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ORIGINAL ARTICLE

Er,Cr:YSGG laser influence on microleakage of class V composite resin restorations

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Abstract One of the most challenging issues following restoration is microleakage. The aim of this study was to investigate the effects of Er,Cr:YSGG laser with and without acid etching on microleakage of class V composite restorations. A total of 68 human intact premolars were selected, disinfected, and randomly allocated to four experimental groups (n=16) as well as positive and negative controls (n=2 each). Dimensionally, similar class V cavities were prepared on buccal surface of each tooth under the following conditions: group 1, bur cavity preparation and chemical etching (BE); group 2, bur cavity preparation and Er,Cr:YSGG laser conditioning (BLc); group 3, Er,Cr:YSGG laser cavity preparation and chemical etching (LE); and group 4, Er,Cr:YSGG laser cavity preparation and Er,Cr:YSGG laser conditioning (LLc). All samples were restored with composite. The teeth were sealed and immersed in 1 % methylene blue for 48 h before being sectioned. The microleakage evaluation was done under a stereomicroscope (×20). The leakage scores were recorded and Kruskal–Wallis and Mann–Whitney tests were used for statistical evaluations. The highest microleakage score was seen in gingival margins of group 4 (LLc) and the lowest in occlusal margins of group 3 (LE). The overall difference in leakage scores among the groups was statistically significant (p<0.001) with gingival margins showing a significantly

Clinical relevance statement It is believed that minimized microleakage of restorative materials can lead to optimal clinical performance in terms of preventing marginal discoloration, secondary caries, and pulpal pathology. This study compares use of laser in preparing and conditioning class V cavities with conventional techniques in terms of reducing microleakage.

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higher score than its occlusal counterparts ($p<0.001$). It was noted that less microleakage could be achieved when cavities were prepared by laser compared to bur. In addition, less microleakage was seen in acid-etched cavities than laser-conditioned counterparts.

Keywords Er,Cr:YSGG laser · Microleakage · Composite

Introduction

Laser application in cavity preparation and enamel and dentin conditioning has had widespread acceptance [1–3]. Erbium family lasers can cut enamel and dentin efficiently due to their significant water and hydroxyapatite absorption [4]. It has been shown that if dental tissues are irradiated by water spray-supplemented Er,Cr:YSGG laser, there will be little, if any, temperature increase because the frictional source of heat production is totally eliminated, meanwhile cutting efficiency will be significantly enhanced [5–7]. This can by highly advantageous because the critical pulpal temperature increase is considered to be only 6 °C which can be easily exceeded while a cavity is being prepared by bur [8]. Histological studies of pulpal tissues of teeth irradiated by Er,Cr:YSGG laser show minimal inflammatory reactions [9, 10]. It has been indicated that application of Er,Cr:YSGG laser beam to enamel and dentin surfaces can cause a number of microscopic changes including creation of minute surface irregularities, lack of smear layer formation, and creation of minimal cracks [6]. Micro-irregularities created by application of pulsed erbium lasers will favor conditioning of the hard dental tissues more specifically on enamel, in which a rough microtexture is left behind due to the involved micromechanical ablation process [11].

Microleakage by definition is referred to as the migration of bacteria, liquids, chemicals, molecules, and ions through tooth-restorative material interface [12, 13]. This is considered the most problematic event following dental restorations and therefore the major reason for secondary caries and the resultant pulpal inflammation [8]. To date, none of the proposed modalities have been successful in thoroughly eliminating it [14].

Numerous studies have been conducted to evaluate the microleakage of composite resin restorations in cavities prepared by erbium lasers. Some of these investigations showed favorable results with laser [7, 15–17] whereas some others failed to indicate laser as an effective means to reduce microleakage [11, 18–23].

This study sought the effects of Er,Cr:YSGG laser when applied for preparing and conditioning class V cavities with and without chemical etching on microleakage of composite resin restorations and comparing it with the conventional method.

Materials and methods

This project was done according to No.13039 Permission Statement from National Committee of Publication Ethics in Azad University, School of Dentistry, Tehran, Iran. In this experimental study, a total of 68 healthy human freshly extracted premolars for orthodontic reasons were included. The teeth with caries, cracks and structural abnormalities were excluded after a thorough inspection under ×5 magnification. The teeth were debrided and disinfected in 0.12 % thymol solution for 24 h [16, 24]. Teeth were stored in distilled water throughout the study (1 month) to prevent drying out.

Cavity preparation, conditioning, and restoring

The samples were divided into four experimental groups, each containing 16 teeth and four teeth were allocated to positive and negative control groups ($n=2$ each). In group 1 (bur cavity preparation and chemical etching (BE)) and group 2 (bur cavity preparation and Er,Cr:YSGG laser conditioning (BLc)), on the buccal surface of each tooth, a non-undercut class V cavity (4 mm long × 3 mm wide × 1.5 mm deep) [20, 21, 25] was prepared using diamond fissure burs (D&Z, Germany) so that the gingival margin was located 1 mm apical to cementoenamel junction and the occlusal margin on enamel. The cavity dimensions were checked by a periodontal probe (Nordent, USA). The bur was discarded after preparing five cavities. In group 3 (Er,Cr:YSGG laser cavity preparation and chemical etching (LE)) and group 4 (Er,Cr:YSGG laser cavity preparation and Er,Cr:YSGG laser conditioning (LLc)), on the buccal surface of each tooth, a class V cavity with the same described dimensions in previous groups was prepared using an Er,Cr:YSGG laser (Waterlase; Biolase Technology, San Clemente, CA, USA) at a panel setting of 3.5 W with 55 % water flow and 65 % air flow, using G6 tips which were 6 mm long and 600 µm in diameter. The laser wavelength was 2.78 µm with frequency of 20 Hz and pulse duration of 140 µs. Free-running pulse mode was selected for irradiation. The pulse energy was set at 175 mJ/pulse. The standard distance between the laser beam source and object was considered 1–2 mm. The groups 1 (BE) and 3 (LE) were acid etched using 35 % phosphoric acid (3 M ESPE, St. Paul, MN, USA) for 10 min according to the manufacturer's recommendations and groups 2 (BLc) and 4 (LLc) were conditioned by Er,Cr:YSGG laser (Table 1). The occlusal half of the cavities were conditioned by Er,Cr:YSGG laser with 20 Hz repetition rate, 35 % air flow, 25 % water flow, 140 µs pulse duration, and a power setting of 1.5 W using the same G6 fiber tips. The gingival half of the cavities were also conditioned by Er,Cr:YSGG laser with 20 Hz repetition rate, 35 % air flow, 25 %

Table 1 Categorization of experimental groups

Experimental group	Treatment	Abbreviation
Group 1	Diamond bur cavity preparation, chemical etching	BE
Group 2	Diamond bur cavity preparation, laser conditioning	BLc
Group 3	Laser cavity preparation, chemical etching	LE
Group 4	Laser cavity preparation, laser conditioning	LLc

water flow, 140 μs pulse duration, and a power setting of 1 W using the same fiber tips. The laser-conditioned cavities were not acid etched. Each fiber tip was discarded after five times of use. Neither chemical nor laser treatment was performed on positive control group samples after cavity preparation, but the negative controls were only acid etched. A water/ethanol-based bonding system [Adper Single Bond 2 (SB; 3M ESPE, St. Paul, MN, USA)] was used as an adhesive and cured according to the manufacturer's instructions and the cavities were filled by Filtek Z250 composite, shade A2 (3M ESPE) incrementally and cured in an overlapping fashion using Mectron LED Curing Unit (Starlight Pro; Mectron S.p.A., Carasco, Italy). The restorations were polished using water-cooled coarse, medium, fine, and ultrafine Moore-Flex Composite Polishing Disks (E.C. Moore Company, Inc.USA). The apical terminus of tooth roots were sealed by sticky wax and two layers of nail varnish (Arcancil, France) were applied to all surfaces except for the restored surface and a 1-mm window around it. This coating was applied to all experimental groups except for the negative control in which the whole surfaces were covered by two layers of nail varnish including the restored area.

Dye penetration and leakage evaluation

All of the samples were soaked in a 1 % methylene blue dye solution for 48 h at room temperature. Afterwards, the samples were rinsed under running water and placed in an acrylic mold. The resultant acrylic blocks were longitudinally sectioned from the midbuccal areas of the teeth so that equal mesial and distal halves were obtained. Microleakage was visualized under stereomicroscope (SZ-X9, Olympus, Tokyo, Japan) at ×20 magnification by an independent and blinded observer and scored as follows:

- Score 0, no dye penetration
- Score 1, dye penetration up to buccal one third of occlusal and/or gingival walls
- Score 2, dye penetration up to buccal two thirds of occlusal and/or gingival walls
- Score 3, dye penetration of occlusal and/or gingival walls up to axio-occlusal and/or axio-gingival intersection
- Score 4, dye penetration along axial wall [26–28]

Data were analyzed by SPSS 15.0 for Windows using Kruskal–Wallis and Mann–Whitney statistical tests.

Results

The statistical tests indicated significant differences among all experimental groups (p=0.007). There were also significant differences between occlusal and gingival interfaces among all experimental groups (p<0.001). In any of the experimental groups, there existed a significant difference between occlusal and gingival interfaces with observably more leakage in the latter (p=0.001). Severe (i.e., score 4) leakage was seen in positive control group whereas no leakage was indicated in negative controls (i.e., score 0). The highest leakage value was observed in gingival interface of group 4 (LLc). The least leakage value was seen in occlusal interface of group 3 (LE; Table 2).

When the groups were compared two by two using Mann–Whitney test, regardless of whether leakage occurred at gingival or occlusal interfaces, a significant difference was observed between groups 1 (BE) and 2 (BLc) as well as groups 2 (BLc) and 3 (LE). There were no statistically significant differences when other experimental groups were compared (Tables 3 and 4).

Discussion

The aim of this study was to evaluate the effects of Er,Cr: YSGG laser with and without chemical etching on microleakage of classV composite resin restorations. Therefore, the experimental groups were treated differently and compared with positive and negative control groups. Cavities in positive control group were prepared with diamond bur and filled without etching or laser conditioning, but nail varnish coating was performed similar to experimental groups. The highest leakage value in this group can indicate the role of etching or laser conditioning in reducing microleakage. Cavity preparation and restoration in negative control group was similar to that in BE group, but nail varnish was applied to all tooth surfaces including the restored area. Lack of dye leakage in negative control can be attributed to the seal provided by the nail varnish.

Several techniques have been proposed in the literature to evaluate microleakage, among which dye penetration being considered as one of the most widely accepted [11, 29]. Organic dyes are used in this technique to assess microleakage. In

Table 2 Leakage score values in experimental groups in both gingival and occlusal margins

Groups	Leakage score		0	1	2	3	4	Total
1 (BE)	Occlusal	*n*	11	3	0	2	0	16
		%	68.8	18.8	0	12.5	0	100
	Gingival	*n*	4	6	6	0	0	16
		%	25	37.5	37.5	0	0	100
2 (BLc)	Occlusal	*n*	10	1	2	3	0	16
		%	62.5	6.3	12.5	18.8	0	100
	Gingival	*n*	1	0	3	2	10	16
		%	6.3	0	18.8	12.5	62.5	100
3 (LE)	Occlusal	*n*	15	1	0	0	0	16
		%	93.8	6.3	0	0	0	100
	Gingival	*n*	8	2	0	0	6	16
		%	50	12	0	0	37.5	100
4 (LLC)	Occlusal	*n*	14	1	0	1	0	16
		%	87.5	6.3	0	6.3	0	100
	Gingival	*n*	3	2	0	0	11	16
		%	18.8	12.5	0	0	68.8	100

this study, 1 % methylene blue was used such as other similar works for its low molecular weight and high penetrability [30]. The major advantages of use of Er,Cr:YSGG laser in this study include lack of temperature increase (a factor capable of inducing irreversible damage to the pulp), its highly effective absorbance in water and hydroxyapatite, its efficient cutting ability on dentin and enamel, lack of smear layer formation, and finally creating minute surface irregularities [6, 7, 16].

Yu et al. [31] showed that Er,Cr:YSGG laser-treated enamel and dentin had more surface roughness compared with those cut by diamond burs. They suggested that laser treatment could be a valid alternative to acid etching and was able to increase bond strength between restorative materials and dentin hard tissue [16, 31]. Similarly, Hossain and colleagues showed that in addition to the lack of smear layer and presence of intact enamel rods as well as exposed dentinal tubular openings in their SEM observations, laser prepared surfaces provided better bond abilities with restorative materials and acid etching could be easily replaced by laser use [7]. The differences between Hossain et al. and our results might have been attributable to the use of primary teeth only. Differences in the structure of deciduous and permanent teeth could have posed such differences, an issue which needs further investigation. In addition, the authors did not have any laser prepared cavity that was acid etched; therefore contrary to our study, the effect of acid etching in laser-prepared cavities could not be assessed. In our study, cavities prepared with laser and etched chemically were most effective in reducing microleakage. It has been shown that acid etching can induce morphologic, chemical, and

Table 3 Comparison of leakage scores between experimental groups using Mann–Whitney *U*-test

Groups	Leakage score					Mean rank	Sum of rank	*P* value
	0	1	2	3	4			
BE	15	9	6	2	0	15.31	245.00	0.002
BLc	11	1	5	5	10	17.69	283.00	
BE	15	9	6	2	0	18.56	297.00	0.177
LE	23	3	0	0	6	14.44	231.00	
BE	15	9	6	2	0	17.97	287.50	0.41
LLc	17	3	0	1	11	15.03	340.50	
BLc	11	1	5	5	10	19.19	307.00	0.003
LE	23	3	0	0	6	13.81	221.00	
BLc	11	1	5	5	10	18.75	300.00	0.203
LLc	17	3	0	1	11	14.25	228.00	
LE	23	3	0	0	6	15.97	255.50	0.111
LLc	17	3	0	1	11	17.03	272.50	

Table 4 Overall comparison of the experimental groups using Kruskal–Wallis test

Groups	Leakage score					Mean rank	*P* value
	0	1	2	3	4		
BE	15	9	6	2	0	58.67	0.007
BLc	11	1	5	5	10	80.31	
LE	23	3	0	0	6	52.30	
LLc	17	3	0	1	11	66.72	

energetic changes on treated surfaces [32]. It has also been stated that it can increase dentin surface roughness and wettability [32]. Similarly, Ergucu et al. [16] demonstrated that cavities prepared with Er,Cr:YSGG laser show considerable microleakage score and therefore suggested laser prepared cavities be acid etched. A major difference in tooth substance removal during acid etching and laser conditioning is based on structural differences between peri- and intertubular dentin [8]. Acid etching can remove more peritubular than intertubular dentin due to a higher mineral content in peritubular dentin. In contrast laser energy absorbance is seen more in intertubular dentin and dentinal fluid due to increased collagen and water content, respectively [33].

Gutknecht et al. suggested the use of acid etching following cavity preparation and did not show any statistically significant difference between cavities prepared with laser or conventional method [11]. They employed class II cavity design, an uncommon microleakage assessment, in which evaluation could only be performed on gingival aspect. Therefore, this study was not capable of determining the influence of laser in reducing microleakage on enamel margins. Regarding this study and also our results, however, chemical etching following Er,Cr:YSGG laser cavity preparation was helpful in reducing microleakage. It appears that class V cavities are more suitable models for microleakage assessment than class II counterparts because laser tip distance with tooth substance is more easily adjustable in class V cavities than class II ones. Additionally, the closer distance between light-curing unit tip and composite surface is more easily achievable in class V cavities and finally, these cavities present more convenience for the practitioner to apply composite increments that collectively may affect microleakage. Marrotti et al. [17] agreed with Lupi-Pegurier [22] in stating that acid etching following Er,Cr:YSGG laser conditioning can help reduce microleakage in class V restorations, but this protocol was not considered in our study. Some researchers have shown lack or negative effects of laser in reducing microleakage, but this might have been due to different laser types used [20, 21, 23].

The majority of authors agree with higher leakage values in gingival rather than occlusal aspects of cavities [18, 24, 34]. This can be attributed to the difficulty in establishing a strong bond to dentin rather than enamel [35]. Dentin contains 50 % (weight) water and organic matter and less surface energy than enamel. Dentin bonding depends on wettability; therefore, mechanical interlock is usually taken into consideration to which removal of smear layer and topographic changes in dentin might be helpful [34].

Conclusion

According to this study, it can be noted that use of Er,Cr:YSGG laser in preparing class V cavities was more influential than conventional bur technique in reducing microleakage. In conditioning the prepared cavities, acid etching outperformed laser conditioning in reducing microleakage. In addition, microleakage was less evident in occlusal compared with gingival aspects.

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