

# Comparative evaluation of surface topography of tooth prepared using erbium, chromium: Yttrium, scandium, gallium, garnet laser and bur and its clinical implications

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## Abstract

**Background:** Erbium, chromium: Yttrium, scandium, gallium, garnet (Er, Cr: YSGG) laser has been successfully used in the ablation of dental hard and soft tissues. It has been reported that this system is also useful for preparing tooth surfaces and etching, but no consensus exist in the literature regarding the advantage of lasers over conventional tooth preparation technique.

**Materials and Methods:** Labial surfaces of 25 extracted human maxillary central incisors were divided into two halves. Right half was prepared with diamond bur and left half with Er, Cr; YSGG laser and a reduction of 0.3–0.5 mm was carried out. Topography of prepared surfaces of five teeth were examined under scanning electron microscope (SEM). The remaining samples were divided into 4 groups of 10 specimens each based on the surface treatment received: One group was acid etched and other was nonetched. Composite resin cylinders were bonded on prepared surfaces and shear bond strength was assessed using a universal testing machine.

**Results:** The SEM observation revealed that the laser prepared surfaces were clean, highly irregular and devoid of a smear layer. Bur prepared surfaces were relatively smooth but covered with smear layer.

Highest bond strength was shown by laser prepared acid etched group, followed by bur prepared the acid etched group. The bur prepared nonacid etched group showed least bond strength.

**Conclusions:** Er, Cr: YSGG laser can be used for preparing tooth and bond strength value achieved by laser preparation alone without surface treatment procedure lies in the range of clinical acceptability.

**Key Words:** Acid etching, bond strength, erbium, chromium: Yttrium, scandium, gallium, garnet laser, laser etching, scanning electron microscope

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## INTRODUCTION

LASER is the acronym for light amplification by stimulated emission of radiation. Albert Einstein first explained the theory

of stimulated emission in 1917, which became the basis of lasers. Lasers were first applied in dentistry for hard-tissue treatments such as caries removal and cavity preparation, as a substitute for mechanical cutting and drilling.<sup>[1]</sup> After the discovery of ruby laser by Maiman, Goldman *et al.* (1964) attempted caries removal using it *in vitro*. Since then, many researchers have investigated the effects of lasers on dental hard tissues and caries using argon, carbon dioxide (CO<sub>2</sub>), and neodymium-doped yttrium aluminum garnet (Nd: YAG) lasers.<sup>[2]</sup>

However, though indicated, most lasers are unable to effectively cut biocalcified tissues. CO<sub>2</sub> and Nd: YAG lasers induce surface

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changes in enamel, but these lasers tend to cause fissuring, cracking, recrystallization or crateriform foci of melting.<sup>[3-8]</sup> Some of the lasers are able to ablate carious material, but they cannot effectively prepare sound tooth structure and, therefore, are not amenable to cavity preparation.<sup>[7,9]</sup> In addition, laser photon energy is complicated by significant elevations in temperature with a potential for deleterious effects on pulpal tissues.

Some of these shortcomings have been compensated after the introduction of erbium, chromium: Yttrium, scandium, gallium, garnet (Er, Cr: YSGG) laser in the field of dentistry. This laser system with a wavelength of 2780 nm, frequency of 20 Hz and pulse energy between 0 and 300 mJ, has Federal Drug Administration: USA approval for several soft and hard tissue procedures. It produces microexplosions during tissue ablation, resulting in macroscopic and microscopic irregularities.<sup>[5]</sup> The laser energy absorbed by water microdroplets is believed to be partially responsible for the hard tissue cutting effects and has been designated as a hydrokinetic system (HKS).<sup>[6,9]</sup> Other points of interest regarding the Er, Cr: YSGG laser includes the fact that melting enamel with this laser increases resistance to acid demineralization.<sup>[10]</sup> Because of this versatility, the Er, Cr: YSGG laser is the first all-in-one laser that make the economics of providing laser therapy more feasible.<sup>[11]</sup>

Another advantage of using laser energy for tooth preparation is that it does not lead to the formation of smear layer. Tooth preparation with rotating instruments leaves a smear layer on the tooth surface which hinders impregnation (enamel or dentin) with the adhesive agent and thus prevents adequate adhesion. Since the report of Buonocore, the standard approach to this problem has been acid etching.<sup>[12-14]</sup> Laser etching has become available as an alternative to acid etching. Laser etching of enamel or dentin has been reported to yield an anfractuous surface and open dentin tubules, both apparently ideal for adhesion.<sup>[3]</sup> Laser radiation of dental hard tissues modifies calcium-to-phosphorus ratio and reduces carbonate-to-phosphate ratio leading to the formation of more stable and less acid-soluble compounds, thus reducing susceptibility to acid attack and caries.<sup>[4,5]</sup>

Although there are many benefits of using laser for etching tooth surface, a different group of lasers alter tooth surface differently and thus affect bond strength in a variety of manner. Compared to acid etching, CO<sub>2</sub> lasers have been reported to increase the bond strength,<sup>[15-17]</sup> whereas Nd: YAG and argon fluoride: Excimer devices have been reported to weaken the bond strength between tooth and composite resin.<sup>[18]</sup>

The purpose of this study is to compare the topographic changes over the tooth surface after preparing it with Er,

Cr: YSGG laser and diamond points. Another parameter assessed is the bond strength achieved over both the prepared surfaces without any surface treatment and following acid etching treatment.

## MATERIALS AND METHODS

A total of 210 extracted maxillary central incisor teeth devoid of caries and restorations were placed in isotonic saline immediately after extraction and stored at room temperature.<sup>[19]</sup> The radicular portions of the teeth were boxed in acrylic resin before preparation.

For the purpose of standardization, labial surface of the same tooth was divided into two halves arbitrarily with a permanent marker [Figure 1] and prepared by two different means as for laminate restoration. Right half of the tooth was prepared with diamond bur and the left half with Er, Cr: YSGG laser. Tooth preparation was performed by the same operator to avoid any bias.

Of a total sample size of 210 teeth, following two groups were created:

- Group 1: Tooth surface prepared with laser (left half of the labial surface)
- Group 2: Tooth surface prepared with diamond bur (right half of the labial surface).

### Tooth preparation

Window type preparation design was chosen. Right, half of the tooth was prepared with diamond bur (SS White Burs, Inc. 1145 Towbin Avenue Lakewood, New Jersey). Facial reduction of 0.3–0.5-mm was carried out using standard grit round end diamond and chamfer cervical finish line was given. Preparation was finished using fine grit round end diamond point. An Er, Cr: YSGG hydrokinetic dental laser (Waterlase C-100, BioLase Tech Inc., California, USA) was used for



**Figure 1:** Maxillary central incisor tooth divided into two halves

preparing the other half of the tooth. Parameter settings used in the study were: Power output at 4 watts, Pulse repetition rate of 20 Hz and pulse duration of 140  $\mu$ s. Laser tip selected was sapphire fiber tip (C-6) with tip diameter of 600  $\mu$ m and tip length of 9 mm.

Laser beam was directed toward the tooth surface in a scanning fashion at a distance of approximately 2 mm and at an angle of 45° to the tooth surface. Laser beam was directed manually, without the use of a fixed support, to simulate clinical conditions as closely as possible [Figure 2]. 0.3–0.5 mm reduction of the labial surface was done. Prepared tooth is shown in Figure 3.

### Scanning electron microscope examination

A total of 10 tooth samples were selected at random after tooth preparation and examined under scanning electron microscope (SEM) to compare the surface topography of tooth prepared using laser and diamond bur. Selected samples were fixed in neutral buffered formalin to remove traces of moisture. The prepared specimens were sputter coated with gold in a vacuum chamber and were viewed in SEM machine (Carl Zeiss AG, EVO-50 series, NTS GmbH, Oberkochen Germany) at a resolution of  $\times 500$ .

### Surface treatment

After tooth preparation, the prepared teeth were divided into 4 subgroups of 100 samples each based on the surface treatment procedures they were subjected to [Table I].

#### Phosphoric acid etching

It was done with 37% phosphoric acid gel (SwissTEC, Composite Resin, Coltene, Whaledent, Switzerland), followed by washing with water after 30 s. Tooth surface was air dried for further bonding steps.

#### No etching group

In this control group, no surface treatment was done on the prepared tooth surface. They were directly subjected to the bonding procedure.

**Table 1: Table showing the distribution of samples into different groups and their respective bond strength values**

Group	Sample size (n)	Mean bond strength (in MPa)	Std. Deviation
IA			
Laser prepared-non acid etched	100	25.1620	2.5541
IB			
Laser prepared-acid etched	100	31.7360	2.8753
2A			
Bm prepared-non acid etched	100	9.9520	1.2936
2B			
Bm prepared-acid etched	100	30.1410	2.4256

### Bonding composite resin to tooth surface

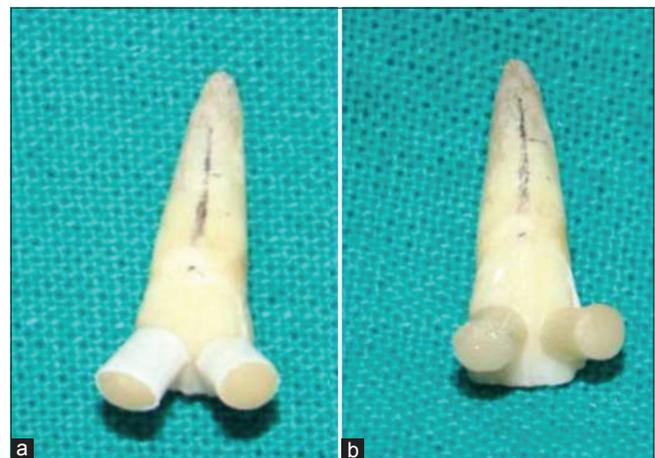
Single coating of the bonding agent (SwissTEC, Composite Resin, Coltene, Whaledent, Switzerland) was applied with the help of applicator tips and cured for 20 s. Each tooth received



**Figure 2:** Laser irradiation of the left half of tooth



**Figure 3:** Prepared tooth surface



**Figure 4:** (a) Resin packed using plastic sleeves, (b) bonded resin cylinders

2 bonded composite resin (SwissTEC, Composite Resin, Coltene, Whaledent, Switzerland) cylinders, one on each of the prepared surfaces. For uniformity of the size of composite resin cylinders, a plastic tube of 3 mm inner diameter and 5 mm height was filled with composite resin and placed perpendicular to the tooth surface [Figure 4a]. The composite resin cylinder was subjected to the curing light for 60 s, moving the light to assure uniform curing of the entire cylinder [Figure 4b]. Prepared specimens were stored in distilled water at room temperature for 24 h, followed by bond strength testing.<sup>[19]</sup>

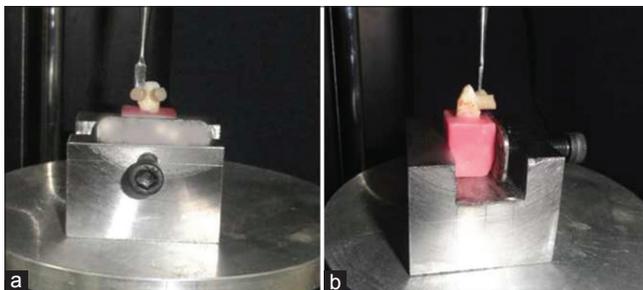
Samples were tested for shear bond strength with a universal testing machine (A-271800102, Ogawa Seiki Co., Ltd, Japan) using a knife-edge bonded cylinder and were at a distance of 1 mm from the tooth surface [Figure 5]. Tests were performed at a crosshead speed of 1.0 mm/min until the composite cylinder was dislodged from the tooth. The force to dislodge the bond between the composite resin and tooth was recorded as a peak load in Newton. Shear bond strength in megapascals (MPa) were determined by dividing the peak load by the surface area of each cylinder. The bond strength ( $d$ ) values (expressed in MPa) were calculated using the formula:  $d = L/A$ , where  $L$  is a load (in  $N$ ), and  $A$  is the adhesive area.

Bond strength data were analyzed with a 2-factor analysis of variance, with the level of significance of  $P < 0.05$ . *Post-hoc* comparisons of means were performed using *t*-tests with  $P$  values adjusted for multiple comparisons (Bonferroni method).

## RESULTS

### Bond strength assessment

Highest bond strength was observed in Group 1B; that is, laser prepared the acid etched group, followed by Group 2B, that is, bur prepared, and acid etched the group [Table I]. Group 2A, that is, bur prepared the nonacid etched group showed least bond strength. Statistical analysis revealed that the difference in the bond strength values in Group 1A ( $25.1620 \pm 2.5541$ ) and Group 1B ( $31.7360 \pm 2.8753$ ) was statistically significant ( $P > 0.05$ ). The mean bond strength in 2A group,



**Figure 5:** Specimen attached to fixture for bond strength assessment, (a) frontal view, (b) lateral view

that is, tooth prepared using bur with no acid etching treatment was  $9.9520 \pm 1.2936$  MPa, for 2B group, that is, bur prepared and acid etched group was  $30.1410 \pm 2.4256$  MPa. The difference in bond strength between these two groups was statistically significant ( $P > 0.05$ ).

The difference in bond strength values between all the groups is significant sparing the Group 1B, that is, laser prepared acid etched and 2B, that is, bur prepared acid etched where the difference is found to be insignificant.

### Scanning electron microscopic observations

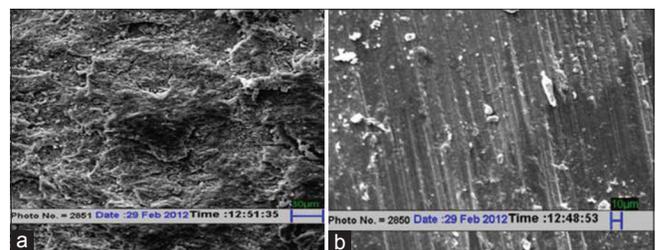
The SEM examination was performed at a magnification of  $\times 500$ . The SEM observation revealed that the laser prepared surfaces were clean and devoid of a smear layer. Laser tooth surface was highly irregular; sharp jagged projections were evident on the laser prepared surface with some evidence of prism structure. Significant surface craters and subsurface fissuring was evident [Figure 6a].

Nonetched bur-cut enamel surfaces were relatively smooth, but they were covered with smear layer. Preparation lines created by the movement of bur over the enamel surface are clearly evident. These surfaces fail to show prism structure because of masking by a diffuse smear layer [Figure 6b].

On laser prepared surface, there is a lack of smooth continuous margin which is evident on the bur prepared surface. Presence of this diffuse marginal topography along laser prepared surface might necessitate the use of the bur to define the margins.

## DISCUSSION

Though the use of high-speed handpieces and dental burs for tooth preparation save on time, they might lead to increased sensitivity after tooth preparation. Furthermore, subsequently they need some sort of surface treatment for bonding between the tooth and composite resin. Lasers have been proposed and used for tooth preparation owing to their ability to reduce sensitivity after tooth preparation.<sup>[20,21]</sup> It has also been reported that there is a significant decrease in discomfort levels for the laser system at the time of tooth preparation for subjects who



**Figure 6:** Scanning electron microscope view of the tooth surface, (a) laser prepared, (b) bur prepared

declined to receive local anesthetic in comparison to the use of high-speed handpieces and burs.<sup>[22]</sup>

The SEM observations of the laser and bur prepared surface revealed that the lased tooth surface was irregular and there was also the absence of a smear layer with some evidence of prism structure; Nonetched bur-cut enamel surfaces fail to show prism structure because of masking by a diffuse smear layer. The topographical features are very much similar to the one observed by Lin *et al.*<sup>[23]</sup>

The present study is in accordance with the study conducted by Hadley *et al.*<sup>[22]</sup> They compared the cavity preparation using conventional air turbine handpiece and Er, Cr: YSGG laser powered system using a split-mouth design. The restoration retention was similar between the two treatment groups with added advantage of statistically significant decrease in discomfort levels for the laser system at the time of cavity preparation when performed without the use of local anesthetic.

In the present study highest bond strength values were seen in laser prepared acid etched group, followed by bur prepared the acid etched group and the differences between them being statistically insignificant. Laser prepared nonetch group had bond strength significantly lower than the above two groups. Lin *et al.*<sup>[23]</sup> found similar results while assessing the shear bond strength of composite bonded to tooth structure treated with an Er, Cr; YSGG-powered HKS and carbide bur. Even they reported no significant differences in shear bond strength between etched bur-cut and etched laser-cut enamel.

Data obtained from this study is against the results obtained by Martínez-Insua<sup>[24]</sup> as they found that adhesion to dental hard tissues after Er: YAG laser etching is inferior to that obtained after conventional acid etching. The probable reason could be that enamel and dentin surfaces prepared by Er: YAG laser etching show extensive subsurface fissuring that is unfavorable to adhesion. This difference could be attributed to the difference in the nature of the laser used and thus the effect on the tooth surface.

Another inference drawn from the present study implies that pretreatment of the tooth surface with Er, Cr: YSGG laser did not increase the effectiveness of conventional acid etching of enamel. This is the reason why on both laser and bur prepared tooth surfaces which were subjected to acid etching, the difference in bond strength values was insignificant. Similar inference was drawn by Moslemi *et al.*<sup>[25]</sup> and they also reported that pretreatment with Er, Cr: YSGG laser did not increase the effectiveness of conventional acid etching of enamel in sealant bonds. These results disagree with the study of Usümez *et al.*<sup>[26]</sup> who concluded that surface treatment with Er, Cr: YSGG laser

and 37% phosphoric acid produce similar bond strength values on the tooth surface.

It can be proposed that laser powered HKS is an efficient, effective, precise and safe device for the removal of caries and for the preparation of tooth structure for restorations. It also offers an alternative to the vibratory and auditory irritation that attends conventional air turbine/bur.

Though time taken by laser to complete tooth preparation is much more than high-speed handpiece and bur,<sup>[22,23,27]</sup> they can still be considered as an alternative mode of preparing tooth owing to their desensitizing effect on tooth, reduced need of anesthesia during tooth preparation,<sup>[22]</sup> no sense of vibration, additional advantage of enhancing the bond strength. Use of lasers for tooth preparation can also solve the problem of sensitivity faced while preparing the vital teeth for crown. Unlike conventionally used acid etchants, they do not cause surface demineralization which increases the likelihood of caries initiation. In fact Er, Cr: YSGG laser has been shown to increase acid resistance of enamel and dentin upon irradiation.<sup>[9]</sup>

### Future directions

It is unquestioned that the patient avoidance of restorative dentistry is based upon the perceived association of such procedures with pain. There is a strong argument that laser-assisted tooth preparation, caries control, and bonding techniques will find growing acceptance. But no single *in vitro* test provides an accurate indication of the intraoral environment. Further investigations including the effect of thermal cycling and long-term water storage on bond strength assessment needs to be done. Furthermore, the effect of exposing tooth surfaces to different laser power settings during etching and tooth preparations needs to be further addressed.

The results thus obtained, present a valid premise for further *in-vivo* studies to evaluate the potential of lasers for tooth preparation and etching.

### CONCLUSIONS

Within the limitations of this study, following conclusions were drawn:

- SEM revealed that significant differences exist in topography of bur-and laser-prepared surfaces with laser prepared enamel surface being more irregular and rough
- The bond strength value in laser prepared acid etched group was significantly higher than laser prepared nonetched group. Similarly among bur prepared surfaces, bond strength was higher in an acid etched group
- Laser prepared the nonacid etched group had shown significantly higher bond strength values compared to bur

prepared the nonacid etched group, which has shown least mean bond strength of all the study groups

- Highest bond strength was shown by laser prepared acid etched group, followed by bur prepared acid etched, but the difference here was found to be statistically nonsignificant.

It was found in the present study that Er, Cr: YSGG laser can be used for preparing a tooth. Though bond strength value for restorative resins achieved by laser preparation alone without use of any other surface treatment procedure is less than that achieved after acid etching of bur prepared surface, the values are still clinically significant and acceptable.

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