A scanning electron microscopic study to determine the effect of different etching techniques on enamel surface.

Heba Y. Ismail [1], Sanaa A. Soliman[2] and HalaMounir[2]

[1] Health Radiation Researcher, National Centre for Radiation Research and Technology, Cairo, Egypt.
[2] Department of Orthodontics, Faculty of Oral and Dental Medicine, Cairo University, Cairo, Egypt.
hebaun@yahoo.com

Abstract: Ideal etching to enamel surface is a challenging procedure. This study was conducted to determine the effect of sandblasting and laser irradiation on enamel versus conventional etching by studying the changes using scanning electron microscope. Sixty seven non-carious molar teeth were divided into 3 groups twenty two molars each. Group L: Enamel irradiated with Er:Cr;YSGG. Group S: Sandblasted at 65-70 psi. Sub-group SO: Sandblasted + bonded by Solo stick primer. Group P: Sub-group PT: Etched with 37%phosphoric acid. One molar was left unetched while Six molars were randomly selected, disked and prepared for scanning electron microscope examination. The results of this study indicate that conventional acid etching and Er:Cr;YSSG laser etched techniques can be used for etching of enamel surface and further bonding of metal orthodontic molar tubes as these two techniques have the most favorable etching patterns.Er;Cr:YSSG can be used as an alternative method for conventional acid etching technique in etching enamel surface for bonding orthodontic molar tubes.
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Key words: enamel acid etching, laser etching, sandblasting, SEM of etched enamel surface.

1. Introduction

In the past, the majority of literature addressed to band teeth as the line of treatment of choice, to avoid the need to rebond accessories especially in the posterior regions. The ultimate goal is that orthodontic attachments are secure enough on enamel surface to allow engagement of archwire and possible attachments, on the same time to be removed without damaging the surface. This raised the question whether is it safer to bond or band teeth? The banding procedure is not performed with utmost care it can damage periodontal tissues and increase the chance of decalcification caused by leakage beneath the bands. On the other hand, direct bonding of brackets and other attachments has become a common technique in fixed orthodontic treatment as it does not require prior band selection and fitting and has the ability to maintain good oral hygiene and improve esthetics. In conventional acid etching, the etchant roughens the enamel microscopically resulting in a greater surface area by dissolving minerals in enamel (hydroxyapatite crystals) to form “the mechanical lock”. After polymerization, the adhesive is locked as proved by **[1]** into the surface and contributes to micromechanical retention.

Several techniques have been introduced in the literature to increase the bond strength which include: sandblasting and laser etching techniques. Sandblasting (air abrasion) was introduced in orthodontics in 1940s in an attempt to achieve proper etching for the enamel surface which would result in a better bond strength through aluminum oxide particles that are emitted from a specific handpiece at a high speed which produces roughness in the enamel surface **[2-4].**

The word laser is an acronym for Light Amplification by Stimulated Emission of Radiation, the first laser introduced to dentistry was the helium-neon laser followed by Nd;YAG and CO_2 laser, then the erbium family (Er;YAG&Er;Cr), which has some advantages such as having no vibration or heat. These characteristics made the erbium family more popular in orthodontics **[5].** The purpose of this study was to compare the effect of etching by different techniques on enamel using the new Er;Cr YSSG laser, sandblasting versus the conventional acid etching technique.

2. Material and Methods

1-Sample selection

Sixty seven first molar teeth extracted for periodontal reasons were collected from the outpatient clinic of the dental educational hospital, Cairo University to be used in the present investigation. The molar teeth were selected free of caries, hypoplasia, macroscopic cracks, abrasions on the buccal surface as assessed by visual examination. The teeth were stored in saline for a maximum of 1 month and it was changed weekly to prevent bacterial growth and mimic oral conditions till the time of use. The patients were informed verbally about the possibility that their teeth could be used in a study and the teeth were anonymized and de-identified prior to the author's access to them.

2-Sample Classification

The sample was divided into three groups 22 molars each:

Group L: Enamel irradiated with Er:Cr;YSGG for 20 seconds.

Group S: Sandblasted at 65-70 psi for 20 seconds.

Group P: Enamel etched with 37% phosphoric acid.

One molar was left unetched and six molars were randomly selected for scanning electron microscopy to determine the topography and morphology of the treated enamel surface (two from each group).

3-Etching procedure

Group L (Laser etched):

WaterLase (BioLase Technology, Inc., San Clemente, CA, Globe Company, USA) was used in this study as it has a unique, powerful wavelength and water/air spray that cuts, etches and shapes target tissues without contact, heat, vibration or pressure.

In the present study the following specifications was used: The pulse used had frequency 15Hz, 2W power. The energy was 133mJ, water delivery via the handpiece was 30% and air was 50%. The laser energy was delivered via a flexible wave guide to a contra angled turbo handpiece. The beam was aligned perpendicular to the molar enamel surface in a non-contact mode with a fixed distance of 3 mm away from the laser tip in a sweeping motion. Then, the surface appeared frosty white after the etching procedure. No washing was undertaken following laser etching. Fig (1).

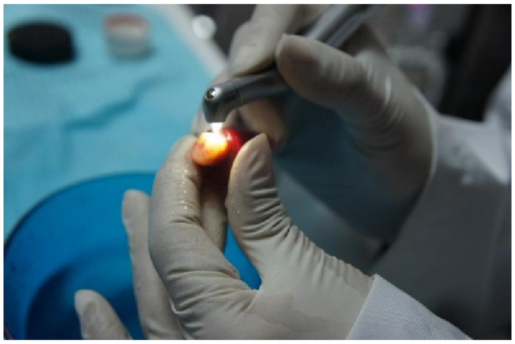

Fig. 1: laser etching of molar buccal enamel using Er:Cr;YSGG laser. Tiff

Group S (Sandblasting etched):

Enamel surface of molars was etched by using a sandblasting handpiece with aluminum oxide having a particle size of 50um. Sandblasting particles were directed perpendicular to the enamel surface at a distance of 5mm followed by rinsing by air/water spray for 20 seconds. The surface appeared frosty white after the etching procedure. Fig (2).

Fig. 2: sandblasting etching of enamel surface. Tiff

Group P (Acid etched):

The molars were etched by 37% phosphoric acid (Ormco Co; USA) for 20 seconds. Rinsing with water spray was performed afterwards and proper dryness of the surface using air spray. Fig (3)

Fig. 3: 37% phosphoric acid etching of enamel surface. Tiff

4-Investigation of the Enamel Surface

Scanning electron microscope examination:

Ref. [6] classified five types of etching patterns.

Type **I:** Enamel prism cores preferentially removed, giving honeycomb like appearance. It is the most favorable type of etching pattern.

Type II: The peripheral regions of the prisms were removed leaving relatively unaffected prism cores, giving cobblestone appearance.

Type III: Had areas corresponding to both Types 1 and 2.

Type IV: Pitted enamel surface as well as structures which look like an unfinished puzzle.

Type V: Flat smooth surface.

a- Preparation of the samples

The unetched molar and six first molars were randomly selected, one from each subgroup after etching, they were studied using scanning electron microscope (SEM) to determine the topography and morphology of the etched enamel surface. Six enamel blocks app 5x5mm were cut with a cooled diamond disk to remove the root and the lingual part of the crown.

b- Mounting and Coating

Samples were dried and placed on copper studs then they were coated by a highly conducting layer of gold sputter (20um thickness) using a fine coat apparatus in which the specimens were glued to studs and fixed inside the apparatus then the gold particles were spurred on their surfaces in a cycle of 10 minutes. Then they were examined by a JEOL-JSM 5400 SEM. Photos of SEM were then oriented and results were concluded after studying the photos. The SEM has a range of magnification of x15-200,000 and a resolution of 4nm. The instrument produces three dimensional images because of the large depth of field which is 3500 times that of light microscope. The photos were taken by two different magnifications (x500 times and x1500 times) for better visualization and studying the effect of every etching technique. Fig (4).

Fig.4: scanning electron microscope device. Tiff

3. Results

Scanning electron microscope (SEM)

Scanning electron photomicrographs of enamel surfaces were evaluated to investigate the etching pattern, resulted from each of the three etching techniques used.

1. For enamel surface:

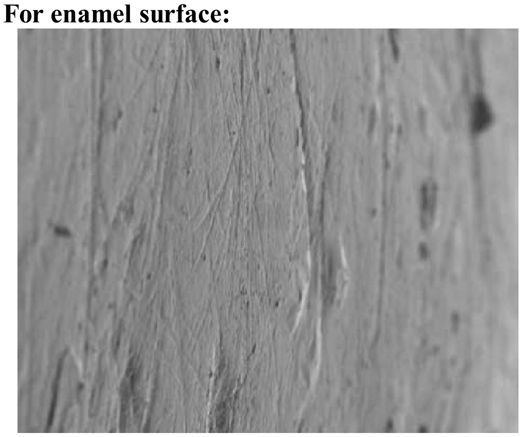

Fig. 5: SE micrograph of normal enamel surface of 1st molar (original magnification x500) showing that the surface is rough with the opening of enamel prisms are sealed.

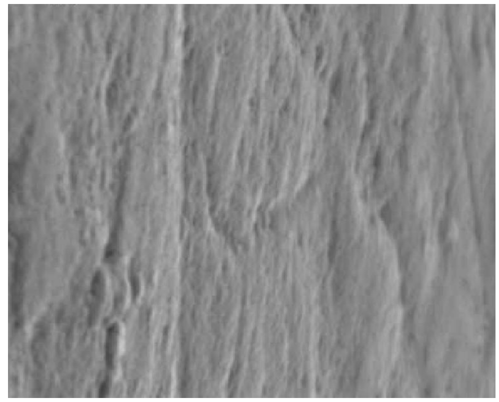

Fig. 6: Higher magnification of the same specimen (original magnification x1500) showing that surface defects are minimal and fissures are following the natural shapes of enamel prisms.

2. Er;Cr:YSSG laser etched enamel surface :

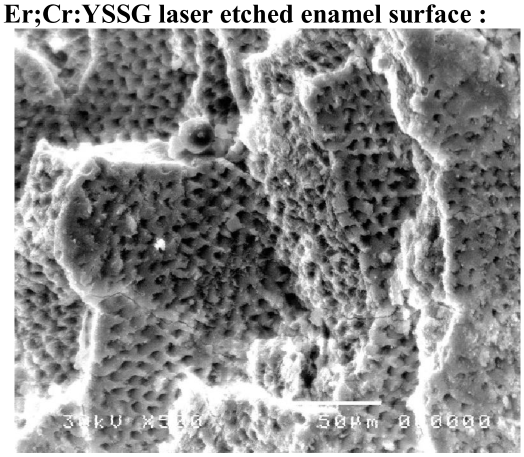

Fig. 7: SE micrograph of laser etched enamel of 1st molar (spec. No 1, original magnification x500) illustrating the honeycomb-like appearance.

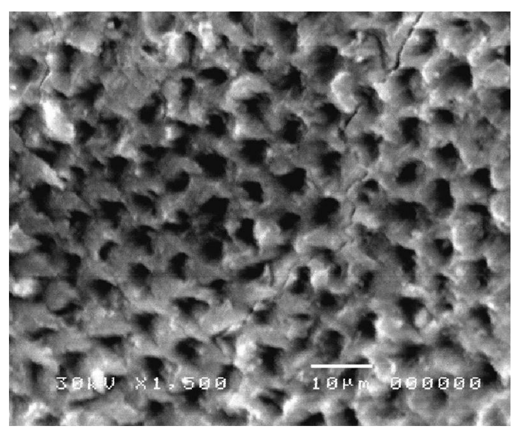

Fig. 8: Higher magnification of fig 7 (original magnification x1500) revealing micro cracks and distinct prismatic boundaries that aid in resin penetration.

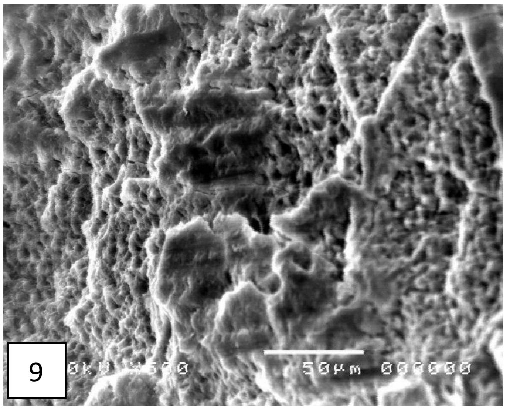

Fig. 9: SE micrograph of laser etched enamel for 1st molar (spec. No 2, original magnification x500) revealing distinct enamel prisms and well defined prismatic outline.

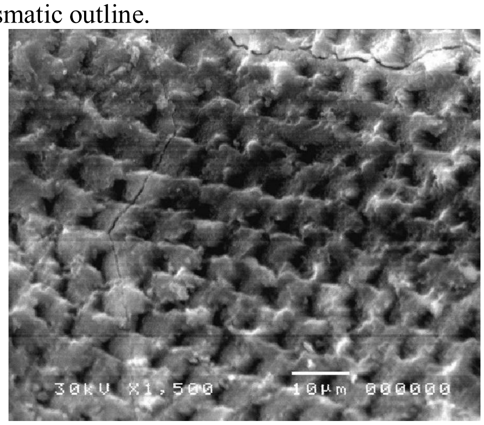

Fig. 10: Higher magnification of fig 9 (original magnification x1500) showing micro-cracks, uniform prismatic outline and rough surface resulting from interprismatic globular appearance. This suggests type I etching pattern.

3. Sandblasting etched enamel surface:

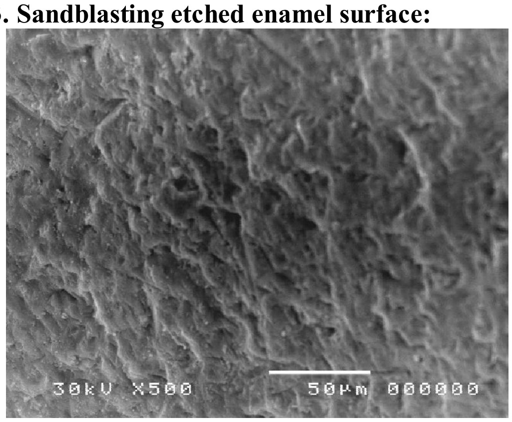

Fig. 11: SE micrograph of sandblasting etched enamel for 1st molar (spec. No 1, original magnification x500) showing confluence of prismatic and interprismatic structures and loss of the normal architecture of enamel.

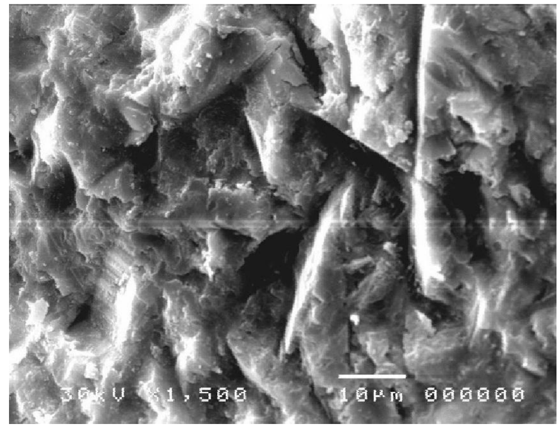

Fig. 12: Higher magnification of fig 11 (original magnification x1500) showing irregular surface due to tissue removal and marked loss of prismatic structure.

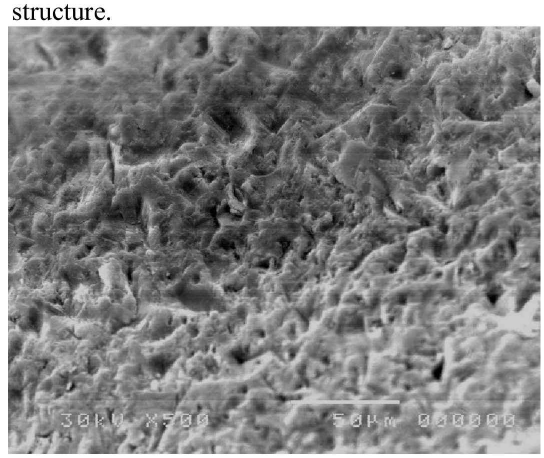

Fig. 13: SE micrograph of sandblasting etched enamel for 1st molar, (spec. No 2, original magnification x500) demonstrated irregular rough surface and interprismatic globular structures.

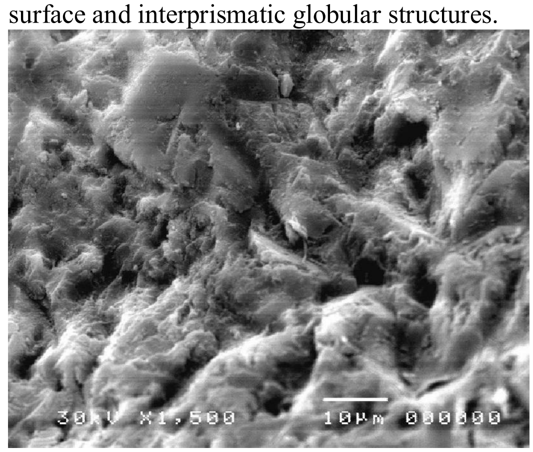

Fig. 14: Higher magnification of fig 13 (original magnification x1500) showing irregular surface with alternating micro porosities and globular deposits suggesting loss of enamel prisms. This suggests type IV etching pattern which has the most unfavorable effect on enamel surface.

4. Phosphoric acid etched enamel surface:

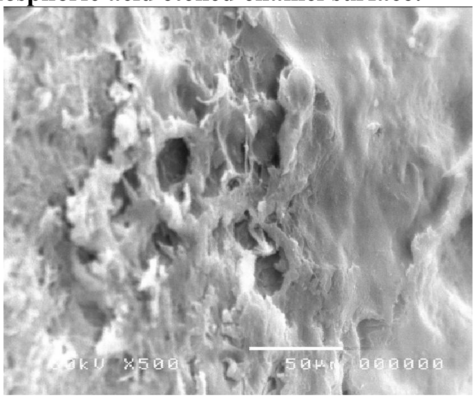

Fig. 15: SE micrograph of phosphoric acid etched enamel for 1st molar, (spec. No 1 original magnification x500) revealed prominent surface destruction and loss of prismatic architecture.

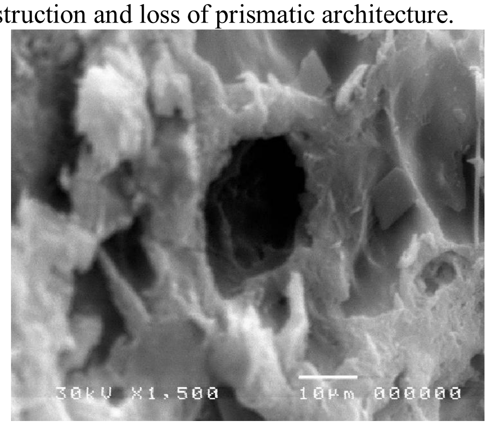

Fig. 16: Higher magnification of fig 15 (original magnification x 1500) demonstrating disturbed surface topography, deep pores and globular structures. They revealed type II etching pattern, where preferential removal of enamel prism core takes place, and the prism peripheries are relatively intact.

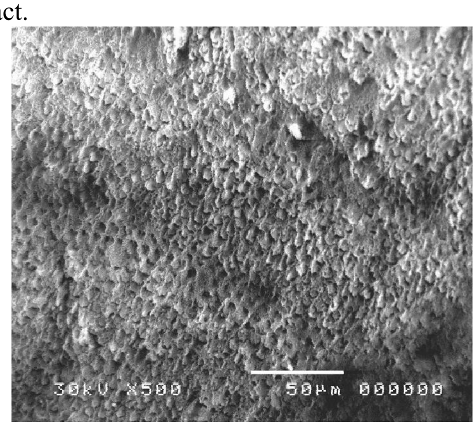

Fig. 17: SE micrograph of Phosphoric acid etched enamelfor 1st molar (spec No 2, original magnification x500) showing focal loss of prismatic core material, while prism peripheries are relatively intact.

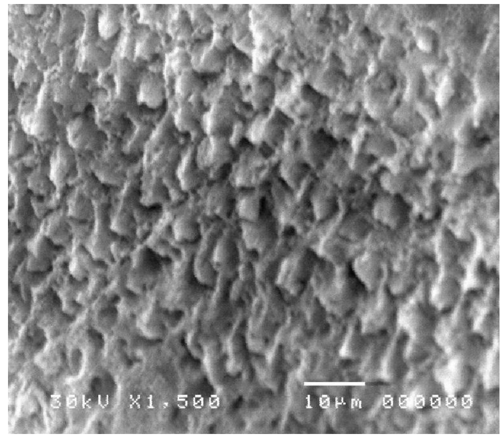

Fig. 18: Higher magnification of fig 17 showing the top of the keyhole is preserved, suggesting that the center and bottom of the keyhole have been dissolved.

4. Discussion

The shear bond strength (SBS) of bondable molar tubes is a challenging clinical procedure, tubes bonded to molars using self-cured or light-cured resins showed around 14% failure. This may be attributed to the difficulty in maintaining proper isolation of the posterior region, inadequate adaptation of the attachment base to the tooth surface, stronger masticatory forces, different etching times, and individual variations related to enamel composition, as claimed by ***Vercelino et al*** **[7]** and ***Mohammed M.*** **[8].** This higher rate of failure revealed a need to try finding other factors than the resin to increase the bond strength and decrease the failure rate consequently.

Three etching techniques were included in this study. Laser etching (Er:Cr;YSGG), sandblasting etching and phosphoric acid etching. The sample of the present study included sixty seven molars which was divided into three groups based on the type of etching technique used while, one molar was left unetched to study the intact enamel surface**.**

Sandblasting etching was used to produce enamel surface roughening as it has been believed that sandblasting removes unfavorable oxides, contaminants and increases surface roughness, thereby increasing surface energy and bonding surface area as proved by ***Chung et al.*** **[9].**

Er:Cr; YSSG Laser has been recently introduced to dentistry, due to its benefits as an ideal instrument to perform safe and minimally invasive treatment. The Er,Cr:YSGG laser used in the present study created laser-energized, atomized water droplets that acted as cutting particles. This laser system creates precise hard tissue cuts by the laser energy interacting with water at the tissue interface, called a hydrokinetic system. Laser energy was delivered through a fiber optic system to a sapphire tipped terminal. The wavelength was constant 2780 nm & the power output used in this study was 2W, 15Hz which is the most efficient watt and frequency used for etching enamel surface as proved by ***Ozer et al.*** **[10].**

Conventional 37% phosphoric acid was used in this study group, since it was considered as the most accepted and widely used acid etching agent that was capable of producing the most retentive bonding condition, as proved by ***Legler et al***. [**11].**

As **surface enamel integrity** is also our concern, a 20 seconds etching time was used to minimize the amount of enamel loss as advised by many authors: **[12-16].**

Scanning Electron Microscopic (*SEM*) study of the differently etched enamel surfaces was conducted to evaluate and compare the etching pattern and its aggressiveness between the three groups. Such evaluation was advocated by many authors **[4]-[17]-[18]-[19]-[20].** This was carried out in order to find the etching technique that had the least deleterious effect on enamel surface.

SEM investigations showed a honeycomb-like appearance of laser-etched enamel (Fig. 7), suggesting *type I* etching pattern that aided in the penetration of resin, as described by**10.** However with higher magnification there were micro cracks suggesting cutting in different planes which resulted from the laser successive etching points adjacent to each other. This is the most favorable type of etching pattern according to ***Silverstone et al.*** **[6].** This was in agreement with ***Hossain et al.*** **[21]** who compared the surface roughness of enamel following the Er,Cr:YSSG laser irradiation and acid etching using scanning electron microscope and found out that the surface is rough with no smear layer or enamel cracks.

On the other hand, the **sandblasting group** showed confluence of prismatic and interprismatic structures, erosions and loss of the normal architecture of enamel surface suggesting type IV etching pattern, (Figs. 11, 12, 13 and 14). *SEM* images showed loss of interprismatic structure as proved by ***Chung et al.*** **[18],** which had the most deleterious effect on enamel surface. However, ***Van Waveren Hogervorst et al.*** **[4]** quantified the surface enamel loss that results when an air-abrasive technique is used and found out that the enamel loss associated with sandblasting is equal to or smaller than that resulting from acid etching.

Finally, the **phosphoric acid** group showed focal loss of prismatic core material, while prism peripheries were relatively intact (Figs.15 and 16). While, with higher magnification**,** prisms showed preservation for the top of the keyhole and dissolution of its bottom as was advocated ***by Zanet et al***. **[20]** **and *Cal-Neto et al*. [22]** suggesting type II etching pattern.

SEM* investigation** had assured that the most deleterious effect on enamel surface was observed with sandblasting etching group, as some specimens showed an irregular surface due to tissue removal and marked loss of prismatic and interprismatic structures, with alternating microporosities and globular deposits suggesting loss of enamel prisms as described by ***Silverstone et al **[6]** On the contrary, the safest and least deleterious effect on enamel surface was observed with laser etching group where it showed the most favorable type of etching pattern, type I.

Further investigations for methods other than etching techniques, as variation in base design and bondable molar tube materials are suggested.

5. Conclusion

Er;Cr:YSSG can be used as an alternative method for conventional acid etching technique in bonding orthodontic brackets as it was found to have the safest effect on enamel surface. This was on the contrary to the sandblasted system which had recorded a higher shear bond strength value but with the most deleterious effect on enamel surface.

Conflict of interest statement:

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

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Corresponding author:
Heba YehiaAbd el Rahman Ismail Health Radiation Researcher, National Centre for Radiation Research and Technology, Cairo, Egypt.
Email: hebaun@yahoo.com

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