Original Article

Effect of Different Modes of Erbium:yttrium Aluminum Garnet Laser on Shear Bond Strength to Dentin

E Kucukyilmaz, MS Botsali[1], E Korkut[2], Y Sener[2], T Sari[3]

Department of Pediatric Dentistry, Faculty of Dentistry, Izmir Katip Celebi University, Cigli, Izmir, [1]Department of Pediatric Dentistry, Faculty of Dentistry, Selcuk University, Selcuklu, [2]Department of Pediatric Dentistry, Faculty of Dentistry, Necmettin Erbakan University, Karatay, Konya, [3]Department of Prosthodontics, Faculty of Dentistry, Bezmialem Vakif University, Istanbul, Turkey

Date of Acceptance:
29-Mar-2016

Abstract

Objectives: The aim of this study was to evaluate the effect of different surface treatments on the shear bond strength (SBS) of resin composites to dentin using total etch dentin bonding adhesives. **Materials and Methods:** Sixty extracted human molars were flattened to obtain dentin surfaces. The samples were divided into three groups (n = 20): Group I: 37% phosphoric acid + optibond FL + resin composite; Group II: Erbium:yttrium aluminum garnet (Er:YAG) laser (medium short pulse [MSP] mode, 120 mJ/10 Hz) + optibond FL + resin composite; Group III: Er:YAG laser (quantum square pulse [QSP] mode, 120 mJ/10 Hz) + optibond FL + resin composite. After the specimens were prepared, the SBS test was performed at a crosshead speed of 0.5 mm/min. The fractured specimens were examined under a stereomicroscope to evaluate the fracture pattern. Statistical analyses were performed with one-way ANOVA and Tukey's honestly significant difference tests. One sample of treated dentin surface from each group was sputter-coated with gold, and scanning electron microscope (SEM) images were captured. **Results:** Acid etching showed significantly higher SBS than the other groups ($P < 0.05$). However, the difference between Er:YAG MSP and QSP mode groups was not statistically significant ($P > 0.05$). SEM images of the acid-etched dentin surface showed opened dentinal tubule with a regular surface, but Er:YAG MSP mode treated surface was irregular. The surface treated with Er:YAG QSP mode represented wide dentinal tubules with a clean and flat surface. **Conclusion:** Using different modes (MSP and QSP) of Er:YAG laser for dentin surface treatment before application of total etch adhesives is still not an sufficient alternative compared to acid etching.

Keywords: *Acid etching, dentin conditioning, erbium:yttrium aluminum garnet laser, quantum square pulse mode*

Introduction

Many recent studies in the field of restorative dentistry aim to investigate the reliability of bonding between dental materials and dental hard tissues.[1,2] Restorative materials must provide a fully integrated and strong adhesion to dental hard tissues to ensure the success of clinical treatment and long-term retention of adhesive restorations.[1,3] The most efficient mechanism for adhesion is thought to be micromechanical retention.[1,2,4]

The enamel is mainly composed of an inorganic substance called hydroxyapatite, which sufficiently bonds to composite resins owing to the anchoring effect produced by acid etching.[1,2,4] On the other hand, dentin is composed of more than 50% organic substances, mainly collagen and water, which may consequently decrease the bonding ability of composite resins to dentin. The key to achieving sufficient adhesion to dentin is the method of preparation before application of an adhesive to the dentin surface.[5-7] There are several

Address for correspondence: Dr. E Korkut,
Department of Pediatric Dentistry, Faculty of Dentistry,
Necmettin Erbakan University, Karatay, Konya, Turkey.
E-mail: emrekorkut86@hotmail.com

Access this article online

Quick Response Code:

Website: www.njcponline.com

DOI: 10.4103/1119-3077.181402

How to cite this article: Kucukyilmaz E, Botsali MS, Korkut E, Sener Y, Sari T. Effect of different modes of erbium:yttrium aluminum garnet laser on shear bond strength to dentin. Niger J Clin Pract 2017;20:1277-82.

studies concerning the pretreatment of the dentin surfaces in the literature. Different types of acids have been often used for conditioning prior to the application of adhesive materials.[5,6] Moreover, new dentin conditioning methods have been developed to obtain higher bond strengths in the field of adhesive dentistry.[7-10]

In recent years, lasers are being increasingly applied in the field of dentistry, and their use for preparing the dental hard tissues prior to restoration has been suggested.[10,11] The microscopic and macroscopic irregularities resulting from laser therapy do not cause demineralization of the dentin surface and also open dentin tubules without creating a smear layer. This suggests that the combined use of the laser therapy with adhesive materials may be useful in increasing bond strength.[12-15] Studies have shown that erbium:yttrium aluminum garnet (Er:YAG) lasers form a microretentive surface, leading to increased bonding strength when used on enamel and dentin.[13,16-18] Parameters such as pulse duration and pulse energy can be adjusted to ensure a higher bond strength on the surface where the laser is applied. Current studies are investigating the optimal parameters for Er:YAG laser use to eliminate the acid-etching step on different surfaces.[19-23] Recently developed quantum square pulse (QSP) mode provides short low-energy Er:YAG laser pulses delivered at an optimal rate, which results in both higher efficiency and precision with minimal thermal adverse effects.[24-27] Dentin surfaces conditioned with QSP mode Er:YAG laser have been shown to be sharp and well-defined with higher surface quality, required for high bond strength.[21,24,25] In addition, it has been claimed that QSP mode significantly reduces the undesirable effects of laser beam scattering and absorption in the debris cloud during hard tissue ablation.[24,27]

In literature, there are many studies concerning the surface conditioning effect of Er:YAG laser, but only few studies have mentioned the effects of the medium short pulse (MSP) and QSP modes. Therefore, this study aims to evaluate the effect of different modes of the Er:YAG laser on shear bond strength (SBS) of adhesive resins to dentin. In addition, the treated dentin surfaces were evaluated morphologically under a scanning electron microscope (SEM). The null hypothesis tested was that there is no difference between SBS values of the dentin irradiated with different pulse settings of the Er:YAG laser and the acid-etched surface, followed by the application of a total etch adhesive.

Materials and Methods

Preparation of the specimens

A power analysis established by G*Power Version 3.1.3 (Franz Faul, Universität Kiel, Germany) software, based on an equal ratio among groups and a sample size of 60 teeth would provide over 85% (actual power = 0.86528) power to detect significant differences with 0.60 effect size and at the $\alpha = 0.05$ significance level (critical $F = 2.5279439$; noncentrality parameter $\lambda = 14.6000$).

Sixty extracted sound human mandibular molars were collected and stored in chloramine solution at 4°C. The teeth were cleaned with a scaler and water/pumice slurry and were embedded in polyester resin. The occlusal enamel was completely removed to obtain a flat dentin surface. Prepared dentin surfaces were polished with 600-grit paper for 60 s to create a standard and clinically relevant smear layer. A smooth surface of dentin was obtained for all specimens, and teeth were randomly divided into three groups ($n = 20$), representing the three different surface treatments to be investigated [Table 1].

Laser application

A contact hand piece (H14 C, Fotona d.d, Ljubljana, Slovenia) with a sapphire tip (8 mm long, 1.3 mm diameter) was used to treat dentin surfaces with laser irradiation. The Er:YAG laser (LightWalker, Fotona, Ljubiana, Slovenia) with MSP and QSP modes was used with settings of 120 mJ, 10 Hz, and 1.20 Watts for 4 s. During irradiation, the level of water spray level was 6 and the distance between the sapphire tip and the target surface was 2 mm. The distance of the sapphire tip was standardized by a custom-made apparatus with a holder, and the whole surface was scanned for 30 s with the tip perpendicular to the dentin surface.

Bonding procedures

A multistep, total etch bonding agent (Optibond FL, Kerr Dental, Orange, USA) was used for all groups after application of different surface conditioning methods. The bonding procedures were performed according to the manufacturer's instructions. The primer was applied for 15 s, and then gently air-dried for 5 s. The adhesive was then applied and light cured for 20 s with a light curing unit (Demetron A1, Kerr Dental, Orange, USA). A composite resin restorative material (Filtek Z250, 3M Unitek, California, USA) was bonded to all dentin specimens using a split Teflon mold with an inner diameter and height of 3 mm × 3 mm. The mold was secured to the specimen, and then two 1.5 mm increments of composite were light cured separately for 40 s each. The Teflon mold was removed and specimens were stored in water at 37°C for 24 h.

Shear bond testing

SBSs of the specimens were tested for failure using a universal testing machine (Instron Corp., Canton, MA, USA) with 0.5 mm/min crosshead speed with a knife-edge blade. The load at failure was recorded in Newtons (N) and the bond strength was calculated in MPa by dividing the load at failure by the adhesive surface area (mm^2). The data obtained from SBS tests were analyzed using one-way ANOVA and Tukey's honestly significant difference tests ($\alpha = 0.05$).

Fractured specimens were examined by a stereomicroscope (CX41, Olympus, Tokyo, Japan) at ×20 magnification to determine failure modes and were classified as cohesive (100% cohesive failure in the tooth substrate), adhesive (100% adhesive failure between the tooth substrate and adhesive resin), or mixed (mixed failure with adhesive failure and cohesive failure in the tooth substrate).

Scanning electron microscope evaluation

A treated dentin surface from each of the three groups was used for the SEM evaluations. Samples were sputter-coated with gold and inspected using a SEM (Evo LS10, Carl Zeiss, Oberkochen, Germany). The whole surface was examined and the most representative areas were photographed at ×1500.

Results

The mean SBS values and standard deviations (SD) for the groups are presented in Table 2. A comparison between the groups revealed that acid-etched group showed significantly higher bond strength than the other groups ($P < 0.05$). The difference between Er:YAG MSP and QSP-treated groups was not statistically significant ($P > 0.05$). The modes of failure for the specimens after the SBS test are presented in Table 3.

Scanning electron microscope observations

The acid-etched dentin specimen showed a regular surface with opened dentinal tubules, without smear layer [Figure 1]. Laser-irradiated dentin surfaces had irregularities caused by laser beam scattering and exhibited a flaky surface appearance without a smear

Table 1: Dentin surface pretreatment and adhesive material applied to the specimens

Groups	Dentin surface pretreatment	Adhesive material
I	37% phosphoric acid	Optibond FL + composite resin
II	Er:YAG laser MSP mode 120 mJ, 10 Hz, 1.20 W	Optibond FL + composite resin
III	Er:YAG laser QSP mode 120 mJ, 10 Hz, 1.20 W	Optibond FL + composite resin

QSP=Quantum square pulse; MSP=Medium short pulse; Er:YAG=Erbium:yttrium aluminum garnet

Table 2: Mean shear bond strength values (MPa) and standard deviations of each group

Groups	*n*	Mean±SD
Acid etching	20	16.61±1.99[a]
Er:YAG MSP	20	11.24±1.03[b]
Er:YAG QSP	20	10.77±1.07[b]

Different letters label statistically significant differences according to the *post hoc* test ($P<0.05$). QSP=Quantum square pulse; MSP=Medium short pulse; SD=Standard deviation; Er: YAG=Erbium:yttrium aluminum garnet

Table 3: Distribution of failure modes within groups for shear bond strength (*n*=20)

Groups	Adhesive	Cohesive	Mix
Acid etching	11	6	3
Er:YAG MSP	19	0	1
Er:YAG QSP	17	1	2

QSP=Quantum square pulse; MSP=Medium short pulse; Er:YAG=Erbium:yttrium aluminum garnet

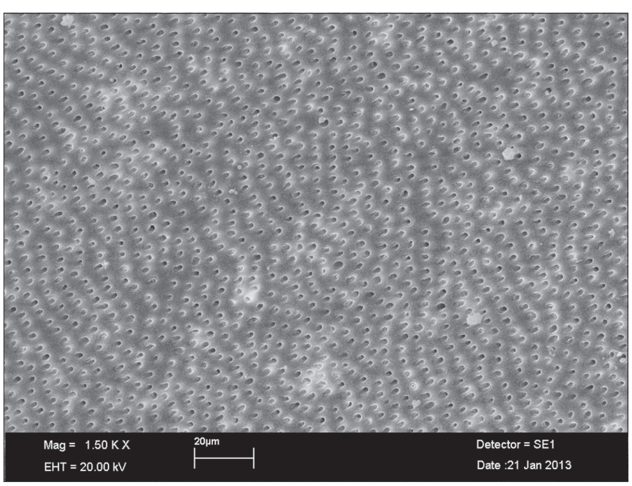

Figure 1: Scanning electron microscope images of the dentin surface etched with 37% phosphoric acid: The dentin surface is regular and clean of smear layer, showing wide open dentinal tubules

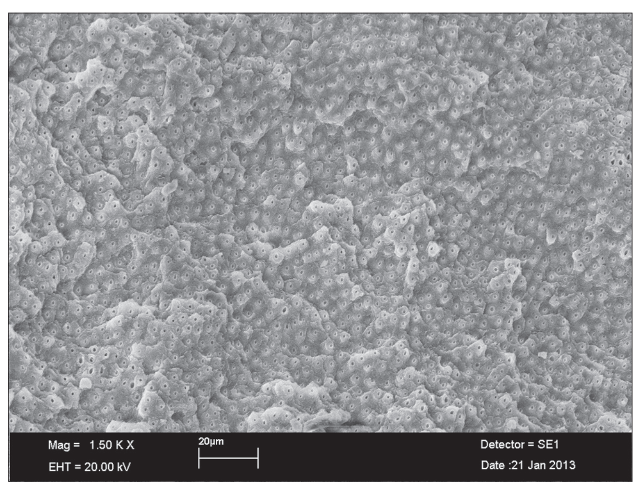

Figure 2: Scanning electron microscope images of the dentin surface conditioned with erbium:yttrium aluminum garnet laser medium short pulse mode: Surface is irregular and clean of smear layer and the dentinal tubules are opened

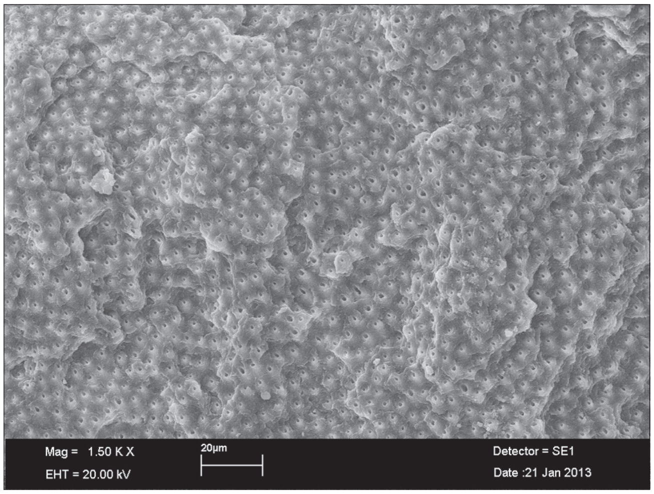

Figure 3: Scanning electron microscope images of the dentin surface conditioned with erbium:yttrium aluminum garnet laser quantum square pulse mode: the dentin surface is perfectly clean and flat, showing wide open dentinal tubules

layer [Figures 2 and 3]. The QSP-mode-treated specimen exhibited a cleaner and flatter dentin surface than did the MSP-mode-treated surfaces. This is thought to be due to the reduced scattering effect of the QSP mode [Figures 2 and 3].

Discussion

Dentin conditioning with acid etching is a commonly used method to create a microretentive dentin surface without a smear layer.[5,6] It is well known that etching with phosphoric acid increases the bond strength between adhesive materials and dental hard tissues.[1,4] However, it is also emphasized that acid etching causes demineralization of the enamel and dentin surfaces and could possibly induce secondary caries around the composite restorations.[2,4] In accordance with the developments in dental laser technology over the years, conditioning of dental hard tissues with Er:YAG lasers has been widely investigated.[8,11,20,28] It was reported that dentin tissue irradiated with Er:YAG laser showed a microscopically rough surface and opened the dentinal tubules and sterilized the dentin surfaces without smear layer production or excessive demineralization.[8,12,13,16] Therefore, it is thought that Er:YAG laser irradiation may be adequate for dentin preparation in the bonding of the adhesive materials.

The present study was designed to compare the surface morphology of dentin surfaces conditioned with acid etching, Er:YAG laser with MSP mode, and QSP modes as well as the bonding abilities of composite resins to these prepared surfaces. According to the results, the acid-etched group showed higher bond strength values than the other groups. Therefore, the null hypothesis was rejected.

There are several studies in literature that investigated the bonding strengths of Er:YAG laser-irradiated surfaces.[16-18] However, results were conflicting and even disputable. Some researchers assumed that the characteristics of the flaky laser-irradiated surface made the surface suitable for bonding procedures as it enlarged the surface area available for bonding.[10,18,28,29] Lee *et al*.[28] claimed that Er:YAG laser irradiation could be an alternative option to conventional acid-etching methods. Similarly, Basaran *et al*.[29] reported comparable SBS values obtained from Er:YAG laser-irradiated surfaces and acid-etched surfaces. In contrast, many other studies investigating the effects of laser irradiation on bond strengths to dentin showed that acid-etched dentin surfaces produced higher bond strengths, than laser-irradiated dentin surfaces.[13,30,31] Dunn *et al*.[32] reported that SBS of the laser-etched dentin and enamel was inferior to that of conventional etching with 37% phosphoric acid. The results of the present study demonstrated that acid-etched dentin surfaces produced higher SBS than did various modes of Er:YAG laser-irradiated dentin surfaces, corroborating the findings of Ceballos *et al*.,[13] Eguro *et al*.,[33] and Ramos *et al*.[34] SEM images from the present study showed the flaky appearance of laser-irradiated dentin, described by Aoki *et al*.[35] as the cuff-like appearance of peritubular dentin. This may cause non-infiltration of resins following laser irradiation, resulting in lower bond strengths. The present study demonstrated that the SBS of laser-irradiated dentin was not satisfying compared to that of acid-etched dentin. Furthermore, a higher incidence of adhesive failures was observed in laser groups, indicating poor interaction between the adhesive resin and the tooth substrate.

The power and irradiation settings of the laser devices may have a larger influence on adhesion than what was first assumed. In particular, pulse duration and pulse energy of the Er:YAG laser are the most significant determinants for adhesion to the dentin surface.[36] High-pulse energy, provided by the Er:YAG laser, may cause some thermal deposition and long pulses have undesirable scattering effects on dentin.[20,22,24] However, using low-pulse energy and short pulse duration is inefficient for conditioning or ablating dentin surfaces.[20,21,26] With the development of the QSP mode for the Er:YAG laser, it is possible to split each pulse into several shorter pulses without loss of speed and effect.[25,26] The QSP mode helps avoid unwanted effects such as absorption and scattering of the laser beam in the debris cloud. Shorter pulses also mean less thermal effects on dental hard tissues.[21,24,25] There are only a limited number of studies in the literature that compare the effects of QSP mode with other surface conditioning methods. Sağır *et al*.[36] suggested that Er:YAG laser etching with MSP and QSP modes could be an alternative to acid etching because it provides higher or comparable SBS values. Nevertheless, Altunsoy *et al*.[19] reported that the highest microtensile bond strength was obtained from acid-etched dentin surfaces, while the MSP-and QSP-mode-treated groups showed weaker bond strength properties. Similarly, the present study demonstrated that dentin conditioning with Er:YAG laser MSP and QSP modes were not as effective as conventional acid-etching methods.

Conclusion

According to the results of the current study, it can be concluded that using different modes (MSP and QSP) of the Er:YAG laser for the treatment of dentin surfaces prior to the application of total etch adhesives is not an effective alternative to acid etching.

Despite the advances in adhesive dental materials and the achievement of greater bonding to dentin, experts should be careful when using the Er:YAG laser for the pretreatment of dentin prior to bonding procedures. The etching step should not be eliminated until further evidence-based studies report more effective parameters for the conditioning the dentin surfaces using lasers.

Further studies should be conducted to assess the superficial and sub-superficial layers of irradiated dental hard tissues and materials. This would ensure more effective application of new techniques in the field of adhesive dentistry.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Peumans M, De Munck J, Mine A, Van Meerbeek B. Clinical effectiveness of contemporary adhesives for the restoration of non-carious cervical lesions. A systematic review. Dent Mater 2014;30:1089-103.
2. Peumans M, Kanumilli P, De Munck J, Van Landuyt K, Lambrechts P, Van Meerbeek B. Clinical effectiveness of contemporary adhesives: A systematic review of current clinical trials. Dent Mater 2005;21:864-81.
3. Nakabayashi N, Kojima K, Masuhara E. The promotion of adhesion by the infiltration of monomers into tooth substrates. J Biomed Mater Res 1982;16:265-73.
4. Breschi L, Mazzoni A, Ruggeri A, Cadenaro M, Di Lenarda R, De Stefano Dorigo E. Dental adhesion review: Aging and stability of the bonded interface. Dent Mater 2008;24:90-101.
5. Tani Y, Togaya T. Dentin surface treatment without acids. Dent Mater J 1995;14:58-69.
6. Tani Y. A new non-acidic pretreatment of dentinal smear layer. J Dent Res 1991;70:362-79.
7. Toledano M, Osorio E, Aguilera FS, Cabrerizo-Vilchez MA, Osorio R. Surface analysis of conditioned dentin and resin–dentin bond strength. J Adh Sci Technol 2012;26:1-3.
8. Pisani-Proença J, Erhardt MC, Amaral R, Valandro LF, Bottino MA, Del Castillo-Salmerón R. Influence of different surface conditioning protocols on microtensile bond strength of self-adhesive resin cements to dentin. J Prosthet Dent 2011;105:227-35.
9. Hajizadeh H, Ghavamnasiri M, Namazikhah MS, Majidinia S, Bagheri M. Effect of different conditioning protocols on the adhesion of a glass ionomer cement to dentin. J Contemp Dent Pract 2009;10:9-16.
10. Korkmaz Y, Ozel E, Attar N, Ozge Bicer C. Influence of different conditioning methods on the shear bond strength of novel light-curing nano-ionomer restorative to enamel and dentin. Lasers Med Sci 2010;25:861-6.
11. Kato C, Taira Y, Suzuki M, Shinkai K, Katoh Y. Conditioning effects of cavities prepared with an Er, Cr:YSGG laser and an air-turbine. Odontology 2012;100:164-71.
12. Ken-Ichi T, Kazunobu S, Shizuko I, Kouji A. Resin-dentin bonding interface after photochemical surface treatment. Photomed Laser Surg 2015;33:47-52.
13. Ceballo L, Toledano M, Osorio R, Tay FR, Marshall GW. Bonding to Er-YAG-laser-treated dentin. J Dent Res 2002;81:119-22.
14. Sano K, Tonami K, Ichinose S, Araki K. Effects of ArF excimer laser irradiation of dentin on the tensile bonding strength to composite resin. Photomed Laser Surg 2012;30:71-6.
15. Hossain M, Nakamura Y, Yamada Y, Suzuki N, Murakami Y, Matsumoto K. Analysis of surface roughness of enamel and dentin after Er, Cr:YSGG laser irradiation. J Clin Laser Med Surg 2001;19:297-303.
16. Garbui BU, de Azevedo CS, Zezell DM, Aranha AC, Matos AB. Er, Cr:YSGG laser dentine conditioning improves adhesion of a glass ionomer cement. Photomed Laser Surg 2013;31:453-60.
17. Curylofo FA, Messias DC, Silva-Sousa YT, Souza-Gabriel AE. Bond strength of restorative material to dentin submitted to bleaching and Er:YAG laser post-treatment. Photomed Laser Surg 2014;32:495-9.
18. Jaberi Ansari Z, Fekrazad R, Feizi S, Younessian F, Kalhori KA, Gutknecht N. The effect of an Er, Cr:YSGG laser on the micro-shear bond strength of composite to the enamel and dentin of human permanent teeth. Lasers Med Sci 2012;27:761-5.
19. Altunsoy M, Botsali MS, Sari T, Onat H. Effect of different surface treatments on the microtensile bond strength of two self-adhesive flowable composites. Lasers Med Sci 2015;30:1667-73.
20. Bahrami B, Askari N, Tielemans M, Heysselaer D, Lamard L, Peremans A, *et al.* Effect of low fluency dentin conditioning on tensile bond strength of composite bonded to Er:YAG laser-prepared dentin: A preliminary study. Lasers Med Sci 2011;26:187-91.
21. Lukac M, Marincek M, Grad L. Dental laser drilling: Achieving optimum ablation rates with latest generation fidelis laser systems. J Laser Health Acad 2007;7:1-3.
22. Baraba A, Perhavec T, Chieffi N, Ferrari M, Anic I, Miletic I. Ablative potential of four different pulses of Er:YAG lasers and low-speed hand piece. Photomed Laser Surg 2012;30:301-7.
23. Altunsoy M, Botsali MS, Korkut E, Kucukyilmaz E, Sener Y. Effect of different surface treatments on the shear and microtensile bond strength of resin-modified glass ionomer cement to dentin. Acta Odontol Scand 2014;72:874-9.
24. Lukac M, Marincek M, Grad L. Super VSP Er:YAG pulses

for fast and precise cavity preparation. J Oral Laser Appl 2004;4:171-3.

25. Lukac M, Primc NM, Pirnat S. Quantum square pulse Er:YAG lasers for fast and precise hard dental tissue preparation. J Laser Health Acad 2012;1:14-9.
26. Gutknecht N, Lukac M, Marincek M, Perhavec T, Kazic M. A novel quantum square pulse (QSP) mode erbium dental laser. J Laser Health Acad 2011;1:15-21.
27. Mironov E, Mironova Z, Vassileva R, Genova K. New horizons for Er:YAG lasers: QSP mode advantages in the lightwalker AT. J Laser Health Acad 2012;3:12-21.
28. Lee BS, Hsieh TT, Lee YL, Lan WH, Hsu YJ, Wen PH, *et al.* Bond strengths of orthodontic bracket after acid-etched, Er:YAG laser-irradiated and combined treatment on enamel surface. Angle Orthod 2003;73:565-70.
29. Basaran G, Hamamci N, Akkurt A. Shear bond strength of bonding to enamel with different laser irradiation distances. Lasers Med Sci 2011;26:149-56.
30. Martínez-Insua A, Da Silva Dominguez L, Rivera FG, Santana-Penín UA. Differences in bonding to acid-etched or Er:YAG-laser-treated enamel and dentin surfaces. J Prosthet Dent 2000;84:280-8.
31. Kameyama A, Kawada E, Takizawa M, Oda Y, Hirai Y. 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.
32. Dunn WJ, Davis JT, Bush AC. Shear bond strength and SEM evaluation of composite bonded to Er:YAG laser-prepared dentin and enamel. Dent Mater 2005;21:616-24.
33. Eguro T, Maeda T, Otsuki M, Nishimura Y, Katsuumi I, Tanaka H. Adhesion of Er:YAG laser-irradiated dentin and composite resins: Application of various treatments on irradiated surface. Lasers Surg Med 2002;30:267-72.
34. Ramos RP, Chimello DT, Chinelatti MA, Nonaka T, Pécora JD, Palma Dibb RG. Effect of Er:YAG laser on bond strength to dentin of a self-etching primer and two single-bottle adhesive systems. Lasers Surg Med 2002;31:164-70.
35. Aoki A, Ishikawa I, Yamada T, Otsuki M, Watanabe H, Tagami J, *et al.* Comparison between Er:YAG laser and conventional technique for root caries treatment *in vitro*. J Dent Res 1998;77:1404-14.
36. Sagir S, Usumez A, Ademci E, Usumez S. Effect of enamel laser irradiation at different pulse settings on shear bond strength of orthodontic brackets. Angle Orthod 2013;83:973-80.