

## The effect of ER: YAG laser on enamel resistance to caries during orthodontic treatment: An in vitro study

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### ABSTRACT

**Background:** One common undesirable side effect of orthodontic treatment with fixed appliances is the development of incipient caries lesions around brackets, particularly in patients with poor oral hygiene. Different methods have been used to prevent demineralization; the recent effort to improve the resistance against the demineralization is by the application of lasers.

**Materials and method:** Thirty human premolars extracted for orthodontic purposes were used to test the effect of two energy level of ER-YAG laser on enamel resistance to demineralization. The brackets were bonded on the teeth and all the labial surface excluding 2 mm area gingival to the brackets were painted with acid resistance varnish. Three groups were generated. The first group was the control group (A) with no treatment was performed. In the second (group B) and third (group C) groups; teeth were irradiated by ER-YAG laser of 200, 60 mj energy respectively. All the teeth were individually subjected to acid challenge cycle for 30 days. After debonding longitudinal sections were taken and examined under stereomicroscope. The enamel demineralization evaluation was done by taking the average of three depths at the centre of the artificial lesion. Also the enamel surface was classified by an experienced investigator according to acid etch pattern. Comparisons of the average depth values of the groups were performed with ANOVA and LSD tests. The statistical significance level was set at  $p \leq 0.05$ .

**Results:** The results revealed that average lesion depth was significantly deeper at the control group than the laser groups, and it was significantly deeper in group (B) with 200 mj than in group (C) with 60 mj. Enamel surfaces showed deeper pits and craters than in control group.

**Conclusions:** The decrease in artificial caries lesion depth associated with use of the two laser energy level support the ER-YAG laser as a tool to increase enamel resistance to demineralization and white spot lesion prevention.

**Key words:** Demineralization, ER-YAG, laser. (J Bagh Coll Dentistry 2015; 27(1):182-188).

### INTRODUCTION

One of the most difficult problems in orthodontic treatment with fixed appliances is the control of enamel demineralization around the brackets. <sup>(1)</sup> Fixed orthodontic appliances complicate the removal of food debris that results in the accumulation of plaque. Several studies have found an increased amount of plaque around orthodontic appliances. <sup>(2)</sup> Plaque bacteria produce organic acids that cause the dissolution of calcium and phosphate ions from the enamel surface. This dissolution can cause white spots or early carious lesions to form in as little as 4 weeks. <sup>(3,4)</sup> Significant increase in the prevalence and severity of enamel demineralization after orthodontic treatment when compared with untreated control subjects.

The prevalence of white spot lesions in orthodontic patients has been reported between 2% and 96 %.<sup>(5-6)</sup> Sognaes and Stern <sup>(7)</sup> were the first to advocate the potential of lasers to decrease enamel solubility and increase caries resistance. Since that study, several studies have been conducted with different laser systems: argon, Nd:YAG, Er:YAG, Er,Cr:YSSG, and carbon dioxide lasers.<sup>(8-13)</sup> It is well clear that with available technology, only erbium family lasers (Er:YAG and Er,Cr:YSSG) are suitable for this purpose.

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The wavelength of Er: YAG laser is highly absorbed by water and hydroxyapatite <sup>(14)</sup> making it suitable for both hard and soft tissue ablation. Several factors may act together to achieve this reduction in caries susceptibility of lased enamel.

The most likely mechanism for caries resistance is through the creation of microspaces within lased enamel. During demineralization, acid solutions penetrate into the enamel and result in release of calcium, phosphorus and fluoride ions. In sound enamel, these ions diffuse into the acid solutions and are released into the oral environment. With lased enamel, the microspaces created by laser irradiation, trap the released ions and act as sites for mineral re-precipitation within the enamel structure. Thus, lased enamel has an increased affinity for calcium, phosphate and fluoride ions. <sup>(8)</sup>

There are contradictory reports about the effect of Er: YAG laser on decreasing enamel solubility. Cecchini et al. <sup>(9)</sup> used an Er:YAG laser with different parameters of irradiation and reported that lower energies (subablative dose) decreased enamel solubility. Hossain et al. <sup>(16)</sup> reported an increase in the calcium to phosphorus ratio during laser irradiation, which resulted in caries inhibition showed improvement in crystalline structure and had the lowest mineral dissolution compared to control and phosphoric acid-etched specimens. Another study showed that Er: YAG laser treatment reduced the carbonate content and

modified the organic matrix, thus providing caries-preventive effect on enamel. <sup>(17)</sup> However, some studies did not find any significant difference between Er:YAG-lased and non-lased groups with respect to the enamel demineralization. <sup>(18,19)</sup> Apel et al. <sup>(20)</sup> observed that Er:YAG laser was unable to achieve any notable reduction in acid solubility of dental enamel. Some authors concluded that the application of sub-ablative erbium lasers solely for preventive caries treatment does not seem to be sensible under the conditions they studied. <sup>(20,21)</sup> Ahrari et al. <sup>(12)</sup> found in their study that Er:YAG laser does not reduce enamel demineralization when exposed to acid challenge, these conflicting findings brought up the demand to conduct this study for more basic data about Er:YAG laser role against enamel demineralization.

## MATERIALS AND METHODS

Thirty human premolars extracted for orthodontic purposes were selected for this study. In transillumination examination, the selected teeth should have healthy enamel on the buccal surface, without attrition, fracture, restoration, congenital anomalies and structural defects. There was no history of chemical substance application such as hydrogen peroxide for these teeth.

After cleaning the teeth from blood and debris, they were placed in thymol containing water for inhibiting bacterial growth until their use. The buccal enamel surfaces of the teeth were pumiced for 10 seconds, washed for 30 seconds, and dried for 10 seconds with a moisture-free air spray. Before etching, a self-adhesive tape with a cut-out window the size of the bracket base was applied to each tooth to prevent etching and sealing of enamel areas that would later not be covered by the bracket. Conventional etching was performed with 37% phosphoric acid for 15 seconds followed by rinsing for 30 seconds and drying for 10 second.

All the teeth were bonded with Edgewise premolar metal brackets with light cured composite Resilience ® (Ortho technology Co., USA). The bracket was placed gently onto the centre of the labial surface using a clamping tweezers and pressed firmly into place. The adhesive tape and the excess adhesive were carefully removed, followed by light-curing for 3 seconds from the mesial and distal sides flash Max 2 light cure unit (CSM dental Aps, Denmark) at a distance of 2mm and a 45° angle to the surface. Acid-resistant varnish was applied to each tooth by leaving a 2-mm rim of exposed sound enamel surrounding the bracket gingivally

and left to set overnight. The teeth were allocated into three groups (n=10) according to the caries prevention way :

Group A: Control group with no caries prevention method .

Group B: Lased with 200 mj energy and 4 Hz frequency of Er:YAG laser at a distance of 12mm with water for 20 seconds, the beam diameter at the focal area was 1.0 mm .

Group C: Teeth lased with 60 mj energy and 2 Hz frequency of Er:YAG laser at a distance of 4mm with water for 20 seconds, The beam diameter at the focal area was 1.0 mm.

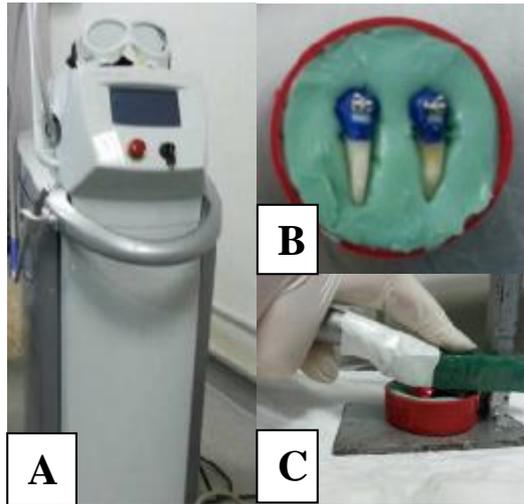
Lasing method of the teeth in group B and C was done by using Kavo laser unit (2060) (Figure 1A). The teeth were placed in plastic jar cover filled with heavy body dough (Figure 1B) and the buccal surface facing the laser handpiece which had been fixed in a special holder designed for this purpose at the recommended distance (Figure 1C).

The laser source was fixed while the teeth moved laterally beneath with a uniform motion. Each tooth was placed separately in deionized water in a 10 ml plastic jar labeled with tooth group and number until they were subjected to the demineralization process. Without removing the brackets, all the teeth were challenged by submerging in a demineralizing solution (0.075 M/L acetic acid, 1.0 m M/L calcium chloride, 2.0 M/L m potassium phosphate) at 37°C, the pH was adjusted to 4.3 by pH meter for 17 hour and remineralizing solution (150 m M/L potassium chloride, 1.5 m M/L calcium nitrate 0.9m M/L potassium phosphate) at 37°C, the pH was adjusted to 7 for 7 hour, this procedure were repeated for 30 days.

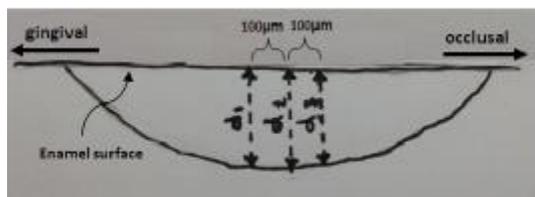
A 5 minute wash with distilled and deionized water was done between the demineralizing and remineralizing phases and at the end of the process. Each tooth cycled separately in individual containers and each solution was changed periodically every day throughout the 30 days procedure. After completing the demineralization procedure, the brackets were removed with straight bracket removing pliers (Orthotechnology Co., USA), then each tooth immersed in 0.5 % methylene blue solution for 24 hours. After that, each tooth was rinsed in tap water and air dried. <sup>(22)</sup>

Ground sections of approximately 100 µm of thickness were made in a coronal-apical direction right by the cusp edge so that each tooth was sectioned longitudinally by using water-cooled low speed saw of a hard-tissue microtome.

Sections were carefully washed and placed in labeled Petri dishes and were oriented longitudinally on glass cover slides, and then the sections were examined under stereomicroscope with maximum illumination. Lesion depth was measured by taking the average of three representative measurements from the surface to the depth of the lesion that were 100 μm apart in the center of the carious lesion. One examiner performed all the measurements. Figure 2 illustrates a lesion depth measurement.



**Figure 1: A, Kavo laser unit (2060) providing ER-YAG laser. B, the teeth were placed in plastic jar cover filled with heavy body dough. C, the buccal surface facing the laser handpiece which had been fixed in a special holder at the recommended distance**



**Figure 2: Magnified view of longitudinal section of demineralized lesion illustrate lesion depth measurement**

The enamel surface was classified by an experienced investigator, according to Ibrahim et al (23) into:

- Type I - Preferential dissolution of the prism cores resulting in a honey-comb-like appearance.
- Type II - Preferential dissolution of the prism peripheries creating a cobble stone-like appearance.
- Type III - A mixture of type I and type II patterns.

- Type IV - Pitted enamel surfaces as well as structures that look like unfinished puzzles, maps or networks.
- Type V - Flat, smooth surfaces.

**RESULTS**

The means values and standard deviation for the groups of this study are summarized in table 1. The results showed that the lowest mean value of the groups of this study was for the group C (group in which the samples was treated with 60 mJ Er:YAG laser) while the highest mean value of the groups of this study was for the group A (Control group).

ANOVA test was performed to identify the presence of statistically significant differences for all group of this study; the result showed that there was high statistically significant difference among these groups.

LSD test was performed to identify the differences between each paired group. The results showed the group A has high statistical significant as compared with group B and group C while the group B has high statistical significant as compared with group C, when P value ≤ 0.05.

**Table 1: The means values and standard deviation for the groups of this study**

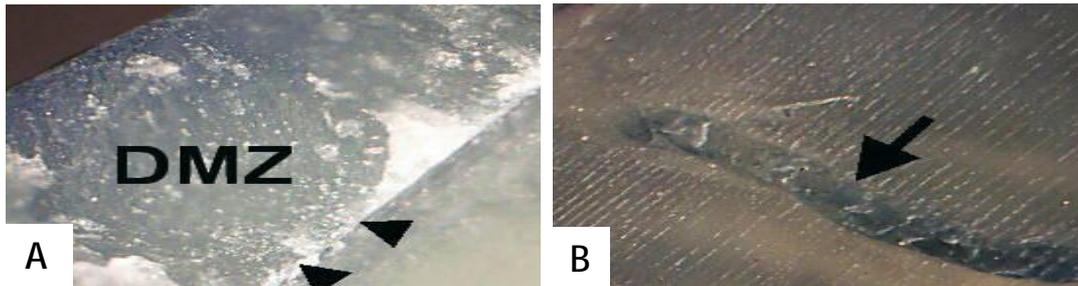
Groups	Mean(μm)	S.D.
Group A	18.7	±2.2
Group B	14.3	±0.63
Group C	10.6	±0.84

**Histopathological study:**

The histopathological examination revealed that the lesion mass difference between the three groups is more significant and well demarcated in the control group. It became smaller in group B and surrounded by remineralized enamel and it even smaller in group C with more remineralized enamel structure, as shown in figures 3a, 4a, 5a.

Difference in the types of enamel surface pattern in tested groups:

Group A has 60% of type IV of enamel surface, 20% of type III of enamel surface and 20% of type V of enamel surface while the group B has 40% of type I of enamel surface, 20% of type II of enamel surface, 20% of type III of enamel surface and 20% of type V of enamel surface while the group C has 60% of type II of enamel surface, 20% of type III of enamel surface and 20% of type V of enamel surface. Figures 3b, 4b, 4c and 5b, 5c illustrate the enamel surface pattern for the three groups.



**Figure 3: A, Photomicrograph view for surface enamel of control group, showed dark demineralization zone extends to dentine enamel junction (arrow head). B, longitudinal ground section shows extension of lesion (arrow) with rough pitted enamel. X4**



**Figure 4: A, Photomicrograph of enamel treated with 200 mJ Er:YAG laser shows remineralized enamel (RE) and underneath it a focal demineralized lesion (arrow) X4. B, View for preferential dissolution of prism cores shows as a honey-comb like appearance (type I) X4. C, pitted enamel prisms (arrows) with deep craters (arrows heads).X4**



**Figure 5: A, Photomicrograph of enamel surface treated with 60 mJ Er:YAG laser shows remineralization zone as a focal translucent area. A small demineralized lesion (arrow) was detected.X4. B, View for enamel prisms placed side by side, prism sheath shows form of ring(arrows). As Cobbl stone form (type III). X10. C, Magnifying view for prism sheath shows thick sides with deep craters (arrows). X20**

## DISCUSSION

The strongly absorbed laser energy in the enamel is converted to heat that boils water abruptly. The boiled water forms high-pressure steam that leads to the ablation process when the pressure exceeds the ultimate strength of the tooth. During the ablation process, water evaporates explosively with tooth particles. The ablated materials and their successive recoil force create craters on the surface and the irradiated surface becomes a flaky structure with an irregularly serrated and microfissured morphology.<sup>(16)</sup> Some researchers suggested that the caries protective effect of laser light has been attributed to the heat produced during laser

irradiation which can cause changes in the chemical and crystalline structure of the enamel.<sup>(16,20,21,24)</sup> On the other hand, this surface morphology of irradiated enamel may be vulnerable to acid attack and mineral loss<sup>(27)</sup> and may be sites of high risk for bacterial accumulation creating favorable conditions for the development of carious lesions.<sup>(18)</sup>

The advantage of etching with phosphoric acid is the high level of bracket bond strength achieved. On the other hand, the loss of mineral crystals, essentially the acid-protecting barrier, is inevitable<sup>(16)</sup>, therefore; this research used the laser around the bracket to test its potential to increase acid resistance of enamel and prevention

of white lesion hazards while keeping the advantage of high shear bond strength of conventional acid etch.

It has been reported that caries preventive effects induced by Er:YAG laser treatment have been shown to depend on number of factors: the energy density of the laser, the irradiation time, the focal distance, and the irrigation conditions. (9,11,15,18,20,24,26,27) Both ablative and subablative doses have been tested to try to decrease the acid solubility of enamel. The ablation threshold of the Er:YAG laser is also a controversial topic: it varies between 7 and 18.6 J/cm<sup>2</sup> in the literature. (26,28,29)

Apel et al (18) suggested Er:YAG laser with energy densities below the ablation threshold, this is not to ablate or melt the surface but to change its structure or chemical composition attempting to increase its acid resistance. Liu et al. (24) assessed the optimal laser energy range between 100 and 200 mJ for the laser induced caries prevention with Er:YAG laser without water cooling and concluded that caries prevention might be achieved by using Er:YAG laser if the optimal ranges of laser parameters were chosen. Altan et al (13) preferred a subablative dose in his study utilized 100 mJ per pulse (12.73 J/cm<sup>2</sup>) with water spray surface cooling and obtained positive results in accordance with the results of Hsu et al. (30) who presented marked caries inhibition using subablative laser parameters.

Also Cecchini et al. (9) evaluated the different settings of Er:YAG laser on enamel acid resistance and reported that lower energies (60-80 mJ) caused a significant reduction in enamel solubility. The temperature increase in pulpal tissue caused by laser irradiation with ablative doses should be considered. From this point of view, White and Goodish (31) determined the safe limits for pulpal health to be 1 W and 10 Hz. By considering the whole, we preferred a subablative dose (60-200) mJ in this study with water cooling to simulate the clinical situation. Both wave length energy showed that there is a marked reduction in the depth of the artificial carious lesion concomitants with Er: YAG laser irradiation, and this reduction was greater in group C (60 mJ), there was a 24% reduction in mean lesion depth in group B and 44% reduction in group C in comparison with the control group and these significant results are in agreement with researches use subablative energies discussed above yet it can't be comparatively analyzed with them as different laser parameter were used.

Another aspect affecting the generated results is the method for assessing demineralization in ER:YAG laser studies making the comparison with other researches even more difficult. While

the present study results were contradictory to that of Ahrari et al (12) who observed a non increase of the enamel resistance to demineralization utilizing 300 mJ of laser beam which was directed manually at 1 mm distance.

Also Ulkur et al (32) stated that 80mJ irradiation with 200  $\mu$ s pulse duration and pulse frequency of 2Hz was found ineffective against enamel demineralization. Also this research disagreed with Rodríguez-Vilchis et al (33) who reported that the acid resistance of enamel due to subablative ER: YAG laser irradiation did not increase significantly compared to control.

In the present study, a lower depth of Caries lesion in the acidic solution of irradiated groups showed that enamel acid resistance was increased under the experimental conditions employed.

However, this effect was more evident for Group C than group B; this can be explained through that the increased enamel resistance to caries associated with lower energy could be compensated by the decreased irradiation distance since more laser effect can be achieved with less distance. The described irradiation distances ranged from contact mode to 17 mm working distance, on focused and/or defocused modes.

Regarding the Er:YAG laser settings advised for dental treatment, the laser irradiation distance is an important parameter, for being directly related to the laser ablation ability and surface morphology. (28,34)

Thus, depending on the established irradiation distance, the incident energy on dental surface increases the ablation depth or amplifies the irradiated site. (34) In fact, the dispersion of the energy occurs when the active tip is far off the substrate, causing a little amplification of the spot size (diameter of the beam) and consequently higher is the irradiated area, decreasing the performance of the laser on the tissue (35), the histopathological finding of lesion size difference between the three groups certainly support the mean lesion depth difference between the three groups discussed above, while the etching patterns were observed to vary between the examined teeth of the same group on contrast to the finding of Cehreli and Altay (36) who stated that all the samples within a group were found to be similar in the extent of surface irregularity. All the three groups showed rough and irregular enamel surface with craters but only the control group enamel showed deeper pitting with type IV dissolution, making the irradiated enamel superior from this point of view.

Within the limitations of this study, Er: YAG laser with subablative energy was found to be an

effective factor to fight white lesion associated with orthodontic brackets.

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### الملخص

**خلفية:** واحد من الآثار الجانبية الشائعة الغير المرغوب فيها خلال المعالجة التقويمية مع الأجهزة الثابتة هو نمو تسوس الاسنان الأولي حول الحاصرات، وبخاصة في المرضى الذين يعانون من سوء صحة الفم. وقد استخدمت أساليب مختلفة لمنع تحلل المينا، الجهود الحديثة لتحسين المقاومة ضد تحلل المينا هو استعمال الليزر.

**المواد والطريقة:** استخدمت ثلاثون من ضواحك الإنسان المقلوغة لأغراض تقويم الأسنان لاختبار تأثير اثنين من مستوى طاقة ال ER-YAG ليزر على مقاومة المينا للتحلل. تم تثبيت الحاصرات على الأسنان وكل السطح الشفوي باستثناء مساحة 2 مم من الجانب اللثوي للحاصرات تم طلائه بواسطة طلاء مقاوم للحموضه. تم إنشاء ثلاث مجموعات. وكانت المجموعة الأولى هي مجموعة السيطرة (أ)، وقد اجريت بدون علاج. في المجموعة الثانية (ب) والمجموعة الثالثة (ج); الاسنان أشعت بالليزر ER-YAG بطاقة 200 ملي جول وطاقة 60 ملي جول على التوالي. جميع الأسنان تعرضت بشكل فردي لدورة التحدي الحمضية لمدة 30 يوماً. بعد ازالة الحاصرات أخذت مقاطع طولية وتم فحصها تحت stereomicroscope. تقييم تحلل المينا تم عن طريق أخذ متوسط ثلاثة أعماق في مركز التسوس الاصطناعي. كذلك سطح المينا تم تصنيفه بواسطة باحث ذو خبرة وفقاً لنمط الحفر الحمضية. المقارنات لمتوسط قيم عمق المجموعات تم اجرائها مع اختبارات ANOVA و LSD. اخذ مستوى الدلالة الإحصائية عند  $P \leq 0.05$ .

**النتائج:** أظهرت النتائج أن متوسط عمق التسوس الاصطناعي كان أعمق بكثير في مجموعة السيطرة من مجموعات الليزر، وهي أعمق بكثير في المجموعة (ب) 200 ملي جول مما كانت عليه في المجموعة (ج) 60 ملي جول، سطوح المينا أظهرت تخدشات وحفر أعمق مما كانت عليه في مجموعة السيطرة.

**الاستنتاجات:** انخفاض عمق التسوس الاصطناعي للأسنان المرتبط باستخدام اثنين من مستوى طاقة ال ER-YAG ليزر مما دعم استخدام الليزر كأداة لزيادة مقاومة المينا للتحلل والوقايه من أفة البقع البيضاء.

**الكلمات الرئيسية:** تحلل المينا، ER-YAG , الليزر.