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EFFECTS OF DIODE LASER IRRADIATION ON MICROLEAKAGE OF COMPOSITE RESTORATIONS IN CLASS I CAVITIES

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ABSTRACT

Aim: The aim of this study was to evaluate the effects of diode laser irradiation on microleakage of composite restorations in class I cavities.

Material and methods: Twenty human premolar teeth were used in this study. Class I cavities standardized to a size of 3x2x2mm dimensions were prepared in each sample. The cavity of each tooth was acid etched using 37% phosphoric acid gel* for 15 seconds. Then the teeth were rinsed with water spray for five seconds. The adhesives were applied to the entire surface of the cavity and air thinned for 15 seconds then light-cured for 10 seconds with light emitting diodes (LED). Cavities were then filled with nanofilled composite and light-cured for 40 seconds. The filled teeth were divided into two main groups (of 10 each) according to surface treatment by laser application or not. Group A: teeth without treatment, Group B: teeth with surface treatment by diode laser application. Dye penetration was measured under a stereomicroscope (Olympus SZ-PT-Japan). Another twenty specimens was prepared and examined by scanning electron microscope. Result: in microleakage assessment there were no significant difference in the microleakage scores at the buccal and lingual cavosurface margin between conventional and diode laser groups.

KEYWORDS: Composite resins, diode laser, SEM

INTRODUCTION

A major shortcoming of light-cured composite resin is polymerization shrinkage. This shrinkage produces contraction stress in a confined structure such as tooth cavity.[1] The contraction stress in resin composite plays an important role in marginal adaptation.[2] When the stress generated by the polymerization shrinkage exceeds the bond strength of adhesive resin to cavity walls and floor, a contraction gap of microleakage is formed.[3,4]

The linear shrinkage of microfilled composites ranged from 2-3% after curing. Hybrid composites and micro-hybrid composite shrank from 0.6-1.4%.[5] such shrinkage caused microleakage, a well-known effect of contraction gaps on the interface of resin and tooth. Saliva, fluid, food residue,

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and microorganisms trapped in the gaps leads to decayed teeth and damaged enamel which is a major problem in current restorative and esthetic dentistry so as to provide a material with high mechanical properties and low polymerization shrinkage. It was anticipated that composites with epoxy resin and nanosilica filler could fulfill these requirements.[6,7]

There have been many efforts at reducing the polymerization shrinkage in resin composites. One approach is through control of components of the composite itself such as the amount and type of matrix resin,[8] the filler level,[9] the curing chemistry,[10] the initiator level,[11] and the addition of non-bonded micro-filler particles.[12] The other approach is performed technically and includes a modified application technique,[13,14] the sandwich restoration with glass ionomer,[15] the use of resin inlay,[16] and controlling the restoration rate by altering light energy[17,18] .

The conditioning effects at the cavity surface, e.g. drying, melting, cratering, cracking, roughening, vary dependent on the chosen laser type. The mechanism of laser tissue interactions are characterized by parameters such as the wavelength of the laser, the pulse duration and repetition, frequency, energy parameters, beam intensity profile, absorption, reflection, etc[19].

Since the invention of the laser by Maiman[20] in 1960, researchers have investigated laser applications in dentistry, and since that time, lasers have added additional revolutionary treatment options for both hard and soft tissue applications in dentistry.

Recently, with laser technology advancement, laser is used to change surface in materials in order to improve the bonding to dental structure [21,22]

Following development of the laser technique and device, the diode laser has gained increasing importance due to its compactness and low cost. The diode laser is recommended because its wavelength is within the infrared range, and thin and flexible fibers can be used. Previous reports demonstrated the bactericidal effects of 810-nm Wavelength[23] and 980-nm wavelength diode lasers.[24]

The purpose of this study was to investigate effects of diode laser irradiation on microleakage of composite restorations in class I cavities.

MATERIALS AND METHODS

The materials used in this study are present in table 1.

TABLE (1) Materials used in this study

Materials	Composition	Manufacturer
Filtek Z/350 Light activated nanofiller resin composite.	The fillers are combination of non aggregated 20nm silica filler, non aggregated 4 to 11nm zirconia filler and aggregated zirconia/silica cluster filler and in organic filler.	3M ESPE, Dental Products St. Paul, MN, USA.
Single Bond Universal Adhesive system	MDP Phosphate Monomer zirconia, alumina and metals without a separate primer -Vitrebond Copolymer -Silane water, initiators, ethanol and filler.	3M ESPE, Dental Products St. Paul, MN, USA
Dye	2% Methylene blue	El-Nasr phamaceutical,Egypt.
Acrylic resin	Acrostone	Acrostone dental factory, Egypt.

Twenty freshly extracted caries-free human premolar teeth were collected for the purpose of this study. The teeth were cleaned by an ultrasonic scaler and stored in distilled water at 37 ˚C before testing.

Class I cavities standardized to a size of 3x2x2mm dimensions were prepared in each sample by conventional bur technique using bur #245 and diamond straight fissured burs using high speed water cooled hand piece. The cavity of each tooth was acid etched using 37% phosphoric acid gel* for 15 seconds. Then the teeth were rinsed with water spray and dried with oil-free stream for five seconds. Then the teeth were rinsed with water spray and dried with oil-free stream for five seconds. The adhesives were applied to the entire surface of the cavity and air thinned for 15 seconds. A gentle stream of dry air was applied to disperse the material into a thin, uniform, shiny appearing surface. The adhesive was then light-cured for 10 seconds with light emitting diodes** (LED). Specimens with thick adhesive layers were produced by the application of one additional coat of adhesive. Additional coats were applied only to the marginal areas of the cavity to avoid pooling. Each layer was light-cured separately for 10 seconds.

Cavities were then filled with nanofilled composite and light-cured for 40 seconds with the tip as close to the surface as possible. Curing radiometer equipment* was used to ensure steady light intensity throughout the polymerization of all specimens. All restorations were finished and polished with a set of solfex discs (3M Company, St. Paul, MN, USA).

The filled teeth were divided into two main groups (of 10 each) according to surface treatment by laser application or not. Group A: teeth without treatment, Group B: teeth with surface treatment by diode laser application.

Methods of Diode laser application

Diode laser irradiation was 980 nm wave length, 2 W powers for 15 sec, in contact mode (Quanta system, Italy) and optic fiber transmission system. The fiber tip diameter with 320 micrometer was positioned perpendicularly to the occlusal pit and fissure areas. Laser irradiation was performed by hand, screening the enamel surface in a uniform motion33. During laser application; all the standard safety concerns were followed during the experiment.

Teeth were prepared for microleakage evaluation by sealing the root apices with acrylic resin and blocks. All other surfaces, except the restorations and 1mm from the margins, were coated with two layers of nail varnish to avoid dye penetration. Teeth were stored in distilled water for 48 hours, and then teeth were immersed in a 2% methylene blue solution for 24 hours. Subsequently, all teeth were sectioned into two half-mesiodistally sections with a low-speed diamond disc* under water coolant.

Dye penetration was measured under a stereomicroscope (Olympus SZ-PT-Japan) at 10x magnifications. Linear dye penetration (in microns) of each specimen in different groups was automatically calculated used the image analysis software (Image Ware, Image J 1.3lb, USA). Linear dye penetration was measured along the gingival floor as well as the axial wall.

The ratio of linear dye penetration was calculated and the percentage of dye penetration obtained for each specimen. Data analysis was performed by a

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* Eco-Etch. Ivoclar Vivadent.
**BG-light-LTD, 4002 Plovdiv, 430-490nm, Bulgaria
***LI-189 Li-Cor Inc, Lincoln, NE 68504, USA.
****CDA65, Germany

one -way ANOVA followed tukey's post hoc test for intergroup comparison.

Results were scored in (0, 1, 2, 3).

- 0= no microleakage
- 1= dye penetration within 1/3 of cavity wall
- 2= dye penetration within 2/3 of cavity wall
- 3= dye penetration spreading along the axial wall

Scanning electron microscope specimens:

The twenty prepared specimens for SEM examination, (**C**$_{I}$…**C**$_{I0}$) and (**D**$_{I}$…**D**$_{I0}$), were sectioned, dehydrated and sputter coated with gold coating Edwards (Sputter Coater) S 150A. Then the specimens were scanned using a scanning electron microscope*

The samples were examined using JEOL (JSM-6390LA) (Analytical Scanning Electron Microscope) in Taif University.

The twenty samples from each group were randomly selected and subjected to vertical cutting (longitudinal sectioning) in the middle of the class I cavity using water-cooled disc in order to evaluate and compare the effect of laser irradiation at the interface of the enamel and composite cavosurface margins using the ESEM.

RESULTS

Microleakage assessment

The microleakage scoring of the dye penetration along the buccal and lingual cavosurface margin of either group [Group A: teeth without treatment, Group B: teeth with surface treatment by diode laser application]. In table (2) shows the descriptive statistics of the microleakage scoring of the dye penetration through buccal and lingual cavosurface margin for conventional group, the dye penetrates through buccal and lingual margins recording score 0 [figure1], 1 and score 2 respectively, As analyzed, there were no significant difference in the microleakage scores at the buccal and lingual cavosurface margin for conventional group.

TABLE (2) Microleakage scores for Conventional group

	Buccal (%)	Lingual (%)	Kruskal -Wallis ANOVA	P
Score 0	3 (30)	2 (20)	0.27	0.83
Score 1	6 (60)	7 (70)		
Score 2	1 (10)	1 (10)		
Score 3	0	0		

**Significant at* $P \leq 0.05$.

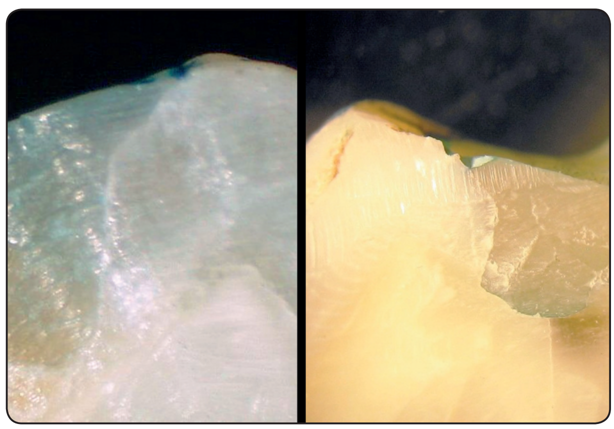

Fig (1) Control specimen score zero even with the artifact

In table (3) shows the descriptive statistics of the microleakage scoring of the dye penetration through buccal and lingual cavosurface margin for diode laser group, the dye penetrates through buccal and lingual margins recording score 0 [figure2], 1

*JSM- T20, JEOL, Tokyo, Japan

[figure3] and score 2 respectively, As analyzed, there were no significant difference in the microleakage scores at the buccal and lingual cavosurface margin for diode laser group.

TABLE (3) Microleakage scores for diode laser group

	Buccal (%)	Lingual (%)	Kruskal -Wallis ANOVA	P
Score 0	4 (40)	5 (50)	0.22	0.89
Score 1	5 (50)	4 (40)		
Score 2	1 (10)	1 (10)		
Score 3	0	0		

**Significant at P ≤ 0.05.*

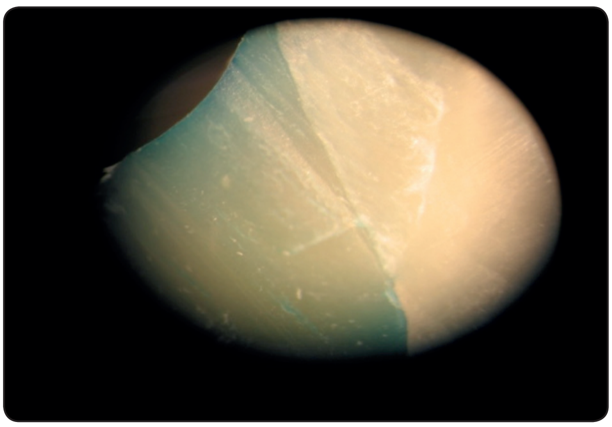

Fig (2) Diode laser microleakage score zero microleakage at buccal cavosurface margin

The results of the comparison of the percentage of the microleakage scores showed in table 4 and figure 4, 5 of conventional versus laser in overall surface (Both buccal and lingual margins). The dye penetrates through surface margins recording score 0, 1 and score 2 respectively, as analyzed there were no significant difference in the microleakage scores at the buccal and lingual cavosurface margin between conventional and diode laser groups.

TABLE (4) Microleakage scores of conventional vs laser in overall surface (Both buccal and lingual margins)

	Conventional	Laser	Kruskal-Wallis ANOVA	p
score 0	5	9		
score 1	12	9	5.22	0.78
score 2	2	2		
score 3	0	0		

**Significant at P ≤ 0.05.*

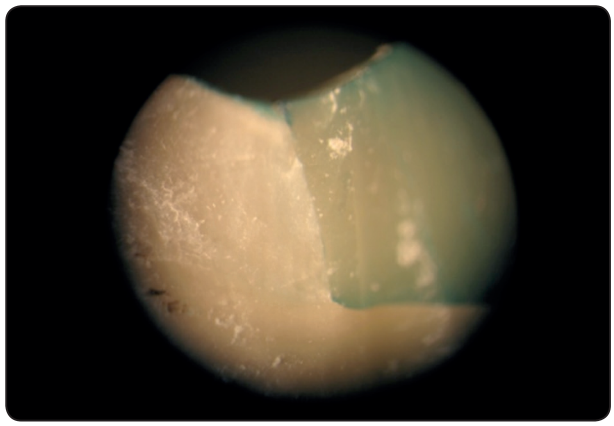

Fig (3) Diode laser microleakage score (1) lingual cavosurface margin

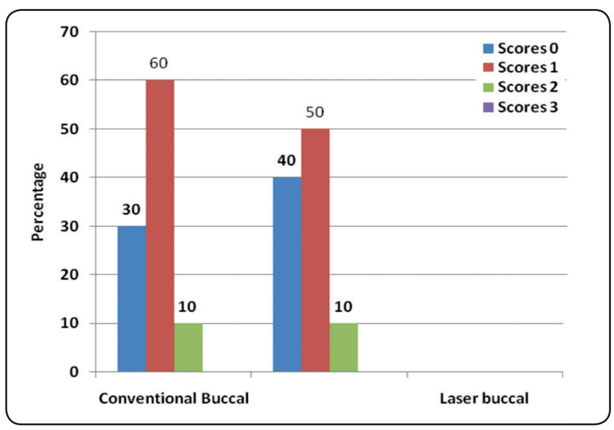

Fig (4) Bar chart of microleakage score of conventional vs laser group in buccal surface

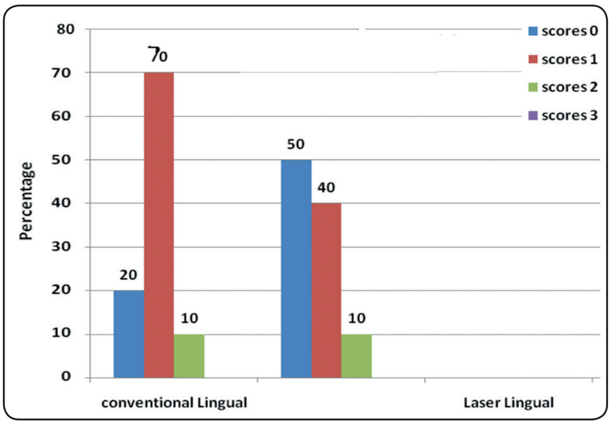

Fig (5) Bar chart of microleakage score of conventional vs laser group in lingual surface

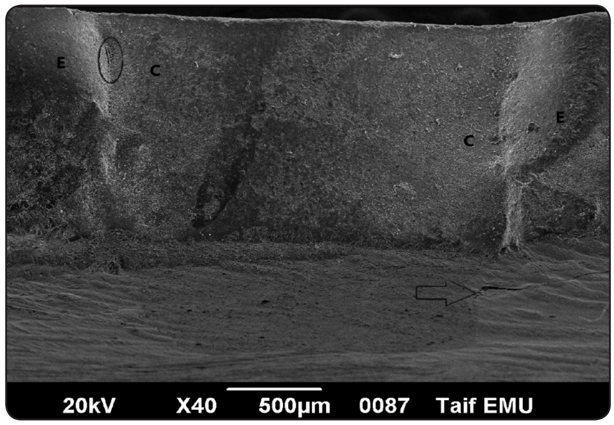

Fig (6) Scanning electron micrograph showing a gap at the periphery of composite restoration and the enamel margin at the buccal surface (oval circle) and another gap at the lingual surface (arrow) X40 E= Enamel, C= Composite.

Scanning electron microscope assessment

The results of the scanning electron microscope micrographs showed the surface effect of diode laser 980 nm when applied at the cavosurface margins of the composite restoration [figure 6, 7]. A clear gap at the periphery of composite restoration and enamel margin at the buccal surface (oval circle) denoting an increased dose of laser effect on that spot due to the hand movement with the fiber tip delivery. Also, another gap at the lingual surface was there denoting slight composite shrinkage leaving this gap. The measurement of the gap that extends along the path of laser applied movement which is about third the spot size of the laser fiber tip (320 μm). Fig (8) shows an axial gap separating composite from the dentin with an average width of 4 μm, this gap was clear with high magnification of X1000. This gap does not extend from the cavosurface margin till the axial wall of the composite cavity, which might be due to the difference in coefficient of expansion between dentin and the nanofilled composite, as a reaction to the rapid heating effect of the diode laser. Fig (9) shows the gap with the area of destruction and loss of composite structure that appears also to be superficial. The areas of destruction was clearly depicted with the higher magnification X2000 in fig (10), showing filler particles and melted fibers, with areas of melting and clumping re-solidified composite resin, with intact enamel and scarce composite debris on the surface.

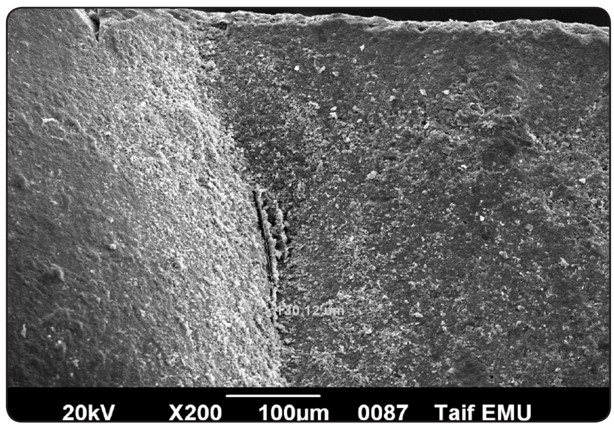

Fig (7) Measurement of the gap at the buccal surface.

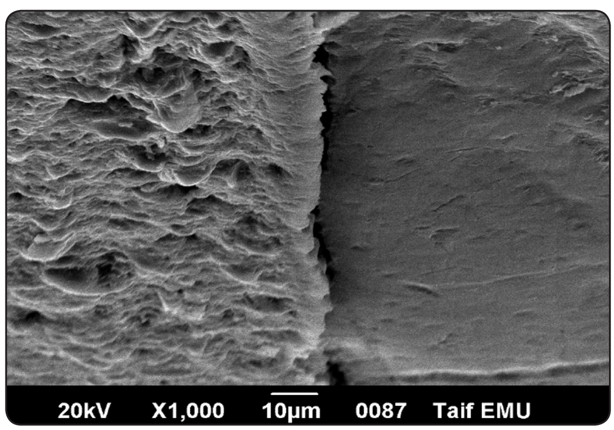

Fig (8) SEM showing the axial gap which shows separation of composite from the dentin X1000.

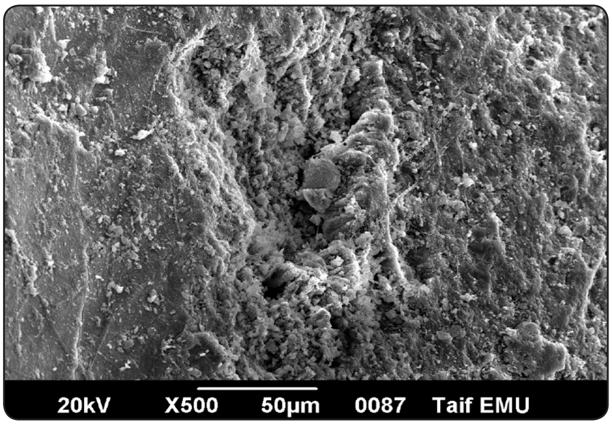

Fig (9) SEM micrograph of the gap with destruction of the composite

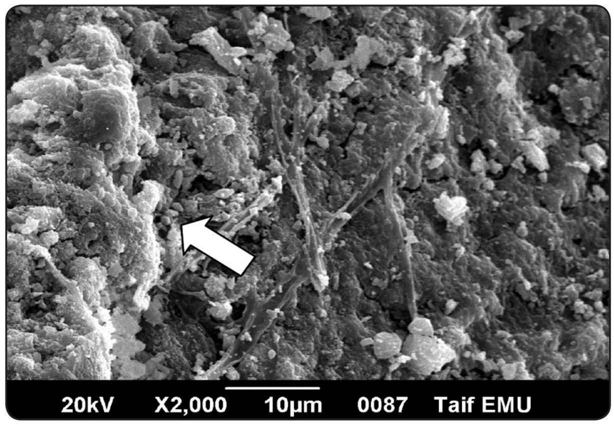

Fig (10) SEM micrograph showing filler particles and melted fibers, with intact enamel.

DISCUSSION

Microleakage was evaluated by the dye penetration, which is the commonly applied method to test the sealing of adhesive, tooth-bonded restorations[25].

Marginal leakage of composite restorations may be influenced by external stress produced during chewing and internal stress produced by polymerization contraction. These stresses may compromise the material's properties, creating marginal openings and deform the tooth substrate.[26,27] The contraction stress of composite depends upon the type and level of filler included. Generally, an increased filler level should contribute to a reduce polymerization shrinkage; since the overall polymerization shrinkage depends on the amount of polymer matrix.[28] On the other hand, the stiffness of the composite is also increased at high filler levels. The high stiffness leads to increased stress for a given contraction strain, according to Hooke's law; therefore, the composite stiffness and the amount of contraction both play important roles in the generation of stress in dental composite restorations.[29,30]

As a rule, the irradiation of diode lasers is poorly absorbed by hard dental tissues and thus allows propagation, scattering, or diffused transmission of light through dentin.[31,32]

Microleakage is defined as the accumulation of bacterial fluids, molecules and ions between the cavity walls and the restorative materials, which is not clinically detectable[33]Widespread use of Diode laser has been reported in root canal treatment to overcome the problem of inadequate penetration of disinfecting agents, elimination of the smear layer produced due to instrumentation and its antimicrobial activity.[34] Lee et al showed that laser irradiation through dentin disks measuring 500 μm eliminates 97.7% of Streptococcus mutans species, compared to a decrease of 54% in bacterial counts with the use of chlorhexidine, demonstrating a higher efficacy for the Diode laser.[35]In the study made by Obeidi et al[36] they discovered a decrease in microleakage with the application of Nd:YAG laser (1094 nm) to the energy of the laser beam. Kwaguchi et al[37] reported that the near infrared Nd:YAG laser had no effect on the marginal microleakage of composite resin restorations; however, Navarro et al[38] reported a decrease in microleakage of composite resin restorations with the application of Nd:YAG laser. Savadi Oskoee et al[39] demonstrated that Nd:YAG and Diode lasers and photodynamic therapy can be used for disinfection of cavities without any detrimental effect on marginal microleakage of composite resin restoration. Due to priority of our studies on enamel using the high power diode laser effect on the marginal integrity of composite restoration on class I, there were lack of researches to revert our results of the microleakage assessment revealed by the dye penetration scoring between the dental composite and the tooth enamel interface, there were no significant difference in the microleakage scores at the buccal and lingual cavosurface margin between conventional and diode laser groups.

The effects of laser wavelengths in the red and near infra-red regions are poorly absorbed by dental minerals. Enamel has a low absorption coefficient (<1cm-^{1}) which means that light wavelengths in this range pass through enamel almost entirely, that are optimally transmitted and scattered through the sound enamel with minimum absorption and low scattering coefficient (400-15cm^{-1}) [40]

This low absorption coefficient of diode laser wavelength in enamel can show a great benefit as it caused rapid elevation of the surface energy during exposure and rapid lose of temperature once stopped. As a result, the action needed is carried out, but in the same time it did not penetrate deeply so it did not affect the pulp or the underling structures.[41]

Our results showed a gap that does not extend from the cavosurface margin till the axial wall of the composite cavity,similar to gaps found in Nermin MY et al study which might be due to increased degree of conversion of the nanocomposite used in tiny areas in addition to the increased enamel surface temperature to 67˚C while intra-pulpal increase only 1˚C [41], causing shrinkage and difference in the marginal adaptation.

Areas showing filler particles and melted fibers, with areas of melting and clumping resolidified composite resin, and intact enamel and scarce composite debris on the surface, are due to the difference in coefficient of absorption between enamel/ nanocomposite and dentin// nanocomposite, when diode laser hits the enamel surface and reaching dentin.

Under the limitations of this present study it can be concluded that the use of the high power diode laser 98o nm did not affect the microleakage at the enamel/nanocomposite cavosurface margins in a significant manner and mostly an intact enamel. It is suggested that future studies can be carried out by implementing the conditions and aging to determine the time factor on the maginal integrity.

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