Received: 8 October 2017 | Accepted: 6 December 2017

DOI: 10.1111/jerd.12360

REVIEW ARTICLE

WILEY

Laser-assisted removal of all ceramic fixed dental prostheses: A comprehensive review

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Abstract

Objective: The aim of this comprehensive review was to assess the effectiveness of erbium lasers in the removal of all ceramic fixed dental prostheses (FDPs).

Overview: Indexed databases were searched without language or time restriction up to and including December 2017 using different combinations of the following keywords: "lasers"; "phototherapy"; "crowns"; "prostheses and implants"; "inlays"; "ceramics"; "dental porcelain"; "zirconium"; "removal"; "debonding"; "fixed dental prostheses"; "veneers"; "laminates"; and "fixed bridge." All levels of available evidence including experimental studies, case reports and case series were included. Six clinical studies reporting a total of 13 cases and 6 experimental studies were included. Results from all studies showed that erbium lasers are effective reducing the shear bond strengths of all ceramic FDPs, in terms of easy removal of the restorations with none or minimal damage to teeth or ceramic surfaces.

Conclusion: Laser-assisted removal of all ceramic FDPs is a promising treatment protocol. Further well-designed controlled clinical trials and longitudinal prospective studies are needed to determine the precise laser parameters and duration of irradiation that could be used for removal of ceramic restorations with varying thicknesses.

Clinical significance

Benefits of lasers over mechanical instrumentation for crown removal encompass efficient restoration retrievability without restoration or teeth surfaces damages; and relatively easier and time effective procedure with no prerequisite for anesthetic agents. It is however imperative for clinicians to be well-trained and exhibit adequate knowledge regarding recommended power settings and laser-safety parameters with reference to interactions between light and different tissues and ceramics.

KEYWORDS
dental materials, prosthodontics

1 | OBJECTIVE

With advancements in modern dental practice and a society with higher esthetic demands, all ceramic fixed dental prostheses (FDPs) have gained popularity among patients and clinicians;[1–3] and are considered a "gold standard" for the restoration of damaged and/or missing teeth.[1] All-ceramic materials, such as lithium disilicate, offer excellent optical effects by mimicking enamel and dentin properties, and are widely used for veneers, reconstructions in the anterior region, and single-unit FDPs.[2,3] Moreover, the new generations of ceramics (such as zirconia) offer also high mechanical stability, and are commonly used as single and multiple-unit posterior FDPs.[4] However, the incorporation of all ceramic FPDs into dental practice has also challenged clinicians in terms of their removal for functional, biological or esthetic failures.[5] Although metal ceramic FDPs (flexure strength of ~120 MPa) are easily sectioned using a diamond or tungsten carbide bur; removal

of all ceramic FDPs (flexure strengths ranged between 200 and 1000 MPa) might be time consuming and distressful for the patient.[6–8] Likewise, higher bond strengths offered by resin-based cements, commonly used to cement all ceramic FDPs, may challenge clinicians' by offering resistance towards a smooth dislodgement of metal ceramic FDPs. Moreover, despite the use of local anesthetic agents, use of traditional instruments used for crown removal, (such as trial crown tractors, chisels and sliding hammer removers or automatic removers), may be a source of discomfort for many patients,. Furthermore, its often demanding to differentiate between the tooth-colored resin based cements and actual dental tissues during sectioning of FDPs using high-speed burs.[9]

A limited number of studies[6,7,10–19] have reported the use of erbium lasers as a suitable alternative to remove all ceramic FDPs. Erbium lasers such as erbium, chromium:yttrium scandium gallium-garnet (Er:CrYSGG) and erbium:yttrium-aluminum-garnet (Er:YAG) emit light at a wavelength ranging between 2780 nm and 2940 nm.[20] The light emitted by Er:YAG lasers is well-absorbed by hydrated biological tissues, including dental hard tissues (such as enamel and dentin).[17] Therefore, Er:YAG lasers are commonly used to remove caries and treat the surfaces of restorative materials.[21–23] Likewise, Er:YAG lasers have also been used to debond ceramic brackets.[24,25] Studies[26,27] have proposed that Er:YAG lasers light be transmitted through the ceramic brackets and be selectively absorbed by water molecules and residual monomers in the resin cements, resulting in reduced bond strengths and ceramic brackets debonding from the teeth surfaces. Based in these mechanisms, the first report regarding the use of erbium laser in the removal of FDPs appeared nearly a decade ago. In a case- report, Broome[10] reported the removal of 8 feldspathic veneers with an Er:CrYSGG laser. The results showed no evidence of surfaces damage in teeth or veneers.[10] Experimental results by Rechman et al.[6] showed that Er:YAG laser can debond all ceramic crowns (lithium-disilicate and zirconium-oxide) without damaging underlying tooth structures. Similar results have been reported in other experimental[7,13–15,19] and clinical[10–12,16–18] studies. However, to date there are no guidelines available for laser-assisted removal of all ceramic FDPs. Moreover, a review of indexed literature assessing the role of erbium lasers in the removal of all ceramic FDPs is yet to be documented. Therefore, the aim of this comprehensive review was to assess the effectiveness of erbium lasers in the removal of all ceramic FDPs.

2 | OVERVIEW

All levels of available evidence including experimental studies (*in vitro* and *ex vivo*), case reports and case series were included. Review articles, commentaries and letters to the editor were not sought. PubMed (National Library of Medicine), Google-Scholar, Scopus, EMBASE, MEDLINE (OVID) and Web of Science databases were searched without language or time restriction, up to and including December 2017 by two authors (SVK and VRM) to identify studies that assessed the role of erbium lasers in the removal of all ceramic FDPs. The following Medical Subject Headings (MeSH) were used: (1) lasers, (2) phototherapy, (3) crowns, (4) prostheses and implants, (5) inlays, (6) ceramics, (7) dental porcelain and (8) zirconium. Other related non-MeSH terms that were used included: (a) removal; (b) debonding, (c) fixed dental prostheses, (d) veneers, (e) laminates, and (f) fixed bridge. To identify articles that could have been missed during the initial search, hand searching of the reference list of potentially relevant studies was also performed. Any disagreements among the authors (SVK and VRM) in the study selection were resolved via discussion and consensus among the authors.

Six clinical studies[10–12,16–18] reporting a total of 13 cases were identified. These cases were reported between the years 2007 and 2017, in the following countries: Canada, Turkey and United States of America. Three studies[10,17,18] reported 5 cases where erbium lasers were used to remove 17 ceramic veneers; whereas, 4 studies[11,12,16,17] reported the removal of 19 ceramic crowns. The general characteristics of the clinical studies[10–12,16–18] are summarized in Table 1.

Six experimental studies[6,7,13–15,19] assessed the efficacy of erbium lasers in the removal of FPDs, out of which, in 3 studies[14,15,19] veneers were debonded and in 3 studies[6,7,13] crowns and/or copings were removed using erbium lasers. Rechmann et al.[7] evaluated temperature changes in the pulp chamber during laser assisted removal of all ceramic crowns. Gurney et al.[13] compared the time required to remove lithium disilicate crowns using erbium laser and high-speed with diamond burs. The results showed that laser assisted removal of lithium disilicate crowns can be fulfilled in 60–90 s, compared with approximately 360 s with high-speed and diamond burs.[13] Characteristics and outcomes of the experimental studies[6,7,13–15,19] included in this comprehensive review are summarized in Table 2.

Results from all experimental[6,7,13–15,19] and clinical[10–12,16–18] studies showed that erbium lasers are effective in reducing the shear bond strengths of all ceramic FDPs, resulting in an easy removal of the restorations with none or minimal damage to teeth or ceramic surfaces. An explanation for these findings is that the wavelength of Er:YAG lasers (2940 nm) coincides with the main absorption band of water.[28,29] Studies [5,26] have suggested that laser energy is transmitted through the ceramic and vaporizes the components of resin cements (water molecules or residual monomers) by a mechanism known as thermal ablation. This mechanism involves vaporization followed by hydrodynamic ejection.[5] The restoration can be removed intact without any residual cement in the inner surface; the residual cement remains attached to the tooth structure and can be easily removed with a polishing cup, a dull instrument or gauze.[10,13,17] It is therefore tempting to speculate that erbium lasers are a valuable and predictable tool for the removal of all ceramic FDPs.

According to a seminal study by Zach and Cohen,[30] intrapulpal temperature rise of 5.5°C (10°F) can result in thermal trauma and irreversible pulpal necrosis. Studies[31,32] have shown that during cavity preparation and caries removal with Er:YAG lasers, the pulp chamber temperature rise is below the critical value of 5.5°C. An in vitro study[33] compared the temperature variation during tooth preparation between high speed burs and Er:YAG laser, concluding that both interventions generated similar heat increases under water cooling. Therefore, Er:YAG lasers are considered a safe procedure in regard to pulpal

TABLE 1 General characteristics of clinical studies reporting all ceramic FDPs removal with lasers

Author (Country, year)	Cases	Gender (age)	Number of restorations (site)	Ceramic	Type of cement	Type of laser	Laser parameters	Irradiation time in seconds	Beam position	Damageteeth/ restoration	Follow-up in years
Veneers											
Broome[10] (USA, 2007)	1	F (40)	8 (#5 to #12)	Feldspathic	NR	Er, CR:YSGG	4 W 25 Hz	~ 15	Facial (only cervical, oblique angle)	N/N	NR
van As[17] (Canada, 2012)	2	F (35)	4 (#7 to #10)	NR	NR	Er:YAG	5.25 W 30 Hz 175 mJ PW: 300 μs	30–45	Facial, interproximal	N/Y (fractured)	NR
	3	F (45)	2 (#23, #24)	NR	NR	Er:YAG	5.25 W 30 Hz 175 mJ PW: 300 μs	NR	NR	N/N	NR
Kursoglu and Gursoy[18] (Turkey, 2013)	4	F (38)	1 (#8)	Pressable	Resin	Er:YAG	20 Hz 320 mJ	9	Facial	N/N	3
	5	M (66)	2 (#8, #26)	Pressable	Resin	Er:YAG	20 Hz 320 mJ	9	Facial	N/N	1
Crowns											
van As[17] (Canada, 2012)	6	F (40)	4 (#7 to #10)	Lithium disilicate	NR	Er:YAG	6 W 30 Hz 200 mJ	120	Facial, lingual	N/N	NR
Cranska[12] (USA, 2013)	7	F (59)	1 (#30)	Monolithic zirconia	NR	ER:YAG	2.0 W 15 Hz 135 mJ PW: 50 μs FD: 0.7 mm	<60	All surfaces, starting occlusal. Slow painting back and forth motion	N/N	NR
	8	NR	1 (#12, cement retained implant crown)	Bilayeredzirconia	Resin	Er:YAG	1.6 W 8 Hz 200 mJ PW: 50 μs Direct contact	NR	All surfaces, starting occlusal. Slow painting back and forth motion	N/N	NR
	9	NR	2 (#8, #9)	Pressable	NR	Er:YAG	2.0 W 15 Hz 135 mJ PW: 50 μs Direct contact	NR	All surfaces, starting occlusal. Slow painting back and forth motion	N/Y (fractured)	NR

(Continues)

TABLE 1 (Continued)

Author (Country, year)	Cases	Gender (age)	Number of restorations (site)	Ceramic	Type of cement	Type of laser	Laser parameters	Irradiation time in seconds	Beam position	Damageteeth/ restoration	Follow-up in years
Cranska[11] (USA, 2015)	10	M (40)	2 (#25, #26)	Lithium disilicate	Resin	Er:YAG	3.0 W 15 Hz 200 mJ PW: 50 μs Direct contact	NR	All surfaces, starting occlusal. Slow painting back and forth motion	N/Y (fractured lingual margin #26)	NR
	11	M (49)	1 (#18)	Monolithic zirconia	NR	Er:YAG	2.0 W 15 Hz 135 mJ PW: 50 μs FD: 0.7 mm	<120	All surfaces, starting occlusal. Slow painting back and forth motion	N/N	NR
	12	F (68)	2 (#8, #9)	Bilayered zirconia	Resin	Er:YAG	3.0 W 15 Hz 200 mJ PW: 50 μs Direct contact	NR	All surfaces, starting facial. Slow painting back and forth motion	N/N	NR
Spath and Smith[16] (USA, 2017)	13	NR	6 (#6 to #11)	NR	NR	Er:YAG	5.0 W 15 Hz 600 mJ FD: 1 mm	120	All surfaces, starting facial. Scanning motion	N/N	NR

Abbreviations: Er:CrYSGG, erbium, chromium:yttrium scandium gallium-garnet; Er:YAG, erbium:yttrium-aluminum-garnet; NR, not reported; F, female; M, Male; PW, pulse width; N, No; Y, yes; FD, focal distance.

TABLE 2 General characteristics of experimental studies reporting all ceramic FDPs removal with lasers

Author (Country, year)	Study groups	Ceramic thickness in mm	Type of cement	Type of laser (wavelength)	Laser parameters	Irradiation time in seconds	Irradiation protocol	Main outcomes
Veneers								
Morford et al.[19] (USA, 2011)	11 LGC and 13 LD veneers (Human-extracted incisors)	Incisal edge: 1.18 ± 0.12 Middle third: 0.98 ± 0.7 Cervical: 0.76 ± 0.11	Resin	Er:YAG (2940 nm)	10 Hz 100 μs 133 mJ Tip: 1.1 mm FD: 3–6 mm	LGC: 113 ± 76 (31 to 290) LD: 100 ± 42 (48–205)	Laser-painting from incisal edge to cervical (avoiding the thinnest portion)	All veneers were removed without teeth surface damage. All LD veneers were intact. 36% of LGC veneers presented fractures.
Oztoprak et al.[15] (Turkey, 2012)	80 LD discs (Bovine-extracted incisors)	0.7 thickness, 5 mm diameter	Resin	Er:YAG (2940 nm)	5 W 50 Hz 100 mJ Tip: 1 mm FD: 2 mm	Up to 9	Perpendicular. Horizontal movements	Shear test showed significantly lower shear bond strengths for laser irradiated groups compared with control.
Iseri et al.[14] (Turkey, 2014)	60 LD discs (Bovine-extracted incisors)	0.7 thickness and 5 mm diameter	Resin	Er:YAG (2940 nm)	5 W 50 Hz 100 mJ Tip: 1 mm FD: 2 mm	9	Perpendicular. Horizontal movements	Shear test showed significantly lower shear bond strengths for laser irradiated group compared with control.
Crowns								
Rechamn et al.[6] (USA, 2014)	20 LDCAD and 10 ZirCADfull contour crowns 10 ZirCADcrowns with featheredge preparation (Human-extracted molars)	LDCAD O=1.91 ± 0.25; B=1.68 ± 0.15; L=1.75 ± 0.26; MD=1.82 ± 0.21 ZirCAD featheredge O= 0.90 ± 0.1; B= 0.96 ± 0.05; L: 0.95 ± 0.05; MD= 0.98 ± 0.04 ZirCADregular margin O= 1.89 ± 0.18; B=1.6 ± 0.08; L=1.55 ± 0.05; MD: 1.57 ± 0.07	Resin	Er:YAG (2940 nm)	10 Hz Pulse duration of 100 μs at 126 mJ/pulse up to 400 μs at 590 mJ/pulse FD: 10 mm	LDCAD 190 ± 92 (85–420) ZirCAD featheredge 226 ± 105 (160–492) ZirCAD regular margin 312 ± 102 (210–501)	All surfaces, starting occlusal. Slow painting back and forth motion	All crowns were removed (with a plier or popped of) without teeth surface damage or restoration fracture. One LDCAD crown presented a hairline fracture at the margin
	8 LDCAD and 8 ZirCAD copings and full contour crowns (Human-extracted molars)	Copings: 0.5 and 1 wall thickness Crowns: 2 functional cusps; 1.5 balance cusps; 1 margins; 1.5 contact point	Resin	Er:YAG (2940 nm)	10 Hz 300 mJ/pulse up to 500 mJ/pulse FD: 10 mm	LDCAD 120 - 210 ZirCAD 120–300	All surfaces, starting occlusal. Slow painting back and forth motion	All copings and full contour crowns were removed (with a plier or popped of) without teeth surface damage or restoration fracture

(Continues)

TABLE 2 (Continued)

Author (Country, year)	Study groups	Ceramic thickness in mm	Type of cement	Type of laser (wavelength)	Laser parameters	Irradiation time in seconds	Irradiation protocol	Main outcomes
Rechman et al.[7] (USA, 2015)	20 LDCAD (Human-extracted molars)	O= 2.24 ± 0.21; B= 1.89 ± 0.18; L= 1.81 ± 0.14; MD: 1.85 ± 0.14	Resin	Er:YAG (2940 nm)	10 Hz 400 μs at 590 mJ Tip: 1.1 mm FD: 5 mm	135 ± 35 (85–210)	All surfaces, starting occlusal. Slow painting back and forth motion	All crowns were removed (with a plier or popped of) without teeth surface damage or restoration fracture. Temperature rise in the pulp chamber averaged 5.4° ± 2.2°C
Gurney et al.[13] (USA, 2016)	25 LD (Human-extracted anterior and premolars)	1.5	Resin	Er, Cr:YSGG	3.5 W and 4 W 25 Hz	3.5 W: 60–90 4 W: 30–60	Continuous motion limited to B, L, and O surfaces	40% of the crowns were removed in the initial attempt. 45% were removed at the second attempt.

Abbreviations: LGC, leucite glass-ceramic; LD, lithium disilicate glass-ceramic; Er:CrYSGG, erbium, chromium:yttrium scandium gallium-garnet; Er:YAG, erbium:yttrium-aluminum-garnet; FD, focal distance; CAD, computer-aided design; Zir, zirconia; O, occlusal; B, buccal; L, lingual; MD: mesial and distal.

temperature rise. However, it is noteworthy that from the literature reviewed, only 1 experimental study[7] measured temperature changes in the pulp chamber during removal of all ceramic crowns. The results showed that the average temperature rise during the removal of computer-aided design E.max crowns was 5.4 ± 2.2°C (range 1.6°C – 11.5°C).[7] Although a constant heat increase was not reported, the risk of pulp thermal changes associated to laser -assisted removal of all ceramic crowns cannot be disregarded. Moreover, 8 out of 13 cases[10–12,16,17] failed to identify the type of cement used. Furthermore, it is well known that lasers energy transmission varies among the different dental ceramics. For example lithium dislicate-reinforced ceramic with a 0.5 mm thickness presents a highest transmission ratio compared with feldspathic ceramics with 1 mm thickness.[5] Studies[10,18] showed that the removal of veneers with <1 mm thickness can be accomplished with short laser irradiation (between 9 and 15 s); whereas, the removal of lithium disilicate and zirconia crowns (increased thickness and surface) varies between 30 and 120s.[11,12,17] It is hypothesized that longer laser irradiation periods results in an increased risk of pulpal temperature rise and concomitant irreversible pulpal damage compared with relatively shorter laser irradiation durations. Therefore, further well-designed studies assessing thermal pulpal changes, using full crowns fabricated with different ceramics and thickness are needed.

It is noteworthy that the experimental and clinical studies[6,7,10–19] included in this review had either a grade-IV (case report, case series, and analyses with no sensitivity analyses) or grade-V (expert opinion) level of evidence. To the authors' knowledge, high quality randomized trials and/or prospective studies assessing the efficacy of laser-assisted removal of all ceramic FDPs are missing in indexed literature. However, the currently available evidence shows that use of erbium lasers in the removal of all ceramic FDPs is a modernization in clinical dentistry, which might be a contemporary substitute for traditional procedures such as crown tractors, chisels and sliding hammer removers.

3 | CONCLUSIONS

Laser-assisted removal of all ceramic FDPs is a promising protocol. Further well-designed controlled clinical trials and longitudinal prospective studies are needed to determine accurate laser parameters, time of irradiation and variations according ceramic properties and thickness.

DISCLOSURE

The authors do not have any financial interest in the companies whose materials are used in this article.

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How to cite this article: Kellesarian SV, Malignaggi VR, Aldosary KM, Javed F. Laser-assisted removal of all ceramic fixed dental prostheses: A comprehensive review. *J Esthet Restor Dent*. 2017;00:1–7. https://doi.org/10.1111/jerd.12360