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ORIGINAL RESEARCH

Evaluation of Microleakage in Class V Composite Restoration using Different Techniques of Polymerization

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ABSTRACT

Aims: The purpose of this study was to evaluate the effect of light intensity and curing cycle of quartz tungsten halogen (QTH) and plasma arc curing (PAC) lights on the microleakage of class V composite restorations.

Materials and methods: A total of 60 freshly extracted human maxillary premolars were used for this study. Standardized class V cavities were prepared and restored with microhybrid resin composite. According to the curing protocol, the teeth were then divided into three groups (n = 20): QTH curing (standard and soft start mode) and PAC high intensity irradiation.

The microleakage was evaluated by immersion of the samples in 50% silver nitrate solution. The samples were then sectioned, evaluated under a stereomicroscope and scored for microleakage.

Statistical analysis used: Dye leakage scores were obtained, and analysis was done using Student's t-test.

Results: Light curing with QTH light in the soft start mode, showed the least leakage in the composite restoration, which was highly significant when compared with the other groups ($p < 0.01$). Light curing with QTH light in the standard mode, showed moderate microleakage, which was statistically significant ($p < 0.05$), when compared with the PAC high intensity curing. Curing with PAC light in high intensity mode resulted in severe microleakage along the cavity margins.

Conclusion: Within the limitations of the study, it may be concluded that:

1. The high intensity PAC light resulted in maximum leakage, when compared to the other groups in the study.
2. The soft start polymerization mode offers a distinctive advantage over the standard curing protocol, in terms of microleakage, for the QTH curing lights.

Clinical significance: In the clinical scenario, soft start curing regimen offers a distinctive advantage over the conventional mode of the QTH curing and the high intensity rapid curing offered by the PAC light.

Keywords: Polymerization shrinkage, QTH curing lights, PAC light, High intensity curing, Soft start polymerization, Microleakage.

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INTRODUCTION

The major problem faced by clinicians when restoring class V cavities with resin composites is how to deal with the marginal quality of the restoration. The most relevant factors related to this are polymerization shrinkage, adhesion to the cavity walls, viscosity and stiffness of composite and flexibility of the cavity walls.[1] A reduction in intermolecular distance from 0.3 to 0.4 nm to 0.15 nm on polymerization of resin was reported. A higher degree of monomer conversion into polymer results in an increase in polymerization shrinkage.[2] Polymerization shrinkage can result in gap formation along the tooth/restoration interface, allowing fluids and bacteria percolation with subsequent microleakage.[3]

Reduction of polymerization contraction stress can be obtained in several ways. Attempts have been made using incremental layering of the composites during insertion and through use of a low elastic modulus liner between the tooth and the restorative composite.[4] A second alternative is the slow curing technique.[5] Several methods that use a reduced initial light intensity or 'soft start polymerization' have been suggested. These include: Step-curing, ramp-curing[6] and pulse-delay.[7] This initial low intensity polymerization can be achieved by two methods, firstly with specific curing lights[8] and secondly by distancing the light source from the resin composite surface.[9]

Clinicians face many choices regarding curing unit selection and exposure technique. The choices involved with contemporary light sources are quartz-tungsten-halogen units (QTH), short-arc xenon lights (plasma arc curing lights—PAC), argon-ion lasers and blue light-emitting diodes (LED). The central controversy involves the rate at which the composite is cured[10] and the development of stresses arising from this rate.[5]

One method of providing extremely high levels of irradiance is PAC units. Light is emitted from glowing plasma composed of a gaseous mixture of ionized molecules and electrons.[11] Curing by PAC light units occurs very quickly. The light curing can polymerize the resin composite in less time, which is compensated for by the intensity.[12]

In order to determine the effects of polymerization mode on marginal leakage, this *in vitro* study compared the results of soft start polymerization with conventional curing of halogen light and high-intensity PAC light methods in the polymerization of a resin composite in class V restorations.

MATERIALS AND METHODS

Selection of Teeth

The study samples comprised of 60 maxillary premolars, extracted due to orthodontic reasons. The teeth were then scaled, and examined under a magnification of 3× using the surgical loupes (Seiler, East Kirkham Avenue, St Louis, MO). Teeth with caries, cervical wear and cracks were excluded from the study.

Instrumentation Technique

Each tooth received a class V cavity preparation (Fig. 1) located 1 mm above the cementoenamel junction (CEJ), with all the preparation margins in enamel. Standardized box shaped class V cavities with a uniform mesiodistal extension of 4 mm, occlusocervical length of 3 mm and depth of 2 mm were prepared with a tungsten carbide bur # 245 Mani INC, Japan in a high speed handpiece (NSK, Japan) with air/water spray.

All the dimensions were evaluated using a digital sliding caliper (Aerospace, China) and a periodontal probe. The cavosurface walls were finished to a butt joint.

Restorative Procedure

After cavity preparation, the cavity walls were etched with 37% phosphoric acid gel (Total Etch, Ivoclar Vivadent, Liechtenstein) and rinsed with air/water spray for about 15 seconds. This was followed by application and light curing of the bonding agent (Adper Single Bond 2, 3M, ESPE, St Paul, MN). Each preparation was then restored incrementally, with a microhybrid composite resin (Z100, 3M ESPE, Paul, MN). One millimiter thick increments of the composite resin were incrementally placed and individually cured.

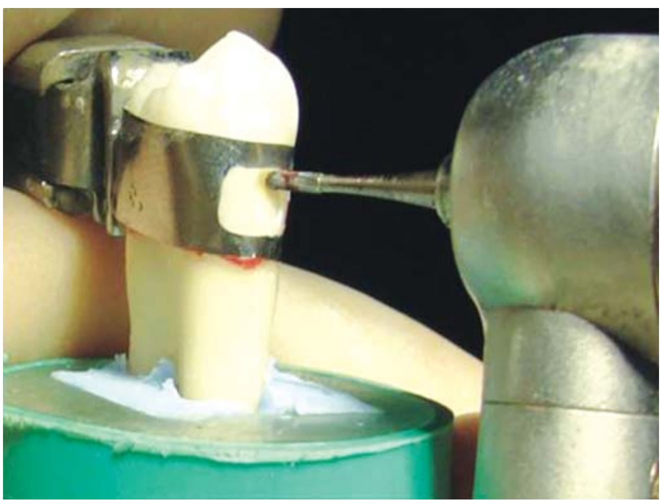

Fig. 1: Preparation of the sample

The teeth were randomly divided into three equal groups (n = 20), according to the light source and curing method used: Group I-QTH light (standard mode-control group), group II-QTH light (soft start mode) and group III-PAC light (high intensity) (Table 1).

Intensity radiometers (Litex, Dentamerica), apart from the inbuilt meters in the curing units, were used to measure the light intensity. All restorations were finished (FG-7612, Gold Finishing Bur, Prima Dental Group, Gloucester, UK), and subsequently polished (Sof-Lex, 3M, ESPE, St Paul, MN).

Microleakage Testing

Samples were subjected to thermocycling for a total of 500 cycles, at 5°C (±1°) and 55°C (±1°), at 15 seconds dwell time at each temperature. The root apices were then sealed with composite resin, and the teeth were coated with two layers of nail varnish, except for a window including the restoration and a 1 mm area around it. Samples were immersed in silver nitrate 50% w/v dye solution for 2 hours, followed by storage in photographic developer solution (Photon, Rahul Photographic Company, India) for 6 hours.

Microscopic Observation

Teeth were sectioned longitudinally in a buccolingual orientation, with a diamond saw (Leco, VC-50, Lakeview Avenue, St. Joseph, Michigan). The sections were examined under stereomicroscope (20×, Leica S4E, Wetzlar, Germany) and photographed to evaluate the degree of dye penetration between the tooth—restorative material interface. The scoring of the dye penetration was done using the image analysis software.

The dye penetration along the tooth—restoration interface was scored by two investigators using a four point scale as 0—no dye penetration, 1—penetration up to half the gingival/incisal wall, 2—penetration along the whole length of the gingival/incisal wall, 3—penetration up to the center of axial wall.

Table 1: Study groups and corresponding lights, with intensities, used in the study

Groups	*Curing light*	*Type of light*	*Mode*	*Intensity*
I	Spectrum 800 (Dentsply)	QTH	Standard (control group)	500 mw/cm^2 for 40 seconds
II	Spectrum 800 (Dentsply)	QTH	Soft start	300-800 mw/cm^2 for 15 seconds, +800 mw/cm^2 for 40 seconds
III	Litex 685 (Dentamerica)	PAC	Standard (high intensity)	2,100 mw/cm^2 for 3 seconds

Mean values for accumulative scores were calculated for each group, and the data was statistically analyzed using Student's t-test.

RESULTS

The results for dye leakage scores in all the groups are shown in Table 2. Group I (QTH-standard mode), group II (QTH-soft start mode) and group III (PAC-standard mode) showed mean dye leakage scores of 1.9, 1.2 and 2.4 respectively (Table 3).

Light curing with QTH light in the soft start mode, showed the least leakage in the composite restoration, which was highly significant when compared with the other groups ($p < 0.01$) (Table 4). Light curing with QTH light in the standard mode, showed moderate microleakage (Fig. 2), which was statistically significant ($p < 0.05$), when compared with the PAC high intensity curing (Table 4). Curing with PAC light in high intensity mode resulted in severe microleakage along the cavity margins (Fig. 3).

DISCUSSION

Polymerization stresses developed at the adhesive interface play an important role on the marginal adaptation of resin composite restorations. The rate at which the polymerization occurs is the main factor related to the tensile forces along the tooth/restoration interface. Cavity configuration (C-factor), plays an important role in the process. The class V cavities prepared in this study, with a C-factor of >3, were associated with high internal contraction stress.

Table 2: Distribution of dye leakage scores in all groups under study

Groups	*Dye leakage scores*			
	0	*1*	*2*	*3*
I	0	6	10	4
II	4	9	6	1
III	0	2	8	10

Table 3: Distribution of mean and SD values of dye leakage scores in all groups under study

Group I (mean)	*Group II (mean)*	*Group III (mean)*
1.90 (0.70)	1.20 (0.81)	2.40 (0.66)

( ): Standard deviation

Table 4: Unpaired Student's t-test values for comparison of mean values of dye leakage score in groups I, II and III

Comparison	*Unpaired Student's t-value*	*p-value*
Group I *vs* II	2.93[a]	<0.01
Group I *vs* III	2.32[b]	<0.05
Group II *vs* III	4.02 [a]	<0.01

[a]Highly significant; [b]Statistically significant

Fig. 2: Group II exhibiting dye leakage

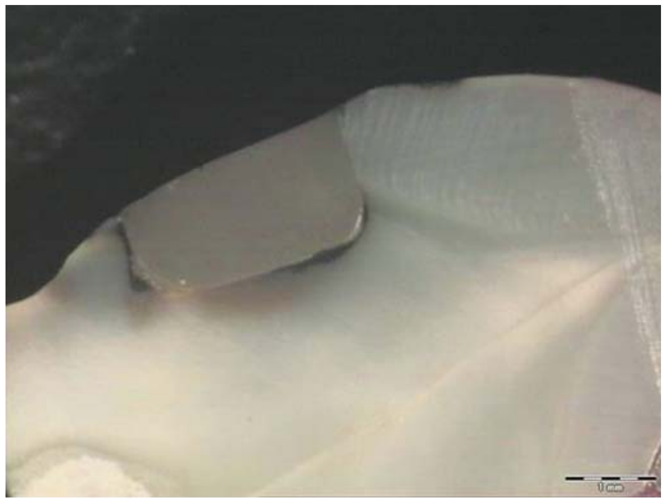

Fig. 3: Group III exhibiting severe dye leakage

The composite material and the bonding agent were standardized in the study to truly evaluate the effects of the variable intensity cycles on polymerization shrinkage. Versluis, Sakaguchi and Douglas[13] examined the contraction stresses of 10 resin composites and found that Z100 exhibited the greatest contraction stress of all the materials tested. This made it a suitable composite for attempts at stress reduction using the different polymerization modes.

Fifth generation bonding systems are good alternatives to total etch three step adhesive systems, and superior to the single step sixth generation adhesive systems, in order to control microleakage.[14] Higher bond strength values have also been confirmed with the wet bonding technique.[15] Hence, the fifth generation bonding agent Adper Single Bond 2 based on the total etch, wet bonding concept was employed in the study.

Recently extracted, intact premolars, for orthodontic reasons, were selected in the study. This ensured that the teeth could be acquired fresh and the age factor, acting as a variable could be avoided. Further, these teeth were caries free, and had no sclerotic dentin, in which the tubules are generally occluded by mineral crystals, and less etchable. Thus, the bond to dentin in such teeth becomes questionable.[16] Hence, use of such virgin dentin was opted in the study.

The above factors, viz the combination of resin composite associated with high polymerization shrinkage and a cavity with a high C-factor, posed a great challenge to the tooth-restorative interface. As all of these factors were standardized in this study, any reduction in polymerization shrinkage could be attributed to the light curing regimen.

Thermally, induced stresses that may lead to gap formation and microleakage at the interface are a result of a mismatch of the coefficients of thermal expansion between the restorative materials and natural tooth structure.[17] The coefficient of thermal expansion of composite (25-60 ppm/°C) is several times larger than that of enamel (11.4 ppm/°C) and dentin (8 ppm/°C).[18] Thermocycling was incorporated in this study with the aim of thermally stressing the adhesive joint at the tooth/restoration interface, by subjecting the restored teeth to extreme temperatures compatible with the temperatures encountered intraorally.

Friedl KH et al[8] investigated the adaptation of class V restorations using the SEM and inferred that the correct diagnosis of gap formations at the resin-tooth interface may get obscured due to marginal swelling of the material, resulting in incorrect observations under SEM, and commented that dye penetration is an important tool in assessing the marginal adaptation. Silver nitrate undergoes a chemical reaction with the reducing substance of the developer solution, and hence does not pose the problem of dissolution and removal, during the sectioning and polishing of samples.[19] It also offers the advantage of attaining information about the internal seal of the restorations and also facilitates the observation of the specimen directly under the microscope.[20]

A great reduction in polymerization shrinkage stress can be achieved by increasing the flow of the composite during the first 10 seconds of the light activation. A low intensity light prolongs the flow time of the composite, decreasing the stress during polymerization[8] however, a high intensity light is necessary for complete polymerization and optimal mechanical properties.

PAC lights have been hailed as time saving devices for dentists. Due to their extremely high irradiance, the manufacturer has recommended 3 seconds irradiation time. But, insufficient cure has been observed with high irradiation and short irradiation time, hence Li Feng and others[21] recommended to at least double the recommended irradiance time, in clinical practice. Hence, a 6 second exposure was selected for the PAC unit.

On comparing the polymerization techniques, the soft start technique presented lower leakage means, whereas the high intensity PAC light exhibited the maximum leakage; this can be explained by considering the chemistry of polymerization.

Role of Curing Characteristics of Resin Composite in Stress Development

The polymerization shrinkage has three didactical phases: The pregel phase, gel point and postgel phase.[12]

During the initial phase of polymerization, the early polymer is still in a flexible and fluid stage. As curing begins, the material flows from unbound surfaces to accommodate for shrinkage. The stress developed from shrinkage can thus be relieved by composite flow, and no stresses are developed at the tooth/resin interface.

The gel point is the phase in which the resin changes from a viscous paste to an elastic solid. At this point, the modulus increases to a stage where the composite can no longer flow. After gelation, flow ceases and cannot compensate for the shrinkage stresses. In this stage, stress is transferred to the tooth. Thus, postgel polymerization results in significant stresses in the surrounding tooth structure and composite-tooth bond.[1]

Although stress relaxation through water absorption is evident in mature composites,[22] this occurs over a long period of time, well after postgel polymerization is complete. Shrinkage-induced enamel microfracture reportedly occurs immediately after polymerization.[23] Hence, the tooth restoration complex is in a prestressed state, even before occlusal stresses result in further coronal deformation.[24]

During the 'soft start polymerization', the intention of the initial irradiation is not to promote a thorough cure of the composite. However, the intensity must have a sufficient penetration capacity so that the initiators of deeper material are activated, leading to a slow but homogenous cure.[1,25] This allows most of the polymerization contraction to occur during the flowable stage of material polymerization, permitting the resin to flow within itself, and preventing it from pulling away from the cavity walls.[26]

The above was clearly reflected in the results of our study where the soft start mode showed distinctive less microleakage, when compared to the standard mode of the curing light.

Several studies in the literature has emphasized the advantages of the slow-start curing over the high intensity curing,[5,9,27,28] using an initial low intensity which was 50, 38, 70 and 45% of the final curing intensity. However contradictory findings have also reported;[8,29,30] these conflicting results may be explained by the differences between the irradiation protocols used. The marginal adaptation of the restoration strongly depends on the initial curing intensity and the relationship between the initial and final curing intensity.[8,9] The studies not confirming the advantages of soft-start irradiation used the initial irradiation features of only 19, 17 or 13% of the final intensity, thereby failing to produce a good marginal quality, resulting in increased microleakage.

In the present study, the application of high intensity with a PAC light showed a statistically significant higher leakage, when compared to the other groups. This might be related to the sudden polymerization shrinkage that follows curing with the PAC light. The application of a high intensity light, over a short period of time, causes the composite resin to quickly reach a rigid state of a high level of modulus of elasticity, with consequent stress concentration at the tooth-restoration interface, resulting in poor marginal adaptation.[31] From the study, it was evident that there were significant differences in the leakage between the soft start and standard curing protocols of QTH light, whereby the high intensity PAC light showed the maximum leakage.

CONCLUSION

Within the limitations of the study, it may be concluded that:

1. The soft start polymerization mode offers a distinctive advantage over the standard curing protocol, in terms of microleakage, for the QTH curing light.
2. The high intensity PAC light resulted in maximum leakage, when compared to the other groups in the study.

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