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Evaluation of the time needed for the debonding of two ceramic materials at two thicknesses using two laser powers of Erbium Chromium: YSGG Laser "A Comparative In-Vitro Study"

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ABSTRACT

Background: Ceramic veneers are a very satisfying treatment option for patients regarding aesthetics as they have highly favorable clinical performance. Nevertheless, the de-bonding of laminate veneers may be needed. The conventional techniques for debonding have been proven destructive. The introduction of laser has been of great help offering an easier and a safer debonding technique. ***Objectives:*** to evaluate the time needed for debonding and the transmission energy ratio through different ceramic materials in two different thicknesses using two different laser powers. ***Materials and methods*****:** Fifty-six ceramic specimens were divided into two main groups (n= 28/group) according to ceramic materials (feldspathic, hybrid ceramic). Then each group was further subdivided into two subgroups (n= 14/subgroup) according to their thicknesses (0.3mm -0.7mm). Each group was subjected to two laser powers (3 watt and 6 watt). Transmission energy was first measured followed by the debonding procedure and then time was recorded. Data obtained was analyzed using three-way (ANOVA) ($P \leq 0.05$) then Bonferroni's post-hoc test. ***Results:*** low power laser showed statistically significant higher mean debonding time than high power (P-value <0.001, Effect size = 0.370). Vita Enamic showed statistically significant higher mean transmission energy than Vita Mark II (P-value <0.001, Effect size = 0.544). 0.3 mm thickness showed statistically significant higher mean transmission energy than 0.7 mm thickness (P-value <0.001, Effect size = 0.325). ***Conclusion:*** Laser use in debonding was proven to be a much easier technique in less time rendering both the ceramic and tooth structure intact.

Keywords: debonding, Er, Cr: YSGG laser, feldspathic ceramic, hybrid ceramic.

INTRODUCTION

With the increased demand for high esthetics and the development in bonding technology and computer aided design/ computer aided manufacture system (CAD/CAM), machinable ceramic veneers have become common in esthetic dentistry.[1,2]

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Different types of ceramic materials are available for CAD/CAM use such as: glass-based ceramics, hybrid ceramics, reinforced glass ceramic, and zirconia ceramic.[1,2,3] Vita Mark II (glass-based) and Vita Enamic (hybrid ceramic) materials are used in the fabrication of ceramic veneers as they both offer high esthetics and they could be milled in thin sections. [3] Ceramic veneers are one of the most satisfying treatment options for patients as they are ultra-conservative and they provide high esthetics.[4]

The longevity of a fixed restoration mainly relies on the quality of the cementation procedure and the type of the cement used. Long term survival rate of ceramic veneers has increased after the introduction of adhesive resin cements.[5] However some failures such as faulty cementation, fracture, recurrent caries or patient dissatisfaction may require the removal of the laminates.[6]

The conventional techniques for debonding such as cutting or grinding previously used to remove ceramic veneers have been proven time consuming and destructive. In addition, the removal of veneers is challenging due to the lack of color contrast between the three phases; tooth structure, cement layer and the veneer.[7,8]

The continuous development in technology leading to the use of laser in the dental field offered an easier and safer technique for debonding of ceramic restorations.[9,10] Laser debonding process was first applied for debonding orthodontic ceramic brackets in 1992. The use of different lasers such as Er: YAG, CO_2 and Nd: YAG has been evaluated since then. However, there are only a few studies in the literature evaluating the effect of Er, Cr: YSGG laser for ceramic restorations removal.

The type and thickness of the ceramic, the type of the resin cement used and the applied laser parameters, such as: the different laser powers and the time of irradiation affects the debonding procedure.[11]

The objective was to compare the effect of the Er, Cr: YSGG laser on debonding time through using two ceramic materials with two thicknesses and to evaluate the transmission energy ratios through them. The aim is to provide clinicians with the best clinical recommended procedures.

The null hypotheses are, first; that there will be no difference in the time needed for the de-bonding of adhesively luted Feldspathic porcelain (VITA Mark II) and hybrid ceramic (VITA Enamic) restorations at two thicknesses (0.3mm, 0.7mm) using low and high-power outputs of erbium chromium laser (3 watt- 6 watt); second, there will be no difference in the amount of energy transmission through them.

MATERIALS AND METHODS

Sample size calculation:

This power analysis is for a 2 x 2 x 2 fixed effect analysis. Each of the three factors (Ceramic type, Thickness, Laser power) included 2 levels. The effect sizes for the three factors are (6.1, 0.4 and 0.4 respectively) based upon the results of Morford CK et al (2011). Using alpha (α) level of (5%) and Beta (β) level of (20%) i.e., power = 80%; the minimum estimated sample size was 7 specimens per cell giving a total of 56 specimens. Sample size calculation was performed using IBM® SPSS® Sample Power® Release 3.0.1.[9,12]

Specimens grouping and study design:

In this study a total of 56 Vita Mark II and Vita Enamic ceramic specimens (Vita Zahnfabrik, Germany) with a width of 4 mm and a length of 8 mm were used (n= 28/group).[11] They were divided into two main groups (n=28), M (Mark II) and E (Enamic). according to type of ceramic material used. Each group was further subdivided into two subgroups (n=14): A (0.3mm) & B (0.7mm), according to the ceramic thickness. Then each subgroup was divided into two divisions (n=7): H (6 Watt) and L (3 Watt), according to the laser power outputs (high or low) they were subjected to.

Sample preparation: Intact maxillary central incisors with average mesio-distal width of 8.7 mm ± 1 at the incisal 1/3 were selected. They were measured by a caliper; they had an average mesio-distal width of 8.7 mm ± 1.

Teeth preparation: Teeth were flattened from the labial surface only (8 x 4 mm) at the incisal 1/3, exposing a surface of a freshly cut enamel. Specially designed self-curing acrylic resin blocks were fabricated using standard cylindrical plastic molds, according to ISO 1567=1999 specification. Teeth roots were fixed in a vertical direction by a paralleling device in the acrylic blocks to ensure centralization.[13] **(Figure 1)**

Figure (1): Long axis of the tooth Perpendicular to the base of the block using a paralleling device.

Teeth were prepared using a diamond stone (a parallel sided diamond stone with round end stone, Brasseler, USA) mounted onto a dental surveyor (paraskop M surveyor, BEGO). Standardized flat enamel surface preparation was attained as the surveyor offers parallelism between the tooth surface and the bur providing a standard reduction.[14] **(Figure 2)**

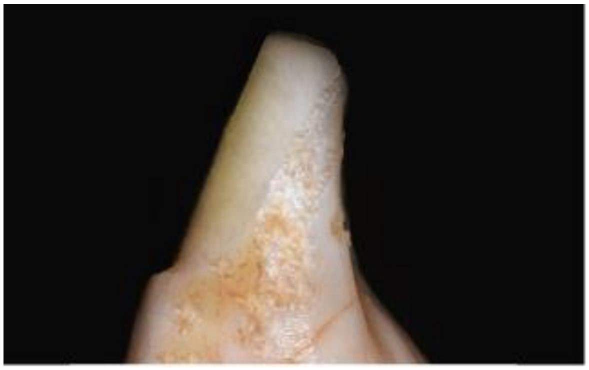

Figure (2): Flattened enamel surface "proximal view"

Ceramic specimens' construction: Fifty-six VITA Mark II and Vita Enamic ceramic samples (28 each) were cut using the Isomet machine (Buehler, USA) into rectangular specimens 4 mm (width) and 8 mm (length) in two thicknesses 0.3 mm and 0.7 mm. Ceramic specimens were finished to simulate those processed by CAD/CAM systems by using four sandpapers of (1000, 800, 600, 400, 200) grit sizes. To ensure standard surface topography of all specimens and surface finish, sandpapers were used by the same operator in the same direction for 10 times.[15] Their dimensions were confirmed by using a digital caliper (Iwanson).[16]

Transmission energy testing of Er, Cr: YSGG laser:

Energy transmission was measured using a Nova II laser power meter (Ophir Optronics, Israel) through the ceramic materials by the irradiation of the ceramic specimens on one side with the pre-determined laser parameters and then transmitted laser energy was measured on the other side of the ceramic specimens.

Teeth surface treatment:

Prepared surface of teeth was etched with phosphoric acid 35% (gel) (scotchbond, 3M ESPE, USA) for 15 seconds, then rinsed with water for 30 seconds. Single bond universal adhesive (3M ESPE, USA) was applied to the prepared teeth and scrubbed for 20 seconds then it was gently dried for 5 seconds. The bonding agent was not light cured according to the manufacturer's instructions. Light curing the bonding agent may interfere with the proper seating of the ceramic specimens.[17]

Ceramic surface pre-treatment:

Porcelain Etch (9% buffered hydrofluoric acid, Ultradent, Inc, USA) was applied on VITAMARK II and VITAENAMIC specimens for 60 seconds then rinsed as per manufacturer's instructions. Silane coupling agent (Ultradent Products, Inc, USA) was then applied in a thin layer. After that it was left to evaporate and air dried for 30 seconds prior to application of the luting cement.[18]

Bonding procedures:

A custom-made cementation device was fabricated and a specially designed loading alignment apparatus was machined from wood in order to aid in load application of 3 kg weight during cementation procedure. Rely X veneer adhesive resin cement (translucent shade 3M ESPE) was applied using single syringe tip to the ceramic specimens which were then seated on prepared teeth surfaces. The resin cement was then light cured using LED light curing unit (Elipar S 10, 3M, St Paul, USA)[2].[19] Tack cure from the facial surface was done to secure the ceramic specimens in place for 5 seconds. Excess cement was removed from the margins using sharp explorer, then light curing was applied at different directions: labial, palatal, mesial and distal for 30 seconds.

Debonding procedure:

Debonding of the ceramic specimens was done using Er, Cr: YSGG laser (Waterlase IPLUS BIOLASE, USA) of 2780 nm wave length, using the following settings: power settings either 3-watt or 6-watt, same frequency of 20Hz, cooling air was 60% and water was 80%. Hand piece: MGG6-4 mm sapphire (Biolase, San Clemente) (non-contact mode) was used, based on previous studies where those parameters were found effective for ceramic debonding procedures.[1,20,21]The hand piece tip was positioned perpendicular (in a non-contact mode) at a 3-5 mm distance from the ceramic specimens and laser emission was performed with horizontal movement parallel to the surface. The distance of application was standardized every time before starting laser application. The handpiece was grasped while the assistant measured the distance between the lens of the handpiece and the specimen's surface. Laser irradiation procedure continued until the ceramic specimens were lifted off the tooth surfaces affected by ablation pressure during the irradiation.[1] A stopwatch was used to measure the time taken for the debonding.

Mode of failure:

Both teeth and ceramic specimens (Vita Mark II and Vita Enamic) from each group were sputter coated with gold layer, and analyzed using scanning electron microscope (Quanta FEG 250, FEI Co., Netherlands) to evaluate the mode of failure after laser debonding and examine the surface features at an accelerating voltage of 30 K.V. and a 20000X magnification. The modes of failure were classified into 3 types. Type1: Adhesive failure between the inner surface of the ceramic specimen and the resin cement, in this type most of resin cement remained on the tooth surface. Type2: Adhesive failure between the resin cement and the tooth surface, where most of resin cement remained on the inner surface of the ceramic specimen. Type3: Cohesive failure within the resin cement.

Statistical Analysis:

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). All data showed parametric distribution. Three-way ANOVA test followed by Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test is significant. The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY:IBM Corp.

RESULTS

A- Transmission energy:

Three-way ANOVA results showed that ceramic type, ceramic thickness and laser power had a statistically significant effect on mean transmission energy (P-value <0.001) regardless of other variables. The interaction between the three variables also had a statistically significant effect on mean transmission energy (P-value <0.001, Effect size = 0.017). Since the interaction between the variables is non-statistically significant, the variables are independent from each other. Vita Enamic, 0.3 mm ceramic thickness and high laser power output (6 watt) showed higher amount of energy transmission than Vita Mark II, 0.7 mm thickness, and low laser power outputs. **(Table 1)**

B- Debonding time:

Results of three-way ANOVA test showed that ceramic type, ceramic thickness and laser power had a statistically significant effect on mean debonding time (P-value <0.001) regardless of other variables. The interaction between the three variables also had a statistically significant effect on mean debonding time (P-value < 0.005). Since the interaction between the variables is statistically significant, the variables are dependent upon each other. Vita Enamic

Table (1): The mean, standard deviation (SD) values and results of three-way ANOVA test for comparison between transmission energy values of ceramic types with different interactions of variables.

Thickness	Laser power	Vita Mark II		Vita Enamic		*P*-value	Effect size *(Partial eta squared)*
		Mean	±SD	Mean	±SD		
0.3 mm	Low power	1.757	0.091	2.846	0.53	<0.001*	0.465
	High power	2.568	0.407	3.504	0.316	<0.001*	0.383
0.7 mm	Low power	1.44	0.097	1.801	0.375	0.034*	0.088
	High power	2.626	0.275	3.006	0.114	0.029*	0.096

**: Significant at P ≤ 0.05*

material, 0.3 mm thicknesses and low power output (3 watt) showed higher mean of debonding time than Vita Mark II, 0.7 mm thicknesses and high laser power output (6 watt). 0.7 mm ceramic thickness showed statistically significant higher mean debonding time than those of 0.3 mm thickness. **(Table 2), (Figure 3)**

Table (2): The mean, standard deviation ±(SD) values and results of three-way ANOVA test for comparison between debonding time (in seconds) of the two ceramic thicknesses, regardless of their types and Laser powers.

0.7 mm		0.3 mm		*P*-value	Effect size *(Partial eta squared)*
Mean	±SD	Mean	±SD		
33	22.3	29.8	14.1	0.033*	0.091

**: Significant at $P \leq 0.05$*

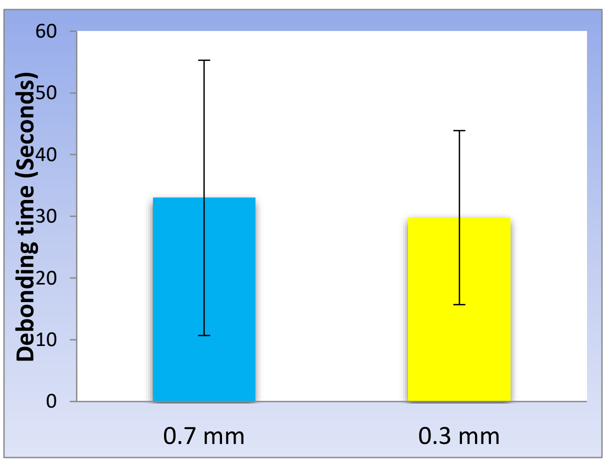

Figure (3): Bar chart representing mean and standard deviation (±SD) values for the debonding time in seconds of the two ceramic thicknesses, regardless of their type and Laser powers.

C- Mode of failure:

Scanning electron microscopic analysis of the all the deboned specimens (tooth-ceramic) showed type III cohesive failure within the cement where both teeth and ceramic surfaces were completely covered by a thick layer of resin cement. **(Figures 4-7)**

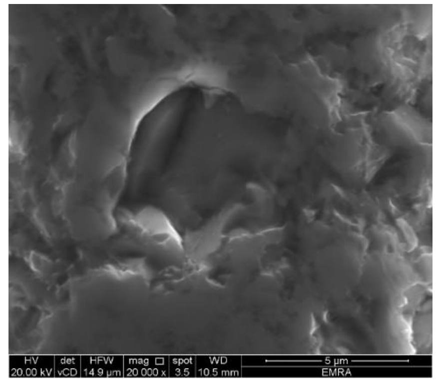

Figure (4): A micrograph showing a cohesive feature within the cement, x 20000 mag. "ceramic side"/ VITA MARK II (0.3 mm thickness, power output 6 watt).

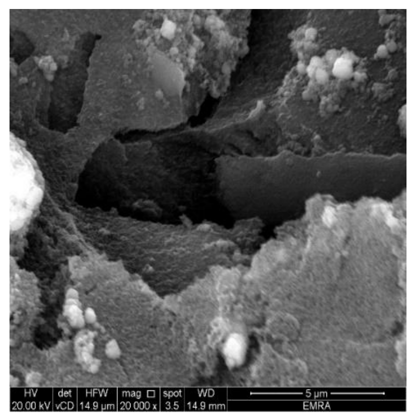

Figure (5): A micrograph showing a cohesive feature within the cement, x 20000 mag. "tooth side"/ VITA MARK II (0.3 mm thickness, power output 6 watt).

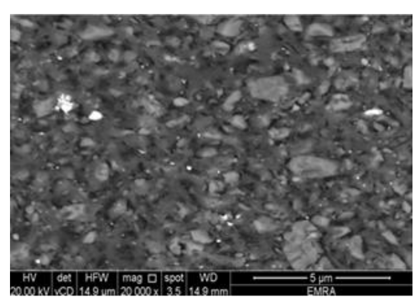

Figure (6): A micrograph showing a cohesive feature within the cement, x 20000 mag, "ceramic side"/ Vita Enamic (0.3 mm thickness, power output 6 watt).

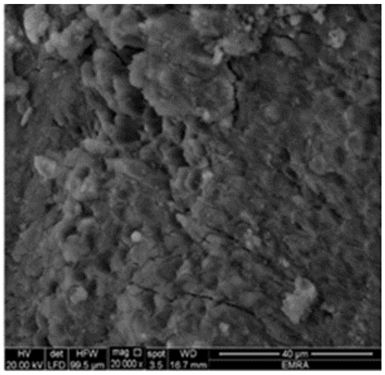

Figure (7): A micrograph showing a cohesive feature within the cement, x 20000 mag, "tooth side"/ Vita Enamic (0.3 mm thickness, power output 6 watt).

DISCUSSION

In the present study central incisors were flattened from the labial surface only, exposing a surface of a freshly cut enamel, and leaving the dentin unexposed to obtain ideal bond strength with the resin cement. Preparation of the teeth was standardized using a diamond stone mounted onto a dental surveyor. This was in accordance to Giraldo H. et al.[20]

IsoMet saw was used to cut out specimens from both CAD/CAM VITA Mark and VITA Enamic blocks to standardize the required thicknesses for all groups at 0.3 mm and 0.7 mm.[22] Thicknesses of 0.3 mm and 0.7 mm were selected as they were found to be common thicknesses for laminate veneers. This study was conducted to corelate its results to ceramic veneers debonding in accordance to Kang. W et al.[23,24]

Resin adhesive cement mainly depends on the micromechanical interlock with the tooth structure and polymerization of the resin monomers into the etched tooth substrate, so using natural teeth within this study was mandatory.[25] Also natural teeth were selected to mimic natural bonded surfaces and the hardness of dental tissues.[9,26]

Both laser power outputs (3 watt and 6 watt) were selected as they were reported to be effective in debonding ceramic restorations. This was in accordance to Zanini et al and Giraldo et al.[20,27]

The quality of the laser is highly affected by the distance between the laser head and the surface. It was recommended by literature to set the distance to 3-5 mm as it was proven to be more efficient than the contact mode type in decreasing the debonding time and in allowing for further heat diffusion without causing the probable thermal damage. These findings were in agreement with Albalkhi et al and Rechman et al.[1,16]

The results of this study showed that the ceramic type, thickness and the laser power had a statistically significant effect on the mean debonding time regardless of other factors. The interaction between the three variables also had a statistically significant effect on the mean debonding time.

Therefore, the first null hypothesis which stated that there will be no difference in the time needed for the de-bonding of adhesively luted Feldspathic porcelain (VITA Mark II) and hybrid ceramic (VITA Enamic) restorations at two thicknesses (0.3mm, 0.7mm) using low and high powers of erbium chromium laser was rejected.

Concerning the results of the influence of laser power on the debonding time. It was shown that as the laser power increased, the time needed for debonding of the ceramic specimens decreased.[14,16] This could be attributed to the ability of high laser powers to cause thermal ablation by elevating the temperature of resin cement causing vaporization and blow out, leading to the cement's decomposition. Low laser powers, on the other hand, cause thermal softening of the bonding agent which takes longer time (Alikhasi et al).[11]

The results of this study showed that ceramic type, thickness and laser power had a statistically significant effect on the mean transmission energy regardless of other factors.

Therefore, the second null hypothesis which stated that there will be no difference in the transmission energy ratios of adhesively luted Feldspathic porcelain (VITA Mark II) and hybrid ceramic (VITA Enamic) restorations at two thicknesses (0.3 mm, 0.7mm) adhesively luted using low and high powers of erbium chromium laser was rejected. The previously mentioned results corroborate with Rechman et al, who tested the possibility that enough laser light could be transmitted through ceramic samples. Ablation will occur in the cement- ceramic interface. This was also in accordance with Ghazanfari.R et al.[16] Additionally, Zanini's et al study validates our results, as they verified that Erbium laser could be transmitted through ceramic laminates cemented by Rely X Veneer cement, after performing the Fourier- Transformed Infrared Spectroscopy (FTIR).[27]

Regarding the results of the effect of ceramic type on transmission energy, mean transmission energy was found to be higher in VITA Enamic than in VITA Mark II specimens. These findings might be attributed to the difference in the chemical composition of both ceramics. Vita Enamic has a higher crystalline structure (75%) than Vita Mark II (<20%) allowing great amount of laser energy transmission.[28] These findings are in accordance with previous studies that stated that ceramics with highly crystalline structures have high energy transmission values. [9,24,29] Sari *et al*. conducted a study to test laser transmission energy ratio through dental ceramics. They found that Emax showed 88% transmittance while Vita Mark II showed 68%. These findings were related to the high crystalline phase of lithium disilicate reinforced ceramics.[29] 0.3 mm ceramic thickness showed higher energy transmission levels than the 0.7 mm ones. This could be related to the decreased laser transmission with the increased ceramic thickness. These findings were in agreement with Rezvaneh Ghazanferi et al, who revealed that the amount of laser transmission through ceramic crowns and veneers is affected by the thickness and the composition of the restoration. Another study by Al-Maajoun also concluded that the laser transmission decreases with the increase in the restoration's thickness.[16,30,29]

The low irradiation power output (3 watt) used in the current study, showed less amount of laser energy transmission when compared to the high one (6 watt). This could be attributed to the liability of low energy power output to result in a less defined penetration zone of the resin cement, where the outermost layer of the ceramic remains interlocked with the resin cement; leaving the underlying ceramic intact and thus causing less energy transmission.[18,21]

Type III cohesive failure within the cement in all of the debonded specimens could be attributed to the ability of laser to soften the outer surface of the resin cement and targeting the water content of the cement, causing micro explosions within the water content of the cement. These finding corelates with Karagoz et al who stated that cohesive failure was found within the cement layer as the debonding laser procedure degrades the resin cement without damaging either the tooth structure or the veneer.[31]

One of the limitations of the current study is that it was in-vitro which doesn't simulate the intraoral environment. Furthermore, only one resin cement material was used. In addition, only two different ceramic materials were tested for energy transmission.[22]

Therefore, further studies are needed to study the performance of those materials in vivo. Also, multiple resin cements should be tested to ease the process of generalization of the results. A wider variety of ceramic materials should be tested to ensure that all ceramic materials can be de-bonded using an Er, Cr: YSGG laser.

CONCLUSION

Within the limitations of the study the following conclusions could be drawn:

1. Vita Mark II, 0.3 mm thickness ceramics, and high laser power outputs showed shorter duration for debonding compared to low laser output (3 watt), Vita Enamic ceramic material (polymer infiltrated ceramic) and 0.7 mm thickness ceramics.
2. High laser power output (6 watt), Vita Enamic ceramic material, and 0.3 mm, thickness ceramics allowed more amount of energy transmission.
3. Mode of failure was mainly cohesive (within the resin cement) in both ceramic

materials and thicknesses, using different laser power outputs.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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