Review Article

APPLICATION OF THE HIGH-INTENSITY LASER THERAPIES ON CERAMIC BRACKETS DEBONDING: A LITERATURE REVIEW

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Abstract

Ceramic brackets were introduced to orthodontic practice since decades ago. Apart from the esthetic advantages of ceramic brackets, the debonding procedure is a challenging issue for both orthodontists and patients. Ceramic bracket debonding can, therefore, lead to problems. Numerous techniques have been proposed for solving the debonding problem. So, the aim of the current study was to determine application of the ER:YAG and Er,Cr:YSGG laser on ceramic brackets debonding using PubMed and Medline database English literature by the terms "ER:YAG", "Er,Cr:YSGG", "Debonding ceramic" and "Brackets". In conclusion, the Er:YAG and Er,Cr:YSGG lasers caused no damage to the bracket. Er:YAG lasers effectively remove adhesive from the bases of ceramic brackets.

Key words: *ER:YAG, Er,Cr:YSGG, Debonding, Ceramic brackets.*

Introduction

Ceramic brackets were introduced to orthodontic practice since decades ago. An increasing number of adult patients who care the esthetic of their teeth prefer ceramic brackets instead of metal brackets, and the diversity of ceramic brackets brands has increased. However, ceramic brackets are mainly classified as mono crystalline or polycrystalline, depending on whether they contain single crystal or poly crystal units.[1] Apart from the esthetic advantages of ceramic brackets, the debonding procedure is a challenging issue for both orthodontists and patients. Ceramic bracket debonding can, therefore, lead to problems such as enamel tear outs as a result of the debonding forces exceeding the cohesive strength of the enamel or the bracket itself, bracket failures because of rigid and brittle properties of the material and patient discomfort.[2] Numerous techniques have been proposed for solving the debonding problem, including wood burning pens, warm air dryers, electro thermal debonding devices, ultrasonic instruments and lasers. These methods thermally soften the adhesive by heat transmission through the ceramic bracket.[3] Recently laser application was introduced for ceramic bracket debonding.[4] So, this paper is part of Ph.D. thesis and the aim of the current literature review was to determine application of the ER:YAG and Er,Cr:YSGG laser on ceramic brackets debonding.

Material and Methods

The keywords used for the literature search for this review was peer-reviewed articles following keywords: YAG, Er × Cr:YSGG × Debonding ceramic × Brackets. Related articles were also scrutinized. Hand search was also driven. The search was carried out using Biological Abstracts, Chemical Abstracts, and the data bank of the PubMed and Medline database updated to 2018. The references found in the search were then studied in detail.

Ceramic brackets

Ceramic brackets are bonded to tooth surfaces via three different mechanisms: mechanical bonding, chemical bonding or a combination of both. Considering enamel fractures during debonding of ceramic brackets with chemical retention, a new generation of ceramic brackets with mechanical retention was invented.[5] The bond strength of ceramic brackets with mechanical retention was found to be equal to or less than that of stainless-steel brackets. The rate of failure for ceramic brackets with mechanical retention has not been reported. Ceramic brackets are certainly more fragile than the commonly used metal brackets. Thus, they are probably prone to fracture during debonding. However, debonded brackets which remain intact do not lose their angulation accuracy, torque and contour of the base.[6]

Debonding

Considering the increasing number of orthodontic patients, and need for bracket repositioning in some cases, or inadvertent bracket debonding during treatment, standardization of rebonding procedures such as secondary enamel conditioning is necessary to maximize the efficiency of treatment and reduce costs.[7] Debonding of orthodontic brackets is an inevitable situation in orthodontic treatment. Once the teeth have been moved into more ideal locations and the occlusion is acceptable, the brackets are removed. Numerous techniques have been developed to try to minimize patient sensitivity and enamel damage during the debonding procedure.[8] It is estimated that 150-160 µm of enamel could be lost during bracket removal. Enamel damage is of clinical importance because the concentration of fluoride is greatest at the surface of enamel. If this layer of enamel is removed during bracket debonding, then the tooth surface will be more susceptible to demineralization.[8] Ceramic bracket debonding can, therefore, lead to problems such as enamel tear outs as a result of the debonding forces exceeding the cohesive strength of the enamel or the bracket itself, bracket failures because of rigid and brittle properties of the material, and patient discomfort.[4] Removal of brackets includes side effects, such as enamel fractures; due to the lower fracture, toughness of enamel in addition to the fracture of the bracket itself and pain from debonding associated with extensive debonding force used have been reported. Due to the brittle nature of the ceramic bracket, fractures occur more easily as compared to metal. It has been suggested that when the debonding forces exceed the cohesive strength of the enamel or the bracket itself, fracture of the enamel surface or the bracket will occur.[9]

The location of bond failure is also of importance when it comes to enamel damage. There are four possible locations for bond failure: bracket-adhesive interface, within the adhesive, tooth-adhesive interface, within the tooth. The site of bond failure will determine the level of enamel damage incurred. A bond failure at the bracket-adhesive interface will have the least probability of causing enamel damage. However, accompanying the decreased probability of enamel damage is an increase in chair side time required to clean remaining adhesive from tooth surfaces.[10] Various methods have been proposed for solving the debonding problem, such as wood burning pens, warm air dryers, electrothermal debonding devices, ultrasonic instruments and lasers. These methods thermally soften the adhesive by heat transmission through the ceramic bracket.[4] Gonçalves *et al*.[11] proposed the laser irradiation of already infiltrated dentin adhesive systems, prior to their polymerization. This technique promoted increased bond strength values of simplified dentin bonding systems irradiated with the Nd:YAG laser in microtensile and shear bond strength tests. According to those authors, laser irradiation could increase bond strength by determining a higher penetration of dentin bonding systems into dentin or promoting the development of a substrate where dentin and adhesive are fused by the action of the laser.[4]

Fracture toughness

Bracket failure is usually caused by the application of inappropriate masticatory forces or because of poor bonding technique, but sometimes the clinician decides to intentionally detach one or more brackets and reposition them in order to obtain a proper tooth position. Recycling the dislodged attachments and rebonding them can be beneficial, reducing treatment costs for both the orthodontist and the patient. The recycling process is basically defined as removing adhesive from the bracket completely to provide the possibility of bracket reuse, without damaging the bracket backing or distorting the slot dimensions. Recycling of metal brackets can be performed by specialized companies or in the dental office.[12] Both chemical and thermal methods may be used for industrial bracket recycling. However, a significant decrease in bond strength has been demonstrated in most studies using industrial recycling.[13] Furthermore, commercial bracket recycling is time consuming and demands special appliances and materials, and is therefore impractical to perform at the dental office. Today, although industrial methods of bracket recycling are not commonly used by most practitioners, reconditioning of one or more accidentally dislodged brackets to be reused in the same patient, is still popular.[13] Bracket failure is an undesirable experience frequently observed in clinical orthodontic practice. This usually occurs as a result of patients' applying heavy forces to orthodontic attachments or because of shortcomings in the bonding technique. Furthermore, the clinician may occasionally decide to intentionally reposition one or more attachments to achieve the best treatment results. If the optimum bond strength is maintained and on the condition that no damage is caused to the bracket base or slot dimensions, reusing a dislodged ceramic bracket after removing adhesive from the base can be considered as a suitable option to reduce treatment costs and to save office inventory. Various techniques have been employed for recycling metal orthodontic brackets.[14] However, the delicate base surface of ceramic brackets is more prone to damage than that of the metal brackets, and thus, selecting an appropriate in-office method for reconditioning of ceramic brackets becomes challenging.[14]

Laser applications for dental tissues

In Dentistry, lasers are used in two major applications: bio stimulation and surgery. The lasers applied for bio-stimulation procedures in other words, for the activation of regenerative and healing processes are the so-called low-level laser therapy (LLLT) and operate under 500 mW. For this purpose, the diode and helium neon (HeNe) lasers stand out, depending on their active medium. Lasers that work beyond the 500 mW range are applied for high-intensity laser therapies (HILT), also called surgical lasers, given their tissue cutting capacity. For such uses, the CO2, Nd:YAG, Erbium (Er:YAG, and Er,Cr:YSGG) and diode lasers are the main examples.[15] In orthodontics, LLLT has been applied to relieve pain associated with orthodontic movements, accelerate bone regeneration after rapid maxillary expansion and enhance orthodontic tooth movement.[16] Although there are several protocols for using LLLT, its effectiveness is determined by the frequency of applications in-between the activation appointments, which makes it less attractive as a routine procedure. HILT, on the other hand, has become increasingly popular among orthodontists.[16] It is used for quickly and effectively addressing soft tissue complications associated to orthodontic treatment through bloodless and atraumatic surgical interventions.[15] The benefits of using HILT for soft tissue oral surgery include better hemostasis, decreased postoperative pain and infection rate, minimal tissue contraction, little or no need for sutures, shorter surgical stages, decreased trauma, edema and scarring, besides the reduced need for local anesthetics.[15]

Different laser applications for dental tissues should meet satisfy certain criteria. The attention has been focused on using the laser radiations for treatment of soft and hard tissues whereas, laser beam application to sites within the oral cavity and well-focused to perform soft tissue treatment and surgery, enamel etching for dental orthodontic applications were a natural outcome of the studies of laser effects on dental hard tissues,[17] including conversion some of laser beam energy to thermal energy causes thermally-induced changes to a depth of 10-20 μm within the enamel layer,[18] that means adjustment of laser power output to avoid deleterious effects on the underlying dental tissues and etching occurred at low levels of laser power, structure changing of the surface related to laser beam energy and irradiation focus.[19] Some studies were using ER:YAG or Nd-YAG laser in etching enamel surface for direct bonding of orthodontic applications means adjustment of laser power output to avoid deleterious effects on the underlying dental tissues and etching occurred at low levels of laser power.[20] On other hand, various studies were about the acid-etched surfaces and phosphoric acid resulted in Variable changes of the organic and inorganic contents of teeth, although some etching and discoloration noticeable but phosphoric acid is frequently used to prepare the surface of the tooth for the adhesion of orthodontic attachments or resins.[17]

The Erbium laser family

There are two distinct wavelengths that use erbium: Erbium, chromium: YSGG (2780 nm) has an active medium of a solid crystal of yttrium scandium-gallium-garnet that is doped with erbium and chromium and Erbium:yttrium-aluminum-garnet (Er:YAG) (2940 nm) has an active medium of a solid crystal of yttrium aluminum garnet that is doped with erbium. Caries removal and tooth preparation are easily accomplished by both the lasers. The Er:YAG laser.[21] Erbium, chromium: yttrium-scandium-gallium-garnet (Er,Cr:YSGG) laser has also been used successfully for surface treatment of dental composites, with similar effects to that of the air-abrasion technique.[22] The prime chromophore in current laser application with hard tissue is water; the absorption peak at around 3.0 mm wavelength identifies the Er:YAG and Er,Cr:YSGG wavelengths as the lasers of choice. The first dental laser – the Nd:YAG 1,064 nm – was marketed as being suitable in tooth cavity preparation – a claim that was quickly deemed to be erroneous for clinical relevance. Early research into this claim supported the ablative effect of the 1,064 nm wavelength on accessible pigmented carious lesions.[23]

Reports

Since the early 1990s, lasers have been used experimentally to remove ceramic orthodontic brackets. Each of the four major dental laser wavelengths (diode, CO_2, Nd:YAG, and Er:YAG) have been utilized to try and help with debonding these brackets. Oztoprak and colleagues developed a new method to debond ceramic brackets using the Erbium YAG laser wavelength (2,940 nm). They found that short durations of three to nine seconds with moderately high energies of 4.2 W were effective and safe for this procedure. Enamel was not affected by the laser energy, and the pulpal temperature rise was measured to be below the 5.5°C threshold, at which point irreversible changes to the pulp can occur. Although erbium lasers have been shown to safely remove orthodontic brackets without damaging increases in pulpal temperature, research should continue, to ensure that the initial studies showing safety with laser removal of bonded veneers and crowns are also confirmed. The erbium family of lasers exists between 2,780 nm (Er:CrYSGG) and 2,940 nm (Er:YAG). These wavelengths are well absorbed in water and hydroxyapatite and their absorption in these tissue compounds makes it possible to ablate both soft tissue and hard tissue compounds, which both consist partially of water. Enamel has 6% water, bone has 22% water and soft tissue is composed of approximately 80% water. The mechanism of action of ablation with erbium lasers.[24] The erbium laser wavelengths are absorbed in water molecules and cause a rapid expansion of these molecules. The rapid expansion causes micro-explosions, and this, in turn, creates an ablation crater of 200-300µm in hard tissue. On efficacy of the Er,Cr:YSGG laser in reconditioning of metallic orthodontic brackets, Ahrari *et al.*[22] reported aluminum oxide blasting and Er,Cr:YSGG laser were efficient in removing adhesive from bracket bases, and resulted in significantly higher bond strength than for new brackets. Er,Cr:YSGG laser can promote the use of recycled brackets by providing shear bond strength values comparable to sandblasted attachments, and not significantly different from the mean initial bond strength.[22] Also, Mirhashemi *et al.*[6] reported recycling of ceramic brackets with Er:YAG laser is an efficient in-office method which causes the least damage to the bracket base. However, all methods of bracket recycling showed acceptable shear bond strength. Han *et al.*[25] compared with new brackets, shear bond strength was lower after sandblasting but not after exposure to an Er:YAG laser. The Er:YAG laser caused no damage to the bracket. Er:YAG lasers effectively remove adhesive from the bases of ceramic brackets without damaging them. Ahrari *et al.*[14] on reconditioning of ceramic orthodontic brackets with an Er,Cr:YSGG laser reported the application of Er,Cr:YSGG laser was efficient in removing adhesive from bases of debonded ceramic brackets because it produced comparable bond strengths to new brackets while reducing the risk of enamel damage during debonding. Devjee *et al.*[26] revealed for stainless steel brackets, the sandblasting method was superior to the Er:YAG laser, as the recycled brackets showed a higher shear bond strength. For ceramic brackets the Er:YAG laser recycled group had the highest recycled shear bond strength therefore was the best method of recycling ceramic brackets. Sohrabi *et al.*[27] reported Er, Cr:YSGG laser was effective in removing the remnants of bonding material from the base of ceramic brackets without any interference with the ceramic base itself, demonstrating that it might be a suitable method for rebonding ceramic brackets. Also, the Er,Cr:YSGG laser can be used for effective debonding of stainless steel orthodontic brackets.[28]

Conclusion

Laser debonding has also been evaluated as an alternative to mechanical debonding. Laser debonding can break down the adhesive by one of three methods: thermal softening, thermal ablation, and photoablation. Thermal softening results in the bracket sliding off the tooth when the laser heats up the adhesive until it softens. This is a relatively slow process and can cause an increase in both tooth and bracket temperatures. Thermal ablation still debonds the bracket by thermal softening, but the heating is so fast that the rise in temperature of the adhesive causes it to go into its vaporization range. This causes the bracket to release from the tooth surface. As diode lasers have become a part of clinical setting, the application of laser for debonding ceramic brackets can be studied whether they could be used for easier debonding by softening the adhesive. The Er:YAG and Er,Cr:YSGG lasers caused no damage to the bracket. Er:YAG lasers effectively remove adhesive from the bases of ceramic brackets.

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