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Parameter-Dependence of Marginal Microleakage in Er:YAG Laser Ablated and Modified Dental Preparations

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ABSTRACT

Previous studies have shown that the status of the residual tooth surface after hard dental tissue ablation using laser irradiation may vary depending on the parameter combinations and cooling mechanisms used. The purpose of this investigation was to assess the effects of Er:YAG laser cavity preparation at different fluences on microleakage of glass ionomer and composite resin restorations. In freshly extracted clinically and radiographically healthy human anterior teeth, standardized Class V cavities were prepared using the dental drill or the Er:YAG laser (Quantronix 294). Fluences of 10-40J/cm² were used at a p.r.r. of 1 Hz and pulse durations of 250us under an air/water coolant spray. 33 teeth were included in each subgroup; 3 teeth were used for light microscopy and SEM; 15 underwent conventional restoration with glass ionomer and 15 with composite resin. After immersion in 5% methylene blue, dye penetration was measured linearly in 5 standardized locations on each of the bisected samples. Using the Pearson correlation coefficients, microleakage correlated strongly with laser fluence for glass ionomer (p=0.0238) and for composite resin (p=0.0099) restorations. Results differed significantly between the 2 restoration types (p<0.05). In conclusion, the parameters used during laser ablation of dental tissues must be carefully controlled to optimize clinical outcome.

Keywords: Er:YAG laser, microleakage, composite resin, glass ionomer cement, interface

1. INTRODUCTION

A wide range of lasers have been investigated for their ability to ablate healthy and carious hard dental tissues. The Er:YAG laser emits at a wavelength of 2.94μm, which matches the resonance frequency of the vibrational oscillations of water molecules contained in the teeth. Thereby, the absorption of the Er:YAG irradiation is strongly enhanced, resulting in high efficiency. The sudden vaporisation of water molecules is associated with a pressure gradient. Small microexplosions are responsible for the breakup of the hydroxyapatite structure. This process has also been associated with pressure-induced microcrack formation in dental hard tissues. Such fissures could compromise the effectiveness of restorative measures and facilitate the development of new decay.

Laser-induced alterations in the tooth surface may have beneficial or deleterious clinical effects. These may, for example, include melting, cratering, charring or cracking and chemical changes in surface composition to enhance or hinder bonding and retention of restorative materials to the irradiated surfaces. The capability for complete caries removal and speed of cavity preparation must also be evaluated.

Several researchers have investigated the use of lasers for intentional modification of tooth surfaces to improve the tooth surface-to-restoration interface. In these studies, lasers were usually used solely for surface treatment after conventional cavity preparation. Most of these investigations were performed using fairly long-pulsed or continuous wave (Cw) Nd:YAG or CO2 lasers, which would tend to induce significant temperature increases during irradiation, giving rise to concerns about pulpal tolerance of such procedures. The results obtained in these studies varied enormously, ranging from laser-enhanced bonding of dentine with composite resins, to marginal microleakage attributed to the effects of laser irradiation. Microleakage can cause retentive failure in filling materials, permit seepage of foreign agents leading to secondary decay or pulpal pathology, and contribute to tooth sensitivity. This wide range of results demonstrates that further investigation and quantification of the issues involved is necessary prior to clinical application of lasers to restorative procedures.

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The purpose of this investigation was two-fold:

1) to assess the effects of Er:YAG laser preparation at various fluences on microleakage in glass ionomer cement (GIC) restorations and
2) to assess the effects of Er:YAG laser preparation at various fluences on microleakage in composite resin restorations.

2. MATERIALS AND METHODS

2.1. Sample Preparation

30 extracted permanent human teeth with no clinical and radiographical evidence of decay and with cervical lesions measuring approximately 1-2 mm (h) x 2-4 mm (w) x 1-2 mm (d) were subdivided into 3 groups of 10. In the first subgroup, 5 conventional cavities were prepared for GIC restorations, and 5 for composite resin restorations at a fluence of 10 J/cm². In the second and third subgroups, laser treatment occurred at a fluence of 25 J/cm² and 40 J/cm² respectively.

2.2. Restoration with Glass Ionomer Cement

All the cavity surfaces were cleansed with KETAC (Espe-Premier, Norristown, PA 19404) dentin conditioners for 10 seconds, rinsed with water for 30 seconds, and air-dried for 10 seconds. The KETAC-FIL was prepared, applied, exposed and glazed according to manufacturer’s instructions. Sof-Lex Pop-On polishing discs beginning from the coarse disc (#1982M), progressing to the medium disc (#1982F) and to the fine disc (#1982) were used for trimming and polishing.

2.3. Restoration with Composite Resin

After cavity preparation, surfaces were rinsed with water. The samples were then air-dried for 10 seconds. Prisma VLC DYCAL base/liner was applied and polymerized according to manufacturer’s instructions. The enamel was acid conditioned with a caulk conditioner gel (37% phosphoric acid) for 60 seconds, rinsed with water for 15 seconds and Probond primer applied. Probond Adhesive was applied, cured for 20 seconds and the cavity was filled incrementally with Prisma AP.H VLC Hybrid Composite (Dentsply International Inc., Milford, DE 19963-0359). Using coarse (#1982M), medium (#1982F), and fine (#1982) Sof-Lex Pop-On polishing discs, restorations were trimmed and polished.

2.4. Laser Device

Irradiation was performed using a flashlamp-pumped Er:YAG laser (Quantronix 294). The duration of the total laser pulse was approximately 250μs. Within this time, a pulse train of single spikes of approximately 1μs (FWHM) each was emitted. The laser light was focused perpendicularly onto the specimens by means of a quartz biconvex lens.

2.5. Dye Penetration

The restored specimens were immersed in a 5% methylene blue dye for 24 hours as described by Kaplan et al. 38, then sectioned longitudinally at 1/3 and 2/3 of the width of the prepared cavity. This provided a total of four surfaces for evaluation per tooth 39. Dye penetration was measured linearly, to its furthest extent using an Olympus light microscope (Olympus Optical Co., Ltd., Japan). It was scored according to a numerical system described by Hegarty et al. 39.
(0) No dye penetration
(1) Dye penetration up to the enamel/dentin junction
(2) Dye penetration up to one half of the depth of the cavity
(3) Dye penetration along the whole depth of the cavity
(4) Dye penetration along the whole depth of the cavity and along the base of the restoration
(5) Dye penetration along the whole depth of the cavity and along the base and into the dentin covering the pulp.

The four measurements made for each tooth were averaged to obtain one final score for each tooth.

3. RESULTS

3.1. Microleakage measurements

Microleakage measurements are depicted in Figure 1.

In the teeth filled with Glass Ionomer Cement, using the Pearson Correlation Coefficient, increased fluence correlated with increased microleakage (p=0.0238); in the teeth filled with composite resin, a stronger correlation was observed (p=0.0099).

4. DISCUSSION

Throughout this investigation, care was taken to avoid dehydration of tooth samples in order to duplicate intra-oral conditions as accurately as possible. For each of the groupings established, specimens were used with carious lesions of approximately the same size and localization. These measures were instituted as such factors significantly affect the results of bonding studies.

In this investigation, removal of carious and especially of healthy enamel was slow; this is attributed to the lower water content and greater strength of enamel as compared to dentin. Speed of carious dentin removal was reasonably quick, and could be comparable to that achieved by conventional methods.

Glass Ionomer restorations were occasionally discoloured by the methylene blue dye, even in the absence of leakage at the tooth-restoration interface. This could have resulted from penetration of the dye into the restorative material, which appeared microscopically less homogeneous than the composite resin. Although some microleakage occurred with both materials, composite restorations recorded more specimens with deeper dye penetration than did the Glass Ionomer restorations, suggesting that the dentinal tubules were better sealed at the tooth-restoration interface by the Glass Ionomer product. This is in agreement with the findings of Kaplan et al, who observed less microleakage in non-retentive cavities using Glass Ionomer cement than composite resin. Interestingly, they also reported a superior bond in retentive cavities using composite resin than Glass Ionomer Cement, attributing this apparent contradiction to different handling and retention/bonding mechanisms and properties.

Glass Ionomer Cement, after physically wetting the dentine surface, bonds chemically to the surface. The cavity’s surface morphology, which is affected by laser irradiation, will also be a factor in determining the GIC’s bonding capability. Composite resins bond mechanically by flowing into microroughnesses on the tooth surface. Thus, the determination made in these investigations that marginal microleakage after laser preparation is affected to a greater extent when using composites than when using Glass Ionomer Cements may indicate that laser-induced surface morphological changes are probably the main mechanism contributing to this effect.

In conclusion, these preliminary studies demonstrate the importance of identifying the effects of various laser parameters on the ensuing tooth-to-retoration interface.

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| FLUENCE | COMPOSITE RESIN | GLASS Ionomer CEMENT |
|---------|----------------|---------------------|
|         | ML. Scores: 0, 1, 2, 3, 4, 5 TOT. | ML. Scores: 0, 1, 2, 3, 4, 5 TOT. |
| 10 J/cm² | No of teeth: 4 1 0 0 0 0 1 | No of teeth: 5 0 0 0 0 0 0 |
| 25 J/cm² | No of teeth: 3 1 0 1 0 0 4 | No of teeth: 4 0 1 0 0 0 2 |
| 40 J/cm² | No of teeth: 2 2 1 1 0 0 7 | No of teeth: 2 2 1 1 0 0 4 |

Fig. 1

Depicted are the number of teeth which scored each of the possible numerical dye penetration scores according to the following scheme:

(0) No dye penetration
(1) Dye penetration up to the enamel/dentin junction
(2) Dye penetration up to one half of the depth of the cavity
(3) Dye penetration along the whole depth of the cavity
(4) Dye penetration along the whole depth of the cavity and along the base of the restoration
(5) Dye penetration along the whole depth of the cavity and along the base and into the dentin covering the pulp.

Four standardised measurements were made and averaged to obtain one final score for each tooth.