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Effects of Nd: YAG Laser Irradiation on the Adaptation of Composite Resins to Root Dentin

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Abstract

One of the most important goals of the restoration of endodontically treated teeth with a composite resin post system is to achieve good adaptation of the composite material to dentin walls to prevent microleakage apically and coronally. In post core systems, to avoid microleakage between the dentin wall and resin material, laser irradiation may seem to be an alternative therapy for increasing adaptation quality.

The aim of this study was to investigate the adaptation of a packable composite resin to lased root canal dentin when it was used as post material.

Forty-five freshly extracted human teeth were selected and post spaces were prepared. The teeth were divided into three groups. In group 1 the dentin of the post spaces were etched with 35% phosphoric acid, in group 2 the dentin surfaces were irradiated with an Nd: YAG laser, and in group 3 the dentin surfaces were initially treated with the laser and then etched. The teeth of all groups were obturated with a bonding agent and composite. The groups were divided into two subgroups: a group for the scanning electron microscope (SEM) study and a group for the microleakage study.

The lased group showed poor adaptation and more microleakage was detected ($p<0.05$; variance analysis). The laser beam and acid-etching showed no advantage compared to the acid-etching alone ($p>0.05$).

The Nd: YAG laser irradiation adversely affects adhesion to dentin for using composite resin as a post material and does not constitute an alternative to acid-etching.

Keywords: Acid etching, Nd: YAG laser, SEM, resin composite

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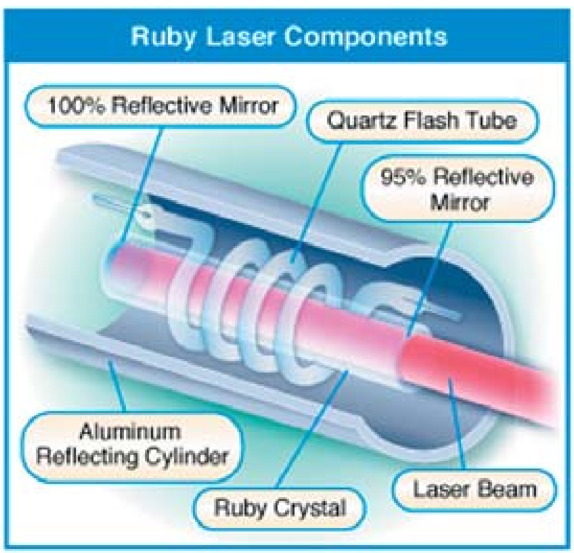
Introduction

Ever since Maiman developed ruby lasers in 1960, they have been used experimentally and clinically in dentistry.[1] By varying a number of parameters (pulse mode, irradiation time, frequency, and energy outputs), several types of lasers have been suggested for oral soft tissue procedures, curing light activated materials, and treating or cutting dental substrate.[2] Such devices include the CO_2 laser, excimer laser, and the Nd:YAG laser.

Stern and Sognnaes[3] and Goldman et al.[4] began their studies on hard dental tissues by investigating the use of a ruby laser to reduce subsurface demineralization. A reduction in permeability to acid demineralization of enamel after laser irradiation was found.[1]



Er-YAG lasers emit a wavelength of 2.94 μm which coincides with the major absorption of water. This emitted energy is well-absorbed by hydroxyapatite and has been shown to remove dental hard tissues more effectively than other laser systems.[5]

Several characteristics of lased dentinal tissue have previously been considered advantageous for resin bonding. These include the formation of a microscopically rough substrate surface without demineralization, open dentinal tubules without smear layer production, and dentin surface sterilization.[6, 7, 8] Er-YAG laser irradiation of dentin before composite filling provided shear bond strength results that were better than those achieved with acid-etching. It is suggested laser treatment might be replaced with acid etching as a pre-treatment procedure for dentin bonding.[7]

Recently, it has been demonstrated light-cured resin composites can be used as filling materials instead of gutta-percha.[9] In 1987 Lui[10] introduced a reinforcement technique involving the reconstitution of lost intraradicular dentin in conjunction with the creation of a size-matched canal post of a predetermined length to support a functional post-core. This technique involves the acid etching of the internal radicular dentin in combination with adhesive bonding and lining of the thin canal walls with resin composite. A new canal post was also reconstructed with the bonded resin composite. This technique re-established the continued serviceability of badly damaged non-vital teeth, which were previously deemed unrestorable and, consequently, destined for extraction.[11]

Newly developed condensable or packable composites were introduced as an alternative to amalgam. These resins have annual wear rates equal or superior to those of amalgam.[12, 13] The initial polymerization shrinkage of these composites is reported to be reduced. Their coefficient of thermal expansion is reported to be reduced and close to that of amalgam. There are also improvements in their handling properties, which should improve marginal adaptability. These composites are not sticky due to a modification of the filler particles by the manufacturer, and they do not slump; their high viscosity allows packing.[14] Some studies have suggested composite resins can be used as a post instead of a metal dowel in root canals.[15, 16]

Several characteristics of the lased dentinal tissue have previously been considered to be advantageous for resin bonding. They include the formation of a microscopically rough substrate surface without demineralization, open dentinal tubules without smear layer production, and dentin surface sterilization.[6, 7, 8] In post core systems, to avoid microleakage between the dentin wall and resin material laser irradiation may seem to be an alternative therapy for increasing adaptation quality.

The aim of this study was to investigate the adaptation of a packable composite resin to lased root canal dentin when it was used as post material.

Materials and Methods

Forty-five freshly extracted human single-root teeth with mature apices were selected for the study. After surface debridement with a hand scaling instrument, the teeth were stored in saline solution until used. Their crowns were removed with a cut at the enamel-cement junction using a low speed diamond saw. The working length was established as 1 mm less than the apical foramen with a #15 K-file (Antaeos, München, Germany). Each canal was prepared with a #40 file at working length and was irrigated with frequent utilization of 2.5 ml of 5.25% sodium hypochlorite solution. After instrumentation, the canals were irrigated with 2 ml of distilled water and dried with paper points (Diadent, Korea). The root canals were then filled with gutta-percha (Dendia-Werk, Austria) and AH26 (Dentsply, Germany) using the lateral condensation technique. Coronal gutta-percha was removed using the mechanical technique for post space preparation. In order to obtain a good apical seal 15 mm of gutta-percha was left in the apical portion of the canal. Post spaces were prepared with a #6 parapost drill (Whaledent, NY, USA). This drill has a diameter of 1.75 mm.

Forty teeth were randomly divided into three groups. In group 1 the dentin of the post spaces were etched with 35% phosphoric acid gel (Scotchbond, 3M Dental Products, USA) for 15 seconds, rinsed with water for 20 seconds, and dried. In group 2 the dentin of the post spaces were irradiated using a 320 μm Nd: YAG laser fiber (Settings: 2 W, 20 ppS, for 40s). During this time, the optical fiber was used in a back-and-forth motion spirally to make contact with all of the internal root canal surfaces. In group 3 the dentin surfaces were initially treated with the laser and then etched as in group 1 with 35% phosphoric acid. This was followed by the application of the dentin bonding agent (Gluma, Heraus Kulzer, Germany) on the root canal dentin and light cured for 20 seconds. Then packable resin composite (Solitaire, Heraus Kulzer, Germany) was inserted and hand condensed into the post spaces using an incremental placement technique. Each increment was approximately 2 mm thick and was light cured (Hilux Dental Curing Light, Benlioglu, Turkey) for 40 seconds. This procedure was repeated until the post spaces were filled with composite resin to a depth of 5 mm. Then the apical portions of the teeth were removed at the level of gutta-percha/composite combination (Figure 1). The specimens were subjected to a thermocycling regimen of 500 cycles with water baths between 5°C and 55°C.

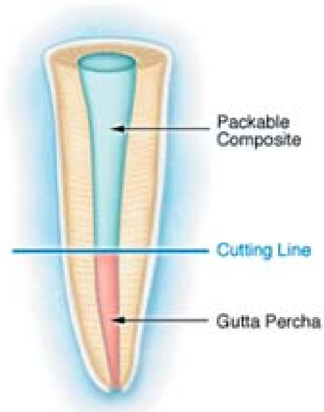


Figure 1. Removing the apical portion from gutta-percha and resin combination aspect.

Each of the three groups were divided into two subgroups. Ten teeth from each group were chosen randomly and prepared for the microleakage investigation and five teeth for the scanning electron microscope (SEM) evaluation (Jeol JSM-840 a Scanning Microscope, JEOL, Tokyo, Japan). The samples were observed carefully at the composite-dentin interfaces and photographs were taken.

The specimens, which were prepared for the microleakage test, were coated with nail polish, excluding 2 mm of the apical tip of the root. The teeth were then immersed in 0.5 % basic fuchsine for 24 hours and rinsed.

For the negative control group, the post spaces of two teeth were filled with composite resin and nail polish was applied to all of the surfaces. For the positive control group, the post spaces of two teeth were left empty. They were immersed in basic fuchsine for 24 hours. Then each tooth was subsequently sectioned longitudinally.
The dye penetrations were measured under a stereomicroscope (Olympus SZ 4045, Tokyo,

Table 1. The microleakage evaluation scale of Kytridou et al.[17]

Depth of Penetration	Score
No leakage	0
0 -1 mm	1
1 - 2 mm	2
2 - 4 mm	3
More than 4 mm	4

Japan) at x6 magnification, and the scores were recorded according to the microleakage criterion of Kytridou et al.[17] (Table 1). A statistical analysis of the data was made by using the Analysis of Variance and Scheffe Test.

Results

According to the results of the microleakage evaluation of this study, the specimens in group 2 (laser+composite) showed the most microleakage. While a statistically significant difference was found between group 1 and group 2 ($p<0.05$), a statistically significant difference was not found between group 2 and group 3 ($p>0.05$). Additionally, there was a statistically significant difference between group 1 and group 3 ($p< 0.05$). The negative control group showed no microleakage, and the positive control group showed full microleakage.

The SEM evaluation revealed group 1 showed the most wall adaptation (Figure 2).

In group 2 and group 3 the wall adaptations were worse than in group 1 (Figures 3 and 4).

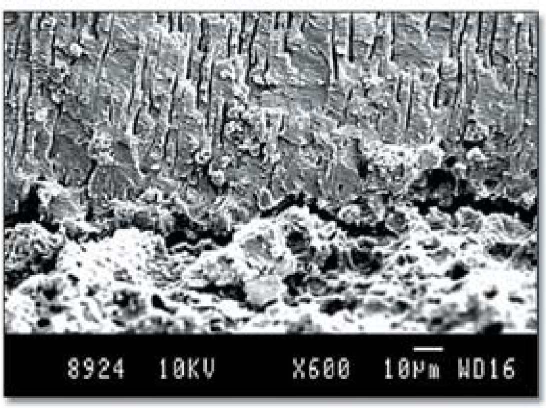


Figure 2. The dentin of the post spaces were etched with 35% phosphoric acid gel (group 1). This group showed the most wall adaptation in the SEM pictures.

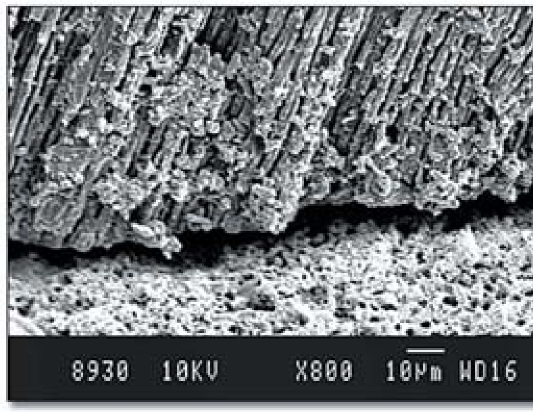


Figure 3. The dentin of the post spaces were irradiated using a 320 µm Nd: YAG laser fiber (group 2). The wall adaptations were worse than in group 1.

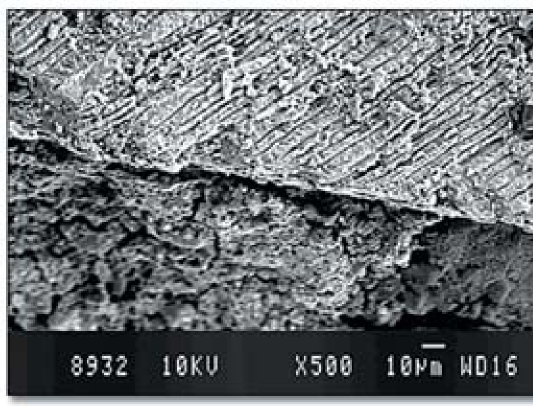


Figure 4. The dentin surfaces were initially treated with the laser and then etched with 35% phosphoric acid (group 3). The wall adaptations were worse than in group 1.

Discussion

Acid-etch is the accepted preparation method for adhesion of composite materials to enamel or dentin. However, it has some disadvantages:

- damages to tooth structure (pulp, dentin);
- clinical manipulation involves drying, wetting, then drying again;
- removal of the etchant with a syringe can cause damage to adjacent enamel or soft tissues
- its treatment times are relatively long.[17]

Recently, new innovative methods, such as lasers, have been suggested for creating retention areas for resin bonding.[17-24] Some researchers[17, 20, 22, 24] have also demonstrated laser irradiation or air abrasion to roughen enamel or dentin surfaces produced higher composite bond strengths than acid etching. However, these systems also have some disadvantages. The Nd: YAG laser beam causes an increase in heat.[25]

Cox et al. [20] studied the effects of pulsed Nd: YAG laser radiation on enamel and dentin. They observed melted dentin, crazing on the surface, slight debris formation, and modification of dentin tubule structure where the tubule periphery had melted.

Reduced calcium (Ca) and phosphorus (P) contents of lased dentin and enamel surfaces, respectively, suggested laser-induced changes in the organic components of the hydroxyapatite crystals. These changes may be indicators of the melting and re-crystallization process of the dentin surface.[27, 28] However, the increase in Ca content of the lased enamel and P level of the lased dentin was an unexpected result. This may be due to differences in the organic-inorganic contents of enamel and dentin and laser exposure time.

Ariyaratnam et al.[25] concluded morphologically lased dentin showed an apparently melted surface with partial obstruction of the dentin tubules as well as cracks along the lased surface. Adhesion to laser-treated dentin can be explained by the mechanical retention provided by resin tag formation and the infiltration of adhesive resin into the micro-irregularities in the lased, mineralized layer. It was composed of a scaly surface layer in which collagen fibrils were completely melted and vaporized.[6] However, laser irradiation of dentin produced a favorable surface for mechanical bonding of resin composite.[1] In the present study laser etching of dentin with the Nd: YAG laser did not achieve superior bonding when compared with the conventional dentin bonding in microleakage groups.

In this study the Nd: YAG laser was used to determine its effects on adhesion between composite resin and root canal dentin. The SEM evaluation of the laser beamed surfaces showed the micro-spaces in the dentin-composite interfaces. It showed laser treatment decreased the adhesion of composite material to dentin.

The surfaces irradiated with laser were homogeneous and smooth. In the SEM analysis the new surfaces formed with a laser beam did not allow for the adaptation of the composite resin. In the third group the better adaptation of the composite to the newly formed smooth surfaces was provided after the laser irradiation procedure. The adaptation of the composite to the dentin walls was very good in group 1 and group 2.

The laser irradiation group did not produce a dye penetration-resistant interface, and the laser group demonstrated the highest degree of microleakage. This may be the result of the presence of a fused layer in which interfibrillar spaces were lacking. This probably restricted the diffusion of composite resin into the subsurface of the intertubular dentin resulting in more leakage. Ceballo et al.[29] reported similar results using the Er-YAG laser.

When acid etching was used after the Nd: YAG laser irradiation, a decrease in adhesion to the dentin canal walls was observed. The use of phosphoric acid followed by water rinsing may appear to have eliminated the surface laser-modified layer.

Conclusion

The Nd: YAG laser irradiation adversely affects adhesion to dentin and does not constitute an alternative to acid etching. Laser irradiation and acid etching did not show any advantage compared to the acid etching alone.

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