M D J

Evaluation of the effect of dentin treatment with CO2 laser and air abrasion on the microleakage of composite restoration.

Dr. Nada A. Mahdi, B.D.S.,
Dr. Abdul-Karrim J. Al-A zzawe, B.D.S., M.Sc.

Abstract

Objectives: The purpose of this study was to compare the microleakage of composite restoration at dentin following treatment with CO2 laser, Air Abrasion, Combination between them and acid.

Methods: 100extracted maxillary premolars (caries free), stored in distilled water, were used. Flat occlusal dentin surfaces were grounded wet on 600- grit silicon carbide paper. Cube cavities were prepared at the center of the occlusal surfaces. Teeth were then distributed randomly in to five groups, 20 teeth each:

Group A: Teeth were treated by CO_2 laser (with 10.6 µm wave length, 6 W, 0.2 s and 2 H z).

Group B: Teeth were treated by air abrasion (using aluminum oxide particles size 50 micrometers and air flow handy device at 1.2 cm distance with 15 seconds perpendicular application, air pressure was 2.75 bar and water pressure was 0.6 bar).

Group C: Teeth were treated by 37% phosphoric acid for 20 seconds.

Group D: Teeth were treated by CO^2 laser and 37% phosphoric acid.

Group E: Teeth treated by air abrasion and 37% phosphoric acid.

All the cavities were restored with the same bonding and composite materials and stored in distilled water in an incubator at 37^o C. Half of each group were stored for 1 day and themocycled between 5-55^{o}C, (10 cycles) while the other half were stored for 14days and thermocycled between 5-55^{o}C, (140 cycles). Then teeth were immersed in the 2% methylene blue dye and the extent of the dye penetration was recorded according to an ordinal scale. Data were analyzed using non- parametric statistical tests (Chi-square and Mann-Whitney)

Results: Microleakage in acid etched cavities was significantly higher than that achieved after laser treatment or air abrasion either isolated or followed by acid etch.

Conclusion:The use of CO_2 laser, air abrasion to condition dentin significantly reduced the microleakage of composite restoration, while there was no significant decrease in microleakage when using acid etching on dentin following CO_2 laser or air abrasion. There was statistically increase in microleakage with in times when using acid to condition dentin.

Key words CO2 laser, Air abrasion, Microleakage, Dentin treatment.

Introduction

A major problem in restorative dentistry is the lack of adhesion of dental restorative materials to mineralized dental tissues. The resulting gaps may influence the retention of the restorative material, increase secondary caries, or cause inflammatory reactions in the dental pulp**.** Therefore, in resin restorations, a perfect and permanent adaptation to dental tissues is required. Microleakage of composite restorations result from polymerization shrinkage and the different of coefficients of thermal expansion of composite resin and tooth structure **(1)**

It is known that microleakage of composite resin restoration in enamel is significantly reduced by acid etch technique. However, no similar claim has been made for acid etching when a margin of restoration is located in dentin **(2) .**

The restoration of cavities having margins partly or totally located in dentin is an unresolved problem in operative dentistry **(3)**.

Investigators have discovered the capacity of different lasers to roughen tooth structure in a manner analogous to the acid-etch technique prior to bonding composite resin material to dentin or enamel **(4).**The word ((laser)) is an acronym for *L*ight *A*mplification by *S*timulated *E*mission of *R*adiation. Lasers are devices that generate or amplify light and cover radiation at wavelengths ranging from infrared range to ultraviolet and even soft X-ray range **(5).** The CO_2 radiation is within the infra-red region of the electromagnetic spectrum, with a wave length of 10.6 µm, and it is absorbed strongly in dental enamel, dentin and cementum**(6).**

Air abrasion is utilization of the kinetic energy of a well defined sharply focused stream of tiny aluminum oxide particles propelled by high-velocity air pressure **(7)**.

Since the beginning of the 1990s, the air abrasive technique has again become the subject of dental research. This technique was invented in the 1940 and has been further developed and adapted to today's demands. The air abrasive treatment changes enamel and dentin surfaces in away that can lead to an improvement of bond strength to tooth structures **(3).**

Materials and Methods

One hundred freshly extracted ,caries- Free, human upper premolars were used in this study. They were Hand scaled, cleaned and stored in distilled water**.** The roots of the teeth were sectioned horizontally at cemento-enamel junction.The crowns embedded in acrylic blocks with exposing 2mm from the occlusal surfaces by using specialy design aluminuium mold.

2 mm from the buccal surfaces of the blocked teeth was ground under stream of running water (to obtain flat dentin surface) with 600 -grit silicon carbide paper by rotofix machine (BEGO, Germany). A cylindrical cavity was prepared with butt joint margin. A tungsten carbide fissure bur (no. 3) in turbine hand piece (W&H, Astria) was used with proper water cooling to prepare the cavities in the center of middle third on the exposed occlusal dentin surfaces. A tungsten carbide fissure bur (no. 3) in turbine hand piece was used with proper water cooling to prepare the cavities. each cavity was 3mm in diameter, and 1.5mm in depth and these dimensions were checked by aid of vernier (China).

The 100 sample were divided randomly to 5 groups:

Group A: Dentin surfaces were conditioned using pulsed CO_2 laser, model BLITIZ 50 SV ASA, Italy, with a 10.6 µm wave length, pulse duration of 0.2 seconds under good water cooling at a power of 6 watts and the repetition rate chosen was 2 Hz. The laser beam delivered perpendicular to the cavity from a 63mm distance using specially fixing device.

Group B: Air polishing spray (Air flow handy device, EMS) was mounted to a special fixing device to apply a spray of air, water and aluminum oxide particles (Germany) size 50 µm to cavity at a perpendicular direction and 12mm distance to give a focal spot of 3mm in diameter centered to the cavity for 15 second. According to manufacturer instruction: air and water pressure were 2.75, 0.6 bar.

Group C: Apply total etch 37% phosphoric acid (3M dental product) on the dentin surface and allow a reaction time of 15 seconds (according to manufacturer's recommendation), rinsed for 10 seconds, and excess water was removed.

Group D: Using combination of treatments beginning with CO2 laser and followed by application of 37% phosphoric acid.

Group E: Using combination of treatments beginning with Air abrasion and followed by application of 37% phosphoric acid.All the cavities are restored with the same bonding (scotchbond bonding system ethanol, water 65%) and composite materials (3M dental product Z100, shade A2). Removing the excess water from the cavity surface by applying gentle air for 5 seconds at distance of 1 cm to maintain a wet dentin surface. Two consecutive coats of bonding was applied to the cavity, using a fully saturated brush tip for each coat, then light cured for 10 seconds**.**The composite was placed immediately and adapted with a hand instrument; the surface was covered with celluloid strip (Hawe-NeosDental, Bioggio Switzerland) and glass slide (Cod Glol, Germany). The composite through the glass slide was cured for 40 seconds using astralis 5 light cure device (Ivoclar vivadent) at 500mW/cm2, holding the light emission window as close as possible to the glass slide **(manufacturers instruction).** The restoration was finished and polished with silicon polishing bur for 5 seconds.

According to aging and thermocycling each group were subdivided into two subgroups and were stored in deionized distilled water in a container inside incubator (Pdy fix-wet Germany) at $37^{o}C$. Subgroups A1, B1, C1, D1, E1 stored for 24 hours and thermocycled 10 cycles using thermocycling machine (Al-Qaisi& Al-Khafaji) which contains two water paths, one maintained at $5\pm2^{o}C$ and the other $55\pm2^{o}C$ **(8).**The immersion time was 30 sec in each path with 5 second transfer time. Subgroups A2, B2, C2, D2, E2 stored for 14 days and thermocycled 140 cycles. Teeth surfaces were sealed with two coat nail varnish except 1mm around restoration then were immersed in 2% methylene blue dye at $37^{o}C$ for 24 hours, after that the teeth were thoroughly washed, scrubbed and allowed to dry**.** Then the teeth were sectioned longitudinally, mesiodistally through the center of the restoration by using diamond wheel bur mounted on a sectioning machine (Accutom, Denmark) with a water cooling. The depth of dye penetration was measured for each restoration using stereomicroscope (Leitz Wetrzlar, Germany) under magnification X40 by two examiners. Marginal leakage was evaluated by measuring the linear penetration of the dye according to the scores in the table **(8).**

0, No penetration

1, Penetration in to dentin part of cavity wall but not including pulpal floor of the cavity wall.

2, Penetration including pulpal floor of the cavity wall. Non – parametric statistical methods were used to analyze and asses the results.The leakage between each subgroup at each time intervals were compared using Chi square test while Mann Whitney test was performed to compare subgroups at two time intervals. Significance was considered at the $p < 0.05$, highly significance was considered at $p < 0.001$.

Results

Microleakage scores obtained for each subgroup are shown in table 1

Chi-square test indicated no significant differences between subgroup A1 and subgroup B1while there was significant differences between subgroup C1 and either subgroup A1 or subgroup B1.There was a significant differences between the subgroups using combination of treatment (A1, B1) and subgroup (C1)while there was no significant differences between the subgroups (D1, E1) and subgroups (A1, B1) as shown in table 2.

And there is no significant differences between subgroup A2&B2 while there was highly significant differences between subgroups A2, B2 when comparing with subgroup C2. There was a highly significant differences between the subgroups D2, E2 using combination of treatment(laser+acid and air abrasion+ acid) and subgroup C2 while there was no significant differences between the subgroups D2, E2and subgroups A2, B2 as shown in table 3.

The differences between the amount of linear dye penetration of subgroups aged for one and subgroups aged for two weeks was analyzed by Mann- whiteny test which shows no significant differences for subgroup treated with laser or treated with air abrasion at the two time intervals while there was significant differences when using acid either alone or followed laser or air abrasion at two time intervals.

Discussion

Microleakage test is a method of testing the efficacy of the material or a combination of materials to establish bond to both enamel and dentin **(8).**

Bonding to dentin represents a greater challenges; dentin is an intrinsically wet organic tissue penetrated by a tubular labyrinth containing the odontoblastic process which communicates with the pulp **(9).**

An important factor that influences leakage is the composite and adhesive nature so one adhesive system and one composite resin were tested. The same references composite and bonding system were chosen in order to compare the performance of the etching technique.

CO_2 laser radiation is within the infrared region of the electromagnetic spectrum with a wave length of 10.6 µm, this laser wave length is absorbed strongly in dental enamel, dentin and cementum **(10).**

Walsh 1996 found that the highest of the energy settings used 6 J produce temperature changes (both in crown and root) which were greater than the 2.3 ^oC pulpal damage threshold. The energy that was use in this study is 1.2 J which is far below the threshold value of the pulp 2.2 ^oC, so that, lased dentin surface revealed no major thermal effects such as crack, carbonization, fusion or charring (11).

Todea et al 1995 indicated that CO_2 laser can be used on dentin surface for different clinical applications without damaging pulp tissue if the cooling system is employed and the exposure time is shorter than one second, so the exposure time used in this study is 0.2 second (12).

A pulsed mode was chosen in this study rather than continuous mode, because continuous wave can produce varying degree of pulp necrosis while pulsed wave provide the opportunity for cooling between exposure pulses **(11).**

The energy density obtained in this study was 16.99 J/cm^2 producing surface roughness on dentin that measured by a Profilometer (a device measure the degree of roughness in magnification X1000) which previously determined by pilot study.

The result of this experiment indicate that there is statistically decrease in microleakage for group treated with CO_2 laser when compared with group treated by 37% phosphoric acid. This agree with **Cooper et al 1988** who measured the bond strength of composite to lased dentin and to acid etch dentin and reported increase bond strength when adhesive restoration are applied on dentin surface treated with CO_2 laser (13) but disagreed with **Cruz 2000** who found that CO_2 laser (3W, 2Hz, 50 ms) treated group had similar result with acid etched group (14). Also disagree with **Abudallah& Al-Hashimi 2005** who measured the bond strength of composite to CO_2 lased dentine (8W, 2Hz, 0.5s) and acid etched dentin and concluded that acid etched dentin yielded a higher value of shear bond strength than CO_2 lased dentin (15).

Using CO_2 laser on dentin caused localized melting and recristallization, produce fungiform projections on dentin and undercuts surface similar to that of acid etching techniques of enamel **(16).**

Laser etching is a process of continuous vaporization and microexplosions due to vaporization of water trapped within the hydroxyappitite matrix **(4).**

Lased dentin surfaces present several characteristics that appear to be advantageous for adhesive resin composite bonding including dentin sterilization, opening of dentinal tubules, a surface with a microirrigularities without a smeared layer that promote a micro-mechanical bonding and no demineralization of peritubular and inter tubular dentin. There is no demineralization of its surface and no collagen matrix is exposed which is necessary for the formation of hybrid layer **(1).**

Visuri et al 1996 suggested that the greater presence of peritubular dentin which has a greater mineral content than intertubular dentin may result in better bonding to dentin (17).

Another difference between acid and laser action related to dentin is their effect on the morphology of dentinal tubules. When an acid etchant is applied, the peritubular dentin is preferentially etched resulting in funnel shaped opening to the tubules and this morphology may contribute with polymerization shrinkage to pull the tags away from the walls. Laser irradiation produces no demineralization of the peritubular dentin and the dentinal tubules remain open with no widening **(1).**

When acid is applied after CO_2 laser irradiation, a microirrigular surface and open tubules are obtained, so hybrid layer and resin tag formation occurs and this situation could positively influence the adhesion between dentin and resin, Although no significant difference where found between group treated by CO_2 laser and group treated by CO_2 laser followed by acid and this disagree with **Cruz 2000** who found that CO_2 laser treated group had a significant lower microleakage scores when compared with group treated by CO_2 laser and acid (14).

Use of air abrasion to produce rough surface on dentin with parameter previously was chosen in pilot study. Using air flow handy device in a perpendicular direction to the cavity with 12mm distance to give a focal spot of 3mm in diameter for a 15 seconds and 2.75 bars which produced a rough surface on dentin that measured by Profilometer device in previously determined pilot study.

The result show no significant differences between group treated with air abrasion and group treated with CO_2 laser but there is a significant decrease in microleakage for group treated with air abrasion compared with acid treated groups .Also no significant differences between group treated with air abrasion and group treated by air abrasion followed by acid.

This coincide with **Manhart et al 1999** who measured the bond strength of composite resin to air abraded dentin and acid etch dentin resulting in higher bond strength of composite resin to air abraded dentin than to acid etch dentin (7) while disagreed with **Roader et al 1995** who concluded that maximum bond strength achieved with group using combination of treatment (air abrasion and acid) (2). Also discoincide with **Geitel et al 2004** who believed that pretreatment of the dentin surface with acid etching showed higher tensile bond strengths than pretreatment with air abrasion, the air abrasive technique is not an alternative to conventional acid treatment, therefore additional acid etching is recommended when the air abrasion is applied (3).

The impact of uncountable energetic alumina particles on the dentin lead to a characteristic, very rough and irregular surface, increasing surface area which will cause a wave like surface **(7).**

The wettability for the dentin adhesive seems to be enhanced by air abrasion **(2).**

When using a 37%phosphoric acid to etch the abraded dentin lead to open dentinal tubules , increase the dentin permeability and dissolve inorganic hydroxyapitite crystal of dentin structure **(7),** although no significant difference was found, in this study, between group treated by air abrasion and group treated by air abrasion followed by acid

The results of this study show that groups treated with 37% phosphoric acid either isolated or combined (after CO2 laser or air abrasion) have a significant increase in microleakage scores after storage for 2 weeks and thermocycled 140 cycles when compared with 1 day storage and thermocycled10 cycles.

Increase in microleakage with aging could be related to disintegrations of bonding agent and gap formation at the composite tooth interface. Some acid used to etch dentin can denaturate the collagen fibrils, this denaturate collagen not protected by adhesive can be even more prone to hydrolysis over time and reduction of longevity **(18)**

The application of an acid etchant produces demineralization of intertubular and peritubular dentin resulting in a demineralized collagen matrix. In order to create a hybrid layer, the resin has to penetrate in between the collagen fibers and reach the undemineralized surface **(1).**

The presence of collagen network resulting from acid etching has been constantly questioned as an important structure for dentin bonding since it has been shown that resin monomers do not fully diffuse through it to reach intact dentin. This incomplete penetration produces a porous layer of exposed collagen subjected to hydrolysis and degradation resulting in microleakage and failure over time **(19).**

Also results of this study show that groups treated by CO_2 laser or air abrasion have no significant differences in microleakage at the two time intervals.

Conclusions

Under the condition of this in vitro study, the following conclusions are drawn:

1. None of the dentin conditioning techniques (CO_2 laser, air abrasion, acid etching) was able to prevent microleakage.
2. CO_2 laser and air abrasion significantly reduced the microleakage when using to conditioning dentin surface.
3. Using acid etching on dentin following CO_2 laser or air abrasion did not reduce microleakage.
4. With time dentin acid etching shows the highest score of microleakage.

References

1- Ceballose L, Osorio R, Toledano M and Marshall G. Microleakage of composite restorations after acid or Er:YAG laser cavity treatments. Dent Mater, 2001; 17: 340-6.

2- Roeder LB, Berry EA, You C and Powers JM: Bond strength of composite to air abraded enamel and dentin. Oper Dent, 1995; 20(5):186-90.

3- Geitel B, Wischneweski R, Jahn KR, Barthel CR, Zimmer S and Roulet JF: Tensile bond strength of composite to air abraded dentin. Oper Dent, 2004; 29(1):69-74.

4- Yazici AR, Frentzen M and Dayangac B. In vitro analysis of the effects of acid or laser etching on microleakage around composite resin restorations. J Dent, 2001; 29:355-61.

5- Aschheim K and Dale B. Esthetic Dentistry: A clinical approach to techniques and materials. Second edition, A Harcourt Health Sciences Company, St. Louis Philadelphia London Sydney Toronto, 2001; Ch. 22:441-443.

6- Sahabi S, Brockhurst PJ and Walsh LJ: Effect of tooth related factors on the shear bond strength obtained with CO2 laser conditioning of enamel Ast Dent J,1997;42(2): 81-4.

7- Manhart J, Mehle A, Schoeter R, Obester B and Hickel R: Bond strength of composite to dentin treated by air abrasion. Oper Dent, 1999; 24(4):223-32.

8- Iso/Technical specifications, 11405, Dental Materials- testing of the adhesion to tooth structure. Second edition, 2003: 1-15.

9- Perdigao J and Lopes A. The effect of etching time on dentin demineralization. Quint Int, 2001;32:19-26.

10- Sahabi S, Brockhurst PJ and Walsh LJ: Effect of tooth related factors on the shear bond strength obtained with CO2 laser conditioning of enamel Ast Dent J,1997;42(2): 81-4.

11- Walsh LJ: Pulpal temperature changes during low-power hard-tissue CO2 laser procedures. Braz Dent J, 1996; 7(1):5-11.

12- Todea C, Miron M and Petre M. Dentin and pulp temperature response after CO2 laser exposure. University of medicine and pharmacy, School of dentistry, Department of oral rehabilitation and dental emergencies.(abstract)

13- Cooper L, Myers M and Nelson D. Shear strength of composite bonded to laser pretreated dentin. J Prosth Dent, 1988; 60: 45-9.

14- Cruz AN: In vitro analysis with CO2 laser and phosphoric acid cavity treatment, either isolated or combined, in marginal leakage of CL V restorations with composite resin. Dissertation (MSc in Restorative Dentistry)- School of Dentistry, University of Sao Paulo, 2000. (abstract)

15- Abudallah H and Al-Hashimi W: Evaluation of shear bond strength of composite resin bonded to CO_2 laser treated dentin with three different adhesive systems. Thesis for the degree of master in

Conservative Department, College of Dentistry, Baghdad University 2005.
16- Gonzalz M, Banderas JA, Rodrigues V and Castana VM: Particle-induced x-ray emission and scanning electron microscopic analysis of the effects of CO2 laser irradiation on dentinal structure. J Dent, 1999; 27: 595-600.
17- Visuri S, Glibert J, Wright D, Wigdor H and Walsh J. Shear bond strength of composite bonded to Er:YAG laser-prepared dentin. J Dent Res, 1996;75: 599-605.
18- Olivera S, Pugach M, Hilton J, Watanable L, Marshall S and Marshall G. The influence of the dentin smear layer on adhesion: a self etching primer vs. a total-etch system. Dent Mater, 2003;19:758-67.
19- Montes M, Goes M, Ambrosano G, Duart R and Sobrinoho L. The of collagen removal and the use of low viscosity resin linear on marginal adaptation of resin composite restorations with margins in dentin. Oper Dent, 2003; 28(4): 378-87.

Figure 1: Study sample

Figure 2: Sample after cavity preparation

Figure 3: CO2 laser device

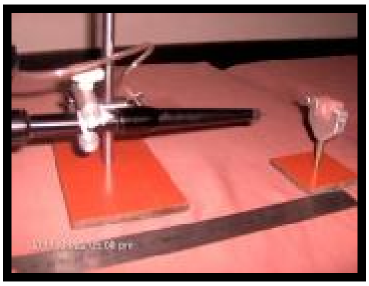

Figure 4: CO2 laser irradiation on dentin surface using a standardized fixing device

Figure 5: Air flow handy device

Figure 6: Air flow handy hand piece on dentin surface mounted in standardized fixing device

Figure 7: Standardized distance of sample from triple syringe

Figure 2.13: Curing of composite

Table 1 Number of microleakage scores for each subgroup

Subgroups	Scores			Subgroups	Scores		
	0	1	2		0	1	2
A1	2	9	9	A1	2	9	9
B1	1	9	10	B1	1	9	10
C1	2	6	12	C1	2	6	12
D1	3	8	9	D1	3	8	9
E1	2	9	9	E1	2	9	9

Table (2) Chi-square between each subgroup at one day storage

	Chi-square	**P-value**	**Sig**
A1&B1	0.386	0.842	NS
A1&C1	12.197	0.002	S
A1&D1	0.259	0.879	NS
A1&E1	-	-	-
B1&C1	15.241	0.001	S
B1&D1	1.111	0.574	NS
B1&E1	0.386	0.824	NS
C1&D1	10.140	0.006	S
C1&E1	12.197	0.002	S
D1&E1	0.259	0.879	NS

Table (3) Chi-square between each subgroup at two weeks storage

	Chi-square	**P-value**	**Sig**
A2&B2	-	-	-
A2&C2	19.773	0.000	HS
A2&D2	0.631	0.729	NS
A2&E2	0.106	0.948	NS
B2&C2	19.773	0.000	HS
B2&D2	0.631	0.729	NS
B2&E2	0.106	0.948	NS
C2&D2	17.66	0.000	HS
C2&E2	19.921	0.000	HS
D2&E2	0.400	0.819	NS

Table (4) Mann Whiteny between one day and two weeks

	Median of one day	Median of two weeks	Mann whiteny	P-value	Sig
Laser	1.00	1.5	0.704	0.672	NS
Air abrasion	1.5	1.5	0.000	1.000	NS
Acid	2.00	2.00	4.06	0.009	S
Laser + Acid	1.00	2.00	3.66	0.043	S
Air abrasion +Acid	1	2	4.03	0.034	S