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ORIGINAL ARTICLE

Comparative Analysis of Er:YAG Laser and Other Dentin Cleaning Protocols: A Scanning Electron Microscopic Evaluation

Hasanönder Gümüş, Mustafa Zortuk, Halil İbrahim Kilinç, Ali Rıza Tunçdemır

ABSTRACT

The purpose of this study was to examine the ability of the Erbium:Yttrium-Aluminum-Garnet (Er:YAG) laser to remove remnants of provisional cement. Thirty caries-free human third molars were prepared for cementation with disk-shaped provisional restoration material. Specimens were randomly distributed among six groups, and provisional cement was removed with a dental explorer (G1), pumice (G2), rotary instrument (G3), or Er:YAG laser irradiation at one of three different settings [200 mJ and 15 Hz (G4), 200 mJ and 20 Hz (G5), and 150 mJ and 15 Hz (G6)] until the dentin surface was macroscopically clean. Electron micrographs were obtained and scored, and results were analyzed using Kruskal-Wallis and Tukey's post hoc tests ($p < 0.05$).

The results suggest that the Er:YAG laser can be used to clean the remnants of provisional cement. Laser application was found to be effective in the removal of provisional cement remnants, whereas the use of an explorer alone was found to be the least effective method tested. To prevent the contamination of luting cements with provisional cement remnants Er:YAG laser can be an alternative method to conventional methods.

Keywords: Er:YAG laser, Dentin cleaning, Provisional cement, Scanning electron microscopy.

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INTRODUCTION

Immediately prior to seating definitive restorations, provisional cement must be removed as completely as possible,[1] since remnants of provisional cement adversely affect bonding between resin-based cements and dentin.[2-4] Various methods have been proposed for the removal of provisional cement.[5-7] Mechanical methods include the use of an excavator, pumice and explorer; however, none of these methods have been found to be fully effective. Rather, remnants of cement have been microscopically observed on surfaces that appeared macroscopically clean.[4,8]

Laser application may represent an alternative to conventional dentin-cleaning techniques; however, no data is currently available in the literature about the efficacy of lasers in cleaning dentin. The Erbium:Yttrium-Aluminum-Garnet (Er:YAG) laser, which was first used in dentistry by Hibst and Keller,[9] is well known for its ability to remove dental hard tissue with minimal injury to pulp and without producing severe thermal side-effects, such as cracking, melting or charring of remaining tooth structure and/or surrounding tissue.[10,11] The Er:YAG laser is able to effectively ablate dental hard tissue because its energy is well absorbed by both water and hydroxyapatite.[12] No studies were found in the literature discussing the use of Er:YAG laser as a cleaning method for the remnants of provisional cement.

This study is aimed to determine the optimum parameters for dentin cleaning using Er:YAG laser irradiation and to compare them with the conventional methods. Based on previous studies regarding laser etching,[13-15] this study examined applications of 200 mJ and 15 Hz, 200 mJ and 20 Hz and 150 mJ and 15 Hz.

MATERIALS AND METHODS

Specimen Preparation

Thirty caries-free, unrestored human third molars previously stored in a 0.5% cloramin T solution at 4°C for up to 1 month after extraction were selected as specimens. Soft tissues were removed with a scaler (H6/H7, Hu-Friedy, Chicago, USA). Teeth were cleaned with pumice, and each tooth was embedded in autopolymerizing acrylic resin (Palapress, Heraeus Kulzer, Wehrheim, Germany) using a cylindrical plastic mold 20 mm in height and 20 mm in diameter. Enamel was removed by sectioning the crowns horizontally at the top of the pulp chamber using a low-speed diamond saw (Minitom, Strauss, Copenhagen, Holland).

Cementation of Provisional Restorations

Disk-shaped specimens (10 × 2 mm) were produced using a Teflon mold. Acrylic provisional crown restoration material (Dentalon Plus, Heraeus Kulzer, Wehrheim, Germany) was mixed according to the manufacturer's recommendations. Following polymerization, specimens were removed from the mold and examined for air bubbles and size. Within the working time of the provisional cement

(Cavex, Haarlem, Holland), disk-shaped specimens were cemented to dentin surfaces using a hydraulic press (Rucher PHI, Birmingham, United Kingdom) and a load of 20 psi (140 kPa). Specimens were stored in distilled water at 37 ± 2°C for 2 days.

Experimental Design

Specimens were randomly assigned to one of six groups (n = 5) according to different dentin cleaning regimes as given in Table 1.

Table 1: Different dentin cleaning protocols

	Provisional cement removing method
G1	(control group) explorer
G2	Pumice
G3	Rotary instrument (Opticlean, Kerr, CA, USA)
G4	Er:YAG laser (Fidelis Plus 3, Fotona, Ljubljana, Slovenia) at 200 mJ and 15 Hz
G5	Er:YAG laser (Fidelis Plus 3, Fotona, Ljubljana, Slovenia) at 200 mJ and 15 Hz
G6	Er:YAG laser (Fidelis Plus 3, Fotona, Ljubljana, Slovenia) at 150 mJ and 15 Hz

For each Er:YAG laser group (G4, G5 and G6), the laser was applied with an air/water spray using a pulse duration of 100 µs, tip diameter of 800 nm and working distance (between the tip and the dentin surface) of 0.5 mm.

Scanning Electron Microscopic Analysis

Specimens were sputter-coated with gold (Bal-Tec SCD 050 Sputter Coater; Bal-Tec AG, Liechtenstein) and examined with a scanning electron microscopic (SEM) (LEO 440, UK) at 500×, 1,000× and 1,500× magnification for provisional cement remnants. All micrographs were evaluated by three qualified blinded examiners using the rating system described by Theodoro et al (Table 2).[16] Smear layer removal scores were subjected to statistical analysis, with dentin cleaning regimes G1-G6 considered independent variables. The nonparametric Kruskal-Wallis test was used for comparisons among groups and Tukey's post hoc test was used for multiple pairwise comparisons. All statistical analysis was conducted using the computer software SigmaStat (Aspire Software International, WA, USA).

RESULTS

Group 1

Four specimens were rated 7 (heavy remnants of provisional cement, partially open dentinal tubules), and one specimen was rated 6 (moderate smear layer, partially open dentinal tubules).[16]

Group 2

Four specimens were rated 3 (no remnants of provisional cement, obliterated dentinal tubules), and one specimen was rated 2 (no remnants of provisional cement, partially open dentinal tubules).[16]

Group 3

Four specimens were rated 5 (moderate remnants of provisional cement, partially open dentinal tubules), and one specimen was rated 4 (moderate remnants of provisional cement, cracking and fissuring).[16]

Group 4

Three specimens were rated 2 (no remnants of provisional cement, partially open dentinal tubules), and two specimens were rated 3 (no remnants of provisional cement, obliterated dentinal tubules).[16]

Group 5

Three specimens were rated 1 (no remnants of provisional cement), and two specimens were rated 2 (no remnants of provisional cement, partially open dentinal tubules).[16]

Group 6

All specimens were rated 2 (no remnants of provisional cement and partially open dentinal tubules).[16]

Results of statistical analysis are given in Table 3. Statistical analysis was performed using analysis of variance (ANOVA), with a minimum sample size of 3.96 required for a 95% confidence level ($p < 0.05$). A non-parametric Kruskal-Wallis test performed with each group as an independent variable showed significant differences in the

Table 2: The rating system used to analyze the micrographs[16]

Description	*Scores*
No smear layer and open dentinal tubules	1
No smear layer and partially open dentinal tubules	2
No smear layer and obliterated dentinal tubules	3
Moderate smear layer and open dentinal tubules	4
Moderate smear layer and partially open dentinal tubules	5
Heavy smear layer and open dentinal tubules	6
Heavy smear layer and partially open dentinal tubules	7

Table 3: Different superscripts indicate post hoc significance ($p < 0.05$)

	Median	*25-75%*
Group 1	7^{a}	7-7
Group 2	3^{cd}	2.25-3
Group 3	5^{ac}	4.25-5
Group 4	2^{bd}	2-3
Group 5	2^{be}	1-2
Group 6	2^{de}	2-2

amount of cement remnants among groups ($p < 0.001$). Tukey's post hoc test showed all groups except G3 (rotary instrument) had significantly less cement remnants when compared to G1 (control group; $p < 0.05$). Statistically significant differences were also found between G3 and G4, G5 and G6 (laser groups; $p < 0.05$) and between G2 (pumice) and G5 ($p < 0.05$).

DISCUSSION

A clinically successful restoration requires durable, predictable bond strength between dental materials and teeth.[17] Remnants of provisional cement on dentin surfaces is one problem that has been associated with ill-fitting restorations.[18]

This study used an SEM to determine the optimum parameters for cleaning dentin with an Er:YAG laser and to compare the results of laser cleaning with those of other dentin-cleaning protocols.

After tooth preparation, dentin is covered with a smear layer composed primarily of cut, mineralized collagen fibers. Although remnants of provisional cement may remain on the smear layer following cement removal,[19] removal of the smear layer will also remove any remnants of the cement.

In line with a study by Terata,[20] in our study, a heavy smear layer was observed on the specimens cleaned with an explorer only (G1) (Fig. 1). With the exception of this control group (G1), remnants of provisional cement were successfully removed from the specimens in all the groups in our study, whereas the specimens in the control group required further cleaning, as the use of a dental explorer alone was unable to remove all provisional cement from the dentin surfaces.

Specimens cleaned with pumice (G2) showed no smear layer and obliterated dentinal tubules (Fig. 2). Grasso et al[6] found that cleaning with pumice removed the remnants of provisional cement more effectively than cleaning with an explorer or with a cotton pellet. However, pumice residue has been shown to remain on dental surfaces following cleaning.[18] Furthermore, the smooth surfaces obtained with pumice may have a negative effect on the strength of the bond between cement and dentin surfaces.

A moderate smear layer, partially open dentinal tubules and cracks and fissures were observed on the specimens cleaned with a rotary instrument (G3) (Fig. 3). Moreover, remnants of provisional cement appeared to be smeared on the dentin surface. Sarac et al[21] showed similar findings, and they concluded that cleaning with a rotary instrument might lead to a decrease in the shear bond strength between dentin and cement as a result of provisional cement plugging dentinal tubules due to the force of rotation. In the present study, the use of a rotary instrument resulted in moderately successful cleaning.

The use of an Er:YAG laser for cleaning has not been previously reported on in the literature. This study found an Er:YAG laser to be effective in removing provisional

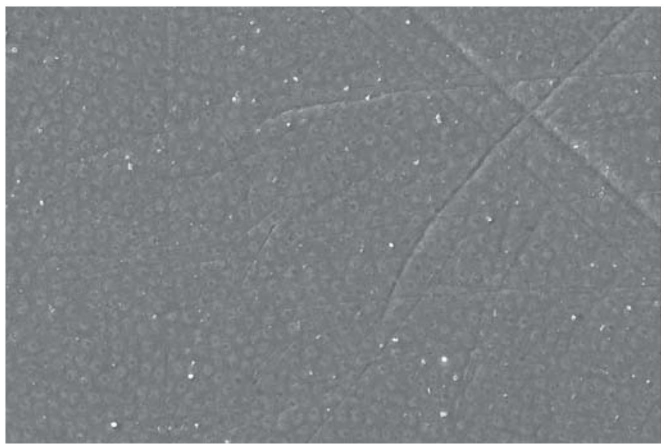

Fig. 2: An SEM micrograph (1500×) of a specimen cleaned of provisional cement using pumice (G2) shows no smear layer and obliteration of dentinal tubules on the dentin surface

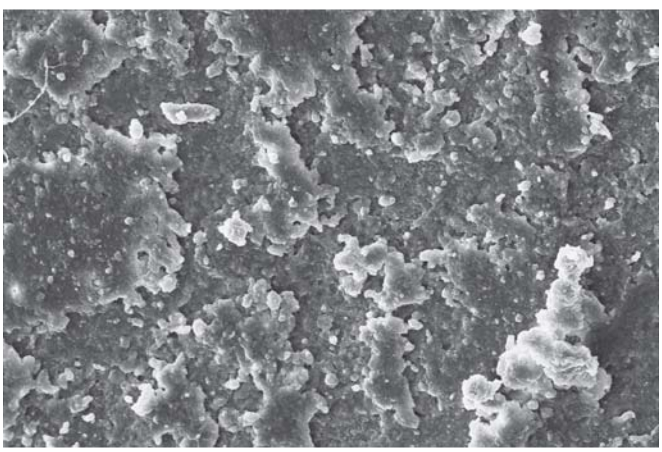

Fig. 1: An SEM micrograph (1500×) of a specimen cleaned of provisional cement using an explorer (control group) (G1) shows a heavy smear layer covering the dentin surface

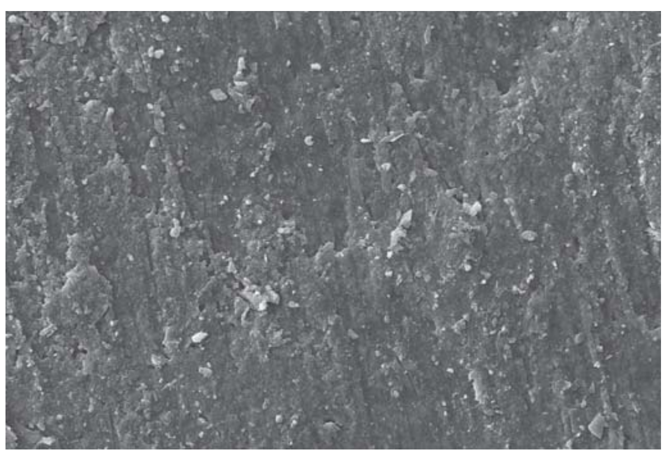

Fig. 3: An SEM micrograph (1500×) of a specimen cleaned of provisional cement using a rotary instrument (G3) shows a moderate smear layer and partially open dentinal tubules on the dentin surface

cement remnants. Moreover, cleaning with an Er:YAG laser (G4, G5 and G6) yielded significantly better results than cleaning with an explorer (G1) and cleaning with pumice (G3), whereas no differences were observed in the results among the different Er:YAG laser protocol groups (G4, G5 and G6).

Although laser irradiation was found to effectively remove the remnants of provisional cement, analysis of micrographs demonstrated laser cleaning resulted in irregularities on the dentin surface; however, no craters, cracks or fractures were observed. These findings are in line with other previous studies.[22-24] In the present study, carbonization was also seen on some specimens cleaned using an Er:YAG laser (G5) (Figs 4 and 5). SEM evaluation showed Er:YAG cleaning produced certain characteristics that are considered advantageous for resin bonding, namely, a rough surface, open dentine tubules and no smear layer. However, Er:YAG laser irradiation was also found to produce chemical changes and denaturation of the dentin surface. Denatured dentin surfaces typically exhibited a scaly appearance with melted collagen fibrils.[25] This indicates changes in the binding energy of the dentin surfaces, suggesting that further studies, especially with regard to bond strength testing, are required.

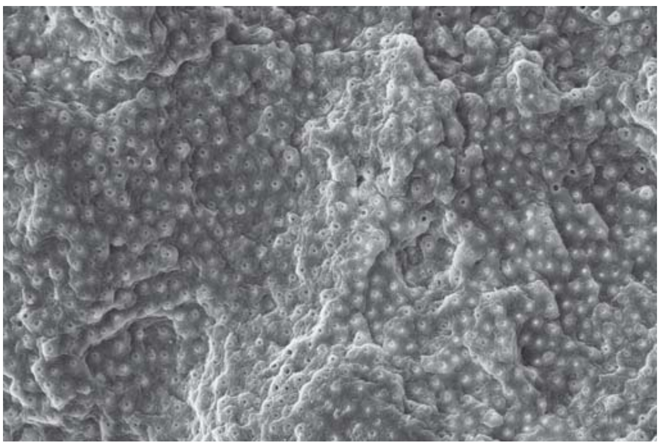

Fig. 4: An SEM micrograph (1500×) of a specimen cleaned of provisional cement using an Er:YAG laser at 200 mJ and 15 Hz (G4) shows no smear layer and partially open dentinal tubules on the dentin surface

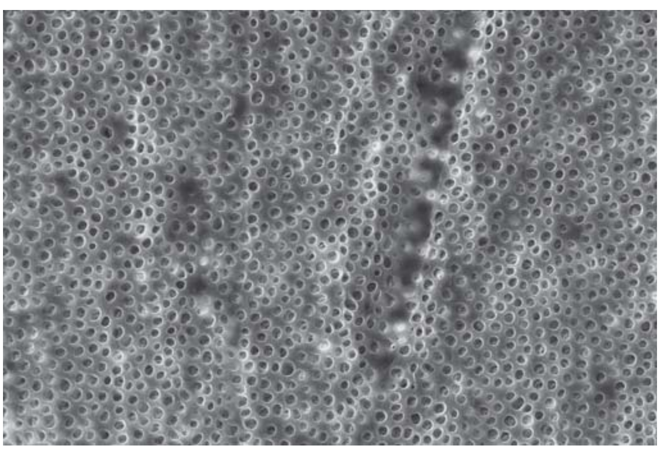

Fig. 5: An SEM micrograph (1500×) of a specimen cleaned of provisional cement using an Er:YAG laser at 200 mJ and 20 Hz (G5) shows no smear layer and wide-open dentinal tubules on the dentin surface

Despite the successful removal of provisional cement remnants by laser cleaning, the findings of this study suggest that laser cleaning may also remove a certain amount of tooth structure, which, although minimal, could affect the fit of the final crown.

As with all *in vitro* SEM studies, the present study has certain inherent limitations. Moreover, the use of different provisional cement and/or different dentin-cleaning agents may have produced different results. Thus, further studies are required to better understand the effects of laser cleaning on restoration success.

CONCLUSION

Within the limitations of this study, significant differences were found among the different cleaning techniques evaluated. Laser application was found to be effective in the removal of provisional cement remnants, whereas the use of an explorer alone was found to be the least effective method tested.

REFERENCES

1. Terata R, Nakashima K, Kubota M. Effect of temporary materials on bond strength of resin-modified glass-ionomer luting cements to teeth. Am J Dent 2000;4:209-11.
2. Terata R, Nakashima K, Obara M, Kubota M. Characterization of enamel and dentin surfaces after removal of temporary cement effect of temporary cement on tensile bond strength of resin luting cement. Dent Mater J 1994;2:148-54.
3. Watanabe EK, Yamashita A, Imai M, Yatani H, Suzuki K. Temporary cement remnants as an adhesion inhibiting factor in the interface between resin cements and bovine dentin. Int J Prosthodont 1997;5:440-52.
4. Woody TL, Davis RD. The effect of eugenol-containing and eugenol-free temporary cements on microleakage in resin bonded restorations. Oper Dent 1992;5:175-80.
5. Bachmann M, Paul SJ, Luthy H, Scharer P. Effect of cleaning dentine with soap and pumice on shear bond strength of dentine-bonding agents. J Oral Rehabil 1997;6:433-38.
6. Grasso CA, Caluori DM, Goldstein GR, Hittelman E. In vivo evaluation of three cleansing techniques for prepared abutment teeth. J Prosthet Dent 2002;4:437-41.
7. Sarac D, Bulucu B, Sarac YS, Kulunk S. The effect of dentin-cleaning agents on resin cement bond strength to dentin. J Am Dent Assoc 2008;6:751-58.
8. Abo-Hamar SE, Federlin M, Hiller KA, Friedl KH, Schmalz G. Effect of temporary cements on the bond strength of ceramic luted to dentin. Dent Mater 2005;9:794-803.
9. Hibst R, Keller U. Experimental studies of the application of the Er:YAG laser on dental hard substances: I. Measurement of the ablation rate. Lasers Surg Med1989;4:338-44.

10. Keller U, Hibst R. Experimental studies of the application of the Er:YAG laser on dental hard substances: II. Light microscopic and SEM investigations. Lasers Surg Med 1989;4:345-51.
11. Scatena C, Torres CP, Gomes-Silva JM, et al. Shear strength of the bond to primary dentin: Influence of Er:YAG laser irradiation distance. Lasers Med Sci 2011;3:293-97.
12. Kameyama A, Kato J, Aizawa K, et al. Tensile bond strength of one-step self-etch adhesives to Er:YAG laser-irradiated and non-irradiated enamel. Dent Mater J 2008;3:386-91.
13. 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;7:616-24.
14. Gurgan S, Kiremitci A, Cakir FY, et al. Shear bond strength of composite bonded to Er,Cr:YSGG laser-prepared dentin. Photomed Laser Surg 2008;5:495-500.
15. Trajtenberg CP, Pereira PN, Powers JM. Resin bond strength and micromorphology of human teeth prepared with an Erbium:YAG laser. Am J Dent 2004;5:331-36.
16. Theodoro LH, Zezell DM, Garcia VG, et al. Comparative analysis of root surface smear layer removal by different etching modalities or erbium:yttrium-aluminum-garnet laser irradiation. A scanning electron microscopy study. Lasers Med Sci 2010; 4:485-91.
17. Ergun G, Cekic I, Lassila LV, Vallittu PK. Bonding of lithium-disilicate ceramic to enamel and dentin using orthotropic fiber-reinforced composite at the interface. Acta Odontol Scand 2006;5:293-99.
18. Kanakuri K, Kawamoto Y, Matsumura H. Influence of temporary cement remnant and surface cleaning method on bond strength to dentin of a composite luting system. J Oral Sci 2005;1:9-13.
19. Rosales-Leal JI, Osorio R, Toledano M, Cabrerizo-Vilchez MA, Millstein PL. Influence of eugenol contamination on the wetting of ground and etched dentin. Oper Dent 2003;6:695-99.
20. Terata R. Characterization of enamel and dentin surfaces after removal of temporary cement study on removal of temporary cement. Dent Mater J 1993;1:18-28.
21. Sarac D, Sarac YS, Kulunk S, Kulunk T. Effect of the dentin cleansing techniques on dentin wetting and on the bond strength of a resin luting agent. J Prosthet Dent 2005;4:363-69.
22. Aoki A, Miura M, Akiyama F, et al. In vitro evaluation of Er:YAG laser scaling of subgingival calculus in comparison with ultrasonic scaling. J Periodontal Res 2000;5:266-77.
23. Folwaczny M, Mehl A, Haffner C, Benz C, Hickel R. Root substance removal with Er:YAG laser radiation at different parameters using a new delivery system. J Periodontol 2000;2:147-55.
24. Yamaguchi H, Kobayashi K, Osada R, et al. Effects of irradiation of an erbium:YAG laser on root surfaces. J Periodontol 1997;12:1151-55.
25. Omae M, Shinnou Y, Tanaka K, et al. XPS analysis of the dentin irradiated by Er: YAG laser. Dent Mater J 2009;4:471-76.

ABOUT THE AUTHORS

Hasanönder Gümüş (Corresponding Author)

Assistant Professor, Department of Prosthetic Dentistry, Faculty of Dentistry, Erciyes University, Melikgazi, Kayseri-38039, Turkey Phone: +90-3524380656, Fax: +90-3524380657, e-mail: ondergumus@yahoo.com

Mustafa Zortuk

Associate Professor, Department of Prosthetic Dentistry, Faculty of Dentistry, Erciyes University, Kayseri, Turkey

Halil İbrahim Kilinç

Research Assistant, Department of Prosthetic Dentistry, Faculty of Dentistry, Erciyes University, Kayseri, Turkey

Ali Rıza Tunçdemır

Assistant Professor, Department of Prosthetic Dentistry, Faculty of Dentistry, Mustafa Kemal University, Hatay, Turkey