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# Evaluation of 532 nm Q-Switched Nd:YAG Laser and Acid Etching of Class V Composite Restoration: Comparative Histological Study

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**Abstract: Background:** Laser etching may be an alternative to acid etching of enamel and dentin. Several characteristics of irradiated dental hard tissues have been considered advantageous, microscopically rough surfaces without demineralization, open dentinal tubules without smear layer production and dentin surface sterilization. The aim of this study is to determine and compare histology the microleakage in class V cavity restored with a light cured composite after conditioning the samples(tooth surface) with 1-acid etching, 2-Q-switched Nd:YAG Laser etching and finally 3- acid and laser etching. **Materials and methods**: Twenty four non carious human extracted teeth were used in this study. The samples were equally grouped into four groups of six teeth each. A class V cavity was prepared. In group I, tooth surface was etched with a 37% phosphoric acid gel. In group II, the tooth surface was conditioned using a pulsed Nd:YAG Laser alone with a wavelength of 532 nm. The parameters were of pulse energy 60 mJ, pulse repetition rate 6Hz and energy density was 0.48 J/cm$^2$. In group III, the tooth surface was treated with Nd: YAG Laser and then was etched with phosphoric acid. In group IV, the surface was treated with 37% phosphoric acid then irradiated with Nd: YAG Laser; with the same parameters and concentration mentioned in group I and II. The samples immersed in 1% basic fuschin dye to mimic the normal stains in oral cavity and the sections were examined by a stereomicroscope and the readings were scored. **Results:** The results showed that group IV, in which the surface was treated with 37% phosphoric acid and then irradiated with Nd: YAG Laser) recorded the least microleakage of the four groups, where group III, in which the tooth surface was treated with Nd: YAG Laser and then was etched with phosphoric acid)recorded reasonable results better than group I (group I tooth surface was etched with a 37% phosphoric acid gel) or group II , in which the tooth surface was conditioned using a pulsed Nd:YAG Laser alone) **Conclusion:** The use of Q-switched Nd:YAG laser in etching the tooth surface was so effective that it can be used in treating or conditioning the tooth surface to enhance bonding and the best parameters among the tested samples were pulse energy of 60mJ, pulse repetition rate of 6Hz and energy density 0.48 J/cm$^2$.

## Introduction

Resin composites are used to replace missing tooth structure and modify colour of teeth or its contour. This improves facial esthetics (Graig RG, Powers JM. 2002). The sealing of the restorative material against the tooth structure, the quality and durability of the sealing, are major considerations in the longevity of restorations (Szep S, et al., 2003). Till now polymerization shrinkage is one of the biggest disadvantages of composite resin restorative materials. The process of polymerization shrinkage tends to pull the restorative material away from the margins of the cavity (Neena L.D Souza, 2000). During the times of temperature change within the oral cavity, the tooth and the restoration expand and shrink at different rates, due to the difference in the coefficient of thermal expansion between the tooth structure and the restorative material creating a gap at the restoration–tooth interface, where leakage can occur (Sturdevants SA., 2009 and Brian C. Quoa, et al., 2002).

Microleakage is the clinically undetectable passage or seepage of fluids, debris and bacteria between a restorative material and the walls of the prepared tooth (Retiet DH, MandrasRs , 1994 and Piemjaia M, Watanabe A, et al., 2004). Laser etching produces qualitatively different surface profile and roughness significantly different from untreated dentin, laser initially vaporizes water and other hydrated organic components of the tissue, on vaporization, internal pressure increase in the tissue until the explosive destruction of inorganic substance occur (Ceballosa L, Osorioa R, 2001). (Other changes like melting or conditioning of the surface) may occur .This etching has been reported to yield fractured, uneven surface and open dentin tubules. Both are apparently ideal for adhesion. The aim of this study is to histologically determine the microleakage in class V cavity restored with light cured composite after conditioning the tooth surface with acid etching, with Q-switched Nd:YAG Laser etching, and with both acid and laser etching, and to compare them with in vitro microleakage in previously extracted teeth.

## Materials and Methods

Twenty four non-carious teeth were used in this study; they were collected, stored in distilled water at room temperature. All the teeth were cleaned and scaled by hand instruments and air-scaler and then they were polished by pumice and rubber cub using conventional low speed handpiece. A class V cavity was prepared using a kidney shaped template in all the specimens.

**Group (I):** In this group the enamel and dentin were etched with 37% phosphoric acid Gel for 15 second and then rinsed with water for 10 s.


**Fig. (1-a):** Group1. Sample with score 1, revealing microleakage obviously to the half depth of the cavity, X60 1a

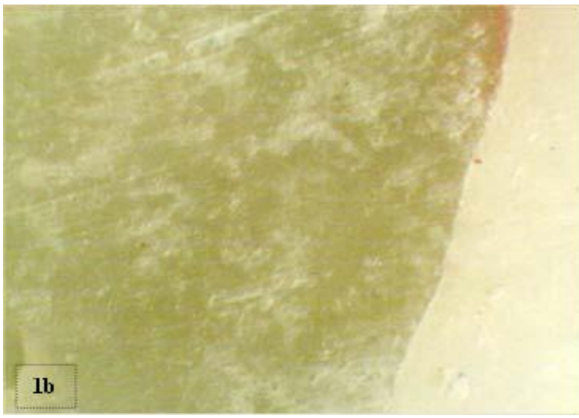


**Fig. (1-b): Group 1.** Sample revealing microleakege in the second level (score 2) dye penetration to full depth of the cavity, X60 1b


**Fig. (1-c): Group 1.** Reveals no microleakeage in the third zone (score3), no dye penetration, X60. 1c

**Group (II):** Enamel and dentin were conditioned using a pulsed Q-switched Nd:YAG laser with pulse energy of 60 mJ at 6 Hz in second harmonic generation.

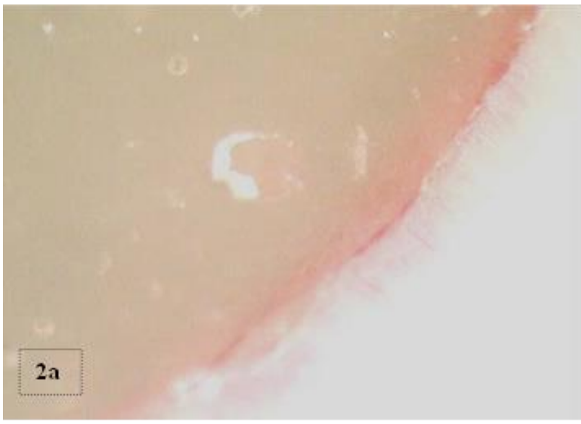


**Fig. (2-a): Group 2.** Sample revealing microleakage at score1.dye penetration passed through this zone.(staining overlapped the filling), X60. 2a

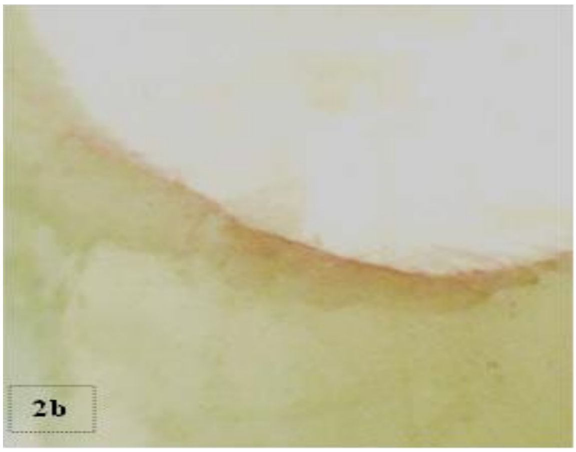


**Fig. (2-b): Group 2 .** Sample in the second level (score 2) where microleakage still obvious, dye penetration passed to the entire depth of the cavity, X60. 2b

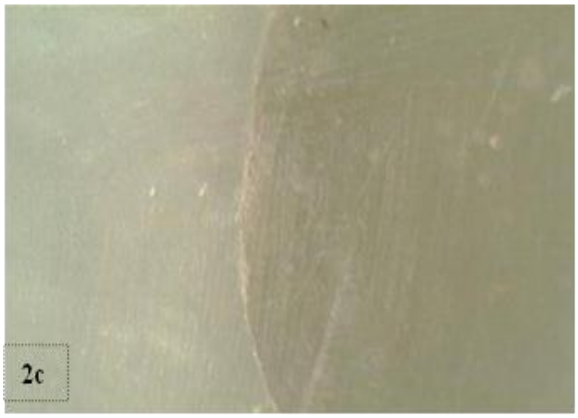


**Fig. (2-c): Group 2.** Score 3 (floor of the cavity) revealing that no dye penetration within or below this zone, X60. 2c

**<u>Group (III):</u>** The cavity surface was treated with Q-switched Nd:YAG laser with the same parameters of Group 2 and after that it was etched with acid in the same procedure mentioned previously in Group I.


**Fig. (3-a): Group 3.** Sample with score 1 revealing microleakage between the walls of the composite and the tooth surface, X60. 3a

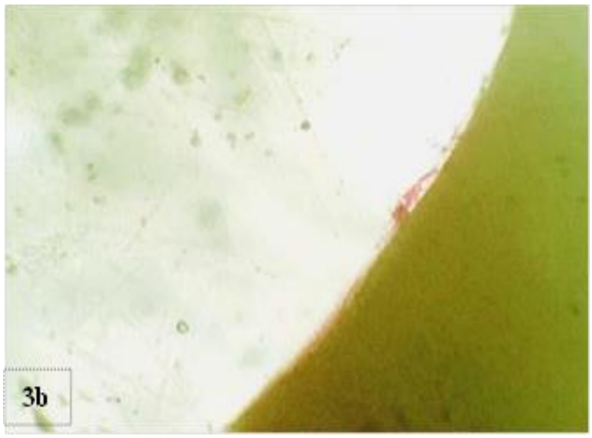


**Fig. (3-b): Group 3.** Sample revealing dye penetration at score 2(full depth of the cavity), penetration at cervical region but not entire wall .2cinvolvement,X60. 3b


**Fig. (3-c): Group 3.** Sample revealing no microleakage at score 3, no dye penetrated to the floor of the cavity and no axial wall involvement, X60. 3c

**<u>Group (IV):</u>** The surface was etched with acid and after that it was treated with Q-switched Nd:YAG laser in a similar steps mentioned above in Group II


**Fig. (4-a): Group 4.** Samples revealing microleakage at score 1, dye only penetrated to the half of the depth of the cavity with minimal spread,X60. 4a

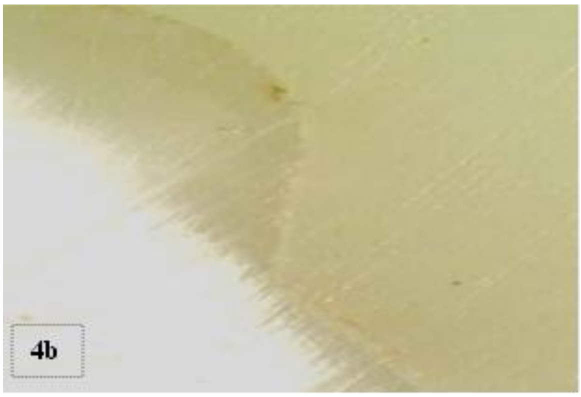


**Fig.(4-b): Group 4**. Revealing no microleakage at score 2 (no dye penetration below the half of the depth of the cavity), X60. 4b


**Fig. (4-c): Group 4.** Sample at score 3 revealing no dye penetration at the floor of the cavity, magnification X 60. 4c

Samples Thermocycling: All the samples were subjected to different temperatures by thermocycling them with 500 cycles of 6-60 C° with a dwell time of 30 second between cycles which stand for one minute each. This is to simulate the oral cavity condition where the teeth and fillings are continuously subjected to different temperatures of food and drinks 2 Preparation of teeth: Teeth were dried and their apices were restored by the same material of the cavity filling (tetric N-ceram)the samples were then painted with a colourless nail varnish allowing it to dry well and then the painting was repeated again one more time with the same material. Sample sectioning: The teeth were sectioned with longitudinal direction passing through the restoration by cutting the long axis of the teeth (by using a rotary cutting machine). The slice thickness should not exceed 600 micron and each tooth is cut in three slices (three serial sections) in order to examine the whole cavity depth. The slides were examined under stereomicroscope using the magnification of (X60) to evaluate the microleakage which was observed by the dye penetration between the cavity walls and the restoration.

Mean of different readings microleakage scored as:

0= No dye penetration at all

1= Dye penetration along the interface to ½ of the depth of the cavity wall.

2= Dye penetration to the full depth of the cavity wall, but not including the axial wall.

3= Dye penetration to and along the axial wall.

The result of this research depended basically on Double Blind Technique where the slides were examined separately by the researcher alone followed by the supervisor alone with the slides unnumbered then the results were taken blindly and finally compared with the both results to find the final scores of microleakage.

## Results

The results include histological findings; samples were examined under stereomicroscopy for microleakage clues or traces which appeared as a purplish line or discoloration between the borders of the composite filling and the tooth surfaces. This line definitely reveals microleakage.

Results of group I (Acid etching only): In this group, the surface of the tooth was treated with 37% phosphoric acid and the histological sections of samples revealed two distinct zones (levels) to be recognized as a microleakage. The first zone or level is the most oral one where it begins from the oral surface of the tooth and below down to about 1mm as shown in Figure 1a, while the second zone starts from it and below to also about 1 mm down to the pulp direction where the full thickness of the cavity was involved in basic fuschin dye discoloration (score 2) as demonstrated in Figure 1b, and Figure 1-c. The third zone is not affected by microleakage.

Results of group II (Q-Switched Laser etching only): In this group, the Q-switched Nd:YAG laser with 532 nm was used to etch the tooth surface instead of the routine acid etch. The histological sections revealed also 2 zones or levels of microleakage, the first one is the most outer part of teeth(oral) down to the half of the depth of the class V cavity as illustrated in Figure 2-a, while the second layer penetrates down to the full depth of the cavity in the pulpal direction as seen in Figure 2-b, but not involving the floor of the cavity nor the axial wall (score 2) as shown in Figure 2-c.

Results of group III (Q-Switched Nd:YAG Laser etching then acid etching). In this group the teeth surfaces were conditioned with the Q-switched Nd:YAG laser irradiation and then the teeth surfaces were etched with the 37% phosphoric acid. The histological findings revealed that the microleakage of the dye through the composite-teeth walls were much less. Although the two previously mentioned layers still present (score 1) as shown in Figure 3-a, the number of the second layers or zones were less. Only 2 samples showed microleakage at this level (score 2) as illustrated in Figure 3-b, where the dye is not totally penetrated through the entire sectional slice as shown in Figure 3-c.

Results of group IV (Acid etching and Q-Switched Nd:YAG Laser etching).

In this group, the teeth surfaces were etched with 37% phosphoric acid and then were conditioned with the Q-switched Nd:YAG laser irradiation. The histological sections of the samples gave the best impression of the least microleakage that happened among the tested groups, where the penetration could be diagnosed only in one zone or level which is the most outer (oral) layer of the samples (score 1) as shown in Figure 4-a. The microleakage is localized only in the most outer (oral) layer in all the slides, the basic fuschin dye is not penetrated any further below down as shown in Figures 4-b and 4-c.

## Discussion

Significantly none of the methods used in this study to stop microleakage proved its total effectiveness.

This study showed that no specimen completely show no microleakage (score 0). The type and concentration of acid used in the etching is 37% of phosphoric acid. The parameters of the Q-switched Nd:YAG laser used in this in vitro study were really the key of this study. Different parameters were used with many trials and examinations under the stereomicroscope, it was found that Nd:YAG laser beam of 60 mJ pulse energy and 6 Hz pulse frequency and $0.48 J/cm^2$ energy density gave the best results , that's to say well etching and no co-lateral damages, below this energy no etching achieved while increasing the energy will cause smoothening of the tooth surface rather than etching it: as increasing the energy over 120 mJ lead to a noticeable charring in the specimens.

The application of an acid etchant produces demineralization of intertubular and peritubular dentin. This will cause the collagen matrix to mineralize 1, 7.

When using the laser irradiation to etch the tooth structure there is advantage of the absence of smear layer formation due to thermo-mechanical mechanism of action. Another difference between acid and laser etching related to dentin is the morphology of dentinal tubules. By acid application the etching includes peritubular dentin resulting in funnel shaped openings of the tubules and this morphology may contribute with polymerization shrinkage to pull the tags away from the walls9 but Nd:YAG laser irradiation does not cause any demineralization of the peritubular dentin and the dentinal tubules remain open with no widening that allows the development of resin tags. Actually a chalky whitish surface was the result of irradiating the bevelled surface of the tooth (by the recommended parameters mentioned) and it was similar to that surface etched with the 37% phosphoric acid. It considered as the most suitable surface for bonding and successful composite filling (irregular surface and more surface area) (Armengol V, Laboux O., et al., 2003). However, this study revealed that all the samples showed no dye penetration could reach the floor of the cavity or involve the axial wall.

The least microleakage results of the examined specimens was group 4 (acid etching followed by Q-Switched Nd:YAG laser etching) where the dye penetration could not pass through the prepared class V cavity by more than 1/2 of the depth of the cavity wall or even less, as many slides when examined under stereomicroscope revealed that there is really a microleackage starting from the outer surface of composite filling passing along the interface between the filling and tooth surfaces or walls, yet some histological slides showed that the dye penetration does not reach to the entire thickness of the sections which is about 600 jm, while the results of other methods shared the penetration of dye to or more than 1/2 of the cavity depth.

In acid etching alone or Nd:YAG laser etching alone methods (group I and group II ) the dye penetration were greater, the microleakage could be diagnosed in the full depth of the cavity; whereas in the Nd:YAG laser +acid etching method the results were much better than acid etching alone or laser etching alone as some slides showed the penetration to the full depth of the cavity although some slides did not.

In all the trials where laser used, it played a major role in treating the tooth surface by creating irregular surface needed in good bonding procedure. When tooth surface irradiated with Nd:YAG laser beam with the recommended parameters (mentioned previously) this will produce micro- explosions during hard tissue ablation that results in macroscopic (chalky appearance) and microscopic irregularities, Laser initially have been absorbed by the water molecules in the tooth structure causing vaporization with the other hydrated organic components of tissues , on vaporization internal pressure builds up within the tissue until the explosive destruction of organic substances occur, micro-irregularities make the enamel surface micro- retentive and enhance the mechanism of adhesion (Lizz CodJE ,Vanduerwe WP. 1992).

In this study it was found that the acid etching alone is not a completely effective method of enhancing bonding or preventing microleakage. The effectiveness of conventional etching might be weak to adequately dissolve the smear layer and expose the collagen network (Van Meerbeek B, et al., 2002). Actually microleakage can happen when the tooth- filling surfaces are continuously facing different degrees of temperature that will leads to a continuous thermal expansion and/or contraction. With laser etching both the bonding is enhanced and microleakage decreased obviously.

The results in this study may come into agreement with the fining of Keller and Hibst (1990), and Visuri et al. (1990) who have shown that when bonding composite to tooth structure, the Er:YAG laser alone or combined with acid etching may produce a surface with bond strength equal or better than that produced by acid etching alone (K.I.M Delma, et al., 2005). However the increase of laser pulse energy delivered to tooth surface causes deeper crater pattern on tooth surface which may influence the final composite restoration adaptation to the cavity wall (Roebuck E.M, Whitters CJ., 2000). Because this study is an in vitro one, basic fuschin dye has been used to mimic the dyes and other staining materials present in food and drinks and by which microleakage could be diagnosed.

In conclusion, the Q-switched Nd:YAG laser etching can be used in treating or conditioning the tooth surface to enhance bonding. It may be as equal as to the regular acid etching or even more effective and with the recommended parameters is an efficient technique to decrease microleakage if combined with the regular acid etching technique. The best parameters amongst the tested samples were: pulse energy of 60mJ, pulse repetition rate of 6Hz and energy density of 0.48 $J/cm^2$.

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# تقييم ليزر نيديميوم- ياك ذو الطول الموجي532 نانومتر بالمقارنة مع التخديش الحامضي في الحشوة الراتنجية من الصنف الخامس

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**الخلاصة** : الهدف من هذه الدراسة هو تحديد التسرب المجهري ((Microleakage تحت حشوة الكومبوزت الراتنجية في الحفرة السنية من النوع الخامس بعد معاملة سطح السن بواسطة التخديش الحامضي،او بواسطة التخديش الليزري، او بواسطة التخديش الحامضي والليزري معا ومقارنة هذه الطرق فيما بينها لمعرفة اية طريقة ادت الى التسرب المجهري الاقل. اختيرت عينة لهذه الدراسة مكونة من اربع وعشرون سنا مقلوعا خالية من التسوس قلعت من اماكن مختلفة ومن مرضى باعمار مختلفة لاغراض تقويم الاسنان او قلع كونه سن مطمور،تم تقسيم العينات الى اربع مجاميع تحتوي كل مجموعة على ستة اسنان وتم تحضير حفرة سنية من النوع الخامس في كل عينة. المجوعة الاولى: سطح السن تمت معاملته بواسطة الخدش الحامضي حيث استخدم حامض الفسفوريك بتركيز 37% ولمدة 15 ثانية لهذا الغرض. المجموعة الثانية: سطح السن تمت معاملته بواسطة الخدش الليزري وقد استخدم ليزر النيديميوم – ياك في الطورالتجانسي الثاني (second harmonic generation)وطول موجي 532 نانو متر وبمعايير 60 ملي جول لطاقة النبضة الواحدة وبتردد نبضات 6 هرتز حيث افترضت كاحسن المعايير بحسب هذه الدراسة. المجموعة الثالثة: سطح السن تمت معاملته بواسطة الخدش الليزري بنفس المعايير المستخدمة في المجموعة الثانية ثم بعد ذلك تمت معاملة سطح السن الخدش الحامضي كذلك بنفس مواصفات الحامض المستخدم في المجموعة الاولى. المجموعة الرابعة: سطح السن تمت معاملته بواطة الخدش الحامضي بنفس التركيز والطريقة المستخدمة قي المجموعة الاولى ثم بعد ذلك تمت معاملة سطح السن بالخدش الليزري وبنفس المعايير المستخدمة في المجموعة الثانية. بعد ذلك تم اكمال الحشوات باستخدام حشوة الكومبوزت الراتنجية لكل العينات بنفس المواد المستخدمة ومن ثم تعريض العينات لمعالجة حرارية(حمام مائي) مكون من 500 دورة تتراوح درجة حرارته مابين 6-60 درجة مئوية حيث ان زمن كل دورة دقيقة واحدة. بعد اخراج العينات من الحمام المائي تم اجراء الحشوات لنهاية جذور العينات بنفس مادة الحشوات الرئيسية(الكومبوزت الراتنيجي) ثم صبغت العينات بطبقتين من صبغ الاظافر الشفاف ماعدا منطقة الحشوة ومساحة 1 ملمتر حولها. غمرت العينات بمحلول يحتوي على صبغة البيسك فوكسين بتركيز 1% لمدة 24 ساعة ،ثم اخرجت العينات وتركت لتجف وبعد ذلك قطعت طوليا مرورا بالحشوة من عدة مستويات ،تم بعد ذلك فحص العينات لتعيين مدى التسرب المجهري للصبغة بين الحشوة وحافات الحفرة السنية وذلك باستخدام المجهر الضوئي المجسم((stereomicroscope بدرجة تكبير 60 مرة ،تم بعد ذلك قراءة وتسجيل التسرب المجهري في العينات ووضعها في جدول. عند اجراء التحليل للصور المجهرية المتعلقة بالمقارنة بين المجموعات الاربعة ،اظهرت نتائج الدراسة وجود اختلافات بين المجاميع المذكورة وان المجموعة الرابعة كانت هي المجموعة الاقل التي لوحظ فيها وجود تسرب مجهري للصبغة داخل الحفرة السنية. يستنتج من الدراسة ان استخدام ليزر نيديميوم- ياك في تقليل التسرب المجهري تحت حشوة الكومبوزت الراتنجية كان فعالا الى درجة كبيرة تتفوق على الطريقة التقليدية المستخدمة بواسطة الخدش الحامضي.