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Full Length Research Paper

Effects of Er:YAG laser conditioning on the microleakage of class 2 composite restorations

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The purpose of this study was to evaluate the effects of thermocycling and Er:YAG laser conditioning on the microleakage of silorane, packable and nano-filled composites. 512 Class 2 cavities were prepared on 256 premolars. The teeth were assigned to 8 groups 1= Filtek Silorane, 2= Filtek Silorane with laser conditioning, 3= Aelite LS with acid conditioning, 4= Aelite LS with laser and acid conditioning, 5= Aelite LS with laser conditioning, 6= Filtek Supreme XT with acid conditioning, 7= Filtek Supreme XT with laser and acid conditioning, 8= Filtek Supreme XT with laser conditioning. Half of the samples in each group were thermally cycled. All specimens were immersed in basic fuchsine and evaluated with respect to microleakage. The data was analyzed statistically. Thermal cycling and laser conditioning increased microleakage of packable composite, Aelite LS. No effect of them was found in other restoratives. It was concluded that the Er:YAG laser conditioning should be selected according to the restorative material used.

Key words: Er:YAG laser, microleakage, thermal cycling, silorane, composite resin.

INTRODUCTION

Since the introduction of composite resins, research has been directed to improve their mechanical and physical properties in order to have more durable and aesthetic restorations (Leprince et al., 2010). However, there have been still two major drawbacks of them, namely polymerization shrinkage and the related polymerization stress which have been implicated as causative factors for marginal discrepancies in composite restorations (Weinmann et al., 2005; Irie et al., 2002; Loguercio et al., 2004; Sakaguchi et al., 1992). Any marginal discrepancy results in marginal staining, secondary caries and post-operative sensitivity. It is, therefore, the most important reason for the replacement of existing composite restorations (Weinmann et al., 2005).

In an attempt to reduce shrinkage, the main approaches adopted so far are to increase the filler content and to use different types of monomers (Ilie and Hickel, 2006; Choi et al., 2000). Packable composites have an increased filler load and have been introduced to the dental market with the claims of better mechanical properties and decreased polymerization shrinkage (Lopes et al., 2008). Another type of material developed for the same purpose is the nano-filled composite resins with the high filler load and nano-sized fillers, ranging from 5 to 100 nm (Moszner and Klapdohr, 2004). Recently, a new monomer system, silorane which is obtained from the reaction of its chemical building blocks siloxanes and oxiranes, has been developed (Weinmann et al., 2005). The resin suggested to have combined the two key advantages of individual components: low polymerization shrinkage due to the ring-opening oxirane monomer and increased hydrophobicity due to the presence of the siloxane species (Ilie and Hickel, 2009). It has been suggested that silorane composites had good mechanical properties comparable to those of clinically successful methacrylate composite materials due to their reduced polymerization shrinkage (Ilie and Hickel, 2006; Ilie and Jelen, 2007).

In addition to the monomer and filler type or filler load of the restorative materials, the longevity of a composite restoration is also related to the adhesive system.

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Current adhesive systems interact with the enamel/dentine substrate by either removing the smear layer prior to bonding (etch and rinse systems) or by maintaining the smear layer as the substrate and allowing its modification by a low pH primer and adhesive (self-etch systems) (Tay and Pashley, 2002). The self-etch primer systems eliminate the need to rinse in order to reduce the risk of salivary contamination and chair time. It has been found that they reduce the amount of enamel lost during etching (Hosein et al., 2004). It has been also claimed that these systems prevent the risk of defective hybridization due to the simultaneous infiltration of acidic resins into the smear covered dentinee. However, there has been no consensus regarding the superiority of them over the traditional etch and rinse systems (Perdigão and Geraldeli, 2003; Senawongse et al., 2004).

Laser irradiation has been accepted as an alternative method for preparing and conditioning dental hard tissues as it is painless and does not involve vibration or heat (Corona et al., 2003; Keller et al., 1998; Usumez et al., 2002). The erbium: yttrium-aluminium-garnet (Er:YAG) laser is widely used for this purpose because its wavelength (2.94 μm) coincides with the main absorption in hydroxyapatite. Laboratory research and clinical trials have demonstrated the ability of Er:YAG laser to ablate hard dental tissues effectively and safely (Corona et al., 2003). Conditioning of enamel and dentine with laser has been shown to produce surfaces similar to acid-etched surfaces (Visuri et al., 1996). It was also suggested that Er:YAG laser alone or combined with acid etching, produces a surface with a bond strength equal to or better than that produced by acid etching alone (Visuri et al., 1996; Moritz et al., 1996). One of the concerns regarding the laser application has been related to the elimination of microleakage due to the surface alterations created by laser irradiation (Aranha et al., 2005).

In laboratory settings, in order to simulate the conditions of the oral cavity, thermocycling has been the widely used method. The aim is to subject the restoration and tooth to temperature limits similar to those experienced in the oral cavity, which can generate stresses due to differences between thermal expansion of restorative materials and the tooth and the restorative material (Helvatjoglu-Antoniades et al., 2004). It has been suggested that thermocycling stresses the bond between resin and the tooth, and it may affect bond strength, depending on the adhesive system (Miyazaki et al., 1998).

Although there have been numerous studies on microleakage of restorations prepared with laser instead of bur, there has been limited number of studies concerned on the effect of laser conditioning. Of those studies, majority of them focused on enamel conditioning prior to placement of the pit and fissure sealant materials (Moshonov et al., 2005; Borsatto et al., 2004). To the best of our knowledge, there has been no study evaluated the effect of laser conditioning and thermal cycling on different composite restoratives, namely silorane, packable and nano-filled composites. Therefore, the purpose of this in vitro study was to evaluate the effects of both thermocycling and Er:YAG laser conditioning on the microleakage of Class 2 slot cavities restored with the silorane, packable and nano-filled composites.

MATERIALS AND METHODS

256 extracted human premolars without any caries or visible defect were used. The teeth were cleaned and polished with pumice and rubber cups. Standardized Class 2 slot cavities were prepared on both proximal sides with the gingival margin extending 1 mm apical to the cemento-enamel junction using a water-cooled high-speed handpiece and a diamond fissure bur (# 1090, Diatech Dental, Heerbrugg, Switzerland). A new bur was used after every five preparations. The cavities were 3.0 mm wide bucco-lingually, with pulpal floor depth of 2 mm and axial depth of 1.5 mm. One investigator performed all the cavity preparations, while another examined the specimens to ensure that the cavities conformed to the dimensions by using a periodontal probe. The teeth were randomly assigned to 8 main groups with a total of 16 subgroups (n=16/subgroup). All materials were used in accordance with the manufacturers' instructions. Manufacturers and types of the materials utilized in the study are presented in Table 1.The detailed procedures in all groups are as follows:

Group 1 (Filtek Silorane primer + Filtek Silorane adhesive + Filtek Silorane composite)

1a: without thermocycling
1b: with thermocycling

Group 2 (Er:YAG laser conditioning + Filtek Silorane primer + Filtek Silorane adhesive + Filtek Silorane composite)

2a: without thermocycling
2b: with thermocycling

Group 3 (Phosphoric acid etching + One-Step Plus + Aelite LS packable composite)

3a: without thermocycling
3b: with thermocycling

Group 4 (Er:YAG laser conditioning + phosphoric acid etching + One-Step Plus + Aelite LS packable composite)

4a: without thermocycling
4b: with thermocycling

Group 5 (Er:YAG laser conditioning + One-Step Plus + Aelite LS packable composite)

5a: without thermocycling
5b: with thermocycling

Group 6 (Phosphoric acid etching + Adper Single Bond 2 + Filtek Supreme XT nano-filled composite)

6a: without thermocycling
6b: with thermocycling

Group 7 (Er:YAG laser conditioning + phosphoric acid etching+ Adper Single Bond 2 + Filtek Supreme XT nano-filled composite)

7a: without thermocycling
7b: with thermocycling

Table 1. Manufacturers and types of the materials utilized in the study.

Product name	Classification	Composition	Manufacturer
Silorane System Adhesive	Two-bottle self-etch system	Primer: Phosphorylated methacrylates, Vitrebond copolymer, Bis-GMA, HEMA, water, ethanol, silane-treated silica filler, initiators, stabilizers Adhesive: Hydrophobic dimethacrylate, phosphorylated methacrylates, TEGDMA, silane-treated silica filler, initiators, stabilizers	3M ESPE, St. Paul, MN, USA
Filtek Silorane	Posterior composite	Silorane resin,camphorquinone, iodonium salt, electron donor, quartz filler, yttrium fluoride, stabilizers, pigments	3M ESPE, St. Paul, MN, USA
One-Step Plus	Etch and rinse adhesive	Bis-GMA, BPDM, HEMA, co-initiator, acetone, glass fillers	BISCO, chaumburg, IL, USA
ÆLITE LS Packable	Hybrid composite	Bis-EMA, Bis-GMA, TEGDMA, Glass frit, amorphous silica	BISCO, Schaumburg, IL, USA
Adper Single Bond 2	Etch and rinse adhesive	Bis-GMA, HEMA, dimethacrylates, polyalkenoic acid copolymer, initiators, water, ethanol and silica nanofiller	3M ESPE, St. Paul, MN, USA
Filtek Supreme XT	Nano-filled (nano-hybrid) composite	Bis-GMA, Bis-EMA, urethane dimethacrylate, triethylene glycol dimethacrylate, silica nanofiller, zirconia/silica nanocluster	3M ESPE, St. Paul, MN, USA

Group 8 (**Er:YAG laser conditioning + Adper Single Bond 2 + Filtek Supreme XT nano-filled composite)**

8a: without thermocycling
8b: with thermocycling

Er:YAG laser (KAVO KEY Laser KAVO AMERICA - LAKE ZURICH) was used with an output energy of 300 mj, 2 Hz for enamel and 250 mj, 2 Hz for dentine in accordance with the manufacturer's instructions. For phosphoric acid etching each manufacturer's respective etchant was used. For One-Step Plus bonding system, 37% phosphoric acid gel (ETCH-37, Bisco) and for Adper Single Bond 2 bonding system, 35% phosphoric gel (Scotchbond Etching Gel, 3M ESPE). The surfaces were etched 30 s for enamel and 15 s for dentine, rinsed and gently air-dried. A stainless steel matrix (Tofflemire, Teledyne Water Pik, Fort Collins, CO, USA) was adapted to the prepared tooth before incremental insertion and light curing of the restorative material. Composites were incrementally placed with a thickness of approximately 2 mm. Each increment was light cured for 40 s with a LED light curing unit (Elipar FreeLight, 3M ESPE, St. Paul MN, USA).

Immediately after filling, restorations were finished with fine diamond burs and polished with a series of sandpaper disks (Sof-Lex, 3M ESPE, St Paul, MN, USA). The restorations belonging to subgroups a were stored in distilled water for 48 h at 37°C while the others belonging to subgroups b were subjected to thermoycling in tap water 2500 times between 5 and 55°C with a dwell time of 25 s in each bath and a transfer time of 10 s. The root apices of the teeth were subsequently sealed with a composite resin (TPH Spectrum, Dentsply deTrey, Konstanz, Germany). The teeth were coated with two layers of nail varnish leaving 1 mm around the cavity margins. Then, all specimens were immersed in 0.5% basic fuchsine dye for 24 h at 37°C. They were subsequently rinsed under running water to remove the dye and were bisected longitudinally in a mesiodistal direction using a water-cooled, low-speed diamond saw (Isomet, Buehler, Lake Bluff, IL, USA). Sections were observed under a stereomicroscope at 40x magnification (Leica MS5, Singapore) by one examiner in a blind manner (Figure 1). Gingival microleakage values were recorded based on a standard ranking (Sadeghi, 2007):

0. No dye penetration.
1. Dye penetration that extended up to 1/3 of the preparation depth.
2. Dye penetration greater than 1/3, up to 2/3 of the preparation depth.
3. Dye penetration extending to the axial wall.
4. Dye penetration past the axial wall.

The obtained data was analyzed using Kruskal-Wallis test. Pair-wise comparisons were performed by Dunn Test with Bonferroni correction ($p<0.0001$).

RESULTS

Table 2 shows the mean microleakage and Table 3 shows the microleakage scores of the groups. There were significant differences among groups ($p=0.000$). The lowest mean microleakage score was in Group 1b, whereas the highest mean microleakage score was in Group 5b.

Without thermal cycling and laser conditioning, there was no statistically significant difference among the three adhesive and restorative materials used (Groups 1a, 3a and 6a), ($p>0.0001$). With thermal cycling, it was found that thermal cycling did not affect the silorane (Group 1a and 1b) and the nano-filled composite resin (Groups 6a and 6b). However, thermal cycling negatively affected the packable composite resin (Groups 3a-3b and Groups 4a-4b). With thermal cycling, the microleakage values of the silorane composite (Group 1b) were significantly less

Figure 1. The stereomicroscopic photograph of a specimen showing dye penetration past axial walls.

than the other restorative systems (Groups 3b, 6b), (p<0.0001).

Laser conditioning instead of acid etching, significantly increased microleakage values of groups restored with the packable composite (Groups 3a and 5a). The combined use of laser and acid conditioning, compared to laser conditioning alone, significantly decreased microleakage values of groups restored with the packable composite (Groups 4a and 5a), (p<0.0001). No effect of laser and/or acid conditioning in other groups was found (p>0.0001).

DISCUSSION

Several restorative materials have been introduced to optimize the bonding to tooth structure (Chinelatti et al., 2004). Nevertheless, microleakage especially at the gingival margins of composite restorations remains a problem of clinical significance (Aranha et al., 2005). In the present study, in addition to the aim of investigating the effect of laser conditioning, the influence of thermocycling on the gingival microleakage has been evaluated as well. For this purpose, a high number of thermocycling has been included. The results of this study demonstrated that without thermocycling and laser conditioning, there was no difference in gingival micro leakage among the three different restorative materials used. However, with the involvement of thermocyclus, there was less microleakage in the silorane group compared to both packable and nano-filled composite resins. The effect of thermocycling is related with the differences in the linear coefficient of thermal expansion between the tooth and restorative materials (Helvatjoglu-Antoniades et al., 2004). Therefore, during thermocycling mechanical stresses generated by differences in the coefficient of thermal expansion can result in bond failure at the tooth-restorative interface (Crim and Garcia-Godoy, 1987). In addition, due to changing gap dimensions, microleakage occurs via gaps between the restoration and the tooth (Hanning and Friedrichts, 2001; Belli et al., 2001). With thermocycling, the less microleakage values obtained with silorane composite can be attributed to the inherent ring opening polymerization of the silorane monomers which can compensate the volume reduction as the molecules come closer to each other compared to the radical polymerization of the other composites. The lower polymerization shrinkage and related polymerization stress of the silorane composite than methacrylate based composites might have an effect on tolerating the thermally induced stress (Weinmann et al., 2005).

In the past decade, nano-filled composites have been produced with nanofiller technology and formulated with nanomer and nanocluster filler particles (Korkmaz and Attar, 2007). Nanomers are discrete nanoagglomerated particles, and nanoclusters are loosely bound agglomerates of nano-sized particles. The manufacturer suggests that the combination of nanomer-sized particles and nanocluster formulations reduces the interstitial spacing of the filler particles, providing increased filler loading, decreased polymerization shrinkage and improved retention of a polished surface (Moszner and Klapdohr, 2004; Korkmaz and Attar, 2007). However, the results of this study demonstrated no difference between nano-filled and packable composites, with thermocyclus. This result again implies the importance of changing the type of monomer instead of filler type or load.

One of the concerns on the laser irradiation has been whether the surface alterations created by irradiation would result in more or less microleakage compared to conventional procedures (Aranha et al., 2005). In posterior restorations, microleakage occurs more in gingival margins due to the absence of enamel, relatively low number of dentineal tubules and the mainly organic nature of the dentinee (Cagidiaco et al., 1997). If enamel is present at the cervical margin, it is usually thin, aprismatic, and bonds less well to resins (Ceballos et al., 2001). There has been limited research regarding the efficacy of laser conditioning on the gingival margin (Visuri et al., 1996; Ceballos et al., 2001). Ceballos et al. (2001) found no difference in the laser and/or acid conditioned gingival margins of the Class 5 composite restorations. The authors recommended laser conditioning as it presented a surface with micro irregularities without

Table 2. Mean gingival microleakage and standard deviations of the groups.

Group	Mean ± Standard deviation
1**a** Silorane primer+ Silorane adhesive + Silorane	$0.875 \pm 1.65^{h,i,j,l}$
1b Silorane primer+ Silorane adhesive + Silorane **+** TS	$0.075 \pm 0.47^{b,h,i,j,l}$
2a Laser + Silorane Adhesive + Silorane	$0.300 \pm 1.06^{h,i,j,l}$
2b Laser + Silorane Adhesive + Silorane **+** TS	$0.225 \pm 0.89^{h,i,j,l}$
3a Acid + One-Step Plus + Aelite LS Packable	1.400 ± 1.93^{g}
3b Acid + One-Step Plus + Aelite LS Packable + TS	$2.900 \pm 1.80^{a,c,d,e,f,g,h}$
4a Laser + Phosphoric Acid + One-Step Plus + Aelite LS Packable	$0.900 \pm 1.69^{h,i,j,k}$
4b Laser + Phosphoric Acid + One-Step Plus + Aelite LS Packable + TS	$2.971 \pm 1.77^{c,d,e,f,g,k,l}$
5a Laser + One-Step Plus + Aelite LS Packable	$2.825 \pm 1.78^{a,c,e,f,g,i}$
5b Laser + One-Step Plus + Aelite LS Packable + TS	$3.300 \pm 1.53^{a,b,c,d,e,f,g,j}$
6a Acid+ Adper Single Bond 2 + Filtek Supreme XT	1.114 ± 1.74^{a}
6b Acid+ Adper Single Bond 2 + Filtek Supreme XT + TS	$1.600 \pm 1.98^{a,b}$
7a Laser + Acid + Adper Single Bond 2 +Filtek Supreme XT	0.400 ± 1.21^{e}
7b Laser + Acid + Adper Single Bond 2 +Filtek Supreme XT **+** TS	0.648 ± 1.49^{f}
8a Laser + Adper Single Bond 2 + Filtek Supreme XT	0.200 ± 0.83^{c}
8b Laser + Adper Single Bond 2 + Filtek Supreme XT **+** TS	1.457 ± 1.83^{d}
Total	1.321 ± 1.86

* Laser= Er: YAG laser conditioning, Acid= Phosphoric acid etching, TS= Thermal cycling. ** same superscript letters show statistically significant differences between groups

Table 3. Gingival microleakage scores of the groups.

Group	0	1	2	3	4
1a	27	0	0	1	4
1b	31	0	0	1	0
2a	30	0	0	0	2
2b	29	1	0	0	2
3a	20	0	0	0	12
3b	8	0	0	0	24
4a	25	0	0	0	7
4b	9	0	0	0	23
5a	9	0	0	2	21
5b	5	0	0	0	27
6a	22	1	0	2	7
6b	19	0	0	0	13
7a	30	0	0	0	2
7b	27	0	0	0	5
8a	30	0	0	1	1
8b	20	0	0	4	8

a smeared layer that appeared to be advantageous for bonding of the composite restorations to dentinee. In addition, they observed no demineralization of peritubular and intertubular dentinee and no exposed collagen matrix which are necessary for the optimal bonding to dentinee. Visuri et al. (1996) reported higher shear bond strength of composite when it was bonded to Er:YAG laser prepared dentine than to acid etched dentine. The authors also pointed out the importance of non-demineralized peritubular dentine after laser irradiation. The other advantage of laser irradiation on dentinee is the opened dentineal tubules with no widening. The funnel shaped occurred after etching may contribute with polymerization shrinkage to pull the tags away from the walls (Marshall et al., 1997). In accordance with these studies, the results of this study demonstrated that laser conditioning can be an alternative to acid etching when the silorane and nano-filled composites were used. However, laser conditioning increased the microleakage of the packable composite used. Therefore, adequacy of laser conditioning should also be considered depending on the restorative material used. Although this concern has not been widely emphasized in the literature, the importance of material selection in laser applications was also suggested by Aranha et al. (2005). Increased microleakage with packable composites in cavities prepared with laser irradiation was also reported by Corona et al. (2003). The increased microleakage of the packable composite in this study may be related to the increased filler content and a consequent reduction in viscosity of the resin composite, which result in an inadequate adaptation to the tooth. In addition, the packable composites have insufficient matrix available for wetting the cavity wall leading to formation of voids and subsequent microleakage (Radhika et al., 2010; Fan, 1984; Estafan et al., 2000). Radhika et al. (2010) reported increased cervical microleakage of a packable composite compared to a microhybrid and recommended to use flowable composites as the first increment in Class 2 restorations.

The most important advantage of laser etching is decreased susceptibility to acid attacks and reduced secondary caries risk of the lased surface compared to the demineralized surface by conventional acid etching. This mechanism is due to the reduced carbonate-to-phosphate ratio, water and organic components but increased calcium-to-phosphorus ratio as well as mineralization of the ions trapped in the microspaces (Usumez et al., 2002; Oho and Morioka, 1990; Fowler and Kuroda, 1986). These effects are of prior importance in children liable to dental caries because of the complex anatomical structure and incomplete enamel maturation of the erupting teeth (Driessens et al., 1985; Carvalho et al., 1989). The other advantage of laser is the elimination of the isolation of the tooth during laser etching which can significantly aid dentist in moisture control in children who do not accept rubber dam application (Moshonov et al., 2005; Waggoner and Siegal, 1996). Also, the necessity to wash the acid is eliminated which may disrupt children because of its bad taste. However, further research is needed to investigate the compatibility of laser conditioning on both enamel and dentinee with the recently developed adhesive and restorative materials.

Conclusions

Within the limitations of the current research it can be concluded that:

1 Laser conditioning offers no advantage over acid etching and is considerably less expensive to the patient and dentist with respect to instrument cost.
2 Thermocycling has a negative effect on the packable resin composite.

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