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ORIGINAL ARTICLE

Effect of Erbium, Chromium-doped Yttrium, Scandium, Gallium, and Garnet 2.7 nm Laser on Debonding of Computer-aided Design and Computer-aided Manufacturing Endocrowns

[1]Ahmed EL Hawary, [2]Ahmed Abbas, [3]Tarek Harhash

ABSTRACT

The most common method for the removal of all-ceramic restorations is to use a highspeed handpiece with a stone or bur. Unfortunately, this process can be difficult, time-consuming and may lead to the loss of healthy tooth structures. Lasers have been suggested and used to remove ceramic orthodontic brackets, laminate veneers and full anatomical crowns.

Aim: Aim of the present study was to evaluate the debonding effect of erbium, chromium-doped yttrium, scandium, gallium and garnet (ErCr:YSGG) on Computer-aided design and computer-aided manufacturing (CAD/CAM) end crown restorations.

Materials and methods: Overall, 30 molar samples were prepared for this study and divided into two groups as follows:

Group A–(n = 15): Endocrowns subjected to ErCr:YSGG laser application.

Group B–(n = 15): Endocrowns not subjected to the laser (control). Endocrowns were fabricated from lithium disilicate ceramics and manufactured using a CAD/CAM machine. Cementation was done using Bisco Duo Link Universal™ resin cement. ErCr:YSGG laser was used with wavelength 2780 nm, 0.3J energy, 10 Hz frequency and 1000 μm tip size. Pull out test was done using a universal testing machine.

Results: It was found that Non-laser group recorded statistically significant ($p < 0.05$) higher mean value (258.14 ± 63.43 N) for debonding than Laser group mean value (156.66 ± 32.89 N) as indicated by student t-test. Additionally, no carbonization at the dentin/cement interface was observed.

Conclusion: According to the results of this study, ErCr: YSGG application can be considered a conservative method for the debonding of all ceramic endocrowns.

Clinical significance: Some practitioners have been against the use of endocrown restorations due to the difficulty faced in removal and retrieval, the use of laser is an alternative, effective and conservative method.

Keywords: All ceramic restoration, CAD/CAM, Debonding, Endocrown, Effect of erbium, Chromium-doped yttrium, Scandium, Gallium and garnet 2.7 nm Laser on Debonding of CAD/CAM Endocrowns.

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[1]Department of Prosthodontics, MSA University, National Institute of Laser Enhanced Sciences, Cairo, Egypt

[2,3]Department of Prosthodontics, National Institute of Laser Enhanced Sciences, Cairo University, Cairo, Egypt.

Corresponding Author: Ahmed EL Hawary, Department of Prosthodontics, MSA University, National Institute of Laser Enhanced Sciences, Cairo, Egypt, e-mail: ahawary@hotmail.com

INTRODUCTION

Treatment of grossly damaged endodontically treated teeth using all-ceramic crown restorations is a problem facing many practitioners in their daily practice.[1] Caries, fracture and cavity preparation are the main reasons for the decrease in fracture resistance of root canal treated teeth, rather than dehydration or physical changes in dentin.[2] Traditionally, the functional and esthetic restoration of teeth with endodontic treatment and extensive coronal destruction has been achieved by fabricating crowns supported on cast metal post and cores.[3]

With the advancement of adhesives and ceramics, a macro-retentive design is no longer a requirement when there are sufficient tooth surfaces available for bonding.[4] A new type of restoration was developed consisting of a circumferential preparation with a 1.0 to 1.2 mm butt margin and a central retention cavity inside the pulp chamber, thus constructing both the crown and core as a single unit, i.e., a "monobloc". This restoration is called the Endocrown.[5]

Removal and retrievability are needed in cases when the endodontic treatment under the restoration has failed. A meta-analysis of conventional endodontic treatment previously conducted has reported a success rate in the range of 78 to 84%.[6] The major causes of endodontic failures were inadequate obturation (45%) followed by missed canals (32%) and then fractured or dislodged instruments (14%).[7]

As is the case in all ceramic veneers, the most common method for removal of all ceramic endocrown restorations is to use a highspeed handpiece with diamond stone.[8] Unfortunately, due to the high bond strength and color matching qualities of resin bonded ceramics and tooth structure, this process can be difficult, time-consuming and may lead to unnecessary loss of healthy tooth structure. The search for alternative methods that could safely, quickly and predictably debond endocrowns without the risk of iatrogenic damage to underlying tooth structure was therefore greatly needed, seriously investigated and would be encouraged and welcomed.

Since the early 1995, lasers have been used experimentally to remove ceramic orthodontic brackets, which was afterward used in the debonding and removal of porcelain veneers and laminate veneers. Tocchio et al.[9] used Nd: YAG laser at a wavelength of 1060 nm. Oztoprak et al.[10] found that laser application significantly decreased the required debonding load for porcelain laminate veneers. Debonding was said to occur by three main effects, thermal softening, where the bonding agent is softened by heat. Secondly, thermal ablation where resin temperature is raised with high enough laser energy and finally thermally induced photoablation when laser energy interacts with the resin material.[9,11]

MATERIALS AND METHODS

A total of 30 freshly extracted human teeth were selected for this study. They were inspected under proper illumination and magnification (× 2.5) to ensure the absence of cracks or fracture. Teeth of average crown length 6 ± 1 mm, a mesiodistal dimension with average 10 ± 1 mm and buccolingual dimension with average 12 ± 1 mm were selected, while smaller teeth were discarded. The teeth were placed in sodium hypochlorite (NaOCl) 2.5% for 24 hours to remove any attached debris. Teeth were then stored in normal tap water during the experimentation period at room temperature.

The samples were then divided into two groups, Group A n = 15: endocrowns subjected to Er Cr: YSGG laser application and group B n = 15: endocrowns not subjected to the laser (control). The sample teeth were then placed within epoxy resin blocks. Teeth within their respective epoxy blocks were placed on a surveyor (BEGO paraflex, Bremen, Germany) with an attached straight handpiece (Fig. 1) and were marked at a level 1 mm above the cementoenamel junction, demarcating the level of decoronation. using a medium grit disc attached to the straight handpiece the teeth were cut uniformly at the desired level. Access cavity and intracoronal endocrown preparation were performed using an Endo-Z bur (Fig. 2), followed by root canal treatment and obturation for all samples.

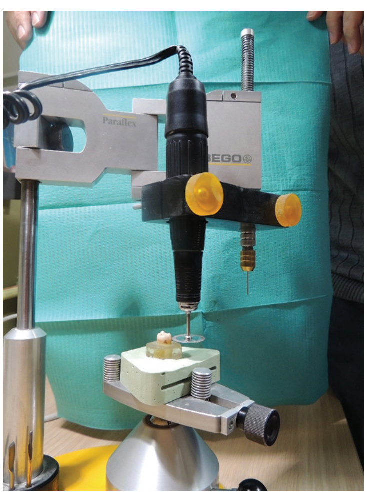


Fig. 1: Surveyor with attached handpiece

Rosetta® SM (HASS, Korea) lithium disilicate glass ceramic blocks were used for the fabrication of the endocrown copings. Scanning of the prepared sample teeth using Freedom HD extra oral scanner, DOF inc.©, Korea and designing of the endocrown copings were performed using Exocad softwareVhf, Germany. Cement gap was designed to be 0.08 mm, and the occlusal surface was designed with an occlusal extension of 5 mm height and 3 mm thickness with a 2-mm wide channelwas added on the occlusal extension to provide a way of pulling the coping during testing (Fig. 3).

To fabricate the endocrown copings, animes-icore® (Germany) CORiTEC milling machine was used. After milling was completed, the endocrown copings were cemented to their respective samples using Bisco (Illinois, USA) Duo Link Universal™ resin cement, to

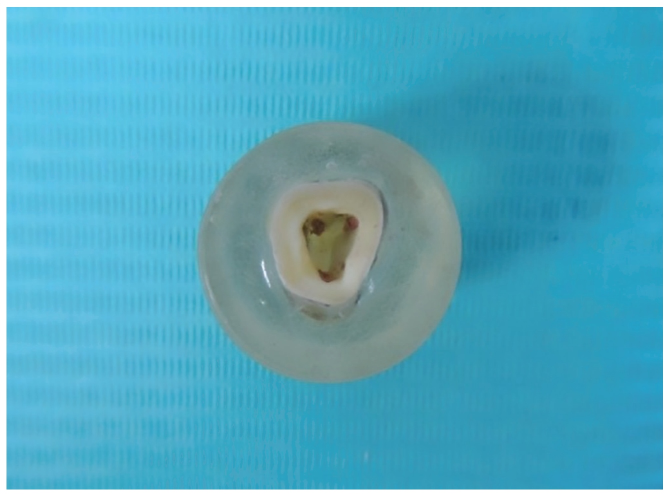


Fig. 2: Endocrown preparation

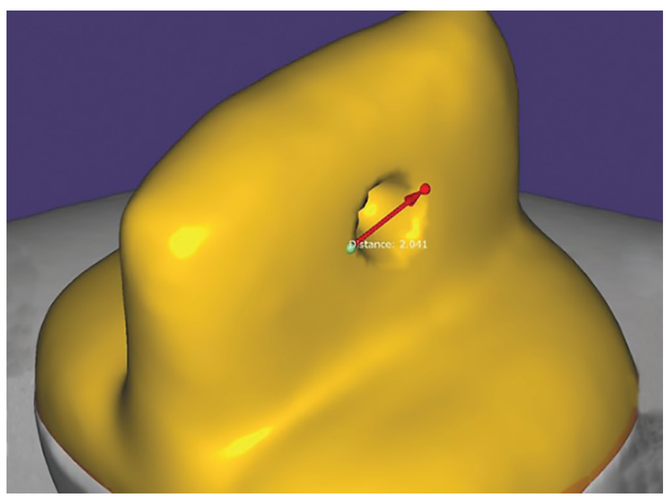


Fig. 3: Designing of the endocrown copings with occlusal extension and channel

ensure the standardization of the cementation procedure a custom-made cementation device was used for these procedures (Fig. 4). All samples then underwent 5000 thermocycling cycles with dwell times set at 25 seconds in each water bath with a lag time of 10 seconds in between.

Lasing was performed using a Waterlase iPlus, BIOLASE© Inc. (Irvine, USA) ErCr: YSGG (erbium, chromium-doped yttrium, scandium, gallium, and garnet) unit, under the laser parameters shown in Table 1. Laser irradiation was started on the occlusal surface of the samples, the irradiation tip was moved in a back and forth movement, like painting the surface with imaginary 2 mm stripes, starting from one contact point to the other for 30 seconds. This was repeated three more times covering the whole of the occlusal surface, after which, the same irradiation pattern was performed along the buccal and lingual walls. Finally, the proximal walls were irradiated in the same fashion but in a direction parallel to the long axis of the tooth (Fig. 5). This pattern resulted in a total irradiation time of approximately 4 minutes, and the irradiation distance was 5 mm away from the ceramic surface, no changing in the transparency of the ceramics or discoloration was observed during irradiation.

Pull out testing of the samples using a universal testing machine (Model 3345; Instron Industrial Products, Norwood, USA) was performed with a load cell of 5000 N and data were recorded using Bluehill Litecomputer software. The endocrown coping was suspended from the upper movable compartment of the testing machine by orthodontic wire loop (1.5 mm) through the hole made during milling. The device was-subjected to a slowly increasing upward vertical load (5 mm/min) until total dislodgment of the crown. The load required to dislodgment was recorded in Newton.

Fig. 4: Custom made cementation device

Table 1: Laser parameters

Wavelength	2780 nm
Energy	0.3 J
Pulse Duration	60 µs (H-mode)
Frequency	10 Hz
Average Power	3 W
Peak Power	5000 W
Tip Size	MZ10 (1000 µm)

RESULTS

The results were analyzed using Graph Pad Instat (Graph Pad, Inc.) software for windows. A value of $p < 0.05$ was considered statistically significant. Continuous variables were expressed as the mean and standard deviation. After homogeneity of variance and normal distribution of errors had been confirmed, a student t-test was done for compared pairs. Sample size (n = 15) was large enough to detect large effect sizes for main effects and pair-wise comparisons, with the satisfactory level of power set at 80% and a 95% confidence level. Descriptive statistics of retention (N) showing mean, standard deviation (SD), minimum, maximum and 95% confidence intervals (CI) (low and high) values for both lased and non-lased are summarized in Table 2 and graphically drawn in Graph 1.

It was found that the retention mean ± SD values recorded for the laser group were (156.66 ± 32.89 N) with the minimum value (106.25 N) and the maximum value (232.02 N). Meanwhile, the retention mean ± SD values recorded for the non-laser group were (258.14 ± 63.43 N) with the minimum value (155.96 N) and the maximum value (253.09 N).The non-laser group recorded statistically significant ($p < 0.05$) higher mean value (258.14 ± 63.43 N) than Laser group mean value (156.66 ± 32.89 N) as indicated by student t-test.

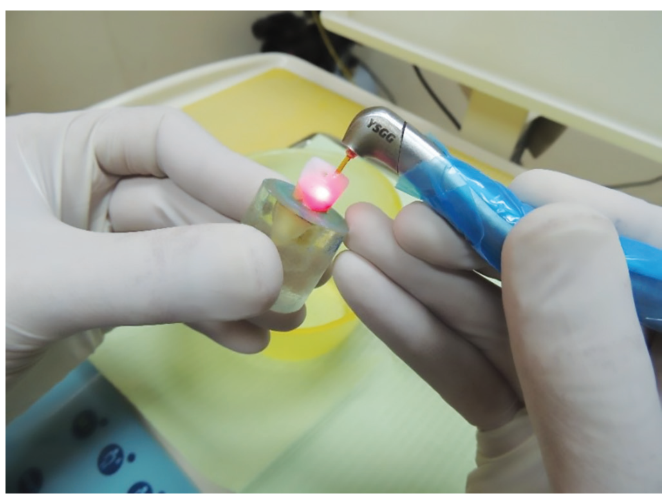
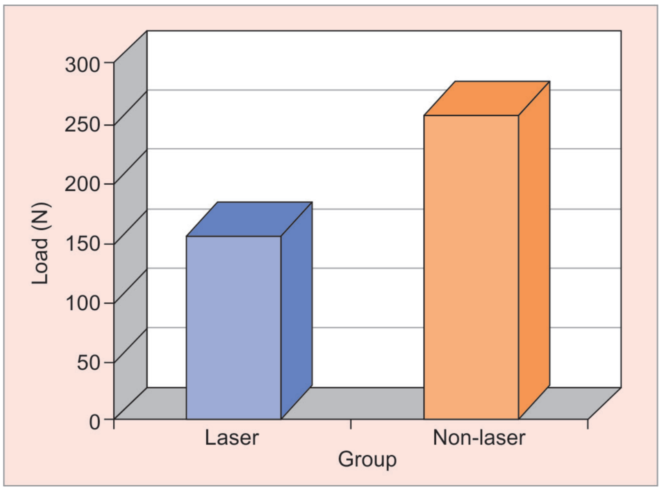


Fig. 5: Laser irradiation of the samples

Table 2: Descriptive statistics of retention results (Mean ± SD) between lased and non-lased groups

Variable		*Mean*	*± SD*	*Range*		*95%CI*	
				Minim.	Maxim.	Lower	Upper
Group	A-Laser	156.66	32.89	106.25	232.02	138.44	174.87
	B-Non-laser	258.14	63.43	155.96	253.09	223.01	293.26



Graph 1: Column chart showing retention results mean values for both lased and non-lased groups

DISCUSSION

Recently, CAD/CAM endocrowns has served as a new method for restoring endodontically treated teeth instead of using a post and core.[12] Endocrowns are onlays that build up and restores damaged coronal potion of a tooth, having an extension into the pulp chamber of said tooth.[13] This extension serves to provide better stabilization and improve adhesion of the restoration.[14] Usually, removal of endocrown restorations was done using a diamond stone or bur, this process was difficult, time consuming and unconservative.

In this study, natural human caries free molars were selected for clinical simulation, as recommended by Aktas et al.[15] Decoronation of the tooth was performed using a surveyor to insure uniformity across all samples, it was done at a level of 1 mm above the cemento-enamel junction in accordance with Rocca et al.[16] Milling of the endocrown samples was done using a CAD/CAM machine to provide predictable quality to the final restoration as well as save time. The use of CAD/CAM offers a more accurate fit, higher durability and more ease of construction, by eliminating human error.[17] Prepared teeth were scanned, and an 80-µm relief[18] cement space was chosen when designing the endocrown copings, this amount of space was considerate optimal by Wilson et al.[19] finding out that there was a significant correlation between increased cement space and decreased seating time and seating discrepancy. The occlusal surface of the endocrown coping was designed with a 5 mm occlusal extension having a 2 mm channel to allow the pulling the copings during retention testing, as was recommended by Saryazdi et al.[20]

Adhesive cementation of all-Ceramic restorations is achieved through resin based luting cements, which require conditioning of both the tooth and the restoration surface before application of the luting resin cement. In this study conditioning of the tooth surface was done through a combination of selective etching and bonding. Although, Peumans et al.,[21] claimed that additional selective etching of enamel does not significantly affect the bonding of ceramic restorations, selective etching was done using 37% phosphoric acid on enamel to ensure maximum bonding and higher retention rate between the restoration and prepared teeth as concluded by Szesz et al.[22]

In this present study it was decided against using abrasion in the conditioning of the endocrown samples because of the difficulty in production of uniform roughness on the fitting surface of the restoration and fear of the potential damage it may cause to the margin which might lead to poor marginal adaptation as noted by Fleming and Addison.[23] Acid etching was performed on the ceramic surface using 9.5% hydrofluoric acid creating a surface that is more accepting for bonding,[24] after which, the application of a silane coupling agent is of utmost importance to increase the chemical bond strength between the resin cement and the endocrown as recommended by Matinlinna et al.[25]

Debonding of all ceramic restorations is based on the thermal softening of the adhesive resin cement.10 This is achieved through thermal-mechanical interaction on the water content in those cements under laser application,[26] despite resin cements being generally less soluble that other luting cements, they still absorb water which in turn allows laser penetration and ablation.[27]

ErCr: YSGG laser was used in this present study as per the recommendation of Gurney et al.,[28] who stated that although it has a less coefficient and has less wavelength than Er: YAG lasers traditionally used in debonding procedure studies, ErCr: YSGG has the same strong absorption in water and lower absorption in hard dental tissues. Laser parameters used were set according to Gurney's study and the laser application procedure was based on the protocol first suggested in 2014 by Rechmann et al.[29] This protocol recommended that the tip be placed 5 mm away from the ceramic surface and then a cross hatch pattern was drawn as if "painting with a paint brush" on the ceramic surface. This procedure resulted in between 3 to 4 minutes of laser irradiation.

Pull out test was chosen in this study, as it has several advantages over other testing methods,[30] such as having better stress distribution, the ability to test irregular surfaces and its efficiency in testing small areas. Results of the pull-out test showed statistical significance between both groups, those with laser application before debonding (group A) and those without (group B), this was in accordance with all previous studies regarding the effect of laser on debonding of either ceramic brackets, laminate veneers or full coverage crowns. But as of writing, this study is the first to prove it on endocrowns that have a much larger thickness than those previously mentioned especially in the intra-radicular portion of the endocrown present within the pulp chamber. Scanning electron microscope images of both the tooth and the restoration surface of group A showed both surfaces covered with the bonding cement indicating an adhesive failure of the cement upon laser application, which is in accordance with Morford et al.[31] findings.

CONCLUSION

According to the results of this present study, laser application, specifically that of ErCr: YSGG could be considered an effective and conservative method for the debonding and subsequent removal of all ceramic endocrown restorations.

CLINICAL SIGNIFICANCE

Some practitioners have been against the use of endocrown restorations because of the difficulty of its removal when needed, according to this present study it is advisable to use ErCr: YSGG laser in the conservative removal of such restorations.

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