Title

Parameter dependence of marginal microleakage in Er:YAG-laser-ablated and -modified dental preparations

Authors

Wilder-Smith, Petra BB
Choi, Sam
Kurosaki, Tom

Publication Date
1998-04-22

DOI
10.1117/12.306012

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

Petra Wilder-Smith[1], Sam Choi[1] and Tom Kurosaki[2]
[1] Beckman Laser Institute and Medical Clinic, University of California, Irvine, CA 92612, USA
[2] Epidemiology Division, Dept. of Medicine, University of California, Irvine, CA 92612, USA

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/cm^2 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 [1-15]. 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 [16]. 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 [16].

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 [17-26]. 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 [27-37]. Most of these investigations were performed using fairly long-pulsed or continuous wave (Cw) Nd:YAG or CO_2 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 [35], to marginal microleakage attributed to the effects of laser irradiation [27,28]. 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.

---

[1] Further author information:
PWS: Email: pwsmith@bli.uci.edu; Tel: 714 824 4713; Fax: 714 824 8413.

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/cm^2. In the second and third subgroups, laser treatment occurred at a fluence of 25 J/cm^2 and 40 J/cm^2 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 [40].

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 [38], 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.

Supported by: DOE Grant DE903-91ER 61227, ONR N00014-90-0-0029, NIH RRO1192, UCI UROP Undergraduate Research Grant

REFERENCES

1. Wigdor HA, Walsh JT Jr, Featherstone JD, Visuri SR, Fried D, Waldvogel JL (1995) Lasers in dentistry. Lasers in Surgery and Medicine 16:103-33.

2. Zakariasen KL, MacDonald R, Boran T (1991). Spotlight on lasers. A look at potential benefits. Journal of the American Dental Association 122:58-62.

3. White JM, Goodis HE, Setcos JC, Eakle S, Hulscher BE, Rose CL (1993). Effects of pulsed Nd:YAG laser energy on human teeth: a three-year follow-up study. Journal of the American Dental Association 4:45-51.

4. Gordon TE (1967). Single surface cutting of normal tooth with ruby laser. J Am Dent Assoc 74:398-402.

5. Brune D (1980). Interaction of pulsed carbon dioxide laser beams with teeth in vitro. Scand J Dent Res 88:301-305.

6. Stern RH, Sognnaes RF (1964). Laser beam effect on dental hard tissues. J Dent Res 43:873.

7. Melcer J, Chaumette MT (1984). Treatment of dental decay by CO_2 laser beam: Preliminary results. Laser Surg Med 4:311-321.

8. Matsumoto K, Nakamura Y, Wakabayashi H, Arima M, Yamada Y, Kikuchi K (1980). A morphological research on the cavity preparation by ArF:excimer laser. Jpn J Consev Dent 33:1139-1142.

9. Neev J, Liaw LH, Raney D, Fujishige J, HO P, Berns M (1991). Selectivity, Efficiency, and Surface Characteristics of Hard Dental Tissues Ablated With ArF Pulsed Excimer Lasers. Lasers in Surgery and Medicine 11:499-510.

10. Frentzen M, Koort H J. Thiensiri (1992). Excimer Lasers in Dentistry: Future Possibilities with Advanced Technology. New Technological Developments 23:117-133.

11. Lee J, Cheung E, Wilder-Smith P, Desai TJ, Liaw LH, Berns MW (1995). Thermal, Ablative and Physicochemical Effects of XeCl Laser on Dentine. Biomedical Optics 2394: 188-195.

12. Machida T; Wilder-Smith P; Arrastia AM; Liaw LH; Berns MW (1995). Root canal preparation using the second harmonic KTP:YAG laser: a thermographic and scanning electron microscopic study. Journal of Endodontics 21(2):88-91.

13. Wilder-Smith P, Lin S, Nguyen A, Liaw L-H, Arrastia A, Lee J and Berns MW. Morphological Effects of ArF Excimer Laser Irradiation on Enamel and Dentine. Lasers in Surgery and Medicine (Accepted for Publication).

14. Hibst R; Keller U. Experimental studies of the application of the Er:YAG laser on dental hard substances (1989). Lasers in Surgery and Medicine 9:338-51.

15. Kelsey WP 3d; Blankenau RJ; Powell GL (1991). Application of the argon laser to dentistry. Lasers in Surgery and Medicine 11(6):495-8.

16. Niemz MH (1996). Lasers in dentistry. Laser -Tissue Interactions pp. 178-196

17. Boehm R, Rich J, Webster J, Janke S (1977). Thermal stress effects and surface cracking associated with laser use on human teeth. Journal of Biomechanical Engineering 77:189-194.

18. Sandford MA, Walsh LJ (1994). Differential thermal effects of pulsed vs. continuous CO_2 laser radiation on human molar teeth. J clinical las med sur 12:139-142.

19. Cox CJ; Pearson GJ; Palmer G (1994). Preliminary in vitro investigation of the effects of pulsed Nd:YAG laser radiation on enamel and dentine. Biomaterials 15(14):1145-51.

20. Anic I, Vidovic D, Luic M, Tudja M (1992). Laser induced molat tooth pulp chamber temperature changes. Caries Res 26:165-169.

21. Shariati S, Pogrel MA, Marshall GW, White JM (1993). Structural Changes in Dentine Induced by High Energy, Continuous Wave Carbon Dioxide Laser. Laser in Surgery and Medicine 13:543-547.

22. Nelson DGA, Wefel JS, Jongebloed WL, Featherstone JDB (1987). Morphology, histology, and crystallography of human dental enamel treated with pulsed low-energy infrared laser radiation. Caries Res 21:411-426.

23. Kantola S, Laine E, Tarna T (1973). X-ray diffraction study of dental enamel exposed to a CO_2 laser. Laser-induced effects on tooth structure. 31:366-379

24. Dzubur AA, Vidovic D, Tudja M (1993). Temperature and surface changes of dentine and cementum induced by CO_2 laser exposure. Inter Endodontic J 26:284-293.

25. Arcoria CJ, Lippas MG, Vitasek BA (1993). Enamel surface roughness analysis after laser ablation and acid-etching. Journal of Oral Rehabilitation 20:213-24.

26. Spencer P, Trylovich DJ, Cobb CM (1992). Chemical Characterization of Lased Root Surfaces Using Fourier Transform Infrared Photoacoustic Spectroscopy. Journal of Periodontology 63 (7):633-636.

27. Liberman R, Eli I, Imber S, Shlezinger I (1990). Glass ionomer cement restorations: the effects of lasing the cavity walls on marginal microleakage. Clinical Preventive Dentistry 12:5-8.

28. Scherman L, Zeboulon S, Goldberg M (1990). [Use of the CO_2 laser in enamel-dentine bonding procedures: experimental findings]. Actualities Odonto-Stomatologiques 44:365-82.

29. Silberman JJ, Dederich DN, Vargas M, Denehy GE (1994). SEM Comparison of Acid-Etched, CO_2 Laser-Irradiated, and Combined Treatment on Dentine Surfaces. Lasers in Surgery and Medicine 15:269-276.

30. White JM, Goodis HE, Rose CM, Khosrovi, Hornberger B (1992). Shear bond strength of Nd:YAG laser treated dentine. J dent Res Abstracts of Papers Abstract No. 1048 70:397.

31. Dederich DN, Hinkleman KW, Albert A, Tulip J (1989). Effects of carbon dioxide laser on dentine bonding. J Dent Res Abstracts of Papers Abstract No. 10 68:868.

32. Shaw PR, Dummett CO Jr., Sarkar NK, Lancaster DM (1993). Effect of a Nd: YAG laser treatment on dentine-resin shear bond. J Dent Res Abstracts of Papers Abstract 271 72:131.

33. Marshall GW, Watanabe L, Strawn SE, Marshall SJ, White JM, Goodis HE (1993). Adhesion of new bond agents to lased and unlased dentine. J Dent Res Abstracts of Papers Abstract 235 72:133.

34. Laurell K, Dodd B, Johnston W (1993). ND:YAG laser effects on dentinal bonding. J Dent Res Abstracts of Papers Abstract 235 72:137.

35. Cooper LF, Myers ML, Nelson DGA, Mowery AS (1988). Shear strength of composite bonded to laser pre-treated dentine. J Prosthet Dent 60:45-49.

36. Walsh LJ, Abood D, Brockhurst PJ (1994). Bonding of resin composite to carbon dioxide laser-modified human enamel. Dental Materials 10:162-166.

37. Visuri SR, Gilbert JL, Wright DD, Wigdor HA, Walsh, Jr. JT (1996). Shear strength of composite bonded to Er:YAG laser -prepared dentine. J Dent Res 75 (1): 599-605.

38. Kaplan I, Mincer HH, Haris EF, Cloyd JS (1992). Microleakage of composite resin and glass ionomer cement restorations in retentive and nonretentive cervical cavity preparations. Journal of Prosthetic Dentistry 68(4):616-623.

39. Hegarty SM and Pearson GJ (1990). The effectiveness of dentin adhesives as demonstrated by dye penetration and SEM investigations.J of Oral Rehab (17)351-357.

40.Pashley DH (1991). In vitro simulations of in vivo bonding conditions. American Journal of Dentistry 4(5):237-40.

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/cm^2	No of teeth: 4	1	0	0	0	0	**1**	No of teeth: 5	0	0	0	0	0	**0**
25 J/cm^2	No of teeth: 3	1	0	1	0	0	**4**	No of teeth: 4	0	1	0	0	0	**2**
40 J/cm^2	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.