10.5005/jp-journals-10022-1010

ORIGINAL RESEARCH

An Evaluation of the Surface Condition of Dentin and Its Effect on Microleakage of Metal Copings luted with Glass Ionomer Cement: An *in vitro* Study

Sheetal Parab, Sabita M Ram

ABSTRACT

Aim: The aim of the study was to evaluate the surface conditioned dentin and its effect on microleakage of metal copings luted with glass-ionomer cement.

Objectives: (1) To evaluate the morphology of unconditioned and conditioned dentin, (2) to evaluate the elemental composition of unconditioned and conditioned dentin, (3) to evaluate and compare the microleakage of metal copings luted with glass-ionomer cement to unconditioned and conditioned dentin, (4) to correlate the effect of dentin conditioning on the microleakage of metal copings luted with glass ionomer cement.

Materials and methods: The surface conditioning methods utilized were GC dentin conditioner (group II), air abrasion with 50 µm aluminum oxide (group III) and Er: YAG laser at 120 mj with 10 Hz frequency (group IV). These methods were evaluated and compared with unconditioned dentin (group I) for morphological and elemental analysis using ESEM and correlated for their effect on microleakage of metal copings luted with glass Ionomer cement (Fuji I).

Results: The results of microleakage observed for each group were statistically analyzed by Leven's test, One-way ANOVA and Schiff's test. Unconditioned dentin (group I) showed the maximum microleakage. Er:YAG laser (group IV) irradiation with less power density showed significantly minimum microleakage compared to all other groups, followed by air abrasion (group III) and GC dentin conditioner (group II).

Conclusion: Air abrasion and Er: YAG laser conditioning showed less microleakage than surface conditioning with dentin conditioner.

Keywords: Surface conditioning, Glass ionomer cement, Er:YAG laser, Air abrasion dentin conditioner.

How to cite this article: Parab S, Ram SM. An Evaluation of the Surface Condition of Dentin and Its Effect on Microleakage of Metal Copings luted with Glass Ionomer Cement: An *in vitro* Study. Int J Laser Dent 2012;2(1):7-17.

Source of support: Nil

Conflict of interest: None declared

INTRODUCTION

In restorative dentistry, the most important aspect is luting of restoration to the existing tooth structure. When microleakage of the oral fluids is not responsible for caries recurrence, it is important to note the marginal approximation between the restoration and the prepared tooth surface. Luting cements form an intermediate factor to enhance retention and maintain the marginal seal. Thus, the adhesion of luting agent to the tooth surface is of great significance in fixed prosthodontics and is often the most important link in achieving clinical success.[1]

Adhesion can be defined as an attraction between the molecules of different materials at their interface. The following criteria are required for adhesion to be achieved: A clean substrate for the intimate access of adhesive to its surface; complete wetting of the substrate surface and liquid to solid transformation of adhesive.[1] Also, more effective the adhesion, less will be the microleakage.

Various luting agents have been used for cementation of cast restorations and each of luting agents have their own merits as well as demerits. Among all the luting agents, glass ionomer cements have proved to be one of the best adhesive cements due to their chemical bonding to tooth structure and they make popular choices for vital teeth because of their physicochemical bonding to the dentin, ability to resist caries, long-term fluoride release, minimal effect on the pulp and low coefficient of thermal expansion.[2]

The bonding mechanism of the conventional glass ionomer is very complex. It consists wetting the tooth surface by free polyacrylic acid, followed by ionic bonding between the carboxyl group in the cement liquid and calcium ions in the tooth structure.[2] Presence of smear layer formed during tooth preparation on dentin can effectively reduce the bond of glass-ionomer to dentin by reducing penetration of polymer into dentinal tubules.[3] Hence, prior to cementation, conditioning of dentin surfaces to remove smear layer is a prerequisite for good adhesion of glass ionomer cement.

In order to optimize the bonding, most authors suggest conditioning the tooth surface with polyacrylic acid.[4-6] Although pretreatment of dentin with polyacrylic acid has been recommended, according to some studies it offers no statistical improvement in tensile bond strength, microleakage and adhesion of the glass ionomer cement.[7-11]

Air abrasion and laser have been recommended as methods of surface treatment to improve adhesion of resin cements prior cementation. However, the surface treatment for luting with glass ionomer cement has been restricted to more traditional methods. The modification of the dentin surface with such treatments may have a direct correlation with microleakage.

It was therefore planned to evaluate the various methods of dentin conditioning which may modify the tooth surface and how the conditioned surface affect the microleakage when metal restorations were luted with glass ionomer cement.

AIM OF THE STUDY

The primary aim of the study was to evaluate the surface conditioned dentin and its effect on microleakage of metal copings luted with glass ionomer cement.

OBJECTIVES

1. To evaluate the morphology of unconditioned and conditioned dentin.
2. To evaluate the elemental composition of unconditioned and conditioned dentin.
3. To evaluate and compare the microleakage of metal copings luted with glass ionomer cement to unconditioned and conditioned dentin.
4. To correlate the effect of dentin conditioning on the microleakage of metal copings luted with glass ionomer cement.

MATERIALS AND METHODS

A comparative study was done to evaluate the surface conditioned dentin and its effect on microleakage of metal copings luted with glass ionomer cement. The method of the study was divided into the following steps:

Collection and Storage of Teeth

Twenty extracted maxillary premolars with no caries, attrition and abrasion were cleaned with ultrasonic scaler and were stored in 0.9% normal saline at room temperature in a sterile sealed bottle.

Mounting of Samples

The teeth were mounted in dental stone with the long axis vertically keeping the cementoenamel junction above the level of the stone.

Standardized Teeth Preparation to Receive Metal Copings

All the twenty premolars were prepared to receive nickel-chromium complete metal copings, using a surveyor and jig assembly to achieve standardized tooth preparation.

Impression Making and Preparation of Dies

Impressions of the prepared teeth were made following one step putty wash impression technique using addition silicon (Aquasil soft putty and light body impression material) and self-cure acrylic resin single tooth perforated custom trays. The impressions were poured using type IV dental stone and dies were prepared using die pins.

Fabrication of Metal Copings

The dies were painted with three coats of die spacer 1mm short of margins.[12-14] Wax separator was applied over all the dies. Each die was dipped twice in the dipping wax to get well adapted internal surfaces and even thickness of the wax pattern. Margin wax and crown wax (BEGO) was used on the rest of the surfaces to complete wax patterns. Sprues were attached to the bulkiest part of the wax pattern.

The wax patterns were invested using phosphate bonded investment material (Calibra express from protechno) and the material was allowed to set for 1 hour. The casting was carried out in the induction casting machine (BEGO) using nickel-chromium base metal alloy (RUBY-MWA) to get metal copings. The marginal discrepancy between all the teeth and copings were checked at 500 × magnification with the help of olympus digital stereo zoom metallurgical microscope (OlympusG × 51). The copings with less than 39 μm discrepancy were chosen and the rest were repeated to get perfected margins.[15,18]

Surface Conditioning of Dentin

The prepared teeth were divided into four groups of five teeth each to carry out conditioning of dentin.

Group I: Unconditioned dentin
Group II: Dentin conditioned with GC dentin conditioner
Group III: Dentin conditioned with air abrasion
Group IV: Dentin conditioned with laser

For group I (unconditioned dentin), surfaces were cleaned with pumice slurry after tooth preparation.

For group II (dentin conditioner), dentin surfaces were conditioned with 10% polyacrylic acid—GC dentin conditioner with an applicator tip in a light scrubbing motion for 10 seconds. The preparations were rinsed with water for 30 seconds.[19-21]

For group III (air abrasion), dentin surfaces were conditioned for 6 seconds with 50 μm aluminum oxide particles using microetcher ERC (Danville engineering) with 0.048/60° nozzle at 120 psi air pressure at a distance of 5 mm from the surface. After abrasion, the surfaces were thoroughly rinsed with vigorous waterspray for 30 seconds to remove residual alumina particles.[22,23]

For group IV (laser), dentin surfaces were conditioned with Er:YAG lasers from fotona Fiedelis III with a 0.4 mm focus beam at 120 mJ energy, 10 J/cm^2 energy density, with repetition rate of 10Hz, for 1.2W power supply at very short pulse duration with R14 handpiece in noncontact mode at a working distance of 2 mm from the dentin surface. The surfaces were irrigated with copious amount of water and air during irradiation.[22-25]

Analysis of Conditioned Surface with Environmental Scanning Electron Microscope

Following surface conditioning teeth from every group were evaluated for morphological analysis with environmental scanning electron microscope (ESEM) and elemental content of calcium (Ca), oxygen (O_2), phosphorus (P) of dentin were measured in atomic percent, net content using energy dispersive X-ray (SEM–EDX) analyzer after applying the atomic number-absorption-secondary fluorescence (ZAF) correction method.[26]

Cementation of Copings and Preparation of Samples for Evaluation of Microleakage

After conditioning type I glass ionomer cement was proportioned and mixed according to manufacturer's instructions. The cement was placed on the internal surface of copings and the copings were placed on the respective teeth by applying digital pressure for 7 minutes.

After initial set, the excess cement was removed from the margin and dental varnish was applied;[14] after which the teeth were removed from their mountings.[11] The samples were stored in artificial saliva at 37°C for 24 hours in a water bath.[13,15,16]

Samples of each group were submitted to thermocycling between 5°C and 55°C for 100 cycles to simulate *in vivo* conditions and stained with 2% buffered methylene blue dye at 37°C for 24 hours. The teeth were embedded in clear acrylic blocks. All the blocks were sectioned longitudinally through the center of the restoration using a carborandum disk so as to get two sections of each sample.[13-18]

Evaluation of Microleakage with Optical Microscope

Four interfaces of each sample were evaluated for the depth of dye penetration under optical microscope (Olympus digital stereo zoom metallurgical microscope—OlympusG × 51) at 50× magnification and the results were noted using an image analyzer.

Marginal microleakage was measured as linear penetration of stain from external margin of luting cement at the cement-tooth interface in µm.

The readings were tabulated and analyzed statistically by applying one-way ANOVA test and Schiff's test.

RESULTS

Surface Analysis of Dentin Surfaces with Environmental Scanning Electron Microscope (ESEM)

Group I: Unconditioned Dentin

The ESEM image of unconditioned dentin showed a relatively flat topography. Under higher magnification the surface of unconditioned dentin showed track lines formed due to the rotary instrumentation, presence of large amounts of loosely attached smear layer on dentin and the dentinal tubules were completely occluded with the smear layer (Fig. 1A).

Elemental analysis of group I—unconditioned dentin surfaces showed smear layer primarily consisting of carbon, oxygen, nitrogen, calcium, phosphorus, silicon, sodium, magnesium and chlorine (Edex 1, Table 1, Graphs 1 and 2).

Group II: Dentin Conditioned with Dentin Conditioner

The ESEM image of dentin conditioned with 10% polyacrylic acid from GC dentin conditioner showed a clear dentinal surface with no smear layer, the clearly visible dentinal tubules of 1 to 3 µm in width and intertubular dentin surfaces with a granulated appearance (Fig. 1B).

Elemental analysis of group II dentin showed reduced Ca and P content as compared to the unconditioned dentin surfaces indicating mild demineralization. The O_2 content was significantly higher than Ca and P content (Edex 2, Table 1, Graphs 1 and 2).

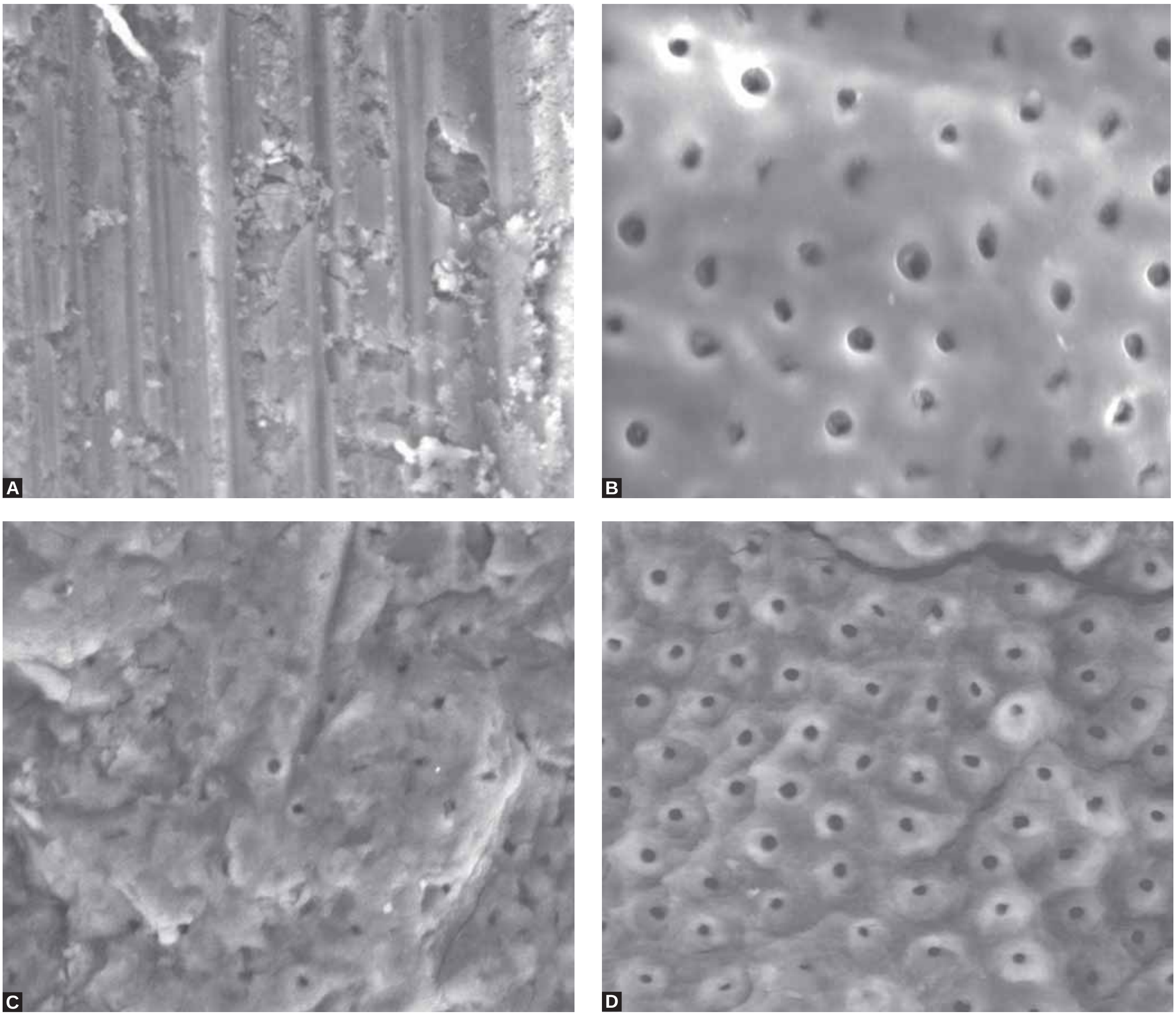
Group III: Dentin Conditioned with Air Abrasion

The ESEM image showed that application of 50 µm aluminum oxide air abrasion produces macroscopically visible irregularities on the dentin surfaces with cracks and some open dentin tubules. Some dentinal tubules were not patent because of the obstruction of the dentinal tubules, possibly due to an increase of the residual dust layer while caring out the air abrasion (Fig. 1C).

Elemental analysis of air abraded surface showed more amounts of Ca, P, O_2 compared to surfaces conditioned with 10% polyacrylic acid (Edex 3, Table 1, Graphs 1 and 2).

Group IV: Dentin Conditioned with ER:YAG Lasers

The ESEM image of the irradiated dentin in this study showed extensive surface roughening and revealed no cracks or thermal damage. Laser-irradiated dentin was deprived of a smear layer thereby opening the orifices of dentinal tubules. Many dentinal tubules, approximately



Figs 1A to D: ESEM analysis at 3000× magnification: (A) unconditioned surface, (B) surface conditioned with dentin conditioner, (C) surface conditioned with air abrasion using 50 µm aluminum oxide, (D) surface conditioned with Er:YAG lasers at 120 mj

1 µm in diameter, were clearly visible throughout the surface, and the intertubular dentin had more ablation than the peritubular dentin, showing a protrusion of the tubules at different planes possibly due to the depletion of intertubular dentin. The peritubular dentin still remained, indicating more resistance to laser energy (Fig. 1D).

The elemental analysis showed that after laser radiation, O_2 content was significantly reduced but Ca and P increased relatively. The ratio of Ca to P in laser-treated dentin was higher than the unconditioned group. Also, the Ca and P content of laser-treated dentin came close to Ca and P content of enamel (Edex 4, Table 1, Graphs 1 and 2).

Analysis of Microleakage with Optical Microscope

Microleakage was measured for 5 samples of each group at four interfaces, using optical microscope with image analyzer at 50× magnification. The measurements for all the samples are listed (Table 2).

The observed results of microleakage for each group were statistically analyzed by Leven's test, one-way ANOVA and Schiff's test (Tables 3 and 4, Graph 3).

DISCUSSION

Microleakage is an important cause of the failure of dental restorations. Microleakage is defined as the seepage of oral fluids containing bacteria and debris between a tooth and its restoration on cement layer. The bacterial ingress has detrimental effect on the remaining tooth structure and the pulp tissue.

Dental luting cements form an important link between a fixed restoration and the supporting tooth structure by sealing the margins and preventing marginal leakage.

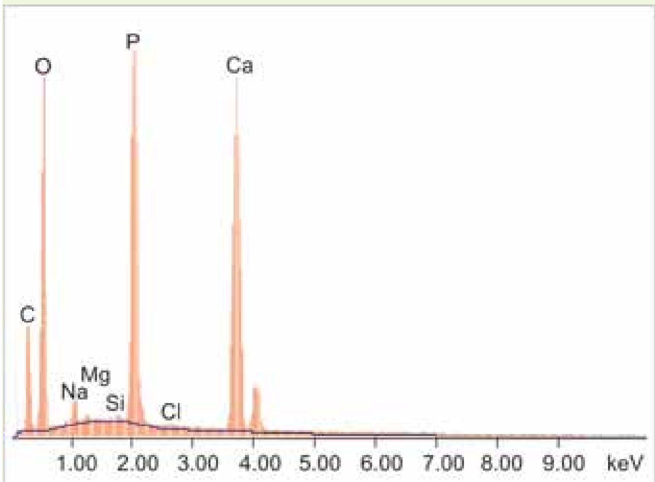
Edex 1: Elemental analysis of group I dentin

E:\DATA\DYPATIL\UNCONDITIONED.spc

Label:UNCONDITIONED

kV:15.0 Tilt:0.0 Take-off:34.9 Det Type:SUTW+ Res:131 Amp.T:102.4

FS: 2775 Lsec: 50



EDX-ZAF Quantification (Standardless)
Element Normalized
SEC Table: Default

Element	Wt%	At%	K-ratio	Z	A	F
CK	**17.91**	29.47	0.0466	1.0506	0.2474	1.0005
OK	**36.80**	45.44	0.0762	1.0306	0.2009	1.0001
NaK	1.06	0.91	0.0049	0.9616	0.4777	1.0014
MgK	0.25	0.20	0.0015	0.9849	0.6261	1.0029
SiK	0.16	0.11	0.0014	0.9787	0.8494	1.0116
PK	**15.49**	9.88	0.1344	0.9445	0.9128	1.0065
ClK	0.24	0.14	0.0021	0.9259	0.9165	1.0175
CaK	**28.09**	13.85	0.2620	0.9484	0.9836	1.0000
Total	100.00	100.00				

Element	Net Inte.	Bkgd Inte.	Inte. Error	P/B
CK	**62.60**	3.78	1.89	16.56
OK	**230.06**	4.86	0.95	47.34
NaK	18.00	13.20	5.24	1.36
MgK	5.62	15.50	15.23	0.36
SiK	4.32	18.40	20.99	0.23
PK	**376.44**	17.98	0.76	20.94
ClK	5.00	10.60	14.48	0.47
CaK	**440.06**	7.80	0.69	56.42

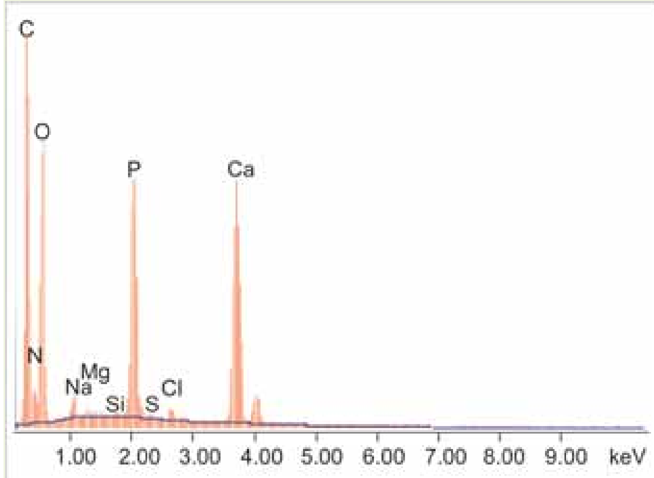
Edex 2: Elemental analysis of group II dentin

E:\DATA\DYPATIL\DENTING CONDITIONER\DENTINE CONDITIONER _002.spc

Label:DENTIN CONDITIONER _002

kV:15.0 Tilt:0.0 Take-off:35.0 Det Type:SUTW+ Res:131 Amp.T:102.4

FS: 2586 Lsec: 50



EDX-ZAF Quantification (Standardless)
Element Normalized
SEC Table: Default

Element	Wt%	At%	K-ratio	Z	A	F
CK	**40.04**	52.96	0.1484	1.0290	0.3600	1.0004
NK	8.84	10.03	0.0119	1.0189	0.1318	1.0004
OK	**25.87**	25.69	0.0507	1.0096	0.1940	1.0001
NaK	0.81	0.56	0.0041	0.9423	0.5281	1.0009
MgK	0.25	0.17	0.0017	0.9653	0.6775	1.0018
SiK	0.10	0.06	0.0009	0.9554	0.8841	1.0073
PK	**8.21**	4.21	0.0715	0.9226	0.9392	1.0047
SK	0.13	0.06	0.0011	0.9465	0.9266	1.0074
ClK	0.40	0.18	0.0035	0.9057	0.9589	1.0128
CaK	**15.34**	6.08	0.1425	0.9277	1.0011	1.0000
Total	100.00	100.00				

Element	Net Inte.	Bkgd Inte.	Inte. Error	P/B
CK	**222.06**	3.00	0.96	74.02
NK	20.70	3.14	3.55	6.59
OK	**170.26**	3.56	1.11	47.83
NaK	16.68	10.00	5.13	1.67
MgK	6.72	11.12	11.33	0.60
SiK	3.12	12.52	24.05	0.25
PK	**222.76**	12.76	1.00	17.46
SK	3.28	11.42	22.04	0.29
ClK	9.32	9.96	8.21	0.94
CaK	**266.24**	6.92	0.89	38.47

Different luting agents vary considerably in solubility, strength and ability to adhere to tooth structures.[6]

The principle merit of the glass ionomer cement lies in its chemically adhesive qualities. The glass ionomer cement adheres to reactive substrates, such as enamel, dentin and base metals. The attractive forces are electrostatic in nature, since both cement and substrates are polar and ionic. Polyanions from the cement actually penetrate the apatite surface with carboxylate groups displacing phosphate groups from the apatite matrix. The ability of the free carboxylate groups present in fluid cement to form hydrogen bonds ensures excellent wetting, a prerequisite to effective adhesion. As the cement sets, these hydrogen bonds are replaced by ionic bridges. Thus, there is very close contact between the ionomer cement and substrate. The glass ionomer cement shows some adhesion to enamel and dentin without prior treatment so that the cement either penetrates through or displaces surface contaminants, or adheres to them. Though numerous studies are available on techniques to improve adhesion of glass ionomer restorative cements to tooth structure with various conditioning agents; the problem of microleakage still persists.

This study was conducted to evaluate the surface conditioned dentin and its effect on microleakage of metal copings luted with glass ionomer luting cement.

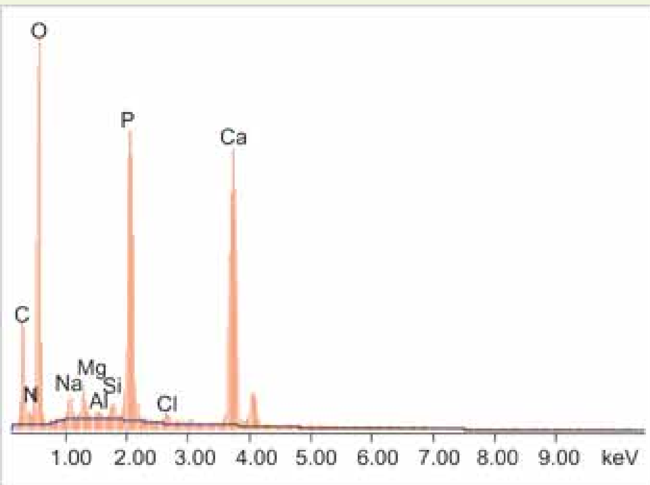
Edex 3: Elemental analysis of group III dentin

E:\DATA\DYPATIL\AIRABRASION\AIRABRASION DENTING_001.spc

Label:AIRABRASION DENTING_001

kV:15.0 Tilt:0. Take-off:34.9 Det Type:SUTW+ Res:131 Amp.T:102.4

FS: 2506 Lsec: 50



EDX-ZAF Quantification (Standardless)
Element Normalized
SEC Table: Default

Element	Wt%	At%	K-Ratio	Z	A	F
CK	**18.79**	29.20	0.0517	1.0444	0.2635	1.0005
NK	4.14	5.51	0.0060	1.0340	0.1400	1.0006
OK	**38.19**	44.56	0.0827	1.0246	0.2114	1.0001
NaK	1.04	0.84	0.0048	0.9561	0.4842	1.0013
MgK	1.10	0.85	0.0068	0.9792	0.6330	1.0025
AlK	0.21	0.15	0.0015	0.9484	0.7532	1.0051
SiK	0.57	0.38	0.0047	0.9719	0.8473	1.0095
PK	**12.73**	7.67	0.1091	0.9381	0.9085	1.0055
ClK	0.46	0.24	0.0039	0.9200	0.9254	1.0149
CaK	**22.78**	10.61	0.2119	0.9424	0.9871	1.0000
Total	100.00	100.00				

Element	Net Inte.	Bkgd Inte.	Inte. Error	P/B
CK	**62.14**	3.36	1.89	18.49
NK	8.38	3.30	6.53	2.54
OK	**223.30**	3.60	0.96	62.03
NaK	15.90	10.64	5.42	1.49
MgK	22.32	11.86	4.30	1.88
AlK	4.72	11.58	15.82	0.41
SiK	13.42	11.94	6.44	1.12
PK	**273.02**	11.56	0.89	23.62
ClK	8.38	8.34	8.45	1.00
CaK	**318.06**	6.12	0.81	51.97

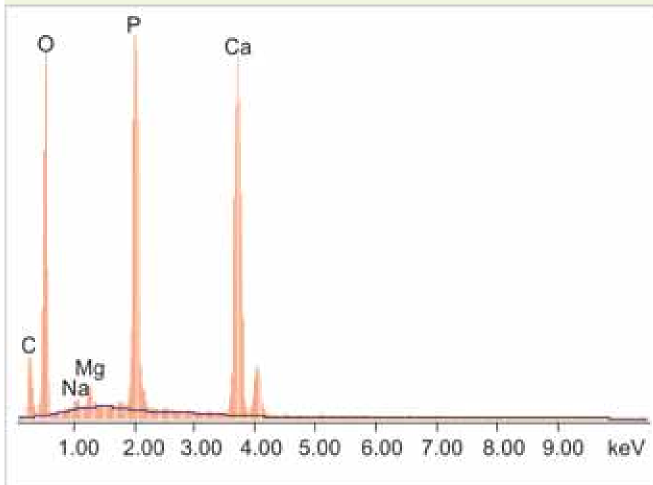
Edex 4: Elemental analysis of group IV dentin

E:\DATA\DYPATIL\120 MJ LASER\120 MJ LASER_001.spc

Label:120 MJ LASER_001

kV:15.0 Tilt:0.0 Take-off:33.7 Det Type:SUTW+ Res:131 Amp.T:102.4

FS: 2461 Lsec: 50



EDX-ZAF Quantification (Standardless)
Element Normalized
SEC Table: Default

Element	Wt%	At%	K-ratio	Z	A	F
CK	**11.75**	20.33	0.0289	1.0546	0.2333	1.0006
OK	**39.64**	51.46	0.0811	1.0345	0.1978	1.0001
NaK	0.59	0.53	0.0026	0.9652	0.4568	1.0015
MgK	0.79	0.68	0.0048	0.9886	0.6093	1.0030
PK	**16.65**	11.16	0.1437	0.9486	0.9039	1.0067
CaK	**30.58**	15.85	0.2855	0.9523	0.9803	1.0000
Total	100.00	100.00				

Element	Net Inte.	Bkgd Inte.	Inte. Error	P/B
CK	**32.60**	2.12	2.63	15.38
OK	**206.94**	3.00	1.00	68.98
NaK	8.16	10.14	9.24	0.80
MgK	14.84	11.44	5.85	1.30
PK	**343.32**	12.04	0.79	28.51
CaK	**409.66**	6.06	0.71	67.60

Twenty extracted human permanent maxillary premolars were selected for the study. The prepared teeth were divided into four groups of five teeth each: One unconditioned dentin group and three groups for surface conditioning using dentin conditioner, air abrasion and lasers.

Following surface conditioning teeth from every group were evaluated for morphological analysis with ESEM and elemental analysis using energy dispersive X-ray (SEM-EDX) analyzer after applying the atomic number-absorption-secondary fluorescence (ZAF) correction method.

The ESEM analysis of surface morphology showed presence of loosely bound smear layer on unconditioned dentin blocking dentinal tubules which was similar to previous studies carried out by Powis, Folleràs, Merson, Wilson and A Lin, McIntyre NS, Davidson RD.[1,4]

The morphological analysis of dentin conditioned with dentin conditioner showed a clear dentinal surface with absence of smear layer and clearly visible open dentinal tubules which is consistent with previous SEM studies carried out by earlier workers.[4]

The dentin conditioned with air abrasion showed macroscopic irregularities with cracks and open dentinal tubules, no surface smear layer. However, some dentinal tubules were obliterated with dentin debris.

Many researchers have investigated the effects of air abrasion on dental hard tissues. Some preferred the use of air abrasion to increase surface roughness. Acid etching is

Table 1: Ca, P, O_2 content of dentin surfaces of four groups

Groups	*Ca%*	*P%*	*O%*	*Net Ca amount*	*Net P amount*	*Net O amount*
Group I: Unconditioned	28.09	15.49	36.80	440.06	376.44	230.06
Group II: Dentin conditioner	15.64	8.21	25.87	226.24	222.76	170.26
Group III: Air abrasion	22.78	12.73	38.19	318.06	273.02	223.30
Group IV: Laser 120 mj	30.58	16.65	39.64	409.65	343.32	206.94

Table 2: Consolidated statistics of microleakage values of four groups

Microleakage group	*N*	*Mean*	*Std. deviation*	*Std. error*	*95% confidence interval for mean*		*Min.*	*Max.*
					Lower	*Upper*		
Unconditioned dentin	20	3193.5020	208.93698	46.7197	3095.72	3291.28	3476.36	2796.94
Dentin conditioner	20	3078.4765	309.34474	69.1716	2933.70	3223.25	3654.47	2542.90
Air abrasion	20	1207.3330	298.5876	66.7662	1067.59	1347.08	2034.19	653.45
ER:YAG laser	20	413.7105	248.75852	55.6241	297.29	530.13	782.93	108.62
Total	80	1973.2555	1233.0058	137.854	1698.86	2247.65	3654.47	108.62

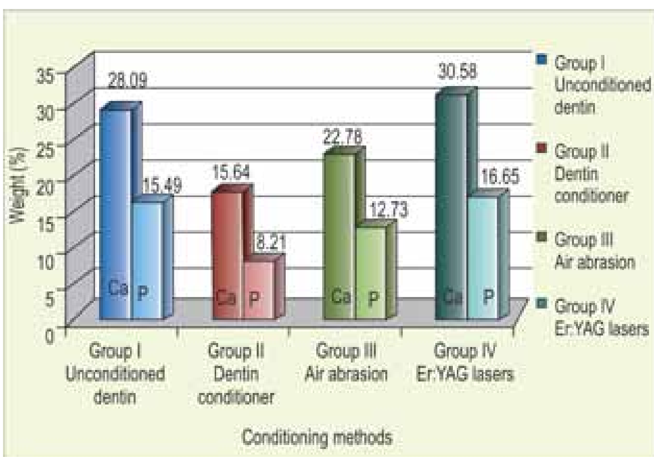
Table 3: The ANOVA test

Microleakage	*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*
Between groups	114586657.253	3	38195552.418	526.138	0.000
Within groups	5517299.945	76	72596.052		
Total	120103957.197	79			

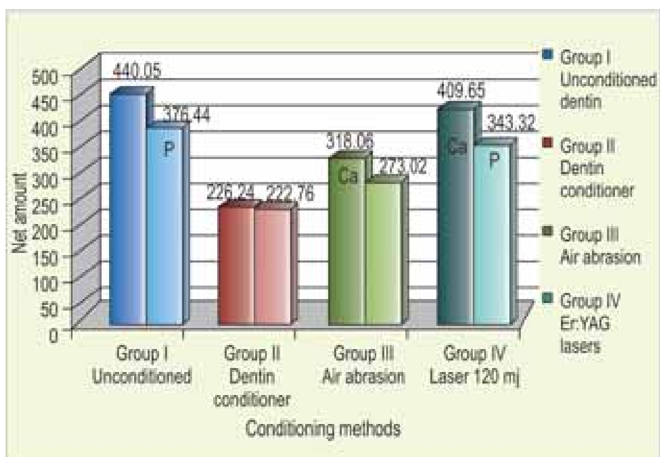
Table 4: The Schiff's test for harmonic mean of microleakage

Groups	*N*	*Subset for alpha = 0.05*		
		1	*2*	*3*
Er:YAG Laser 120 mj	20	413.7105		
Air abrasion	20		1207.3330	
Dentin conditioner	20			3078.4765
Unconditioned	20			3193.5020
Significance		1.000	1.000	0.612

Mean of groups in homogeneous subsets.
Schiff's test using harmonic mean (sample size = 20)



Graph 1: Ca and P weight percentage of four groups

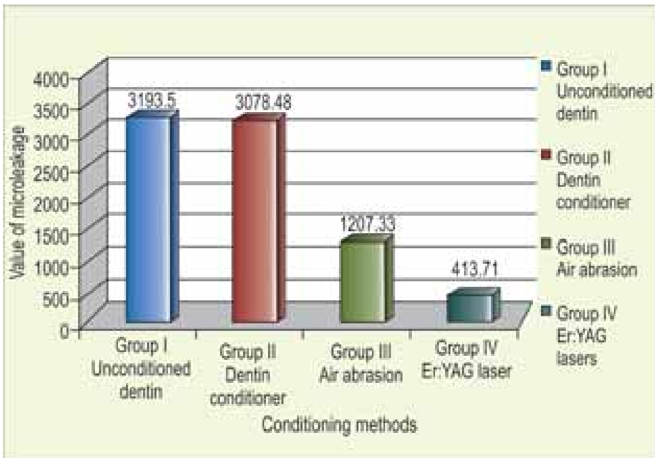


Graph 2: Ca and P net amount of four groups

a form of microetching, whereas sandblasting can be regarded as a form of macroetching.[28]

Previous SEM investigations have revealed the presence of macroscopic superficial alterations on the enamel and dentin surface after aluminum oxide air abrasion.[27-29]

Laser irradiated dentin showed absence of a smear layer, and the orifices of dentinal tubules were opened. Many dentinal tubules, approximately 1 µm in diameter, were clearly visible throughout the surface, and the intertubular dentin had more ablation than the peritubular dentin,



Graph 3: Mean microleakage of four groups

showing a protrusion of the tubules at different planes possibly due to the depletion of intertubular dentin. The peritubular dentin still remained, indicating more resistance to laser energy.

This can be explained by the fact that the peritubular dentin has a high mineral content and lacks collagen as an organic matrix. Contrary to the intertubular dentin, it makes up 92% of the collagen matrix. The collagen matrix is rich in water content and laser energy is absorbed more than the peritubular dentin by the intertubular dentin. In the SEM and color laser three-dimensional (3D) microscopy study carried out by M Hossain, Y Yamada et al after Er:YAG irradiation the laser-irradiated dentin was deprived of a smear layer, and the orifices of dentinal tubules were opened which were similar to the result found in present study.[24]

The mechanism of dentin removal by this laser is called a thermomechanical process in which the emission laser light is absorbed by the water within the hydroxyapatite of a dental hard tissue. The water is then heated and evaporated, resulting in a high pressure of steam that causes a microexplosion of tooth tissue below the melting point of tooth tissue (approximately 1200°C). Tooth surface ablation may vary from a white spot to charring, fusion, roughening, melting, recrystallization, bubble-like inclusions, numerous pores, flaking, and cracking to crater formation. The irregularities and crater-shaped appearance of ablated dentin is comparable to the dentin surface after acid etching. However, the depth of craters formed was restricted to 0.5 mm.[30] This may promote the micromechanical interlocking between dental restorative materials and tooth surface.[31]

The elemental analysis (EDEX) of present study showed that unconditioned dentin surfaces with smear layer primarily consisting of carbon, oxygen, nitrogen, calcium, phosphorus, silicon, sodium, magnesium and chlorine. A higher Ca and P level was also found.[31-33] Previous studies on X-ray photoelectron spectroscopy of newly cut dentin surfaces show that the smear layer formed during cutting of tooth surface with conventional dental burs primarily consisted of carbon, oxygen, nitrogen, calcium and phosphorus.[1] Though, the Ca and P of unconditioned dentin were shown to be more, it was present in the loosely bound smear layer on dentin making it unavailable for bonding. In other words, the organic content of smear layer prevents the penetration of polyanions of cements into hydroxyapatite.

The elemental analysis of dentin conditioned with dentin conditioner showed reduced Ca and P content as compared to the unconditioned dentin surfaces indicating mild demineralization, which was consistent with previous studies.[1,4] Ca and P content of air abrasion group was higher than dentin conditioner group.

However, in the present study after laser radiation O_2 content was significantly reduced, but Ca and P were significantly increased. The ration of Ca to P in laser treated dentin was higher than in dentin conditioner group, air abrasion group; however, it was nearly equal to the Ca and P weight% of unconditioned dentin group**.**

The Er:YAG laser not only ablates dental hard tissues effectively, due to its highly efficient absorption in both water and hydroxyapatite but also produces minimal thermal damage to the surrounding tissues causing surface alterations of dental hard tissues making them irregular and more favorable for restorations.[34]

Laser treatment of dentin causes chemical and morphological changes in dentin along with closure of dentinal tubules. If laser favorably modifies the dentin surface, it is possible to increase bond strength of adhesive luting material. Although, there is evidence that laser radiation of dentin produces favorable surface for mechanical bonding of dentin to resin composite, the bond strength is comparable or may be weaker than that is produced by acid etching as shown by studies carried out by Y Yamada et al also by Amaral et al.[23,25] Unlike resin based systems, glass ionomer cement exhibit an inherent property of bonding physicochemically to enamel or dentin, which can be enhanced by increased amount of Ca and P found in laser-treated dentin.[32-34]

Previous studies have shown laser irradiation altered the dentin causing recrystalization and increased size of hydroxyapatite crystals which come closer to the crystalline structure of enamel. Since glass ionomer cement bonds effectively to enamel, which consist of 98% apatite crystal compared to dentin, the modified and more enamel like dentin surface had superior bonding to untreated dentin.[25,33,35,36]

After cementation of copings with type I glass ionomer cement, samples of each group were submitted to thermocycling and stained. Microleakage was evaluated by the depth of dye penetration under optical microscope at 50× magnification.

From the results of the study, it was seen that the unconditioned dentin group and the dentin conditioner group showed more microleakage than the group conditioned with air abrasion and lasers. Microleakage seen after dentin surface conditioning with ER: YAG lasers is least compared all other conditioning protocol. This could be correlated to the fact that air abrasion and laser conditioning, completely removed the smear layer and improved adhesion of glass ionomer to dentin due to more amount of Ca and P; as shown in ESEM morphological and elemental analysis of this study.

Polyacrylic acid, though is most commonly used conditioner for conventional GICs[6] because it is capable of cleansing the dentin surface without completely unplugging the dentinal tubules.[7,8] The increase in bonding efficiency resulting from conditioning can be attributed to[5] the cleansing effect which removes loose cutting debris following cavity preparation, partial demineralization effect which increases the surface area and creates microporosities and chemical interaction of the polyalkenoic acid with residual hydroxyapatite.[4] However, many *in vitro* studies regarding microleakage under glass ionomer cement highlight the inefficiency of mild acidic treatment to prevent microleakage under glass ionomer.[4-12] The ESEM analysis in this study confirms this fact by showing ability of dentin conditioner to completely remove the smear layer with associated decrease in Ca content and maximum amount of microleakage.

Since, additional stability of the glass ionomer bond to dentin surface is provided by mechanical interlocking of polymer in dentin, mechanical adhesion would naturally be enhanced by greater contact with the irregularities or pores of the substrates.[37,38] This can be proved with the less amount of microleakage seen with air abrasion and laser groups in the present study.[39-41]

The process of dentin removal by the laser is different from the conventional high-speed handpiece; as it induces considerable changes in the surface morphology and physical properties of the dentin. On the other hand, the thermal effect laser irradiation may cause both de/remineralization and deproteinization on the dentin surface.[41] This was not evident in the present study due to less power density of laser used. However, the resultant increase in ratio of Ca:P of laser treated dentin surfaces could be the reason for less microleakage seen with this group. This could be attributed to the increase in the molecular interactions, e.g. polar and ionic interactions between GI cement and laser treated dentin surface.

Within the limitation of this study it was concluded that the morphological analysis showed the maximum surface roughness with air abrasion followed by laser and the least with dentin conditioner. The unconditioned dentin showed the presence of smear layer. There was a direct correlation with the Ca and P content with the microleakage seen in various groups of the study. Air abrasion and laser irradiation were more promising surface conditioning methods to prevent microleakage when copings were lusted with glass ionomer luting cement. However, further research with smaller air abrasion particles and with different power densities of laser is required.

CONCLUSION

1. The morphological analysis (ESEM) showed maximum surface roughness with group III. Air abrasion followed by group IV-laser. Group II—dentin conditioner showed least surface roughness. Group I—unconditioned dentin showed presence of smear layer.
2. The elemental analysis (EDEX) showed increased Ca and P content with group IV. Laser followed by group III—air abrasion. Group II—dentin conditioner showed least Ca and P content. However, group I—unconditioned dentin showed the maximum Ca and P content which was present in the loosely bound smear layer.
3. Maximum microleakage was observed with group I—unconditioned dentin followed by group II—dentin conditioner and group III—air abrasion. group IV—laser showed least microleakage. Microleakage of group I—unconditioned dentin and group II—dentin conditioner was significantly more than that of the remaining two groups. However, the difference in the mean microleakage of group I—unconditioned dentin and group II—dentin conditioner was not significant.
4. Surface morphology and Ca, P content have a direct correlation with the microleakage. In group IV—laser Ca and P content was highest with increased surface roughness, it showed the least microleakage. In group III—air abrasion where surface roughness was maximum but Ca and P content was less; which made the surface less reactive therefore microleakage was more. In group II—dentin conditioner absence of surface roughness and decreased Ca and P content caused more microleakage. Group I—unconditioned dentin showed maximum microleakage due to presence of loosely bound smear layer which caused inadequate bonding.

SUMMARY

The *in vitro* study was conducted for the surface conditioning of dentin prior to cementation of metal copings with type I glass ionomer luting cement. In the present study, surface conditioning was carried out by dentin conditioner, air abrasion and laser. The effect of unconditioned dentin and conditioned dentin was evaluated for microleakage.

Twenty extracted human permanent maxillary premolars were prepared to receive nickel-chromium complete metal copings, using a surveyor and jig assembly to achieve standardized tooth preparation. All the 20-teeth after tooth preparation and fabrication of metal copings were divided into four groups as per the dentin conditioning methods.

- *Group I*: Unconditioned dentin
- *Group II:* Dentin conditioned with dentin conditioner.
- *Group III*: Dentin conditioned with air abrasion
- *Group IV:* Dentin conditioned with ER:YAG lasers.

Following surface conditioning, the dentin surfaces were analyzed for morphological and elemental composition with ESEM and energy dispersive X-ray (SEM-EDX) analyzer.

After cementation of metal copings with glass ionomer cement and staining, microleakage was evaluated by the depth of dye penetration under optical microscope at 50× magnification.

With the ESEM analysis, it was concluded that smear layer was absent in all conditioning groups. However, air abrasion and ER:YAG laser conditioning of tooth surfaces prior to final cementation gave a more favorable dentin surface without demineralization and increasing the surface roughness. This mechanism may be responsible for better adaptation and increased bonding mechanism of glass ionomer cement to dentinal surface.

Elemental composition of dentin surfaces using ESEM—EDX analyzer showed maximum Ca and P content of unconditioned dentin due to presence of smear layer. Dentin conditioner group showed minimum Ca and P content. Laser conditioning caused significant amount of increase in Ca and P net content and atomic percent. The increase in ratio of Ca:P of laser treated dentin surfaces was closer to elemental composition of enamel. These changes in the mineral and organic content of dentin surface may be favorable to increase the molecular interactions, such as polar and ionic interactions between glass ionomer cement and laser-treated dentin surface.

Unconditioned dentin showed maximum microleakage followed by dentin conditioned with dentin conditioner and air abrasion. Er:YAG laser conditioned dentin showed least microleakage. The microleakage of unconditioned dentin and dentin conditioned with dentin conditioner was found to be significantly more than that of the remaining two groups. However, the difference in the microleakage of first two groups was statistically not significant.

Thus, within the limitation of this *in vitro* study, it was concluded that Er:YAG laser treatment and air abrasion could be used as a surface conditioning methods on tooth abutment before final cementation to prevent microleakage under metal copings luted with glass ionomer luting cement.

REFERENCES

1. Lin A, McIntyre NS, Davidson RD. Studies on adhesion of glass-ionomer to dentin. J Dent Res 1992;71(11):1836-41.
2. Tyas MJ, Burrow MF. Adhesive restorative materials: A review Australian Dental Journal 2004;49(3):112-21.
3. Martin John Tyas. Clinical evaluation of glass-ionomer cement restorations. J Appl Oral Sci 2006;14(sp):10-13.
4. Powis DR, Folleras T, Merson SA, Wilson AD. Materials science: Improved adhesion of a glass ionomer cement to dentin and enamel. J Dent Res 1982;61:14-16.
5. Hajizadeh H, Ghavamnasiri M, Namazikhah MS, Majidinia S, Bagheri M. Effect of different conditioning protocols on the adhesion of a glass ionomer cement to dentin. J Contemp Dent Pract 2009;(10)4:9-16.
6. Yilmaz Y, Gurbuz T, Kocogullari ME. The influence of various conditioner agents on interdiffusion zone and microleakage of a glass ionomer cement with a high viscosity In primary teeth. Oper Dent 2005;30(1):105-12.
7. Tyas MJ. The effect of dentin conditioning with polyacrylic acid on the clinical performance of glass ionomer cement—3-year results. Aust Dent J Aug 1994;39(4):220-21.
8. Tay FR, Smales RJ, Ngo H, Wei SH, Pashley DH. Effect of different conditioning protocols on adhesion of a GIC to dentin. J Adhes Dent 2001;3(2):153-67.
9. Tanumiharja M, Burrow MF, Tyas MJ. Microtensile bond strengths of glass ionomer cements to dentine using four conditioners. J Dent Jul 2000; 28(5):361-66.
10. Inoue S, Abe Y, Yoshida Y, De Munck J, Sano H, Suzuki K, et al. Effect of conditioner on bond strength of glass-ionomer adhesive to dentin/enamel with and without smear layer interposition. Oper Dent Nov-Dec 2004;29(6):685-92.
11. Anthony HL, Drdent Tjan, Peach Karl D, Steven L, Vanuenburgh E, Zbaraschuk Richard. Microleakage of crowns cemented with glass ionomer cement: Effects of preparation finish and conditioning with polyacrylic acid. J Prostht Dent Nov 1991;66(5):602-06.
12. Christensen Gordon. Clinically acceptable marginal opening of gold inlays. J Prostht Dent 1966;43;124-28.
13. Crim GA, Franklin G. Microleakage. The effect of storage and cyclic duration. J Prostht Dent 1987;57:574-76.
14. Anthony HL, Tjan, Dunes James R, Grant Ben E. Microleakage of cast gold complete crowns cemented with resin cement. J Prostht Dent 1991; 53:432-35.
15. Mondelli J, Ishikiriama A, Junior JG. Marginal microleakage in cemented complete crowns. J Prostht Dent 1978;40:632-36.
16. Crim GA, Swartz ML, Philips RW. Evaluation of methods of assessing microleakage. J Prostht Dent 1985;54:160-63.
17. Grajower R, Zuberi Y, Lewinstein. Emproving the fit of crowns with die spacers. J Prostht Dent 1989;61:555-63.
18. Rossetti PH, Do Valle AL, De Carvalho RM, De Goes MF, Pegoraro LF. Correlation between marginal fit and microleakage in complete crowns cemented with three luting agents. J Appl Oral Sci Feb 2008;16(1):64-69.

19. Prati C, Nucui C, Montanari G. Effects of various dentine pretreatments on shear bond strength and marginal microleakage of various glass ionomer cements and composite resins. Dent Mater Jul 1989;5(4):260-65.
20. Tjan AH, Peach KD, VanDenburgh SL, Zbaraschuk ER. Microleakage of crowns cemented with glass ionomer cement: Effects of preparation finish and conditioning with polyacrylic acid. J Prosthet Dent 1991;86:309-14.
21. Hewlett ER, Caputo AA, Wrobel DC. Glass ionomer bond strength and treatment of dentin with polyacrylic acid. J Prosthet Dent Dec 1991;66(6):767-72.
22. Melendez EJ, Arcoria CJ, Dewald JP, Wagner MJ. Effect of laser-etch on bond strengths of glass ionomers. J Prosthet Dent Mar 1992;67(3):307-12.
23. Ceballos L, Osorio R, Toledano M, Marshall GW. Microleakage of composite restorations after acid or Er:Yag laser cavity treatments. Dent Mater Jul 2001;17(4):340-46.
24. Apel C, Meister J, Ioana RS, Franzen R, Hering P, Gutknecht N. The ablation threshold of Er:YAG and Er:YSGG laser radiation in dental enamel. Lasers Med Sci 2002;17:246-52.
25. Kobayashi CA, Fujishima A, Miyazaki T, Kimura Y, Matsumoto K, Osada T, et al. Shear bond strength of luting glass-ionomer cement to a dentin surface treated by pulsed Nd:YAG laser irradiation. Int J Prosthodont Sep-Oct 2003;16(5):493-98.
26. Hossain M, Yamada Y, Nakamura Y, Murakami Y, Tamaki Y, Matsumoto K. A study on surface roughness and microleakage test in cavities prepared by Er:YAG laser irradiation and etched bur cavities. Lasers Med Sci 2003;18:25-31.
27. Silmara AMC, Maria Cristina B, Renata Andréa S Sá Rocha, Regina G Palma-Dibb. Microleakage on class V glass ionomer restorations after cavity preparation with aluminum oxide air abrasion. Braz Dent J 2005;16(1):35-38.
28. Mujdeci A, Gokay O. The effect of airborne-particle abrasion on the shear bond strength of four restorative materials to enamel and dentin. J Prosthet Dent Sep 2004;92(3):245-49.
29. Marcelo TO, Patrícia MF, Carlos PE, Glaucia MBA, Marcelo G. Influence of diamond sono-abrasion, air-abrasion and Er:YAG laser irradiation on bonding of different adhesive systems to dentin. Eur J Dent 2007;1:158-66.
30. Soares LE, Resende EB, Brugnera A Jr, Zanin FA, Martin AA. Combined FT. Raman and SEM studies of the effects of Er:YAG laser irradiation on dentin. Photomed Laser Surg Aug 2007;25(4):239-44.
31. Soares Luís ES, Renata AB, Aldo B, Zanin Fatima AA, Resende Erick BP, Jara Walter AA, Martin Airton A. The molecular and morphological changes on dentin elements after the Er:YAG laser irradiation. Lasers Med Sci 2005;18:25-31.
32. Roebuck EM, Saunders WP, Whitters CJ. Influence of Erbium: YAG laser energies on the microleakage of class V resin-based composite restorations. Am J Dent Oct 2000;13(5):280-84.
33. Celik EU, Ergücü Z, Türkün LS, Türkün M. Effect of different laser devices on the composition and microhardness of dentin. Oper Dent 2008 Sep-Oct;33(5):496-501.
34. Karl Stock, Raimund Hibst, Ulrich Keller. Comparisons of the effect of Er:YAG and Er:YSGG laser abalation of dental hard tissue. J Dent Res 1997;71(11):1836-41.
35. H Sazak, C Türkmen, M Günday. Effects of Nd:YAG laser, air-abrasion and acid-etching on human enamel and dentin. Oper Dent 2001;26(5):334-42.
36. Piyanart Ekworapoj, Sharanbir K Sidhu, John F McCabe. Effect of different power parameters of Er, Cr:YSGG laser on human dentine. Lasers Med Sci 2007;22:175-82.
37. Rosenstiel, Land, Fujimoto. Contemporary Fixed Prosthodontics. Missouri, MOSBY; 2007;4:209-52.
38. O'Brien WJ. Dental materials and their selection (3rd ed). Chicago: Quintessence publishing Co 2004;221-25.
39. Lívia AA, Pedro Rafael L, Simone BV, Lucianne CM. Effectiveness of high speed instrument and air abrasion on different dental substrates. Braz Oral Res 2008;22(3):245-51.
40. Corona SA, Borsatto MC, Rocha RA, Palma-Dibb RG. Microleakage on class V glass ionomer restorations after cavity preparation with aluminum oxide air abrasion. Braz Dent J 2005;16(1):35-38.
41. Jose GB, Manuel RP, Javier RN, Benjamin MB, Varela Patino P, Fernando MM, et al. A comparative study of microleakage through enamel and cementum after laser Er:YAG instrumentation in class V cavity obturations, using scanning electron microscopy. J Clin Laser Med and Surg Aug 2002(1); 20(4):197-201.

ABOUT THE AUTHORS

Sheetal Parab (Corresponding Author)

Lecturer, Department of Prosthodontics, Dr DY Patil Dental College and Hospital, Mumbai, Maharashtra, India, e-mail: dr_sheetal27@yahoo.co.in

Sabita M Ram

Dean, Professor and Head, Department of Prosthodontics, MGM Dental College and Hospital, Mumbai, Maharashtra, India