laser debonding procedure. The literature ranked the change in color among dental materials as follow: $\Delta E > 3.7$ = extremely poor match, $\Delta E > 2$ = unacceptable clinically, $\Delta E < 2$ = acceptable clinically and $\Delta E < 1$ visually undetectable. The Vita Easyshade® measures ΔE and expresses the results in simplified manner (32, 33).

In the current study, ΔE of the samples of subgroup A2 (e-max CAD) was (1.46± .22). That was not a statistically significant change and clinically acceptable and this change could be described by scanning electron microscope images which showed that the subgroup A2 subjected to laser showed some ablation spots and this was due to the laser application on the outer surface of the crowns and this positively correlate with the color difference (ΔE). This was in agreement with *Paravina et al.* (34), and *Kurtulmus-Yilmaz et al.* (35).

Samples of subgroup B2 (Vita Enamic) had the highest ΔE values (10.49±3.90) which was very poor match and clinically unacceptable and according to scanning electron microscope images that showed the difference between the non-irradiated crowns of Vita Enamic crowns showed a smooth and polished surface and the irradiated crowns showed a markedly rough surface with multiple spots and fissures. This might be due to the photoablation of the resin in the hybrid ceramic surface by Erbium laser pulses which could cause surface porosity. This could have possibly allowed partial absorption and reflection of the light passing through the crowns, while most of the light could be transmitted to the underlying cement that recorded a different shade value. This could explain the massive change in (ΔE). This explanation was in agreement with *Heffernan et al*. [36] who reported that the amount of absorbed, reflected and transmitted light would depend on the percentage and composition of chemical nature.

On the other hand, the samples of subgroup C2 (InCoris TZI) had the lowest ΔE values (1.06±.15) which were not a statistically significant and clinically acceptable. This could be explained by scanning electron microscope images of the crowns subjected to laser showed a tiny black spot that cannot be seen without a magnification of more than 1000x in comparable to the images of the non-irradiated crowns which showed a shiny glazed surface. This tiny black spot of the crowns' surfaces might be the cause of the slight change of (ΔE) of these crowns. This result was in agreement with *Zhang et al*. [37] who concluded that Er:Cr:YSGG laser changed the optical properties of dental zirconium ceramics making them lower in translucency (ΔE = 1.02).

CONCLUSION

Under the conditions of this in-vitro study, the following could be concluded:

- The Erbium laser aided crowns debonding is the fastest and safest method of crown removal.
- According to the non-significant change in ΔE values of (InCoris TZI) and (e-max CAD) crowns, they can rebond and reuse after Erbium laser debonding, on the contrary of the (Vita Enamic) crowns.

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