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Erbium laser in the debonding of ceramics: a literature review

Laser de érbio na remoção de cerâmicas: uma revisão de literatura

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ABSTRACT

Background: The debonding of crowns and ceramic veneers with laser is already a reality in the clinic. It presents benefits in comparison to traditional removal with the use of a rotating instrument; however, there is still no consolidated protocol and many professionals use it without the necessary scientific basis. **Objective:** The aim of this work was to perform a literature review on the debonding of indirect ceramic restorations using the Er:YAG and Er,Cr:YSGG lasers to provide clinical professionals and the scientific community a careful analysis, and also to guiding the use of irradiation at laser for such procedures. **Methods:** Bibliographic searches were performed in the following databases: Pubmed, Web of Science and Google Scholar. According to the inclusion criteria adopted, twenty-seven clinical and in vitro studies were selected in the period from 2007 to 2021. In the present work, the composition of the crowns and facets, as well as the types of cement and the laser irradiation protocols adopted in the selected studies is detailed. **Conclusions:** It was concluded that the use of erbium lasers for debonding of indirect ceramic restorations proved to be more selective and conservative when compared to removal with a rotary diamond instrument. Furthermore, it was shown to be in more efficient in debonding different types of ceramics. However, there are great variations in the "debonding" protocols, which emphasizes the need for further studies that seek to standardize the irradiation protocols considering the different clinical situations.

KEYWORDS

Veneers debonding; Debonding; Er,Cr:YSGG laser; Er:YAG laser; Ceramics.

RESUMO

Antecedentes: A remoção de coroas e facetas cerâmicas com *laser* já é uma realidade clínica e apresenta benefícios em relação à remoção tradicional com uso de instrumento rotatório diamantado; entretanto, ainda não existe um protocolo consolidado e muitos profissionais o utilizam sem o embasamento científico necessário. **Objetivos:** O objetivo deste trabalho foi realizar uma revisão da literatura sobre a remoção de restaurações cerâmicas indiretas utilizando os *lasers* Er:YAG e Er,Cr:YSGG para fornecer uma análise cuidadosa aos profissionais clínicos e à comunidade científica, além de orientar o uso da irradiação a *laser* para tal aplicação. **Métodos:** As buscas bibliográficas foram realizadas, nas seguintes bases de dados: Pubmed, Web of Science e Google Scholar. De acordo com os critérios de inclusão adotados, foram selecionados vinte e sete estudos clínicos e in vitro no período de 2007 a 2021. No presente trabalho, a composição das coroas e facetas, bem como os tipos de cimento e os protocolos de irradiação *laser* adotados nos estudos selecionados foram detalhados. **Conclusão:** Concluiu-se que o uso dos *lasers* de érbio para remoção de restaurações cerâmicas indiretas mostrou-se mais seletivo e conservador quando comparado à remoção com instrumento rotatório diamantado, além de ser eficiente na remoção de diferentes tipos de cerâmicas. No entanto, existem grandes variações nos protocolos de "*debonding*", o que enfatiza a necessidade de novos estudos que busquem uma padronização dos protocolos de irradiação considerando as diferentes situações clínicas.

PALAVRAS-CHAVE

Remoção de facetas; Remoção; *laser* de Er,Cr:YSGG; *laser* de Er:YAG; Cerâmica.

INTRODUCTION

In 1964 the first laser and medical equipment were developed in the areas of ophthalmology, dermatology and general surgery. In dentistry, applications of lasers in dental tissues were first described in the 1990s, and approval for clinical use in 1997 [1]. We have some types of lasers in dentistry, among those that can be used in hard tissues, we highlight the Erbium lasers that have the ability to cut enamel, dentin, cement and bone, in addition to soft tissues, and remove some pathologies, including caries lesions. Among the advantages reported by professionals and patients when using erbium lasers for the management of hard tissues, are the reduction of uncomfortable noises, decreased intra and postoperative sensitivity, as well as a certain selectivity in the removal of tissues, as each tissue has a specific amount of water. The use of lasers in dentistry can be used in virtually all specialties [2].

Currently, erbium lasers commercially available for dental use comprise of those that emit at 2.78 μm (Erbium-chromium:ytrrium-scandium-gallium-garnet, Er:Cr:YSGG) and 2.94 μm (Erbium-doped yttrium aluminium garnet, Er:YAG) [3] wave lengths. These ones are well absorbed in both water and hydroxyapatite and the absorption by these chromophores allows the ablation of soft and hard tissues. An important detail to be considered is that the Er,Cr:YSGG laser has a greater absorption by the OH^-radicals of hydroxyapatite when compared to the Er:YAG laser, whose greater absorption occurs by the OH^- from the interstitial water. This fact allows higher temperature rises to be achieved during the ablation process performed with the Er,Cr:YSGG laser [3]. Briefly, the ablation process consists of heating and subsequent vaporization of the interstitial water, leading to micro-explosions of this subsuperficial water and the removal of the organic and inorganic portion of enamel and dentin that is above [2].

Erbium lasers are clinically applied to prepare enamel and dentin cavities, to remove decayed tissues, to improve the adhesion of direct restorations, indirect brackets and orthodontic appliances, as well as can be used for porcelain conditioning, dentin hypersensitivity management and since 2007, for the removal of crowns and ceramic veneers. The removal of ceramic crowns and veneers is traditionally performed with a diamond rotary instrument, which can be extremely time-consuming and uncomfortable for the patient. Furthermore, with the use of drills it is not possible to selectively remove enamel, resin cement or even the ceramic veneer [4]. Thus, the removal of ceramics using rotatory instruments can even cause damages in the enamel through the unnecessary removal of the tissue surface if the professional does not do it carefully and with the necessary irrigation. Depending on the energy density applied, the removal of prosthetic pieces with erbium lasers can be selective, considering the compositional differences between dental tissues, cement and ceramic prosthesis. In this way, different doses can be used to remove different tissues and materials, which is useful for preserving the remaining tissue, which cannot be achieved with the use of drills.

Erbium lasers have a strong interaction with the OH^-group present in the water molecules, so the photons will interact with the water molecules present in the resin cement, causing a photoablation it [5-7], that is why the debonding of veneers and crowns.

However, considering the wide variety of cement compositions, as well as the types and thickness of crowns and laminates, the protocols for removing these materials using erbium lasers are quite different in the literature. It is also possible to note that many dental professionals already use the equipment in the office without having appropriate knowledge about the laser conditions, as well as knowledge about the interactions of light with the tissue and even the risks involved if laser irradiation is used improperly. Considering the different dental specialties, literature shows that the use of laser irradiation as an adjunct to conventional techniques has important benefits, and some authors, such as Margolis [8], mentions that the Erbium laser is the "star wars" of dentistry. However, it is important to note that it is possible to achieve satisfactory results without causing damages to the surrounding tissues if we know this technology in depth.

For this reason, in order to guide the establishment of safe and effective protocols that use Er:YAG and Er, Cr:YSGG lasers for the removal of ceramic crowns and veneers, this study proposes to carry out a literature review on the subject.

MATERIAL AND METHODS

We carried out a literature review on the subject of debonding of ceramics with Er,Cr:YSGG laser. For that, PubMed and Web of science were used, in which manuscripts with a combination (and/or) of the following keywords were investigated: veneers debonding, debonding, Er,Cr:YSGG laser, Er:YAG laser, ceramics. The search was restricted between the years 2007 to 2021 considering that there are no publications on this subject, using laser irradiation, in prior years. As the inclusion criteria, it was considered the publication in the English language and peer-reviewed journals, proceedings, dissertations or thesis, which found 27 studies. This search was carried out by two authors working independently of each other and, after the research, the findings were compiled.

RESULTS

Twenty-seven studies were selected for further analysis, including clinical cases, in vitro studies, ex vivo studies and a master's dissertation. In these works, the removal of crowns and laser veneers was approached in different ways, with changes in parameters, types of resin cement, types of ceramics and others. For didactic effects, the results were tabulated according to the type of study: Clinical Cases (Table I), master´s dissertation (Table II), in vitro Studies. (Table III).

CRITICAL REVIEW

The first work on the subject reported in the literature was published in 2007 by Broome [9] in the proceedings of the Pract Proced Aesthet

Table I - Articles from Congress proceedings (Pract Proced Aesthet Dent) and clinical cases

Author (Country, year)	Patients	Ceramic	Cement	Laser	Laser Parameters			Irradiation Time (s)	Density Energy (J/cm²)
					Mean Power (W)	Repetition rate (Hz)	Energy per pulse (mJ)		
Broome (USA, 2007) [9]	ND	Feldspatic	ND	Er,Cr:YSGG	4	25	ND	5-30	ND
Van As (Canada, 2012) [10]	3	IPS Empress Esthetic	Resin Cement	Er:YAG	5.25	30	175	30-45	ND
		IPS Empress Esthetic	Cyanoacrylate Cement	Er:YAG	5.25	30	175	45	ND
		Lithium Disilicate (IPS e max)	Resin Cement	Er:YAG	6	30	200	120	ND
Kursoglu and Gursoy (Turkey, 2013) [11]	2	IPS Empress Esthetic	Resin Cement	Er:YAG	3.5*	20	320	9	~25.5*
		IPS Empress Esthetic	Resin Cement	Er:YAG	3.5*	20	320	9	
Cranska (USA, 2013) [12]	3	Monolithic Zirconia	ND	Er:YAG	2.0	15	135	~60	27*
		Zirconia	Resin Cement	Er:YAG	1.6	8	200	ND	40*
		Presable	ND	Er:YAG	2.0	15	135	ND	27*
Cranska (USA, 2015) [13]	3	Lithium Disilicate	Resin Cement	Er:YAG	3.0	15	200	ND	40*
		Monolithic zirconia	ND	Er:YAG	2.0	15	135	~120	27*
		Bilayered zirconia	Resin Cement	Er:YAG	3.0	15	200	ND	40*
Spath and Smith (USA, 2017) [14]	1	ND	ND	Er:YAG	5	15	600	~120	21.23*
Calabro et al. (Brazil, 2019) [15]	1	Lithium disilicate	Resin Cement	Er:YAG	5	20	250	12 sec to 11 minutes (variation depending on the tooth)	ND
Bernal et al. (Brazil, 2021) [16]	1	Lithium disilicate	ND	Er:YAG	3.4 to 4	20	0.16 to 0.2	~5400 (for 6 elements)	25.39 – 31.74

* Calculated by the authors. ND: Not detailed.
Source: article authors.

Table II - Master's dissertation, in vitro study

Author (Country, year)	Samples	Ceramic	Cement	Laser	Laser Parameters			Irradiation Time (s)	Density Energy (J/cm²)
					Mean Power (W)	Repetition rate (Hz)	Energy per pulse (mJ)		
Phillips (USA, 2012) [17]	30 (6 per group)	Lithium disilicate	resin cement	Er,Cr:YSGG	0	0	0	300	~0*
					2.5	25	100	146	~35.38*
					3.5	25	140	51	~49.53*
					2.5	35	71	300	~25.12*
					3.5	35	100	109	~35.38*

* Calculated by the authors.
Source: article authors.

Dent Congress. In this work, the Er,Cr:YSGG laser was used to peel off the feldspar ceramic as per the protocol mentioned in Table I. Broome [9] describes the mechanism by which the facets were peeled off as a “denaturation” of the resin cement. He suggested that the laser energy passes through the laminate to interact with the ceramic-resin interface, where it selectively excites the water molecules in the resin. The author also noticed that feldspar ceramic veneers take between 5 and 30 seconds to remove, while pressed ceramics usually take between 20 seconds and 2 minutes, looking at darkened areas where there should be “denatured” resin, which he said was polished. After clinical observation, the author also pointed out that the dental structure below the facet was not affected by the laser irradiation, requiring only minor corrections in the preparation for making new laminates [9]. As it is a pioneering work in the area, we consider the author’s conclusions subjective since some methodological details have not been thoroughly described. In addition to that, the analysis carried out in a non-blind manner by a unique examinator may have promoted a bias conclusion of the study.

Following the reports of clinical cases in chronological order of publication, we noted the work of Van As [10] in 2012. This author removed crowns with an Er:YAG laser in the parameters presented in Table I, and concludes that the erbium laser has the ability to quickly remove all-porcelain restorations without causing iatrogens to the underlying dental organ. In addition, the author reported that the use of lasers for this purpose represents great promise for the triad of dental surgeons, patients and dental technicians. However, stated more research was needed to establish adequate protocols for each clinical situation. But, emphasising there was no doubt that the promise of erbium lasers for deboding veneers is an interesting alternative to the traditional methods used today.

In 2013, the work of Kursoglu and Gursoy [11], reports the use of the Er:YAG laser to remove venners in two clinical cases. For removal, the scanning method used was that described by Oztoprak et al. [6,33], with horizontal movements parallel to the structure and irradiation with a focal length of 2 mm. In this study, debonding was recommended due to the presence of fractures due to parafunctional habits, a common occurance when the patient has parafunctional habits, such as bruxism or tightness and does not use relaxation plates. Cranska published clinical cases in 2013 [12] and 2015 [13] using the Er:YAG laser to detach crowns and veneers. In the article published in 2015, the author reported that patients volunteered for the research after reading the previous article published in 2013, in search of treatment performed with laser irradiation. Thus, the authors emphasize the importance of scientific dissemination for the lay population.

In both studies above, the authors concluded that the laser enabled faster, easier and safer removal, but that more research is needed to establish adequate protocols for each clinical situation.

Spath and Smith [14] published clinical case reports in 2017 also using Er:YAG, along with a discussion of the types of materials, preparations and resin cements to be used. The authors concluded that the laser is the most conservative and efficient method of debonding different types of ceramics, especially in the anterior region. If there is adequate retention and strength, a traditional RMGI (resin-modified glass ionomer) cement would be indicated due to its moisture tolerance, easy cleaning and more predictable removal.

Table III - *In vitro* works

Author (Country, year)	Sample	Ceramic	Cement	Laser	Laser Parameters			Irradiation Time (s)	Density Energy (J/cm^2)
					Mean Power (W)	Repetition rate (Hz)	Energy per pulse (mJ)		
Morford et al. (USA, 2011) [5]	10 (5 for each group)	IPS Empress Esthetic	Resin Cement	Er:YAG	0.70-3.5*	10	133	113±76	14*
	10 (5 for each group)	Lithium Disilicate	Resin Cement	Er:YAG	0.93-2.3*	10	133	100±42	14*
Oztoprak et al. (Turkey, 2012) [6]	80	IPS Empress II (Lithium disilicate)	Resin Cement	Er:YAG	5	50	100	3.6 and 9	12.73*
Iseri et al. (Turkey, 2014) [7]	60	IPS Empress II (Lithium disilicate)	Resin Cement	Er:YAG	5	50	100	9	12.73*
Rechmann et al. (USA, 2014) [18]	ND	IPS Empress Esthetic (EE) E.max CAD E.max ZirCAD)	Resin Cement	Er:YAG	1.26 and 5.08*	10	Pulse duration of 100μs at 126 mJ/ pulse up to 300 μs at 508 mJ/ pulse.	~100	~13.26* - ~53.5*
Rechmann et al. (USA, 2014) [19]	ND	IPS E.max CAD Lithium-disilicate (LS2) IPS E.max ZirCAD Zirconiumoxide (ZrO2)	Resin Cement	Er:YAG	~0.55 and 1.89*	10	Pulse duration 100μs at 126 mJ/pulse, and 400ms at 590mJ/ pulse).	E.max CAD 190±92 ZirCAD featheredge crowns was 226±105 ZirCAD crowns with regular margin it was 312±102	~13.26* - ~62.11*
Rechmann et al. (USA, 2015) [20]	20	IPS E. max (Lithium Disilicate)	Resin Cement	Er:YAG	ND	10	560	135±35	~59*
Gurney et al. (USA, 2016) [21]	20 (5 for each group)	IPS E. max (Lithium Disilicate)	Resin Cement	Er,Cr:YSGG	3	25	ND	30 to 90	ND
					3.5	25		30 to 90	
					4	25		30 to 90	
					5	25		30 to 90	
ALBalkhi et al. (Syria, 2018) [22]	48 (8 for each group)	IPS E. max (Lithium Disilicate)	Resin Cement	Er:YAG (No-Contact)	5.4	15	360	~66.66*	~37.9*
				Er:YAG (Contact)	5.4	15	360	~66.66*	~37.9*
				Er:YAG (No-Contact)	4	10	400	~100*	~42.11*
				Er:YAG (No-Contact)	4	15	270	~67.5*	~28.42*
				Er:YAG (No-Contact)	3	10	300	~100*	~31.58*

* Calculated by the authors. ND: Not detailed.
Source: article authors.

Table III - Continued...

Author (Country, year)	Sample	Ceramic	Cement	Laser	Laser Parameters: Mean Power (W)	Laser Parameters: Repetition rate (Hz)	Laser Parameters: Energy per pulse (mJ)	Irradiation Time (s)	Density Energy (J/cm²)
Karagoz-Yildirak and Gozneli (Turkey, 2020) [23]	30 (15 for each group)	Leucite Lithium Disilicate	Resin Cement	Er:YAG	3	10	300	ND	~47.61*
Grzech-Leśniak et al. (USA, 2019) [24]	40 (20 for each group)	Lithium Disilicate / titanium implant abutments	Resin Cement (CR) and Glass Ionomer (RMGI)	Er:YAG	4.5	15	300	CR(Resin Cement) ~196.5 RMGI (Glass Ionomer) ~97.5	~47.61*
Deeb et al. (USA, 2019) [25]	30 (10 for each group)	Lithium disilicate / zirconia implant abutments	resin cement	Er:YAG	4.5	15	300	LT(Long-term): 4 min 42s LTR(Long-term Recemention): 3 min 24 s LTRR(long-term repeated recemention):3 min 12 s	~47.61*
Yilmaz et al. (Turkey, 2019) [26]	20	Lithium disilicate	resin cement	Er,Cr:YSGG	5.5	20	275	180	~97.31*
Alikhasi et al. (Iran, 2019 [27]	57 (19 for each group)	Feldspathic Lithium disilicate MO (medium opacity) Lithium disilicate HT (high translucency)	Resin Cement	Er,Cr:YSGG	2.5	25	ND	103.68 ± 26.76 106.58 ± 47.22 103.84 ± 32.90	ND
Zhang et al. (USA, 2020) [28]	12	ND	Resin Cement	Er:YAG	~0.2 - 0.6*	30	100	328 ± 156	~19.94*
Giraldo-Cifuentes et al. (Colombia, 2020) [29]	42 (21 for each group)	Feldspathic	Resin Cement	Er,Cr:YSGG	3 4	50 100	360J 240 J	~120 ~60	4 2.7
Rabelo et al. (Brazil, 2020) [30]	10	Lithium Disilicate	Resin Cement	Er,Cr:YSGG	1.41	20	~70	~17.73	~25
Zanini et al. (Brazil, 2020) [31]	15 (5 for each group)	Lithium disilicate	Resin Cement	Er,Cr:YSGG	3 3.5	20	~113 ~136	~13.75 ~13.33	40 48.14
Golob-Deeb et al. (EUA, 2021 [32]	12 13	Zirconia	Resin-modified glass ionomer cement (RMGI)	Er:YAG Er,Cr:YSGG	4.5 4.5 5	15 15	300 300	1 m 33.8 s 1m 31.5 s 2m 34.7 s 3m 53.1 s	ND

* Calculated by the authors. ND: Not detailed.
Source: article authors.

Calabro et al. [15] published a clinical case report in 2019 in which the removal of 11 laminate veneers was also performed using Er:YAG. These were made of lithium disilicate with different thicknesses, 0.4 mm and 2.5 mm and had been cemented for 4 months with light-cured resin cement. As the thickness of the laminates was not the same, the removal time was over a variation and averaged 2 min 36 sec. According to the authors, the laminate veneer debonding was satisfactory and presented comfort during the procedure for both the patient and the dentist, mainly for the reduced time of the procedure and for the preservation of the remascating dental organ.

Bernal et al. [16] used the Er:YAG laser, without contact and with an average power of 3.2 to 4.0W and 20 Hz to remove the porcelain prosthesis, as the patient was not satisfied with the final aesthetic result and underwent a 1-year follow-up. The interesting thing about this clinical work is that the removal and cementation of the new crowns were performed on the same day. We see then the union of technologies in this case, as the laser and the Cad-Cam were used to streamline the rehabilitation process. The authors report the laser efficiency in debonding mainly by reducing the working time by 75% when compared to the diamond rotary instrument and highlight that this occurred due to the photoablation that the laser causes in the resin cement.

An important point to be discussed, considering the analysis of the manuscripts mentioned above, is that they are clinical case studies, without the presence of a randomized double blind clinical procedure with an adequate number of patients. Clinical cases, despite arousing the interest for new research to be carried out, give a partial and subjective idea of the real effects of the laser on the dental organ and its adjacent structures, as they present conclusions related to clinical observations without the application of a due statistical test with their standard deviations.

Considering now the study mentioned in Table II, Phillips [17] in 2012 performed a temperature analysis during the Er,Cr:YSGG laser irradiation of 5 different protocols. The temperature measurement was made using a thermocouple, which was left at rest until the reading inside the pulp chamber stabilized at room temperature. At that point, the HH506RA computer software was programmed to take temperature readings at one second intervals and a stopwatch to record the removal time. The author concluded that some protocols can increase the temperature of the pulp even using the water coolant. Furthermore, the 2.5 W / 25 Hz laser group was the safest protocol for removing veneers. Phillips [17] also reports that, after removing some specimens from the veneers, areas of what appeared to be carbonized resin cement were frequently observed both on the surface of the prepared tooth and on the internal surface of the veneer, although the author used refrigeration (30% water / 70% air). This observation is in agreement with the results of other studies [4,34,35], which also concluded that carbonization, fusion and other morphological changes on the tooth surface are more prominent when there is no water jet acting on the target site. According to Phillips [17], during the removal of the prostheses, the water spray is retained on the surface, while the photons heat the cement layer below and, therefore, there is no water in that location. Thus, the cooling effect of the air-water spray should eventually reach the resin-varnish interface; however, for a short period after the initial application, the laser is acting independently of any external cooling effect. For this reason, the author concludes that it would not be surprising to find that intrapulp temperature changes during removal of the laser laminate would be greater than intrapulp temperature changes during cavity preparation using the same laser protocols.

In 2015, Rechmann et al. [20] also performed a temperature analysis during take-off of total ceramic crowns with an Er:YAG laser. They detected an average takeoff time of 135 ± 35s and an increase of 5.4° ± 2.2° C in temperature at the ceramic-cement interface during debonding. The authors emphasize that in 12 of the 20 debonding procedures, the temperature never exceeded 5.5° C. During the remaining eight debonding procedures, the maximum observed temperature was 11.5° C for approximately 15 s in a single sample, while in the remaining seven samples the temperature increase was limited to 6.8 ± 0.5 C. After the temperature peaks occurred, they decreased to a range of 2 to 4° C above room temperature.

The increases above 5.5° C occurred when the irradiations were performed on one side and the additional cooling of the dental syringe on the opposite side to the irradiation. Considering the results reported, it is emphasized the importance of using the correct laser protocols to avoid irreversible damage to the pulp taking into account the classic study of Zach and Cohen [34] that affirm that the pulp temperature increase cannot exceed 5.5° C. The authors also argue that, using lower energies per pulse, it was noticed deterioration of the resin cement and the increase in the removal time, but it reduced the chances of having a harmful temperature increase in the pulp. In this work, it was also observed a large standard deviation due to the low number of samples and due to higher variations considering the time of irradiations and use of the water / air jet. The two studies that studied temperature rises during the removal of veneers emphasize the importance of refrigeration at the time of irradiation, in addition to showing that other factors such as ceramic and resin cement thickness, as well as the irradiation time and amount of energy delivered, can have a positive correlation with the increase in temperature.

The first in vitro study on this subject was published by Morford et al. [5] in 2011. In this work, the Er:YAG laser was also applied to remove facets from human incisors and, to determine the absorption characteristics in the infrared spectral range of the resin cement used, the authors performed FTIR (Fourier transformed infrared spectroscopy) analysis of cements and veneers. FTIR technique revealed a strong peak probably related to silica (1100 cm^{-1}) and also determined that EE (vitroceramic leucite) veneers do not have characteristic bands of H_2O / OH-absorption (3750-3640 cm^{-1} and 3600-3400 cm^{-1}, respectively). The pressed ceramic veneers demonstrated the same characteristic absorption peaks (a strong peak of silica can overlap a phosphate peak, since the veneer contains small amounts of phosphate) and without water absorption bands. Thus, the authors predicted that the photons of the Er:YAG laser are not absorbed, but can be transmitted through the porcelain veneer. In addition, the authors showed that the FTIR spectra of RelyX shade A1 cement showed a strong peak probably related to silica (1100 cm^{-1})and a broad H_2O / OH absorption band (3750 to 3640 cm^{-1} and 3600 to 4400 cm^{-1}, respectively), which corresponds to the emission wavelength of the Er:YAG laser. Thus, RelyX cement absorbs photons from the Er:YAG laser and the ablation of this cement occurs. Therefore, it was observed that the photons of the laser are not absorbed by the facets or crowns, but pass through this material and will interact with the resin cement, promoting photoablation due to absorption by the silica and carbon that constitute the resin cements.

Oztoprak et al. [6] in 2012 and Iseri et al. [7] in 2014 used the Er:YAG laser on lithium disilicate discs bonded to bovine incisors with resin cements. Both works carried out shear strength tests and concluded that the laser reduces the shear stresses of resin cements when compared to non-irradiated groups, and the discs were easily removed from the teeth. The scanning method performed with horizontal movements parallel to the surface, described by Oztoprak et al. et al. [6] is used in several works in the literature, and is also described by the same author in a study carried out for the removal of polycrystalline ceramic brackets [33]. Yilmaz et al. [26] concluded in their study the same fact and added that acid attack adhesive systems showed higher values of shear strength when compared to self-etching systems.

In 2014, Rechmann et al. [18] and Rechmann et al. [19] published two articles on the removal of zirconia and lithium disilicate crowns with the Er:YAG laser. As performed by Morford et al. [5], these authors carried out analysis using FTIR spectroscopy and observed that the ceramic did not have water absorption bands, but the resin cement presented a broad absorption band for H_2O and hydroxyl group. In addition, they found that, depending on the thickness of the ceramic, it transmits between 21% to 60% of the incident laser energy (for the EE-IPS Empress Esthetic-and E.max CAD groups), while the E.max ZirCAD material transmitted only 5% -10% of the incident energy. They concluded that these pulse energies are sufficient to cause photoablation in the resin cement and that the Variolink Venner needed 44% less energy from the laser to be detached. In the second part of the manuscript published in 2014, the researchers observed that all crowns were detached without fractures and damage to the underlying dentin. In resin cement, a deterioration was observed, but no carbonization in dentin and / or in the resin cement interface due to laser irradiation was detected. It was possible to show that different irradiation times may be necessary to detach different materials [19]. These works reveal why it is so difficult to have at an unique laser protocol for removing veneers. For establishment of the protocol, several factors should be considered, such as type of ceramic, material thickness, type of resin cement or not, since we have works that use resin-modified glass ionomer and show us the importance of advancing research in this field. The study of AlBalkhi et al. [22] reported different experimental groups by changing the laser irradiation parameters and the contact mode (contact and non-contact). The authors detected that the contactless mode was more efficient, since the withdrawal of the ceramics was performed more quickly (average of 12.6 s and 96.3 s in the groups without contact and with contact, respectively). The take off tests were performed with different laser parameters and it was noticed that the greater the power used, the shorter the detachment time and the higher the pulp temperature observed. The most observed fracture pattern was types 1 (adhesive failure between the internal surface of the varnish and resin cement) and 3 (resin cement fails in cohesive cementation). Giraldo-Cifuentes et al. [29] used the Er,Cr:YSGG laser and analyzed the fracture pattern after irradiation for ceramic removal. and observed that the fracture pattern was predominantly adhesive in both protocols used (4.0 and 2.7 J/cm^2).

Karagoz-Yildirak and Gozneli [23] applied the Er:YAG laser to remove lithium and leucite disilicate discs cemented in enamel and dentin. The authors compared the shear strength between irradiated and non-irradiated groups. After the shear test, some of them were subjected to re-bonding and a new adhesive strength test and fracture pattern analysis. The authors concluded that irradiation was an effective method for removing ceramic restorations and suggested that there is a relationship between the bond strength values and the failure modes. Similar to what was observed by ALBalkhi et al. [22] and Giraldo-Cifuentes et al. [29], the control and redebonding groups exhibited high bond strength to dental surfaces and most failures in the control and redeboding groups were adhesive and cohesive. According to the authors, the tooth surface and restoration would remain untouched and undamaged. The removal of all-ceramic restorations using the Er:YAG laser did not affect the values of the rebonding force in this protocol.

Yilmaz et al. [26] and Alikhasi et al. [27] both published in 2019 and used the Er,Cr:YSGG laser for the debonding of ceramic veneers. The first study aimed to assess whether different ceramic thicknesses (0.5 mm, 1 mm and 2 mm) and the type of resin cement used could influence the moment of debonding and concluded that the average shear strength decreases as decreasing the thickness of the veneer. In addition, it concluded that total etch type adhesive systems present higher values when compared to self-etching adhesive systems. The second paper, investigated the average variation in veneer removal time according to the type of material 103.68 ± 26.76, 106.58 ± 47.22 and 103.84 ± 32.90 seconds for feldspathic, lithium disilicate MO and lithium disilicate HT, respectively. The author also analyzed the increase in intrapulpal temperature during irradiation and found that it was below 1 °C in all groups following the protocols described in Table III, but a limitation of this study is the fact that the authors used bovine teeth instead of human teeth

Zhang et al. [28] utilized the Er:YAG laser to remove 12 ceramic facets whose composition was not detailed by the authors. After removing the laminates, a morphological analysis was performed using scanning electron microscopy (SEM), in addition to counting the number of pulses during irradiation. The morphological analysis confirmed that the structure of the dentin was not altered when using low energy density (19.94J/cm^2). In addition, the removal occurred without ablation or damage to any dental structure. Despite the data provided by the article, the sample number experimental group was very low (n=12), which leads to a large standard deviation, in addition to the lack of a control group to compare the morphological analyzes.

Grzech-Leśniak et al. [24] used the Er:YAG laser for debonding lithium disilicate crowns from titanium abutments and in November 2019 the same researchers published an article also using the Er:YAG laser to remove lithium disilicate crowns cemented in zirconia abutments [25]. Morphological and temperature analysis was performed in both articles. In their first published work, they used two types of cement, resinous and modified glass ionomer, and concluded that it is faster to remove lithium disilicate crowns with titanium abutments cemented with glass ionomer. The temperature increase was greater in the crown compared to the implant abutment.

The type of cement did not affect the temperature changes.

The heat generated by Er:YAG irradiation did not appear to be high enough to have an adverse effect on implant osseointegration (From 1 to 10 minutes of irradiationranged from 18 ° to 20.8 ° for CR and 18 ° to 23 ° for RMGI on the abutment surface, and 22.1 ° to 24.6 ° for CR and 22 ° to 24.8 ° for RMGI on the crown surface). In the second paper, the variable cementation time was added, in which ten crowns were removed in 48 hours after cementation (short-term group - ST), while another 10 were removed for 6 months after cementation (long-term group - LT). To simulate a clinical situation and the possibility of reusing the crowns removed, the LT group was then collected after 48 hours (LTR). The LTR crowns were replaced again after 48 hours (LTRR). The authors concluded that long-term cementation may increase the removal time of zirconia abutment lithium disilicate crowns using Er:YAG, and this is not an invasive tool for removing stuck cement implants and should be considered a viable alternative. for rotary instruments related to the use of erbium laser for removal of crowns in implants.

Rabelo et al. [30] used the Er,Cr:YSGG laser to peel off ceramic veneers in human teeth submitted to a simulation of radiotherapy in vitro by gamma radiation. The SEM images showed degradation of prismatic structure of enamel after gamma + laser irradiation, which suggests that acid reconditioning for new laminate veneer bonding could be compromised and, mainly, that laser laminate removal protocol in a patient who has undergone radiation therapy to treat head and neck cancer shouldn´t be the same as that used for normoreactive patients.

Using the same laser, Zanini et al. [31] demonstrated the possibility of removal of RelyX U200 cement when used for bonding veneers. The authors reported that the Er,Cr:YSGG laser does not cause morphological changes in the enamel prisms when used for debonding, but that the attenuation coefficient values generated by the optical coherence tomography technique (OCT) suggest that the heat generated during irradiation can lead to interprismatic changes, probably related to chemical ones. In this study it was evidenced the importance of intensifying research aimed at controlling temperature during irradiations. This last study also confirm the findings evidenced by Phillips [17] and Rechmann et al. [20], which carried out a study in the area with the Er,Cr:YSGG and Er:YAG laser, respectively. Both report that if the laser is not used correctly, pulp damage may occur due to temperature increases.

The last study published until the beginning of 2021 was Golob-Deeb et al. [32], a very interesting study that carried out the analysis of temperature increase, removal time and morphological analysis of the remaining enamel. during irradiations with the Er:YAG and Er,CR:YSGG lasers. The work concludes that the average time for crown removal using the Er:YAG laser was 1 min 32.7 sec; for the Er,Cr:YSGG laser was 3 min 13.9 sec. The average temperature changes were 1.41 ± 1.36 °C for the Er:YAG laser and 2.2 ± 0.99 °C for the Er,Cr:YSGG laser. Additionally, through SEM analysis no damage or structural changes caused by the laser treatment of the erbium family was observed, in agreement with the work of Zanini et al. [31]. Despite the work having very promising results, we see as a disadvantage of the study the fact that they used resin-modified glass ionomer cement (RMGI) as cementation material, and this is not the material of choice for cementation of crowns and veneers of ceramic.

DISCUSSION

Debonding with Erbium lasers is promising, as it is a very conservative intervention. The interaction of the laser occurs in the resin cement, more specifically promoting the photoablation of this material, as was demonstrated in the FTIR findings [5]. Er:YAG has great interaction with water and its absorption peaks are 3 μm and 10 μm, while Er,Cr:YSGG has strong interaction with the hydroxyl groups present in the resin cement molecules. The literature suggests that the morphological differences between cavities prepared with the two types of erbium lasers are practically null. Considering the difference in wavelength between Er:YAG (2,940 nm) and Er,Cr:YSGG (2,780 nm), it appears that surfaces irradiated with an Er,Cr:YSGG laser are more thermally affected than those irradiated with a laser Er:YAG [30,31,33,34]. The optical penetration depth of erbium lasers is only a few micromometers: 7 μm in enamel and 5 μm in dentine) [36], but the thermal penetration is greater than the optical penetration. This spread of heat to the adjacent tissues causes chemical changes in the enamel, as observed by the changes in the attenuation coefficients detected by Zanini et al. [31].

A very convenient way to decrease the heat generation on surface and in the pulp chamber is to cover the operation site with a thin layer of water [2]. Thus, a water spray with all erbium lasers is necessary to act as a heat sink and to avoid thermal damage to the underlying tissue. However, the work of Phillips [17] showed that even using water in some protocols, the temperature can rise above 5.5º C depending on the laser energy per pulse adjusted. Rechmann et al. [20] also observed an increase in temperatures above 5.5º C and concluded that irrigation performed improperly can lead to a harmful increase in temperature. In addition to irrigation, other factors may influence in the protocol, such as: composition of the ceramic, its thickness, the type of resin cement and the type of preparation that was made.

We cannot say which protocol is the most adequate or even the statistically ideal one, as we observed studies with quite divergent methodologies due to the large number of variables and combinations, the literature has of the items mentioned previously. Most of clinical studies used a smaller sample size than the ideal, increasing the chance of assuming as true a false premise for the proposed laser treatment technique.

Hence the importance of developing new studies including new materials and techniques that are constantly changing and enter the market every day, with such differentiated characteristics. Although we know that the topic has some limiting factors, including the high investment to develop the studies.

Despite the above, we have within our reach a technology that has real potential to cause less damage when compared to rotary diamond instruments at the time of take-off. It has advantages for both the dentist and the patient, but it must be used with caution in the appropriate parameters for each clinical situation.

CONCLUSION

This literature review showed that:

- Laser take-off is more conservative for different types of ceramics;
- Care must be taken with the temperature rises during irradiations, but when used with the appropriate irrigation protocol of the equipment itself, damage can be avoided;
- There are different protocols used which depend on the type of ceramic and its thickness, type of cement, type of laser, irrigation systems and spray positioning;
- Both Er:YAG and Er,Cr:YSGG lasers are promising and effective lasers for debonding ceramic veneers and crowns, as long as they are employed under safe protocols.

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Authors' Contributions

NAZ: Preparation, data collection, data analysis, Review and editing of the manuscript and rafted the manuscript. ACJ: Preparation, data collection, data analysis, Review and editing of the manuscript. PAA: Preparation, data collection, data analysis, Review and editing of the manuscript. DMZ: Preparation, data collection, data analysis, Review and editing of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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Regulatory Statement

This literature review was conducted through a search strategy in the following electronic databases PubMed, Web of Science and Google Scholar. The search was restricted to publications in the English language in peer-reviewed journals, proceedings, dissertations or theses, in which approval for ethics committee were obtained in their original work.

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