Critical Appraisal

ADHESION TO LASER-PREPARED TOOTH STRUCTURE

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The use of Er:YAG (erbium : yttrium aluminum garnet and Er,Cr:YAG (erbium, chromium : yttrium scandium gallium garnet) lasers for tooth preparation has received much attention in recent years. Several advantages have been attributed to these devices, including a reduced need for local anesthesia for tooth preparation, less vibration to the patient, and more conservative cavity preparation. Another purported advantage has been the contention that adhesion to tooth structure is enhanced compared with other means of cavity preparation, even to the point of eliminating the need for conditioning and/or etching prior to adhesive system application. As the use of bonded, esthetic restorations has increased, it is important to know if this purported bonding advantage is valid. This Critical Appraisal examines evidence in the peer-reviewed scientific literature that contradicts this contention, and discusses concerns regarding the use of lasers in cavity preparation.

COMPARISON BETWEEN Er:YAG LASER AND CONVENTIONAL TECHNIQUE FOR ROOT CARIES TREATMENT IN VITRO

A. Aoki, I. Ishikawa, T. Yamada, et al.
Journal of Dental Research 1998 (77:1404–14)

ABSTRACT

Objective: This study compared the effectiveness and characteristics of Er:YAG laser treatment for root caries treatment to conventional bur treatment.

Materials and Methods: Human anterior and premolar teeth with root caries on the proximal surfaces were used. One-half of the lesion received laser treatment (ML22 Er:YAG laser, Erwin, HOYA Corp., Tokyo, Japan, and J. Morita, Kyoto, Japan) to remove the caries at an energy setting of 180 mJ/pulse and a pulse repetition rate of 10 pulses per second. Following laser treatment, the remaining half of the lesion was treated with conventional round burs in a slow-speed handpiece for caries removal. Caries detector (Caries Detector, Kuraray Corp., Osaka, Japan) was used to aid in caries removal. The time required for caries removal and the Knoop hardness were

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measured, and teeth were examined histopathologically and by scanning electron microscope (SEM).

Results: Er:YAG laser treatment required an average of 2.8 times longer for caries removal compared with bur caries removal. Histopathologically, no major thermal damage was observed on the cavity floor treated with Er:YAG laser, although the dentin surface appeared more irregular macroscopically. SEM observation showed a lack of smear layer on the dentin surface with a scaly or flaky structure, micro-irregularity, and microfissure or microcrack propagation running obliquely or parallel to the cavity floor. There was no significant difference between the lased or bur-prepared dentin Knoop hardness 25 μm below the cavity floor.

Conclusions: Cavity preparation took significantly longer with a laser than with a conventional bur. Although there was no difference in laser- versus bur-prepared dentin hardness 25 μm below the cavity floor, the test methods did not allow the assessing of hardness at the cavity floor surface. This study also provided an overview of issues regarding laser use on tooth structure.

COMMENTARY

The authors noted a number of comparative features between laser and bur preparation. The laser caused less vibration than did the bur. However, the laser produced a loud popping noise, charring smell, and occasional plasma sparking despite the use of water spray. The laser preparation margins were irregular and unclear, and the cavity floor had multiple crater defects. The laser provided no tactile feedback to feel differences in hardness between carious and sound dentin. Although there was no difference in the Knoop hardness number below the cavity floor of lased versus bur-prepared dentin, the test instrumentation only allowed this measurement to be made 25 μm below the cavity floor. Meanwhile, histopathologic examination revealed a slight denaturation of lased dentin 5- to 15-μm deep, and SEM evaluation showed thermal and microstructure degeneration of lased dentin. The authors suggested that this damage, covered by loosely attached fragments, might decrease bond strength. Caries dye was used, and the lased surface always stained light pink, possibly due to open dentin tubules and surface denaturation, while the bur dentin would no longer stain once carious dentin was removed.

MICROTENSILE BOND STRENGTHS OF AN ETCH & RINSE AND SELF-ETCH ADHESIVE TO ENAMEL AND DENTIN AS A FUNCTION OF SURFACE TREATMENT

B. Van Meerbeek, J. De Munck, D. Mattar, et al.
Operative Dentistry 2003 (28:647–60)

ABSTRACT

Objective: The purpose of this study was to determine the microtensile bond strength of a self-etch adhesive and a total-etch adhesive to dentin and enamel surfaces prepared with diamond sonoabrasion, air abrasion, laser irradiation, diamond bur, and silicon carbide (SiC) abrasive paper.

Materials and Methods: Ninety human molars had flat enamel and dentin surfaces prepared with 100-μm diamond burs (Komet, Lemgo, Germany), some of which were bonded and used as one set of controls. The remaining groups were finished wet with 600-grit SiC abrasive paper to form a standard surface, some of which acted as the other set of controls. The experimental groups were then further prepared by one of the following

methods: (1) 1-minute application of a diamond tip for a sonoabrasion system (SonicSys system, Micro, KaVo Dental, Biberach, Germany); (2) 10-second abrasion with 27-µm aluminum oxide particles at 6.5 psi; and (3) uniform irradiation with Er:YAG laser (Fidelis, Fotona Medical Lasers, Ljubljana, Slovenia) at 10 Hz, 120 mJ in short pulse mode. Following tooth preparation, either a two-step self-etch adhesive (Clearfil SE, Kuraray, Osaka, Japan) or a three-step etch-and-rinse adhesive (OptiBond FL, Kerr, Orange, CA, USA) was applied according to manufacturer's instructions. In addition, some specimens in the Optibond FL group were bonded without acid-etching. Z100 resin composite (3M ESPE, St. Paul, MN, USA) was applied and cured in 2-mm increments using an Optilux 500 curing unit (Demetron/Kerr, Danbury, CT, USA). Following water storage at 37°C for 24 hours, the teeth were sectioned and subjected to microtensile bond strength testing.

Results: Clearfil SE bonded equally to enamel regardless of surface preparation. For OptiBond FL, separate etching of the enamel surface significantly improved bond strength, regardless of surface preparation, with the exception of air abrasion in which case the acid-etched enamel surface was nearly statistically higher than nonetched enamel. When considering dentin as the substrate, both Clearfil SE and OptiBond FL bonded least effectively to laser-prepared dentin, and this was significantly lower than all other conditions. Separate acid-etching significantly increased bond strength to laser-irradiated and bur-cut dentin, but not to sonoabraded or SiC-abraded dentin.

Conclusions: Bonding to Er:YAG-irradiated enamel and dentin surfaces, in general, results in significantly lower bonding effectiveness as compared with bonding to diamond-bur prepared surfaces. Subsurface damage initiated by Er:YAG ablation is most likely the major reason for the decrease in microtensile bond strength, which might compromise clinical bonding long term.

COMMENTARY

The authors note that the study clearly shows the need for separate acid conditioning of tooth tissue prior to applying etch-and-rinse adhesive systems. Review of their data, scanning electron micrographs, and review of the literature led them to conclude that Er:YAG irradiation causes subsurface damage that compromises the hybridization effectiveness of adhesive systems.

SHEAR BOND STRENGTH AND SEM EVALUATION OF COMPOSITE BONDED TO Er:YAG LASER-PREPARED DENTIN AND ENAMEL

W.J. Dunn, J.T. Davis, A.C. Bush
Dental Materials 2005 (21:616–24)

ABSTRACT

Objective: The purpose of this study was to evaluate whether the shear bond strength between resin composite and tooth surfaces was affected by high-speed rotary or laser preparation, or etching with laser or phosphoric acid.

Materials and Methods: Two hundred forty human molars were used in this study. The dentin specimens had the occlusal surface removed with sequential use of SiC paper, with the final 0.5 mm prepared with either a #57 carbide bur (Brasseler, Savannah, GA, USA) or an Er:YAG laser DELight laser system (Continuum, Santa Clara, CA, USA) at 30 Hz/140 mJ in a focused, noncontact mode with a spot size of 0.6 mm. The enamel specimens were prepared similarly to the dentin specimens to the buccal surfaces of the teeth, but with laser settings of 25 Hz/240 mJ. Resin composite was bonded to the prepared surfaces without further etching, following laser etching at 10 Hz/35 mJ, or 37% phosphoric acid-etching using Scotchbond Multi-Purpose (3M ESPE). Following 24-hour water storage and 500 thermocycles (5–55°C), shear bond strength testing was accomplished using a wire loop on an Instron universal testing machine (Instron, Norwood, MA, USA). Data was subjected to two-way analysis of variance/Tukey's test. Twelve specimens also were used for SEM evaluation of each of the 12 experimental and control groups.

Results: The acid-etched specimens had significantly higher bond strength than laser etching or no etching for both enamel and dentin. Rotary-prepared enamel and dentin surfaces that were acid-etched had significantly higher bond strengths compared with those same surfaces that were laser-prepared. Laser etching produced higher bond strengths to enamel and dentin than not etching those surfaces. SEM evaluation of rotary-prepared, acid-etched bonded dentin showed a smooth surface with intimate contact between composite and dentin and evidence of good hybridization. In contrast, the SEM of laser-prepared dentin showed an irregular surface, fissuring, surface scaling, and flaking. SEM of acid-etched, laser-prepared bonded dentin revealed detachment of the lased surface from the unaffected subsurface dentin. Similar SEM findings were seen with enamel specimens.

Conclusions: Lased enamel and dentin, whether acid-etched or not, had significantly reduced bond strengths compared with rotary-prepared, acid-etched enamel and dentin. SEM evaluation indicated these results are likely due to tooth structure damage and, possibly, to fused collagen fibrils in dentin.

COMMENTARY

This study confirmed the findings of a number of other studies that laser preparation adversely affects bonding to tooth surfaces, even if the tooth surface is subsequently acid-etched. The authors note that SEM findings of their study found a high incidence of cohesive dentin failures compared with rotary-prepared, acid-etched specimens, and would seem to confirm other results that have shown that there is a lack of resin penetration into Er:YAG irradiated dentin. The proposed reasons for this include a fusing of collagen fibrils, and/or extensive subsurface fissuring, and cracking by the laser.

BONDING TO Er-YAG-LASER-TREATED DENTIN

L. Ceballos, M. Toledano, R. Osorio, et al.
Journal of Dental Research 2003 (81:119–22)

ABSTRACT

Objective: The purpose of this study was to investigate the effect of Er-YAG laser on the ultrastructure of the resin-dentin interface and the bond strength of deep and superficial dentin.

Materials and Methods: Noncarious human third molars were used in the study. Half the teeth were sectioned just below the dentino-enamel junction and ground with 180-grit abrasive paper to reveal superficial dentin and approximately 1.1 mm below this level to reveal deep dentin. Both superficial and dentin surfaces were subjected to acid-etching with 35% phosphoric gel, laser etching with a pulsed Er-YAG laser (Model 002532, KaVo) with a pulse energy of 180 mJ and pulse duration of 250 µsec at a repetition rate of 2 Hz under water cooling, or a combination of laser etching followed by 35% phosphoric acid-etching. Specimens were bonded with Single Bond and Z100 (3M ESPE), stored in 37°C water for 1 day, subjected to 500 thermocycles, and tested for shear bond strength using the Watanabe jig method. Twelve specimens were prepared for transmission electron microscopy (TEM) to assess the status of collagen fibrils within the bonded interfaces.

Results: Bond strength was not affected by dentin depth. However, regardless of the dentin depth, acid-etched dentin surfaces provided significantly higher bond strength compared with laser-etched dentin surfaces, whether or not the laser-etched surface was subsequently acid-etched. TEM analysis showed that the acid-etched specimens produced a 3- to 4-µm-thick hybrid zone containing intact collagen fibrils with crossbanding. Laser-etched surfaces had a thick laser-modified dentin layer with superficial microfissures and an absence of collagen fibrils. The adhesive penetrated only the superficial aspect of the laser-modified dentin. The deeper aspect of the laser-etched surface showed collagen fibrils that were fused together and lacked interfibrillar spaces, as well as partially denatured collagen fibrils that had lost part of their crossbanding. The superficial portion of the laser-modified dentin was absent after 35% phosphoric acid-etching; however, the partial collagen fibril denaturation was still present.

Conclusions: There was a significant reduction in bond strength to lased dentin, regardless of whether the dentin was acid-etched or not. SEM and TEM analysis revealed evidence of denatured collagen in the hybrid zone.

COMMENTARY

The authors noted that laser preparation of dentin surfaces resulted in complete melting and vaporizing of collagen fibrils on the surface. The deeper aspect of the laser-modified dentin contained denatured collagen fibrils that were poorly attached to the underlying dentin. The collagen fibril fusing in this layer likely limited resin diffusion into the demineralized zone, resulting in lower shear bond strength.

SUGGESTED READING

Corona S, Borsatto M, Pecora J, et al. Assessing microleakage of different Class V restorations after Er:YAG laser and bur preparation. J Oral Rehabil 2003;30:1008–14. *Increased microleakage of bonded amalgam, composite, and resin-modified glass ionomer restorations when the cavities were prepared with laser versus carbide bur.*

De Munck J, Van Meerbeek B, Yudhira R, et al. Micro-tensile bond strength of two adhesives to Erbium:YAG-lased vs. bur-cut enamel and dentin. Eur J Oral Sci 2002;110:322–9. *Significant decrease in lased dentin bond strength with both a self- and total-etch adhesive, and a significant decrease in lased enamel bond strength with a self-etch adhesive versus diamond bur preparation.*

Chinelatti M, Ramos R, Chimello D, et al. Influence of the use of Er:YAG laser for cavity preparation and surface treatment in microleakage of resin-modified glass ionomer restorations. Oper Dent 2004;29:430–6. *Significant increase in leakage at both enamel and dentin margins of laser-prepared versus carbide bur-prepared cavities.*

Martinez-Insua A, da Silva Dominguez L, Rivera F, et al. Differences in bonding to acid-etched or Er:YAG-laser-treated enamel and dentin surfaces. J Prosthet Dent 2000;84:280–8. *Significant decrease in bond strength to enamel and dentin if laser-etched versus acid-etched.*

Trajtenberg C, Pereira P, Powers J. Resin bond strength and micromorphology of human teeth prepared with an Erbium:YAG laser. Am J Dent 2004;17:331–6. *Significant decrease in lased, acid-etched enamel and dentin bond strength bonded with a self-etch adhesive, and a significant decrease in lased, acid-etched enamel bond strength bonded with a total-etch adhesive versus those same surfaces prepared with a carbide bur.*

Hossain M, Nakamura Y, Murakami Y, et al. A comparative study on compositional changes and Knoop hardness measurement of the cavity floor prepared by Er:YAG laser irradiation and mechanical bur cavity. J Clin Laser Med Surg 2003;21:29–33. *Significant increase in Ca and P in lased versus bur-prepared dentin likely due to evaporation of organic components as a result of increased temperature in the irradiated area.*

Oliveira D, Manhaes L, Marques M, et al. Microtensile bond strength analysis of different adhesive systems and dentin prepared with high-speed and Er:YAG laser: a comparative study. Photomed Laser Surg 2005;23:219–24. *Significant decrease in lased versus bur-prepared dentin bond strength with a total-etch adhesive; no difference in bond strength between the two surfaces with a self-etch adhesive.*

Kameyama A, Kawada E, Takizawa M, et al. Influence of different acid conditioners on the tensile bond strength of 4-META/MMA-TBB resin to Er:YAG laser-irradiated bovine dentin. J Adhes Dent 2000;2:297–304. *Significant decrease in bond strength to lased dentin conditioned with 10% citric acid/3% ferric chloride (10–3), versus control (SiC) prepared surface.*

Barceleiro M, Mello J, Mello G, et al. Hybrid layer thickness and morphology: the influence of cavity preparation with Er:YAG laser. Oper Dent 2005;30:304–10. *SEM analysis showed that a total-etch adhesive applied to laser-prepared dentin exhibited a significantly thinner hybrid layer that was more irregular and inconsistent versus dentin prepared with a diamond bur.*

THE BOTTOM LINE

Lasers offer an interesting alternative to conventional bur preparation of cavity preparations. Certainly, many purported advantages have been ascribed to lasers for cavity preparation. However, there is adequate evidence in the scientific, peer-reviewed literature to raise serious concerns regarding the routine use of lasers for cavity preparation, particularly for bonded restorations. In addition to the shortcomings mentioned by Aoki and colleagues (1998) including rough, irregular margins, significantly increased preparation time, lack of tactile feedback, and complications with caries dye interpretation, factors are at work that significantly and adversely affect adhesion to tooth structure, particularly dentin. Laser preparation results in an irregular, scaly surface penetrated by microfissures. In addition, the laser results in collagen fibril fusion and denaturation, closing interfibrillar spaces. These features combine to decrease resin infiltration into the prepared surface, a weaker surface dentin structure, and inferior adhesion to the dentin. While four articles have been examined for this Critical Appraisal, many additional articles in the scientific, peer-reviewed literature have been published that corroborate these findings. The reader is referred to these articles in the "Suggested Reading" list. Most importantly, the reader is cautioned about abandoning the proven, scientifically validated adhesion to tooth structure provided from bur cavity preparation in favor of the potentially inferior adhesion provided by laser cavity preparation, at least at this current stage of laser development.

Editor's Note: We welcome readers' suggestions for topics and contributors to Critical Appraisal. Please address your suggestions to the section editor:

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