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ORIGINAL ARTICLE

# Bond strength of self-adhesive resin cement to root dentin. Comparison of photon-initiated photoacoustic streaming technique with needle and ultrasonic irrigation

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**Abstract**

***Objective.*** The aim of this study was to investigate the effects of photon-initiated photoacoustic streaming (PIPS) with various irrigating solutions on the bond strength of a self-adhesive resin cement to root dentin. ***Materials and methods.*** Seventy-two mandibular premolar roots were divided into six groups after post space preparation and treated with a needle irrigation with distilled water and NaOCl, ultrasonic irrigation with NaOCl, PIPS with NaOCl, PIPS with EDTA and PIPS with distilled water at 0.3 W, 15 Hz and 20 mJ per pulse for 60 s. Fiber posts were cemented with a newly marketed, self-adhesive resin cement. The data obtained from the push-out tests were analyzed using analysis of variance (ANOVA) and LSD post-hoc tests ($p = 0.05$). ***Results.*** PIPS with distilled water resulted in higher push-out values than those of needle (with both distilled water and NaOCl) and ultrasonic irrigation ($p < 0.05$). ***Conclusions.*** The use of PIPS may provide higher bond strength of self-adhesive resin cement to root dentin than needle and ultrasonic irrigation techniques.

**Key Words:** *bond strength, fiber post, photoacoustic streaming, self-adhesive resin cement, ultrasonic*

## Introduction

Fiber reinforced composite (FRC) posts have been widely used in restoring endodontically treated teeth to retain coronal restoration. FRC posts have a modulus of elasticity close to that of dentin [1,2]. They also have a good esthetic appearance, with no risk of gingival discoloration of the root surfaces due to corrosive products [3]. The longevity of the restorations depends on many factors, such as the effectiveness and durability of the bonding between the post, dentin, and the adhesive resin cement [4]. Effective bonding can contribute to reduced stress being generated on the root canal walls, thereby strengthening the remaining tooth structure and decreasing the risk of fracture [5,6].

The efficacies of various irrigating solutions were investigated as pre-treatment agents before the FRC post placement [3,7]. Recently, a novel laser agitation technique, photon-induced photoacoustic streaming (PIPS), has been proposed. This technique differs from other agitation techniques insofar as it involves the placement of only the tip into the coronal portion [8]. In this technique, an erbium:yttrium-aluminum-garnet (Er:YAG) laser is used with a radial and stripped tip of novel design at sub-ablative power settings. DiVito et al. [9] demonstrated that it results in a significantly better cleaning of the root canal walls.

Various strategies have been proposed to lute FRC posts to root dentin. Conventional dual-cured resin cements require the prior application of adhesive systems. Self-adhesive cements do not require any surface treatment of the root canals. They are easier to handle and have clinically effective bond strength [10]. The chemical reaction between the phosphate methacrylates in the self-adhesive cements and hydroxyapatite in dentin provides bonding [11].

The aim of this study was to evaluate the effect of PIPS with various irrigating solutions on the bond

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strength to root dentin of a self-adhesive resin cement as compared to needle and ultrasonic irrigation. The null hypothesis of this study was that there were no significant differences among the techniques in terms of adhesion between the self-adhesive resin cement and root dentin.

## Materials and methods

Human mandibular premolar teeth were selected from a collection of teeth that had been recently extracted for reasons unrelated to this study and stored in distilled water until use. Soft tissue and calculus were removed mechanically from the root surfaces with a periodontal scaler. Teeth with root canal treatment, restoration, immature root apices and/or coronal defects were excluded from the study. The teeth were verified radiographically as having a single root canal without calcification. According to these criteria, 72 mandibular premolar teeth were selected.

Each tooth was decoronated using a diamond disc (Diamond disc superflex 910S/220; North Bel, Italy) operated perpendicularly to its longitudinal axis to obtain a standardized root length of 15 mm. A size #15stainless steel K-file (Dentsply-Maillefer, Ballaigues, Switzerland) was moved down in the canal until the file was just visible. The working length was set by deducting 1 mm from this. The root canals were shaped with ProTaper rotary instruments (Dentsply-Maillefer) up to a size #40 (F4) at working length. The root canals were irrigated with 2 mL of 5% NaOCl (ImidentMedEndosolve-HP, Konya, Turkey) between instrument changes. The apexes of the specimens were closed with boxing wax and the root canals were irrigated first for 120 s with 5 mL of 17% ethylenediaminetetraacetic acid (EDTA) as a final flush and then for 120 s with 5 mL of 5% NaOCl, followed by a final rinse with 5 mL of distilled water to remove the smear layer.

The specimens were dried using paper points, with a single gutta-percha cone (F4; Dentsply-Maillefer) slightly coated with AH Plus (Dentsply DeTrey, Kontanz, Germany) and placed into the root canal to the working length. Temporary filling material (Cavit G; 3M ESPE, Seefeld, Germany) was used to seal the coronal orifice. After storage at 100% humidity for 1 week at 37°C; a portion of the root canal filling material was removed with gates-glidden drills. A 10-mm deep post space was made using a 1.4-mm size drill (Cytec Carbon; Hahnenkratt GmbH, Königsbach-Stein, Germany). The specimens were randomly divided into six groups ($n$ = 12), as follows:

- *Needle irrigation with distilled water*: 5 mL of distilled water via a size 27 gauge blunt-tip needle (Ultradent, UT) was used for 60 s in this group.
- *Needle irrigation with NaOCl*: 5 mL of 5% NaOCl was used for 60 s in this group.
- *Ultrasonic irrigation with NaOCl*: 5 mL of 5% NaOCl was continuously activated via an ultrasonic device (Anthos u-PZ6, Imola, Italy). An ultrasonic file (size 15: 0.02 taper) was placed into the post space without touching the walls, enabling it to vibrate freely. The ultrasonic file was activated at 25% power for a total of 60 s.
- *PIPS with NaOCl*: 5 mL of 5% NaOCl was continuously activated via an Er:YAG laser with a wavelength of 2940 nm (Fidelis AT; Fotona, Ljubljana, Slovenia). A 14-mm long, 400-micron quartz tip was inserted into the post space as coronally as possible and applied at 0.3 W, 15 Hz and 20 mJ per pulse for 60 s. The water and air in the laser system were turned off.
- *PIPS with EDTA*: 5 mL of 17% EDTA was activated as stated above.
- *PIPS with distilled water*: 5 mL of distilled water was activated as stated above.

The flow rate of the irrigating solutions in all groups was 0.08 mL/s. After the procedures, the post space was irrigated with 5 mL distilled water and dried using paper points. Self-adhesive resin cement (RelyX U200; 3M ESPE, Seefeld, Germany) was applied directly into the post space. Size #2 carbon fiber posts (1.4 mm diameter) (Cytec Carbon; Hahnenkratt GmbH, Königsbach-Stein, Germany) were inserted into the post space. Excess cement was removed and light-cured for 40 s. The coronal opening was sealed using composite resin and the specimens were stored at 100% humidity, 37°C for 24 h to completely set. Each specimen was sectioned perpendicular to its long axis using a diamond disc (Arbor; Extec, Enfield, CT) and a precision saw (Isomet 1000; Buehler, Lake Bluff, IL) at a low speed with water cooling. Two slices of a 1 ± 0.1-mm thickness were obtained from each tooth ($n$ = 24 for each group). The definitive thicknesses of the slices were recorded after measurement using a digital caliper. The diameter of each post was measured under a stereomicroscope (Zeiss Stemi 2000C; Carl Zeiss, Jena, Germany) at 32× magnification.

A push-out test was performed on each specimen with a universal test machine (AGS-X; Shimadzu Corporation, Tokyo, Japan) at a crosshead speed of 0.5 mm per minute. The maximum load at failure was recorded in Newtons (N) and converted to MPa by dividing the load by A, the bonded area. The bonded area was calculated using the formula $A = 2\pi rh$, where $h$ represents the thickness of the section (mm) and $r$ the radius of the post segment (mm) [12–14].

After the test procedure, each specimen was visually examined under a stereomicroscope (Zeiss Stemi 2000C; Carl Zeiss) at 32× magnification to evaluate

Table I. Bond strength ± standard deviation and failure modes in the groups.

| Group | $n$ | Bond strength ± SD | Failure modes | | |
|---|---|---|---|---|---|
| | | | Adhesive | Cohesive | Mixed |
| Needle irrigation with distilled water | 24 | $4.81 \pm 2.16^{bc}$ | 24 (100) | 0 (0 %) | 0 (0%) |
| Needle irrigation with NaOCl | 24 | $3.50 \pm 2.86^{a}$ | 23 (95.8%) | 0 (0 %) | 1 (4.2%) |
| Ultrasonic irrigation with NaOCl | 24 | $3.93 \pm 2.19^{ac}$ | 23 (95.8%) | 0 (0 %) | 1 (4.2%) |
| PIPS with NaOCl | 24 | $5.20 \pm 1.44^{b}$ | 20 (83.3%) | 3 (12.5%) | 1 (4.2) |
| PIPS with EDTA | 24 | $5.00 \pm 2.43^{bc}$ | 18 (75%) | 5 (20.8%) | 1 (4.2%) |
| PIPS with distilled water | 24 | $6.48 \pm 1.20^{d}$ | 14 (58.3%) | 8 (33.3 %) | 2 (8.3%) |

*Different letters shows the statistically significant differences.

failure mode. Three types of failure were classified: adhesive failure (between the cement and root dentin); cohesive fracture (within the dentin, cement layer or post); and mixed (a combination of the two; cohesive and adhesive). Data were analyzed using one-way analysis of variance (ANOVA) and LSD post-hoc tests ($p = 0.05$). The failure mode data were analyzed using the chi-square test ($p = 0.05$). All statistical analyses were performed using IBM® SPSS® Statistics 20 software (IBM SPSS Inc., Chicago, IL).

## Results

Mean bond strength values, standard deviations and distribution of failure modes after the push-out test are shown inS Table I. PIPS with distilled water resulted in higher push-out values than those of needle (with both distilled water and NaOCl) and ultrasonic irrigation ($p < 0.05$) Figure 1.

For the needle groups, the NaOCl reduced the bond strength compared to distilled water. In the PIPS technique the use of distilled water resulted in higher push-out values than the use of NaOCl or EDTA ($p < 0.05$). There was no significant difference between the use of NaOCl and EDTA on the bond strength to root dentin of self-adhesive resin cement bond strength ($p = 0.743$). There was no statistically significant difference between needle and ultrasonic irrigation with NaOCl regarding the bond strength of self-adhesive resin cement bond strength to root dentin ($p > 0.05$). Adhesive failure between cement and dentin was the most frequent type of failure mode in all groups (Table I).

## Discussion

The results from the present study did not support the null hypothesis, the PIPS technique was found to be superior to needle and ultrasonic irrigation. The higher mean bond strength values observed in the PIPS group may have been due to the fact that this technique is able to remove materials like the debris-smear layer on root canal walls that could negatively affect good bonding [9]. Er:YAG laser irradiation is highly absorbed by hydroxyapatite and water [15,16]. When Er:YAG laser irradiation is absorbed by water, the vapor bubble starts to expand and form a void in

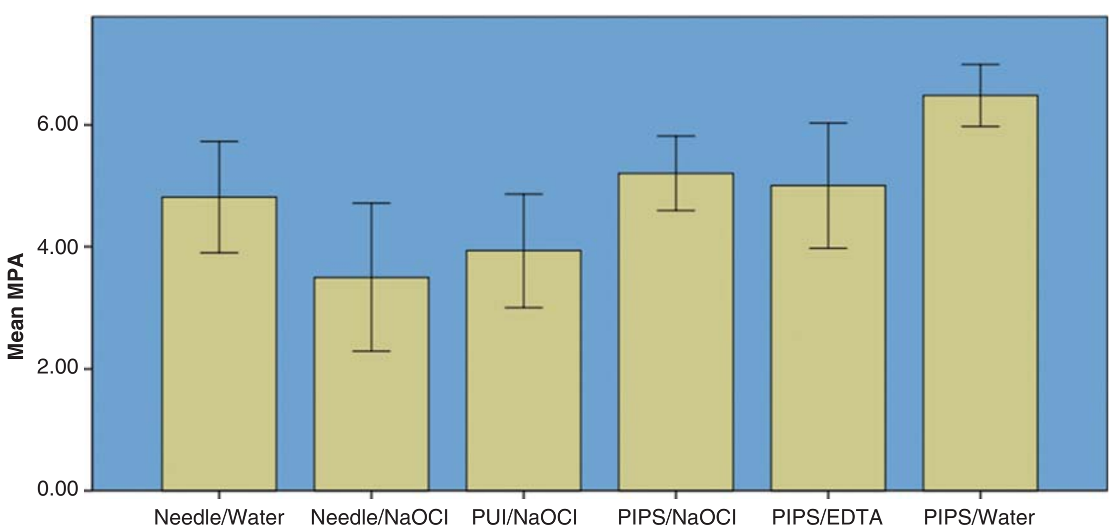


Figure 1. Mean bond strength of self-adhesive resin cement to root dentin after needle irrigation, ultrasonic irrigation, and PIPS.

front of the laser light. This causes shock waves and streaming of the liquid [17,18]. In a previous study, the bubble was shown to increase in size and reached up to 1800 μm in 220 μs [19]. It was observed that, when the laser tip was inserted to 2 mm and 5 mm short of the bottom of an artificial (glass) root canal model, the second cavitation bubbled at the bottom. Thus, it is not always necessary to insert the laser tip up to the apex, because the cavitation bubbles also assist in cleaning the apical region. The present study has confirmed this finding in real human teeth. Although the ultrasonic file was inserted into the apical part of the post space, PIPS was found to be the most effective technique. This suggests that PIPS may be beneficial in obtaining high bond strength between self-adhesive resin cement and root dentin.

Meire et al. [20] investigated the absorption of different endodontic irrigating solutions including water, NaOCl, and EDTA at wavelengths between 300–3000 nm. They found that water and NaOCl showed a markedly high absorption (> 40) at 2.940 nm (Er:YAG laser), while EDTA showed less absorption (= 33.5). Thus, in the present study, PIPS technique described for Er:YAG laser (2.940 nm) was used with different irrigating solutions and the effectiveness of the PIPS technique on the bond strength to the root canal dentin of a self-adhesive resin cement was evaluated for different irrigating solutions. Similar to the findings of Meire et al. [20], the use of distilled water in the PIPS technique was found to be superior to that of NaOCl and EDTA.

In the present study, the recently introduced RelyX U200 was used as self-adhesive resin cement. RelyX Unicem, ancestor of the RelyX U200, chemically interacts with calcium from hydroxyapatite. This interaction is the result of the chelation of the calcium ions by acid groups [11]. NaOCl and EDTA are widely used in the root canals to remove smear layer [21,22]. NaOCl removes the organic components and EDTA demineralized inorganic components. In the present study, NaOCl was found to be reducing the bond strength of self-adhesive resin cement to root dentin. Renovato et al. [14] used RelyX Unicem as a self-adhesive resin cement, which was the previous version of RelyX U200. They investigated the effect of irrigating solutions on the retention of glass-fiber posts luted with self-adhesive resin cement. According to the results of these investigators, EDTA and NaOCl irrigating solutions reduced the bond strength. This finding is harmonious with our findings.

## Conclusion

Within the limitation of the present study, the use of the PIPS technique with distilled water is shown to provide a higher bond strength to root dentin of self-adhesive resin cement as compared to needle and ultrasonic irrigation techniques. Needle and ultrasonic irrigation resulted in similar push-out values. Moreover, the use of distilled water in PIPS technique is shown to be advantageous in increasing the bond strength to the root canal dentin of self-adhesive resin cement tested in this study when compared to the use of NaOCl and EDTA.

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## References

[1] Asmussen E, Peutzfeldt A, Heitmann T. Stiffness, elastic limit, and strength of newer types of endodontic posts. J Dent 1999;27:275–8.
[2] Schwartz RS, Robbins JW. Post placement and restoration of endodontically treated teeth: a literature review. J Endod 2004;30:289–301.
[3] Cecchin D, de Almeida JF, Gomes BP, Zaia AA, Ferraz CC. Influence of chlorhexidine and ethanol on the bond strength and durability of the adhesion of the fiber posts to root dentin using a total etching adhesive system. J Endod 2011;37: 1310–15.
[4] Bonfante EA, Pegoraro LF, de Goes MF, Carvalho RM. SEM observation of the bond integrity of fiber-reinforced composite posts cemented into root canals. Dent Mater 2008;24:483–91.
[5] Boschian Pest L, Cavalli G, Bertani P, Gagliani M. Adhesive post-endodontic restorations with fiber posts: push-out tests and SEM observations. Dent Mater 2002;18:596–602.
[6] Butz F, Lennon AM, Heydecke G, Strub JR. Survival rate and fracture strength of endodontically treated maxillary incisors with moderate defects restored with different post-and-core systems: an *in vitro* study. Int J Prosthodont 2001;14:58–64.
[7] Cecchin D, de Almeida JF, Gomes BP, Zaia AA, Ferraz CC. Effect of chlorhexidine and ethanol on the durability of the adhesion of the fiber post relined with resin composite to the root canal. J Endod 2011;37:678–83.
[8] DiVito E, Lloyd A. ER:YAG laser for 3-dimensional debridement of canal systems: use of photon-induced photoacoustic streaming. Dent Today 2012;31(11):122,124–7.
[9] DiVito E, Peters OA, Olivi G. Effectiveness of the erbium: YAG laser and new design radial and stripped tips in removing the smear layer after root canal instrumentation. Lasers Med Sci 2012;27:273–80.
[10] Nakamura T, Wakabayashi K, Kinuta S, Nishida H, Miyamae M, Yatani H. Mechanical properties of new self-adhesive resin-based cement. J Prosthodont Res 2010; 54:59–64.
[11] Gerth HU, Dammaschke T, Zuchner H, Schafer E. Chemical analysis and bonding reaction of RelyX Unicem and Bifix composites–a comparative study. Dent Mater 2006; 22:934–41.
[12] Goracci C, Tavares AU, Fabianelli A, Monticelli F, Raffaelli O, Cardoso PC, et al. The adhesion between fiber

posts and root canal walls: comparison between microtensile and push-out bond strength measurements. Eur J Oral Sci 2004;112:353–61.

[13] Soares CJ, Santana FR, Castro CG, Santos-Filho PC, Soares PV, Qian F, et al. Finite element analysis and bond strength of a glass post to intraradicular dentin: comparison between microtensile and push-out tests. Dent Mater 2008; 24:1405–11.

[14] Renovato SR, Santana FR, Ferreira JM, Souza JB, Soares CJ, Estrela C. Effect of calcium hydroxide and endodontic irrigants on fibre post bond strength to root canal dentine. Int Endod J 2013;46:738–46.

[15] Paghdiwala AF. Does the laser work on hard dental tissue? J Am Dent Assoc 1991;122:79–80.

[16] Armengol V, Jean A, Rohanizadeh R, Hamel H. Scanning electron microscopic analysis of diseased and healthy dental hard tissues after Er:YAG laser irradiation: *in vitro* study. J Endod 1999;25:543–6.

[17] Brugnera A Jr, Zanin F, Barbin EL, Spanó JC, Santana R, Pécora JD. Effects of Er:YAG and Nd:YAG laser irradiation on radicular dentine permeability using different irrigating solutions. Lasers Surg Med 2003;33:256–9.

[18] Kivanc BH, Ulusoy OI, Gorgul G. Effects of Er:YAG laser and Nd:YAG laser treatment on the root canal dentin of human teeth: a SEM study. Lasers Med Sci 2008;23: 247–52.

[19] Matsumoto H, Yoshimine Y, Akamine A. Visualization of irrigant flow and cavitation induced by Er:YAG laser within a root canal model. J Endod 2011;37:839–43.

[20] Meire MA, Poelman D, De Moor RJ. Optical properties of root canal irrigants in the 300-3,000-nm wavelength region. Lasers Med Sci 2013;27:1307–14.

[21] Ahmetoglu F, Keles A, Yalcin M, Simsek N. Effectiveness of different irrigation systems on smear layer removal: a scanning electron microscopic study. Eur J Dent 2014;8: 53–7.

[22] Kalyoncuoglu E, Demiryurek EO. A comparative scanning electron microscopy evaluation of smear layer removal from teeth with different irrigation solutions and lasers. Microsc Microanal 2013;19:1465–9.