REVIEW ARTICLE

Comparison on Surface Roughness and Its Effect on Bonding between Conventional Bur and Laser Cut Cavities: An *in vitro* Study

¹Preethi Varadan, ²Lakshmi Balaji, ³Deivanayagam Kandaswamy

ABSTRACT

Buccal surfaces of human extracted molars were obtained and divided into three groups for cavity preparation. Class V cavities were prepared using diamond bur for Group 1, tungsten carbide bur for Group 2, and Er,Cr:YSGG laser for Group 3. The surface roughness was measured using a 3D noncontact profilometer. The samples were subdivided into subgroups A and B, where subgroup B underwent additional acid-etching procedure. The temperature rise during cavity preparation was recorded using a digital thermostat. The samples were then restored with composite resin following application of bonding agent and light cured for 20 seconds for bond strength evaluation under Universal Testing Machine at a cross speed of 0.5 mm/minutes. The data obtained were finally statistically analyzed. On surface roughness evaluation, laser group (G3) produced maximum surface roughness when compared to conventional bur groups (G1 and G2). On depth of surface roughness evaluation, additional acid etching increased surface roughness of all three groups with laser group (subG3B) followed by acid etching exhibiting maximum surface roughness. On bond strength evaluation, diamond group (G1) exhibited increased bond strength when compared to laser (G3) and tungsten carbide group (G2). On thermal change estimation, all the three groups (G1, G2, and G3) produced minimal temperature rise which was below 5.5. Despite increased surface roughness produced by laser, conventional diamond bur (G1) produced highest bond strength when compared to laser (G3) and tungsten carbide groups (G2).

Keywords: Dental burs, Digital thermostat, Laser, 3D non-contact profilometer.

¹Senior Lecturer, ²Professor, ³Dean, Professor and Head

¹⁻³Department of Conservative Dentistry and Endodontics Faculty of Dental Sciences, Sri Ramachandra University Chennai, Tamil Nadu, India

Corresponding Author: Preethi Varadan, Senior Lecturer Department of Conservative Dentistry and Endodontics, Faculty of Dental Sciences, Sri Ramachandra University, Chennai Tamil Nadu, India, Phone: +919884185282, e-mail: divya varadan@gmail.com

INTRODUCTION

Success of any restoration mainly depends on adhesion to enamel and dentin.[1] In dentistry, among four adhesion mechanisms, mechanical adhesion still proves to play a prime role in enhancing retention of restoration.[2] Mechanical adhesion is achieved by interlocking of the adhesive with irregularities in the surface of the substrate (tooth).[2] It is presumed that surface roughness and irregularities promote the wettability by increasing surface area and that the bond between the adherend surface and the adhesive will be subsequently stronger.[3]

Mechanical retention was mainly achieved by conventional burs, such as diamond burs and tungsten carbide burs which were commonly used for cavity preparations.[4] However, cavity preparation using rotary burs creates an amorphous layer of organic and inorganic debris, known as smear layer, on the surface of the enamel which interferes on bonding of the adhesive agents to enamel.[5]

Cavity preparation is usually followed by acid etching with 37% phosphoric acid for 15 seconds. Enamel etching with acid removes 10 µm of surface enamel and creates microporous layer which is 5 to 50 µm deep, thereby facilitating formation of resin tags within enamel.[6]

Laser technology has attained popularity over the recent years, and its uses in restorative dentistry includes removal of carious tissue, reduction in dentin hypersensitivity, conditioning of enamel and dentin for adhesive systems, caries prevention in pits, and fissures.[7] Er,Cr:YSGG lasers are group of Erbium laser systems, that operates at a wavelength of 2.780 µm.[8] Erbium lasers produced similar surface to that of conventional phosphoric acid etching.[9] Erbium lasers with appropriate parameters selectively removes hydroxyapatite crystals from enamel producing surface irregularities that could enhance the micromechanical retention.[10]

Recently, three dimensional (3D) optical laser profilometer has been widely used as it provides a noncontact, nondestructive, quick quantitative measurement for surface roughness.[11] It permits multiple descriptions of surface roughness profile of composite resins that is possible beyond two dimensional (2D) surface profilometer.[12,13] Canabarro et al (2009)[14] studied comparative topographic analysis of titanium surfaces using 3D and

2D profilometers and concluded that 3D profilometer was more appropriate analytical method than 2D profilometer due to its ability to describe surface organization.

Conventional burs produce more heat during cavity preparation in comparison to laser systems and induce more deleterious effects on pulp than lasers. To confirm this, temperature rise during cavity preparation using both conventional burs and laser systems were recorded using a digital thermostat.[15,16]

Laser-prepared cavities with or without acid etching on improving bond strength of composite resin restorations have always been controversial.[17-20]

Thus, the aim of current study is;

- To compare the surface roughness of the cavities prepared using conventional burs and laser systems and to evaluate whether phosphoric acid etching, following laser, alters the surface morphology or not.
- To estimate the thermal changes occurring during cavity preparation using laser and bur.
- To analyze the bond strength of composite resin to dentin to cavities prepared using laser and conventional burs.

MATERIALS AND METHODS

Sample Preparation

Twenty-eight freshly removed human molars were obtained. The teeth were stored in 0.5% chloramine solution at 4°C to prevent bacterial overgrowth. Teeth with caries, restorations, hypoplastic areas, cracks, or gross irregularities were not included. The buccal surfaces of each crown were ground with 500 grit abrasive paper under running water in order to provide uniform flat surfaces of enamel. The samples were divided randomly into four groups (Table 1). The groups were prepared using (1) Medium grit diamond bur, (2) tungsten carbide bur (3) Er,Cr:YSGG laser alone, and (4) Er,Cr:YSGG ablation plus conventional acid-etching procedure with 37% phosphoric acid.

Laser group was prepared using Er,Cr:YSGG laser system (Waterlase Millennium™, Biolase Technologies Inc., San Clemente, CA, USA) emitting photons at a

Table 1: The groups and their subclassification depending on etching and armamentarium used

Experimental groups	Subgroups	Armamentarium used
1	A – etching	Medium grit
	B – without etching	Diamond bur
2	A – etching	Tungsten carbide bur
	B – without etching	
3	A – etching	Er,Cr:YSGG laser
	B – without etching	

wavelength of 2.78 µm, pulsed with a time period between 140 and 200 µm. The output power varied from 0 to 6 W. The beam spot size was 0.442 mm² with the use of a 750 µm diameter fiber at the distance of 2 to 3 mm. Irradiation was carried out according to manufacturer's instructions. During initial cavity preparation, laser irradiation was performed in a contact mode for removing enamel with a focused beam of 6 W (67.9 J/cm²) at 90% air pressure level and 75% water level and 20 Hz frequency. As the enamel removal was progressing near dentin, the power was reduced to 3 W (33.9 J/cm²) at 70% air level and 20% water level. The cavities were finished carefully in a noncontact irradiation mode.

In subgroups 1B, 2B, and 3B cavity preparation was followed by additional conventional etching procedure, with 37% phosphoric acid for a period of 15 seconds, while in subgroups 1A, 2A, and 3A only cavity preparation was done, no etching procedure was carried out.

Thermal Change Estimation

The biggest root of tooth sample was amputated and thermocouple was inserted into the pulp chamber. The digital thermostat was fixed by red wax in the pulp chamber, and the temperature was recorded. The red wax was used to prevent the water used as a coolant during cavity preparation from influencing the temperature readings. Within the chamber, the thermostat was placed adjacent to the irradiated area.

Surface Roughness Analysis

The surface roughness of the samples was examined using a 3D noncontact profilometer (Talysurf CCI Lite System, Taylor Hobson Ltd, Leicester, UK) at 50× magnification.

Bond Strength Assessment

After surface roughness evaluation, all the samples were etched with 37% phosphoric acid for 15 seconds (except Group 4 which was already etched) and rinsed with distilled water for the same time. Bonding agent (Meta P & Bond, Meta BioMed, Korea) was applied and light cured for 10 seconds. The samples were then restored with light-cured composite resin and light cured for 20 seconds. Samples were stored in distilled water at 37°C for 24 hours prior to being subjected to the microtensile bond strength test. A Universal Testing Machine (Instron 3382, Canton, MA, USA) was used at a crosshead speed of 0.5 mm/minutes. The data obtained in newton (N) were converted to megapascals (MPa) using the mentioned formula below:

$$1 \text{ MPa} = 1.0 \times 10^{-6} \times \text{N/m}^2$$

Statistical Analysis

The data collected was analyzed with Statistical Package for the Social Sciences (SPSS) 16.0 version. To describe about the data descriptive statistics, mean and standard deviation were used. For bivariate analysis, Mann–Whitney test was used in case of independent samples and Wilocoxon signed-rank test was used in case of paired samples. For mutlivariate analysis, Kruskal–Walli's test was used. In the above statistical tool the probability value p = 0.05 is considered as significant level.

RESULTS

On surface roughness evaluation, Kruskal–Walli's analysis showed Group 3 (laser group) exhibited maximum surface roughness when compared with Group 2 (diamond bur) and Group 1 (tungsten carbide bur). Group 1 showed least average surface roughness among other two groups. On comparison of surface roughness among the subgroups A and B, Man–Whitney analysis and Wilcoxon signed-rank test showed subgroups 1B, 2B, and 3B (etched groups) produced higher surface roughness in comparison to subgroups 1A, 2A, and 3A (nonetched groups) (Table 2).

On surface roughness depth evaluation, Group 3 showed increased depth of surface roughness when compared to both the groups, and Group 1 showed least depth of surface roughness. Among the subgroups, subgroups 1B, 2B, and 3B (etched groups) exhibited deeper surface roughness in comparison to subgroups 1A, 2A, and 3A (nonetched groups) (Table 3).

On microtensile bond strength evaluation, diamond group (G1) showed highest bond strength followed by

Table 2: Mean and standard deviation for roughness parameters

		Average surface roughness (Ra)	
Groups	Subgroups	Mean	Standard deviation
1	1A	0.531	0.244
	1B	0.537	0.137
2	2A	0.206	0.621
	2B	0.216	0.504
3	3A	0.595	0.103
	3B	1.70	0.533

Table 3: Mean and standard deviation for roughness depth parameters

		Surface roughness depth (Rv)	
Groups	Subgroups	Mean	Standard deviation
1	1A	1.38	0.88
	1B	1.62	0.43
2	2A	0.62	0.20
	2B	0.63	0.19
3	3A	1.85	0.38
	3B	3.96	1.23

Table 4: Microtensile bond strength

Groups	Mean ($\times 10^{-3}$) (MPa)	Standard deviation ($\times 10^{-4}$) (MPa)
Diamond (G1)	0.410	0.08117
Tungsten carbide (G2)	0.335	0.08114
Laser (G3)	0.367	0.138

laser group (G3) and tungsten carbide group (G2) respectively (Table 4).

On temperature rise evaluation using digital thermostat both diamond (G1) and tungsten carbide preparation (G2) showed 3 to 4°C rise from room temperature, whereas laser preparation (G3) showed only 2°C rise from room temperature

DISCUSSION

One of the most desirable properties of a restorative material is adhesion to dental substrate as it prevents fracture of the material and marginal leakage. These two are the most prominent factors for failure of the restoration subsequently.[21]

Surface roughness plays as the prime criterion in enhancing adhesion of restoration by increasing the surface area and improving the wettability properties.[3] It is measured in Ra (arithmetic mean) and Rv (depth of surface roughness) values.[3] Though scanning electron microscope (SEM), transmission electron microscope (TEM), mechanical profilometer, light microscope, and atomic force microscope have been used for measuring surface roughness values, the inability of the sensor needles of these devices to penetrate all the irregularities have brought a 3D profilometer into focus. This has the distinct advantage of being noncontact, nondestructive, and quick quantitative measurement for surface roughness providing multiples descriptions of surface roughness profiles beyond the ability of 2D surface profilometer. Hence, this methodology has been used in the current study.[22-24]

Diamond and tungsten carbide burs have been used commonly in restorative procedures for their excellent mechanical retentive qualities in cavity preparation.[4] Numerous studies have compared the surface morphology in cavities prepared using diamond and tungsten carbide burs and concluded that more surface roughness was evident in diamond bur preparation in comparison to tungsten carbide preparation.[2,5,25] The present study, confirming the above literatures also exhibited more surface roughness in diamond groups (1A and 1B) than in tungsten carbide groups (2A and 2B).

However, although diamond produced greater surface roughness than tungsten carbide bur, it had a demerit of producing thick smear layer which might hinder bonding of restoration to enamel surface.[26,27] In order to eliminate

this factor, concept of acid-etching enamel was proposed by Buonocore in 1955, which not only removed the smear layer but also improved mechanical retention by selectively exposing hydroxyapatite formation facilitating resin penetration to a depth of 6 to 12 μm.[28]

Ability of hard tissue removal without smear layer production has brought lasers into modern dentistry replacing these conventional burs.[8,29] Among various lasers, Erbium lasers (high-intensity lasers) are the most efficient and safest system of lasers, showing similarities to acid-etched enamel.[8,29]

Er:Cr:YSGG lasers cut dental hard tissue with the help of its laser-powered hydrokinetic system at infrared wavelength of 2.7 to 3 μm.[30] Microexplosions during laser ablation produces imbricate-patterned surface with an evidently rough aspect without smear layer production.[30]

Although laser produces greater surface roughness, it has disadvantage of increased microleakage. To overcome this, additional phosphoric acid etching was recommended which decreased the microleakage and increased bond strength.[16,31-33] Robles et al[34] compared conventional bur and Er:YAG laser in Class V cavities with or without acid etching and observed higher degree of microleakage without additional etching procedure. Ceballos et al[31] found that laser ablation of enamel alone was not sufficient to prevent microleakage in occlusal enamel compared to cavities that were acid-etched. Pires et al[8] evaluated the shear bond strength values (SBS) of various dental adhesives on Er:YAG lasers, prepared enamel, and concluded that acid etching increased adhesion in laser-treated enamel. Thus lasers were brought into focus in cavity preparation to overcome the disadvantages of conventional burs.

The current study has compared the surface roughness created using both conventional burs and laser and found out that laser produced more surface roughness when compared to conventional burs.

As acid-etching procedure was recommended in laser-prepared cavities by previous studies,[31,34] acid-etching procedure was performed for the mentioned three groups (1B, 2B, and 3B), and our study confirmed the known fact that laser with additional etching procedure (Group 3B) produced maximum surface roughness in comparison to other groups using 3D noncontact, nondestructive profilometer.

During cavity preparation, the temperature rise in the pulp chamber was also recorded in the present study. Laser preparation showed only 2°C rise in temperature, whereas diamond and tungsten carbide burs showed 3 to 4°C, both were below the critical level (5.5) which could cause any detrimental effects to the pulp.[19,20] Hence, the

present study concluded that both conventional burs and lasers are safe for cavity preparation.

Other than surface roughness evaluation, the current study also aimed on evaluating the influence of surface roughness on bond strength to enamel surfaces. Various studies on bond strength evaluation had showed similar or greater bond strength values of laser-irradiated cavities when compared to bur cut cavities. Wanderley et al[32] assessed the influence of Er:YAG laser energy on the shear bond strength of a total etch adhesive system to lased enamel of primary teeth and concluded that bond strengths recorded after laser irradiation were statistically superior to those yielded by the acid-etched control group. Keller and Hibst[33] analyzed the influence of laser on enamel bonding of composite resin and found best results in laser-conditioned enamel rather than conventional acid-etching procedure.

However, laser group in current study exhibited reduced bond strength in comparison with diamond group. De Munck et al[35] assessed the hypotheses that tooth substrate prepared either by Er:YAG laser or by diamond bur is equally responsive to adhesive procedures and observed that cavities prepared by laser appeared less amenable to adhesive procedures than conventional bur-cut cavities. Esteves-Oliveira and Zezell[11] evaluated the tensile bond strength of a self-etching primer system to enamel and dentin surfaces treated with Er:YAG and Er,Cr:YSGG lasers and conventional bur and observed that bond strength for both laser-irradiated groups were statistically lower than for the bur-cut group.

The possible reasons could be as follows:
- Laser irradiation forms acid-resistant layer due to loss of carbonates and formation of new hydroxyapatite-like crystals which compromises bonding due to reduced etching effectiveness. They have been knowingly used in dental caries prevention for this acid-resistant layer. But this hypothesis cannot be considered in this study, as laser showed that on additional acid etching, depth of surface roughness is increased. Thus the surface roughness alone may not be a contributing factor, and the quality of the enamel left behind may also play a major factor for bonding of restoration to enamel.[36,37]
- During cavity preparation, laser works by causing microexplosions in enamel surface, leading to formation of microcracks. However, these crack propagations are not uniform and their depth is variable. Thus enamel surface becomes weaker, and this may be the main reason for weaker bonding of the restoration.[37]
- Diamond, at the same time, produces adequate surface roughness without drastic shift in minerals and crack propagations.

- Even though depth of penetration of acid was less in diamond group which could have been utilized for smear layer removal, still the quality of enamel surface left behind, and surface roughness could have contributed to the bond strength of restoration to enamel surface in diamond group (Group 1B).

CONCLUSION

Within the limitations of the study, the bond strength values differed notably among the conventional bur systems and laser systems. Although laser produced greater surface roughness, conventional diamond burs exhibited better bond strength when compared to laser group. Both the laser and conventional burs systems may be considered safe due to their minimal detrimental effects on pulp during cavity preparation.

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