

Microleakage of porcelain laminate veneers to tooth surfaces prepared with Er: YAG laser

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Abstract:

The Er:YAG laser was proven to ablate enamel successfully. This study was aimed to investigate the applicability of using this laser in preparing the enamel surface for porcelain laminate veneering in comparison with the high-speed handpiece regarding the fracture strength loading of the veneers. Twenty human maxillary central incisors extracted were selected. They were divided into two equal groups [group I and group II], group I: High-speed handpiece prepared specimens and group II: Er:YAG laser prepared specimens for measuring microleakage by a binocular stereomicroscope.

The microleakage assessment results showed a significant difference in the microleakage scores at the incisal margins of [Gr. I (group I)] the high-speed handpiece compared to [Gr. II (group II)] the Er: YAG laser and significance comparing the microleakage scores at the cervical margins of both groups (Gr. I) and (Gr .II). Also, there were significant differences comparing incisal to those at the cervical margins of (Gr.I) the high-speed handpiece and while in (Gr.II) the Er:YAG laser group, a marked significant difference were present between the microleakage scores at the incisal margins compared to the cervical margins. Conclusion: The difference in microleakage assessment between laser and the high-speed handpiece

specimens was significant and could affect the longevity of the porcelain laminate veneers.

Introduction:

As we approach the twenty-first century, researchers in the dental field are faced with the challenge of mastering a rapidly changing technology. Exploring and understanding the possibilities will enable a professional to grow [1]. Entry into the new millennium means adapting to this ever-changing technology, an evolution from simple mechanisms to the boundless era of electro-optics [2]. Researches aimed to study the possible replacement of the bur drill by the laser to remove caries, prepare cavities in enamel and dentin and condition the surface for a reliable restoration bonding. Also, reduce patient anxiety from the pain, noise and vibration of the mechanical drill [3].

In dental research, basic and clinical studies were done with the Er:YAG laser [4, 5]. Comparative studies of pulpal reactions after caries removal and cavity preparation with Er:YAG laser and those with conventional high-speed bur showed pulpal responses that were acceptable with no histopathological differences obtained between them. Studies on the ablated surface morphology by SEM, surface roughness, infrared spectroscopy, microleakage of applied restorations, and bond strength of resinshave made the Er:YAG laser challenging in replacing the high-speed drill [6,7].

Esthetic correction of anterior teeth has been achieved by preparing full crowns for many years and was considered the most predictable and durable method. However, this approach is considered invasive and involves a substantial removal of sound tooth structures and potentially adverse effects on adjacent pulp and periodontal tissues[8, 9].

Bonded ceramics were an exciting new entity for research and development since the 1980s and now accepted as a valid treatment modality. Porcelain laminate veneers have exhibited predictability and experienced an incredibly rapid public acceptance with widespread utilization as one of the most conservative methods of restoring discolored, fractured, and malformed teeth with the least preparation thickness [10].

Many studies have been focused on the clinical efficiency of porcelain veneers in terms of the tooth preparation design, the adhesive system, the quality of the marginal adaptation, the resistance against microleakage, the periodontal response, the fracture resistance and the aesthetic characteristics of the restorations[11,12].

Still little information about the evaluation of the applicability of the Er:YAG laser technique in teeth preparation compared by bur drilling in microleakage resistance and the fracture loading Strength of porcelain laminate veneers as well as the surface morphology with any expected compositional changes that might result[13-15].

The objective of this study was to evaluate the effect of using Er: YAG laser tooth preparation on the microleakage of porcelain laminate veneers.

Material and methods:

The materials that were used in the current study are illustrated in Table (1).

	Materials	Trade/ Manufacturer
1	Impression material used: Heavy and light body (Additional -type silicone) impression material (Putty Soft +Dimension Grant L)	3M ESPE Seefeld, Germany
2	Stone type : (Type IV) dental stone die material	GC Fujirock EP;GC Corp, Tokyo, Japan)
3	Ceramic veneer type: Leucite-reinforced glass-ceramic material, IPS Empress 1	Ivoclarvivadent, Schaan, Liechtenstein
4	Acid Etching & Bonding: 37% phosphoric acid	Total Etch;IvoclarVivadent
5	Bonding agent: Syntac bonding	Syntac Primer and Syntac adhesive; IvoclarVivadent
6	Resin cement used: Transparent dual-polymerizing (Variolink II) resin composite of low viscosity	Variolink II, Ivoclarvivadent
7	Finishing disks	Sof – Lex; 3M ESPE

Methods:

Twenty human maxillary central incisors extracted for periodontal causes with nearly the same crown length and mesiodistal width were selected. Teeth were free from dental caries or any restorations. The teeth were cleaned and stored in normal saline solution at room temperature immediately after extraction.

Grouping of samples:

Twenty extracted central incisors were divided into two equal groups according to preparation method used for laminate veneer; [group I and group II], group I: high-speed handpiece prepared specimens (10 specimens) and group II: Er:YAG Laser prepared specimens (10 specimens) for measuring microleakage by a binocular stereomicroscope.

Specimens and group preparations:

A specially constructed mold to form resin blocks consists of an inner split cylinder and an outer assembling one of (1x2x1cm); the specimens were mounted individually in the acrylic blocks with their long axis perpendicular to the acrylic block surface. All specimens were embedded up to 2 mm below the cemento-enamel junction.

Group I:

Ten central incisors were prepared in a window type preparation. The facial reduction was performed using a self-limiting depth three-wheel-diamond of 0.5 mm^{*} to define the depth cuts, then a 1 mm chamfer diamond stone bur^{**} were used to refine the tooth preparation till the depth grooves, as shown in Figure (1). The gingival

portion of the facial reduction ends with a chamfer finish line that ends 1mm incisal to the cemento-enamel junction.

The extension of the facial reduction proximally till the proximal line angles mesially and distally. The incisal edge was kept intact without an incisal overlap. All tooth preparations were completed entirely in enamel and finished without any sharp line angles. All the specimens were prepared using the high-speed handpiece under water coolant.

Group II:

According to our pilot study made on five central incisors to standardize the technique of laser preparation, the proximal extensions and the laser parameters, energy used of 400-450mJ at 250-350µsec at the frequency of 10 Hz, an air-water spray cooling system of 6ml/min. using the Er:YAG^{***} laser handpiece of spot size 0.63mm, as shown in Figure(2). Three depth cuts similar to the limiting depth cutting three-wheel-diamond stone of 0.5mm, were prepared with the laser till the shank (of the three-wheel stone stands steady on the unprepared enamel, then continuing preparation of all the enamel surface in a steady back and forth movement in a mesiodistal and incisocervical direction following the convexity of the tooth surface. The extension of facial reduction was similar to that of group I as a window type preparation extending proximally from the mesial to distal line angles and incisally to the incisal edge without overlap and cervically ends 1mm incisal to the cemento-enamel junction.

* (834-31-021; Brasseler, Lemgo, Germany)

** (6844-314-014; Brasseler, Germany)

*** (Kavo KEY Er:YAG Laser, Germany)

Impression making and master die fabrication:

Randomly forty specimens (twenty from each group) were selected, and impressions made using heavy and light body (Additional -type silicone) impression material. For each tooth, the impression was made separately in a specially designed perforated copper mold. The impressions were poured with a vacuum mixed improved (Type IV) dental stone die according to the manufacturer's instructions with respect to water/powder ratio and mixing time.

Dies were recovered from the impressions, and two layers of die spacer^{*} were painted at 0.5mm short of the preparations' finish lines. Two coats of die lubricant^{**} were then applied to each die.



Figure (1): Photograph showed a central incisor from group I with indentations of the facial reduction using the self-limiting depth cutting disks.

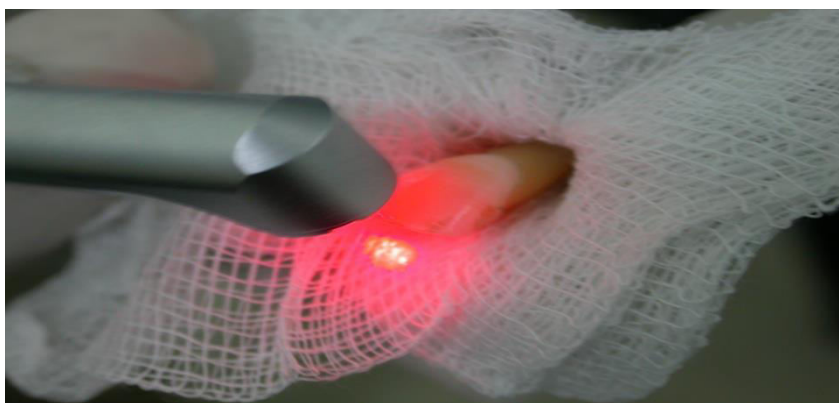


Figure (2): The Er:YAG laser ablation of enamel with the red aiming beam on the surface.

*(Cement spacer, Kerr dental, Orange, Calif.)

** (Die lube; Degussa, South Plainfield, N.J.)

Ceramic Veneer fabrication:

The Veneers were made of a leucite-reinforced glass-ceramic material, IPS Empress 1. All veneers were waxed then sprued. After the investment of the wax patterns, the investment cylinders were preheated in a conventional preheating furnace(Kavo Dental GmbH, Biberach, Germany) to a final temperature of 850 °C. A hot press furnace(IPS Empress EP 5000, IvoclarVivadent) was used for the pressing procedure of the ceramic veneers. The investment cylinders, along with the glass-ceramic ingots, were placed at the center of the press furnace and pressed at a temperature of 1050 °C.

After the divestment, the pressed veneers were cut from the sprues with a water cooled diamond-coated disks(Diaflex, Horico Dental, Berlin, Germany) and cleaned with a jet steam machine(EV1, Sofia, Italy). The veneer fit was verified on the master casts. Two glazing procedures were performed in a porcelain firing oven(Programat P90/P95; IvoclarVivadent), (different IPS Empress ceramic veneers).

The intaglio surfaces of the veneer were airborne-particle abraded with a high-grade alumina* at 2-bar pressure and cleaned with a jet steam machine**.

Acid etching:

Forty of the prepared teeth (20 for microleakage assessment and 20 for fracture load testing) were cleaned and then washed, dried, and etched with 37% phosphoric acid for 15 seconds, then rinsed with water spray, then dried with oil /water-free air spray.

Bonding the ceramic veneers:

The veneers were cleaned with 99% isopropanol, and the intaglio surface of the veneer was etched for 60 seconds with a 5% hydrofluoric acid gel. A silane-coupling agent was then applied to the etched surface with a brush to the ceramic veneer for 60 seconds and then air dried. Then the Syntac bonding***was applied to the etched tooth surface, and the veneers were luted with a transparent dual-polymerizing resin composite****of low viscosity.

* (Type 100, Kavo Dental GmbH)

** (SJ, Silfradent)

*** (3M ESPE, St. Paul, USA)

*** (Variolink II, Ivoclar [Vivadent](#))

The excess cement material was removed with sponge pellets while still soft, and the margins were covered with an air-inhibiting gel before light polymerizing. The ceramic veneers were light polymerized with the light cure system* from the facial to cervical and palatal for at least 60 seconds.

Finishing was performed using hand instruments (# 15 scalpel, Bard-Parker) and the (Sof – Lex) finishing disks.

Microleakage assessment:

1. Sealing of teeth:

Ten teeth of each group with their ceramic laminates luted were removed from saline and dried with oil-free air. The apices of the roots were sealed with composite resin.

Each tooth was coated with clear nail polish except at the incisal edge and at the cervical edge, where one millimeter was left. One layer of the polish is first applied by using of a soft, gentle brush and left to dry, and then a second layer was applied to ensure complete sealing of all other surfaces of the tested specimens. Finally, a third layer of polish was applied, and while still tacky, each tooth was wrapped individually with aluminum foil and adapted using a plastic instrument. After an hour, 1 mm around the incisal and cervical margins of the foil was exposed with a sharp bard parker blade. A final coat of nail polish was then applied over the wrapped foil at the cut edges to ensure proper sealing.

2. Preparation of tracing dye solution:

2% aqueous solution of methylene blue dye was utilized, 2 grams of methylene blue powder were dissolved in 100 ml distilled water, and the solution was adequately agitated to ensure complete dissolution of powder particles.

3. Immersion of teeth in the dye:

The teeth were immersed in the 2% methylene blue dye solution for 4 hours at room temperature; then, the teeth were removed from the dye and rinsed thoroughly under running water for 5 minutes. Then foil was stripped off, teeth cleaned softly and dried.

*(Elipar Free light 2, 3M, ESPE)

4. Sectioning of the teeth:

The teeth specimens with ceramics were sliced labiolingually into three equal slices using a water-cooled 7/8-inch diamond disc rotating at low speed under sufficient water-cooling to avoid overheating and cracking.

5. Microscopic assessment:

A binocular stereomicroscope* attached to a computer was used to investigate the extent of dye penetration, assessing microleakage pattern incisally and cervically of each slice following the scoring system used, in addition, measurement of dye penetration using a micrometer scale. The microleakage scoring system:

- Score 0: no leakage at tooth /veneer interface.
- Score 1: penetration of dye along incisal or cervical margins.
- Score 2: penetration of the dye up to incisal or cervical one-fourth of the tooth/veneer interface.
- Score 3: penetration up to incisal or cervical half of the tooth/ veneer interface.
- Score 4: penetration of dye along the entire tooth/veneer interface.

The micrographs were examined, microleakage scoring pattern incisally and cervically tabulated and measured in a micrometer scale, and results were statistically analyzed using the statistical package SPSS version 15 for windows to analyze non-parametric test using the Chi-Square.

Result:

IV- Microleakage assessment (quantitative evaluation):

The results of the Chi-Square statistical analysis of the microleakage score of all the incisal specimens compared to all the cervical specimens without grouping, show a significant difference (Tab. 2). For more analyzing the data, the Mann-Whitney test was used to show any significant difference between the two groups and the four subgroups (Tab. 3).

Table(3) shows the descriptive statistics of the microleakage scoring of the dye penetration through ceramic laminates at the incisal and the cervical margins for both groups. As analyzed, there were significant differences in the microleakage scores at the incisal margins of (Gr.I) the high-speed handpiece compared to (Gr.II) the Er:YAG laser. Similar results obtained with significance comparing the microleakage scores at the cervical margins of both groups (Gr.I) and (Gr.II).

* (Leica, MZ6 Cold Light Germany)

The statistical analysis comparing the microleakage scores at the incisal to those at the cervical margins of (Gr.I) the high-speed handpiece showed significant difference and while in (Gr.II) the Er:YAG laser group, a marked significant difference were present between the microleakage scores at the incisal margins compared to the cervical margins.

The chart bar in [Figure \(3\)](#) represents the difference in [the](#) percentage of the microleakage scores between the incisal and cervical margins of the high speed handpiece group (Gr.I). the highest scoring percentage recorded in this group was 56.7% for score 2 at the cervical margins and also, 56.7% for score 1 at the incisal margins. [However](#), the least scoring percentage recorded in this group was 10% for score 3 at the cervical margins.

The other chart bar in [Figure \(4\)](#) represents the difference in the percentage of the microleakage scores between the incisal and cervical margins of the Er:YAG laser group (Gr.II). The highest scoring percentage recorded in this group was 66.7% for score 2 at the incisal margins. Nevertheless, the least scoring percentage recorded in this group was 6.7% for score 0 at the cervical margins.

The highest scoring percentage recorded was (66.7% for score 2 at the incisal margins) of (Gr.II) the Er:YAG laser group, and the least scoring percentage recorded was 6.7% for score 0 at the cervical margins, also of (Gr.II) the Er:YAG laser group in [Figure \(5\)](#). This result explains the marked significant difference shown in the statistical analysis in [Table \(4\)](#) comparing the microleakage scores at the incisal margins to the cervical margins of the (Gr.II) the Er:YAG laser group.

Table (2): Chi-Square statistical analysis of the microleakage score of the total incisal compared to the total cervical marginal dye penetration.

	0	1	2	3	Observed N	Chi-Square	P-value
Incisal	0	18	32	10	60	27.934	0.01
Cervical	8	19	30	3	60	28.933	0.0001
Total	8	37	62	13	120	56.867	0.0001

(P<0.05) significant; not significant (P>0.05)

Table(3): Descriptive statistics of the microleakage scoring of dye penetration through ceramic laminates at the incisal and the cervical margins for both high speed (Gr.I) and Er:YAG laser (Gr.II) groups using the Mann-Whitney Test.

			Number	Mean Rank	Sum of ranks	P value
Incisal	Dye penetration score	Gr.I	30	33.15	814.5	0.001 significant
		Gr.II	30	22.85	1015.5	
		Total	60			

Cervical	Dye penetration score	Gr.I	30	29.28	998.5	0.003 significant
		Gr.II	30	17.72	831.5	
		Total	60			

(P<0.05) significant; not significant (P>0.05)

Table (4): Descriptive statistics of the microleakage scoring of dye penetration through ceramic laminates at the incisal and the cervical margins for both high speed (Gr.I) and Er:YAG laser (Gr.II) groups.

			Number	Mean Rank	Sum of ranks	P value
Gr.I	Dye penetration score	Incisal	30	30.05	901.5	0.002 significant
		Cervical	30	30.95	928.5	
		Total	60			
Gr.II	Dye penetration score	Incisal	30	36.38	1091.5	0.003 significant
		Cervical	30	24.62	738.5	
		Total	60			

(P<0.05) significant; not significant (P>0.05)

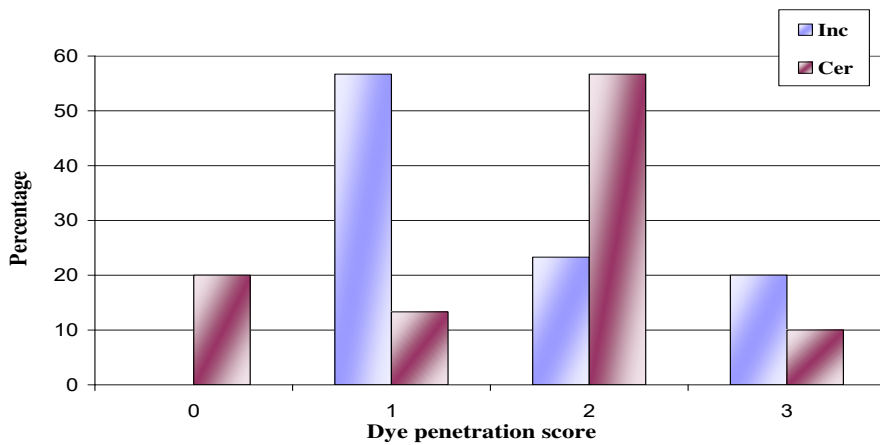


Figure (3): Chart bar showing the difference in microleakage scores between the incisal and cervical margins of the high-speed handpiece group Gr.I in percentage.

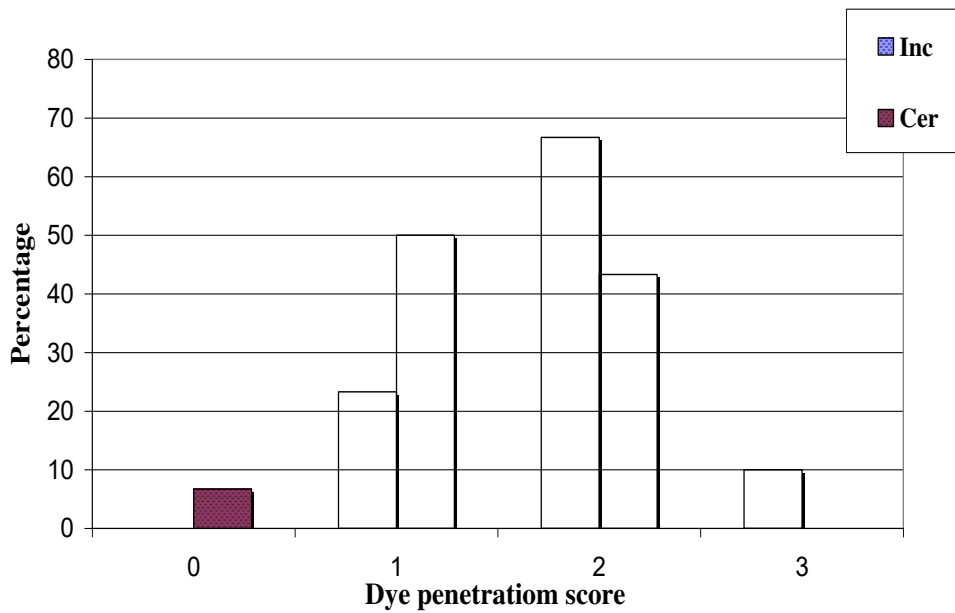


Figure (4): Chart bar showing the difference in microleakage scores between the incisal and cervical margins of the Er:YAG laser group Gr.II

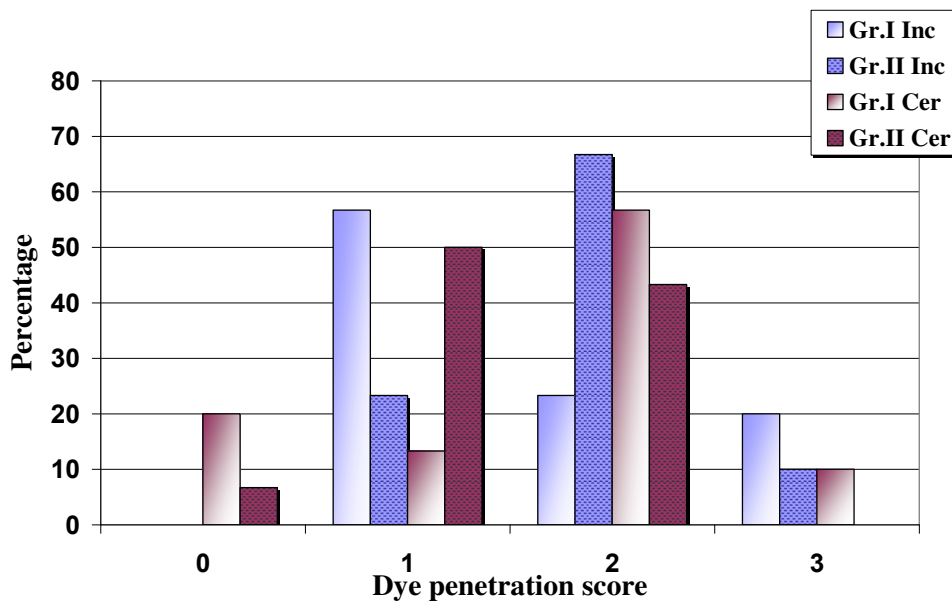


Figure (5): Chart bar showing the differences in microleakage scores between the incisal and cervical margins of the high speed (Gr.I) compared to the Er:YAG laser group Gr.II

Discussion:

Since the year 1960, studies have never stopped investigating the applicability of laser in caries removal and cavity preparation as a substitution of the high-speed dental drill. The Er:YAG laser emitting in the mid-infrared region of wavelength 2.94 μm is found to be efficient and potential in ablation of enamel and dentin with least thermal damage to surrounding unirradiated areas. This laser has a wavelength similar to the

absorption wavelength of water 2.94 μm , causing water-mediated explosive ablation of enamel and dentin which shows a higher ablation than the thermal vaporization caused by other lasers [16,17].

Er:YAG laser is chosen for this study as it has been investigated as the laser that might replace the dental drill for its unique characteristics. The studies have postulated the parameters of pulse energy, frequencies, spot size, and prepared cavities depth either in enamel or dentin to be comparable to the conventional high-speed bur prepared enamel. Also, clinical studies have tested the working time and cavities shape, the teeth sensitivity, noise and vibration during laser application compared to the speed drill [18].

Microleakage is a major factor that has been used in assessing the success of any restorative material used in restoring tooth [19]. Microleakage was evaluated by the dye penetration, which is the commonly applied method to test the sealing of adhesive, tooth-bonded restorations. One of the major dependent factors for microleakage was the luting material [20]. The polymerization shrinkage of the luting resin composite and the difference in thermal expansion coefficient between the luting resin composite and both the tooth and the porcelain veneer causes stress at the tooth/luting composite/porcelain interface. Due to these contraction stresses, the adhesive forces of the two bonded interfaces: the porcelain/luting composite interface and the luting composite/tooth interface, will compete with each other. As a result, the interface with the lowest adhesive forces will debond, namely the luting composite/tooth interface. Microleakage will occur at this interface, breaking this intimate contact and later may lead to staining, post-operative sensitivity and recurrent caries[21].

The results of the microleakage assessment revealed by the dye penetration scoring between the ceramic veneer and the tooth enamel interface, along the incisal and cervical margins show that; there were significant differences in the microleakage scores at the incisal margins of the high-speed handpiece compared to the Er:YAG laser, and significance comparing the microleakage scores at the cervical margins of both groups (Gr.I) and (Gr.II).

The explanation of decreased microleakage at the cervical margin of the laser prepared group can be that; the normal wavy pattern of laser-ablated enamel exposing the enamel rod heads with removal of the enamel smear layer, which is clearly represented at the middle and cervical thirds of the enamel surface. These irregularities cause an increase in surface roughness that will have a greater surface area which has a great role in decreasing the microleakage (dye penetration), which is clearly identified at the cervical margin of laser prepared group having the least microleakage readings [22,23].

Porcelain veneer preparations generally end in this region of aprismatic enamel, which might be largely responsible for the poor marginal sealing reported at the cervical margins of porcelain veneers in vitro prepared by the high-speed drill [24].

Therefore, the tooth preparations of porcelain laminate veneers by Er: YAG laser can decrease the microleakage.

Conclusion:

The difference in microleakage assessment between laser and the high-speed handpiece specimens was significant and could affect the longevity of the porcelain laminate veneers.

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