

Use of photosensitizers activated by photodynamic therapy on the canal disinfection of radicular dentin bonded to Dimethacrylate-based glass fiber post: an assessment of pushout bond strength

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Abstract. – OBJECTIVE: The present lab-based investigation aimed at evaluating the canal disinfectants using photodynamic therapy (PDT) using different photosensitizers, conventional NaOCl, a mixture of doxycycline, citric acid, and a detergent (MTAD) and their impact on the bond strength of glass fiber post to radicular dentin.

MATERIALS AND METHODS: Forty extracted human premolars were gathered and disinfected. The decoration was performed up to the cemento-enamel junction. Using the crown down technique cleaning of the canal was done following rinse with distilled water. All canals were dried with paper points and obturated with gutta-percha. Post space was prepared using peso reamers and samples were randomly allocated into four groups following different disinfection regimes: Group 1 – Methylene blue photosensitizer (MBP) + MTAD; Group 2 – RBP (Rose Bengal photosensitizer) + MTAD; Group 3 – CP (curcumin photosensitizer) + MTAD and Group 4 – 2.25% NaOCl + MTAD (control). Following disinfection, the canals were dried and the post was placed and cemented within the canal. Samples were dissected at coronal, middle, and apical third and placed in a universal testing machine for push-out bond strength (PBS). Debonded surfaces were evaluated for failure modes. PBS was examined using a one-way analysis of variance (ANOVA). The means of PBS were compared using Tukey multiple comparison tests with a significance threshold of ($p < 0.05$).

RESULTS: Group 3 canals disinfected with CP and MTAD had the highest PBS at two levels: cervical (9.57 ± 1.21 MPa), middle (6.37 ± 0.79 MPa), and group 2 canal space disinfected by RBP and MTAD had the maximum PBS in apical portion (5.35 ± 0.42 MPa). No significant difference at all root levels between group 2 (RBP + MTAD) and group 3 ($p > 0.05$). Canal irrigation with group 1 (MBP + MTAD) and group 4 control (2.25% NaOCl + MTAD) exhibited comparable PBS at all three levels of the root.

CONCLUSIONS: CP, MTAD, RBP and MTAD for canal disinfection and bonding of glass fiber post to radicular dentin demonstrated comparable bond values at all three root levels and can be recommended in clinical settings after further investigations.

Key Words:

Photosensitizers, Curcumin, Methylene blue, Rose Bengal, Canal disinfection, Push out bond strength.

Introduction

A positive endodontic outcome is achieved by chemo-mechanical preparation of the diseased root canal with antimicrobial agents (irrigants and medicaments), followed by obturation and coronal repair¹. The Chemo mechanical debridement method of the canals may reduce the bacte-

rial count but does not completely cleanse the canals leading to recurrent endodontic infection²⁻⁴. Apart from chemical cleansing and debridement of endodontically treated teeth to have a good prognosis, an impermeable seal in the coronal area is essential⁵. Sometimes, when there is an excessive coronal structure loss glass fiber-reinforced composite posts (FRCP) are an alternate treatment for repairing teeth. The fiber posts have the benefits of being esthetically favorable, corrosion-resistant, and simple to operate/remove if necessary⁶. The strength of the bond between the dentine-cement interface and the post-cement interface is essential for the retention of adhesively luted fiber-reinforced posts^{7,8}.

Among different chemical cleansers, sodium hypochlorite (NaOCl) is the most common canal disinfectant which debrides the canals for pursuing endodontic treatment and securing the viability of a tooth^{9,10}. It is inexpensive and is diluted in the range of 0.5% to 5.25%. However, its use interferes with the polymerization of resin cement, jeopardizing the post-dentine bond, and has an unpleasant odor and taste^{11,12}.

An alternative biocompatible cleansing solution has been introduced, combining a tetracycline isomer, an acid (citric acid), and a detergent (MTAD). It functions as a disinfectant in the root canal procedure and helps in the eradication of the smear layer with negligible erosion of dentinal tubules¹³. Being a calcium chelator, it delivers a long-lasting antimicrobial effect and optimizes adhesion capacity¹⁴. Two studies conducted by Torabinejad et al¹⁵ and Mortazavi et al¹⁶ revealed that a blend of 1.3% NaOCl as an endodontic irrigant with MTAD as ultimate cleanser was further effective against *E. faecalis* than 5.25% NaOCl with 17% EDTA.

Besides the standard treatment, photodynamic therapy (PDT) is an advanced and revolutionary endodontic disinfectant alternative^{17,18}. This procedure is non-invasive, reproducible, easy to use, and has no cytotoxic effects¹⁹⁻²¹. It improves the treatment outcome by its effective bactericidal property^{12,22}. It shows its effect by a combination of three components: photosensitizer (PS), light source, and oxygen – the so-called photodynamic antimicrobial chemotherapy^{23,24}. This photoactivated disinfection process includes the activation of photosensitizers by a certain wavelength of light to yield oxygen reactive species (singlet oxygen) which, as a result, exhibit antimicrobial activity and ultimately cause cell death²⁵. Even though PDT has resulted

in a significant reduction in the bacterial count, total eradication is neither possible nor guaranteed. Different photosensitizers, as for instance Methylene blue Photosensitizer (MBP), Rose Bengal Photosensitizer (RBP), and Curcumin Photosensitizer (CP), are used for absolute canal disinfection²⁶. They are innocuous (harmless) dyes and are photo-irradiated. Past studies on PDT have shown positive results in its function of cleansing the canals competently²⁷.

To our knowledge from current indexed literature, there seems to be no concrete proof of the disinfection capacities of standard (conventional) regimens (NaOCl, MTAD) and their effect on the bonding integrity of FRCP to radicular dentin. Furthermore, the data related to the efficacy of PDT (with MBP, RBP, and CP photosensitizers) as an endodontic disinfection process are limited. Additionally, no research comparing the new therapeutic techniques to traditional canal disinfection methods has been conducted. It is hypothesized that glass fiber posts will have superior bond integrity after disinfecting root canals with PDT and MTAD than conventional NaOCl and MTAD. Therefore, the present lab-based investigation aimed at evaluating the canal disinfectants using PDT (RBP, CP, MBP) with conventional NaOCl and MTAD and their impact on the bonding strength of glass fiber post to radicular dentin.

Materials and Methods

The current experimental investigation followed a checklist for reporting *in vitro* study (CRIS) guidelines. The study lasted three months. Forty extracted human premolars were gathered. Inclusion criteria: possess a non-carious, non-traumatized, and single straight canal with a closed full apex, and teeth. An ultrasonic scaler (Woodpecker Hw-51 Handpiece Optic Scaler, England, UK) was used to remove attached periodontal ligaments and calculi. All specimens were kept in a 0.5% thymol solution for 48 hours at a temperature of 4°C. To ensure a straight linear canal path, periapical radiographs were captured from both the mesiodistal and buccolingual sides for every examined tooth. De-coronation of specimens up to the cemento-enamel junction was performed employing a diamond bur (Kith Dent Supply, Mumbai, Maharashtra, India) under refrigeration, conserving 12 mm of root length. Specimens were implanted perpendicularly in

heat cure acrylic resin (Ortho Plast, Bulandshahr, Uttar Pradesh, India), using a Teflon mold with a 3 mm radius.

The endodontic process was performed on teeth with a K-file #10 (Dentsply NITI-flex K-File, Berlin, Germany) at a length of 1 mm shorter than the working length. The manual filing was used to expand the canals to a size of 25 K file. Mechanically, the canal was prepared using the crown down approach with the Protaper universal NiTi system (Dentsply Maillefer) which comprises shaping files S1, S2, SX, and finishing files F1 and F2. Canals were irrigated with distilled water during the cleaning and shaping process. Following chemical-mechanical preparation, the canals were dried using paper points (Meta Absorbent Paper Points - 4%, Dehli, India) and finally obturated with gutta-percha (Dentsply Gutta Percha Points, Mumbai, India) with AH Plus sealer (Dentsply AH Plus Root Canal Sealer, Dehli, India).

After completion of the endodontic procedure, the space for post-placement was prepared using three-peso reamers numbered 2, 3, and 4 in order. Gutta-percha was removed up to a 10 mm length. The samples were subsequently disinfected with various chemical irrigations and photosensitizers, and divided into 4 different groups (n=10) based on the chemical disinfectant administered.

Group 1: MBP + MTAD

MB photosensitizer (Sisco Research Lab. Pvt. Ltd, Maharashtra, India) was used to treat group 1 samples. A 50 mg/l solution of MBP was put in the canal for 180 seconds before irradiation. For equal distribution of the light source, a diode laser (Biolase Epic X Dental Diode Laser, Calcutta, India) with a fiber-optic tip (200 m) was employed at a 90° incidence angle. PS was activated using a wavelength of 638 nm, a frequency of 30 Hz, and a power of 2 W. After aspiration of MBP, the canal space was irrigated with MTAD.

Group 2: RBP + MTAD

Specimens in group 2 were treated with RB at a concentration of 5 µM (Innovative, Kalbadevi, Mumbai, Maharashtra, India). RB was activated using a light-emitting diode (LED, Ekon Electronics Kalbadevi, Mumbai, Maharashtra), with a wavelength of 480 nm at a power output of 200 mW and power density of 526 (mW/cm²) with a duration of laser 180 sec. Following RBP, the post space was disinfected by MTAD.

Group 3: CP + MTAD

CP photosensitizer was employed to treat the specimens in group 3. A 2.5 mg/ml solution was poured into the canal for 180 seconds before irradiation. The widespread radiation was achieved using a diode laser with a fiber-optic tip. Afterward, the canal was cleansed with MTAD.

Group 4: 2.25% NaOCl + MTAD (control)

All specimens in the control group were disinfected with a 2.25% NaOCl solution (Acuro Organics Limited, Mumbai, India), followed by MTAD disinfection for 60 seconds with a 30-gauge needle.

Post-Placement

The canals were dried with a paper point after post-space irrigation. The glass fiber post was cleaned in 70% ethanol and air-dried before being cemented in a post-specified area. Following the manufacturer's directions, the post was cemented with Panavia F 2.0 self-etch dual-cure cement (Kuraray Dental, Tokyo, Japan) and a light-emitting diode unit (Woodpecker Dental Curing Light, Bangalore, India) was used for the polymerization of the cement. For around 24 hours, samples were kept at 37°C in a 100% humid environment.

Vertically anchored specimens in acrylic blocks were dissected horizontally at the coronal, middle, and apical thirds using a diamond bur (Kith Dent Supply, Mumbai, Maharashtra) under copious irrigation. From each group, 30 sections were obtained in total (10 each coronal, middle and apical). To assess the bond strength of FRCP to radicular dentin, all slices were placed on a metallic mold of a universal testing machine (Universal Testing Machine-Dual Load Cells - 5kn, 30 kn-For Tensile Shear Adhesion Test, EIE Instruments Private Limited).

The fracture mode of the post following debonding was determined using a stereomicroscope at 40× magnification. The force necessary to debond the fiber post from the radicular dentin (MPa) is deliberated in Mega Pascal (MPa)

$$\text{Debond stress} = \frac{N}{\text{mm}^2}$$

Where N represents the maximum failure load and mm² represents the post-segment bonding area.

Table I. Means and Standard deviations (SD) of Push-out bond strength (MPa) values among experimental groups at cervical, middle, and apical levels of root.

Groups	Cervical	Middle	Apical
Group 1: MBP + MTAD	6.33 ± 0.19 ^{b,A}	5.61 ± 0.12 ^{b,A}	3.35 ± 0.81 ^{b,B}
Group 2: RBP + MTAD	9.47 ± 0.21 ^{a,A}	6.21 ± 1.07 ^{a,A}	5.35 ± 0.42 ^{a,B}
Group 3: CP + MTAD	9.57 ± 1.21 ^{a,A}	6.37 ± 0.79 ^{a,A}	5.01 ± 0.37 ^{a,B}
Group 4: 2.25% NaOCl + MTAD (control)	6.13 ± 1.26 ^{b,A}	5.01 ± 0.36 ^{b,A}	3.42 ± 0.39 ^{b,B}

Sodium hypochlorite (NaOCl); Mixture of Doxycycline, citric acid, and a detergent (MTAD); Methylene blue Photosensitizer (MBP); Rose Bengal Photosensitizer (RBP); Curcumin Photosensitizer (CP). Different superscript lower-case alphabets denote statistically significant difference within the same column ($p < 0.05$). Data with different upper-case alphabets denotes significant difference within each row ($p < 0.05$).

Statistical Analysis

The percentages of adhesive, cohesive, and ad-mixed failure patterns were identified. The means and standard deviations of PBS were examined using a one-way analysis of variance (ANOVA). The means of PBS were compared using Tukey multiple comparisons *t*-tests with a *p*-value significance < 0.05 .

Results

The homogeneity of data was assessed by the Shapiro Wilks test. Table I shows the values of PBS at all three levels: cervical, middle, and apical. Group 3 canals disinfected with CP and MTAD had the highest PBS at two levels: cervical (9.57±1.21 MPa), middle (6.37±0.79 MPa),

and group 2 canal space disinfected by RBP and MTAD had the maximum PBS in apical portion (5.35±0.42 MPa).

Intergroup comparison displayed that there is no significant difference in glass fiber post space disinfection at all root levels between group 2 (RBP + MTAD) cervical (9.47±0.21 MPa), middle (6.21±1.07 MPa), and apical (5.35±0.42 MPa) and group 3 (CP + MTAD) cervical (9.57±1.21 MPa), middle (6.37±0.79 MPa) and apical (5.01±0.37 MPa) ($p > 0.05$). Whereas, canal irrigation with group 1 (MBP + MTAD) cervical (6.33±0.19 MPa), middle (5.61±0.12 MPa) and apical (3.35±0.81 MPa), and group 4 control (2.25% NaOCl +MTAD) cervical (6.13±1.26 MPa), middle (5.01±0.36 MPa) and apical (3.42±0.39 MPa) exhibited comparable PBS at all three levels of root ($p > 0.05$) (Table I, Figure 1).

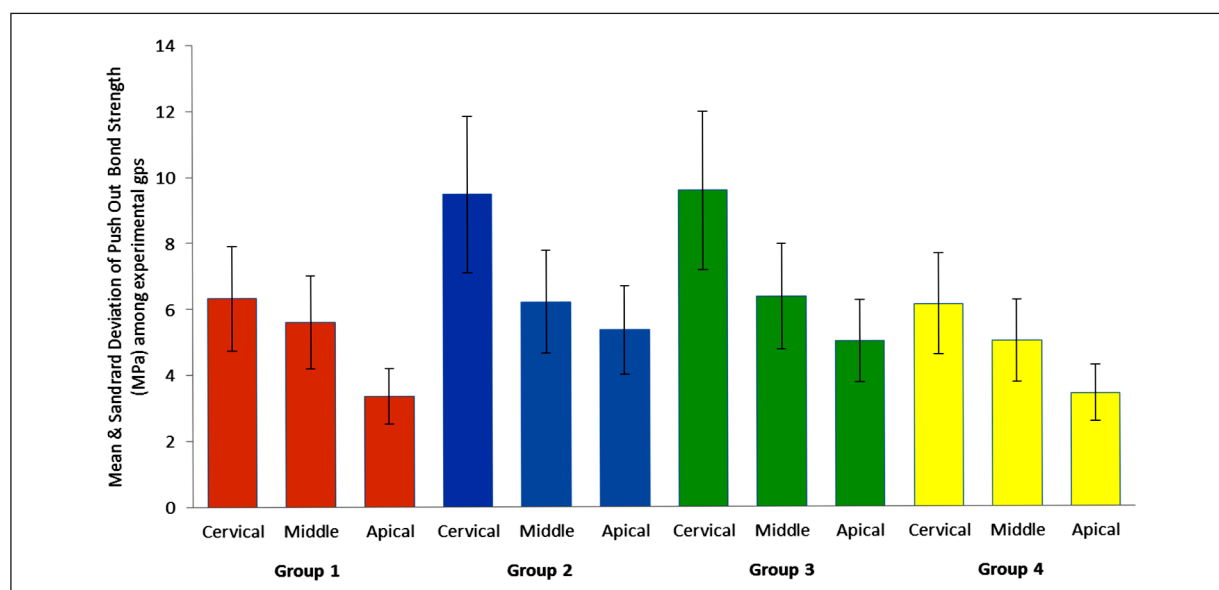


Figure 1. PBS (MPa) values among experimental groups at the cervical, middle, and apical levels of root.

Different superscript lower-case alphabets denote statistically significant differences within the same column ($p < 0.05$).

Data with different upper-case alphabets denote significant differences within each row ($p < 0.05$).

The intragroup comparison demonstrated that group 3 (CP + MTAD) showed the highest bond strength value at two levels, cervical (9.57 ± 1.21 MPa) and middle (6.37 ± 0.79 MPa). Correspondingly, the lowest push-out bond strength was shown by group 4 (2.25% NaOCl + MTAD) cervical (6.13 ± 1.26 MPa) and middle (5.01 ± 0.36 MPa), but in the apical area group 2 had the highest (5.35 ± 0.42 MPa) and group 1 showed the lowest (3.35 ± 0.81 MPa) push out bond strength. All groups had statistically decreased bond strength in the apical third compared to cervical and middle thirds ($p < 0.05$).

Figure 2 presents the results of the fracture analysis according to failure type. Admixed, adhesive between cement and post, and cohesive (within resin cement) failure types were identified. Adhesive failure was the most common type of failure in groups 1, 2, and 4. However, group 3 had a high percentage of admixed failure types in all three root segments.

Discussion

The present *in vitro* study was based on the hypothesis that antimicrobial efficacy and bond

strength of FRCP to radicular dentin after disinfecting root canals with PDT photosensitizers and MTAD will display better results compared to conventional disinfecting technique (2.25% NaOCl and MTAD). The outcome of the current study revealed that better antibacterial characteristics and improved bond strength of FRCP to root dentin were found in samples treated with CP, RBP, and MTAD at all levels (cervical, middle, and apical). As a result, the hypothesis was partially approved. PBS was used to assess the strength between GFP and radicular dentin. The test was useful because it mimicked oral circumstances and transferred stress uniformly throughout the long axis of the radicular dentin²⁸. PBS had a higher sensitivity, easy positioning of samples, and a lower failure rate²⁹. When compared to other testing methods, PBS showed the benefit of measuring several test samples from a single root structure and comparing them to other researched groups.

Specimens in group 4 control treated with 2.25% NaOCl + MTAD at cervical (6.13 ± 1.26 MPa), middle (5.01 ± 0.36 MPa), and apical (3.42 ± 0.39 MPa) exhibited comparable PBS at all three levels of root to samples in group 1 (MBP + MTAD) cervical (6.33 ± 0.19 MPa), middle (5.61 ± 0.12 MPa) and apical (3.35 ± 0.81 MPa). This outcome can be explained in a variety of ways. The antibacterial effect of NaOCl is due to chlorine (Cl) and oxygen (O_2) in NaOCl. NaOCl alone as a canal irrigant reduces bond strength due to its oxidative nature. The released

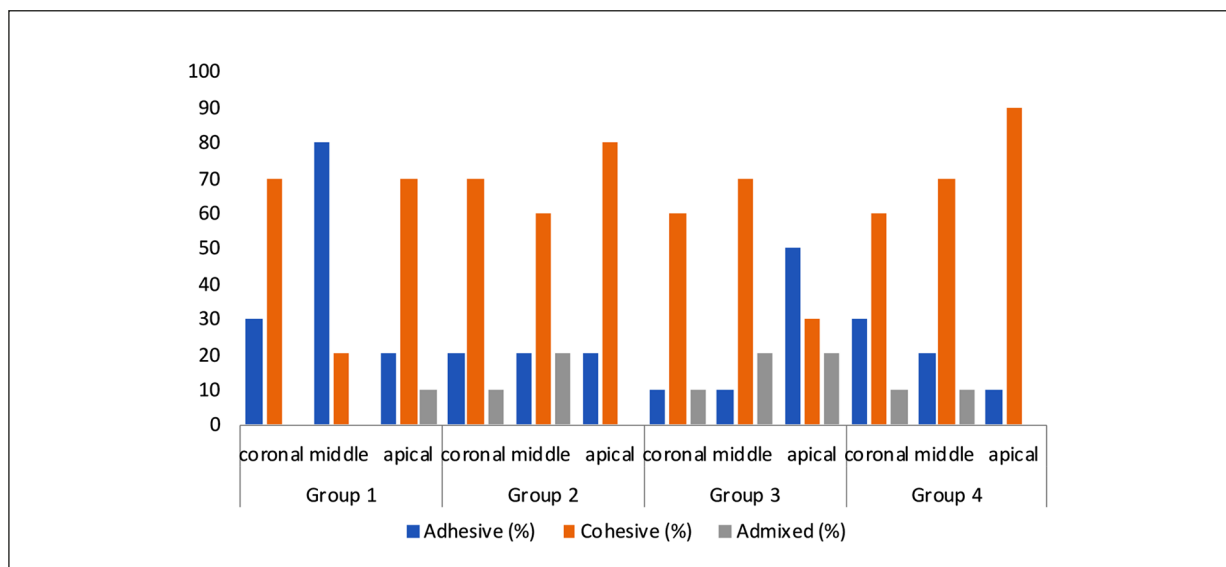


Figure 2. Percentage of fracture according to failure type.

oxygen interferes with resin cement polymerization, decreasing bond strength⁵. Also, collagen degradation happens, which fails links between carbon atoms and dentinal collagen³⁰. The use of MTAD over other irrigation solutions may be advantageous because it appears to be successful in eliminating both organic and inorganic debris, and have an antimicrobial impact³¹. The effect of MTAD on the bonding strength of fiber post to radicular dentin has never been investigated, according to the authors' knowledge. NaOCl when used as a first rinse and MTAD as a final rinse, a chemical reaction occurs, resulting in the production of a brown solution in the root canal³². It has been hypothesized that this is caused by doxycycline absorption in MTAD which hinders the bonding of fiber post to dentin, compromising bond values¹⁴. Moreover, low bond scores were noted at all three levels of root structure when radicular dentin was disinfected by MBP³³. MBP is both cationic and hydrophilic. Poor MBP absorption by Calcium and Phosphate ions in dentin may have influenced the findings of our study and led to the present conclusion which is also consistent with the findings of previous research³⁴.

Canal disinfected by RBP and CP activated by PDT showed increased bond strength at all three levels, cervical, middle, and apical thirds compared to specimens disinfected by MBP and NaOCl. In the authors' opinion, irradiation with a higher concentration of curcumin PS, along with blue LED light activation, caused significant changes in the dentin substrate, promoting the generation of hydrogen peroxide (H_2O_2) that can bind to dentinal components like calcium (Ca^{++}) in hydroxyapatite crystals³⁵. Curcumin is an anionic compound with a hydrophobic polyphenol component, which means it absorbs less water, improving the resin interface and hence escalating bond values³⁶. A recent study³⁷ has demonstrated that curcumin enhanced the bond strength of glass-fiber posts luted to dentin, improving the quality of the adhesive interface. However, it has been anticipated that, due to the anionocity of the material, calcium would precipitate in the apical third decreasing the interaction between the luting agent and the root dentin surface, hence reducing PBS values²⁶. Similar outcomes were revealed by the previous investigational study of Al Ahdal et al²⁶.

Failure modes include admixed, adhesive (cement and post), and cohesive (inside resin cement). The most common type of failure in all

of the analyzed groups was an adhesive failure in groups 1, 2, and 4. In all three root segments, group 3 had a high percentage of admixed failure types. The reported inconsistency in the number of dentinal tubules along distinct regions of root dentin is responsible for heterogenous failure tendency^{18,20}.

Limitations

The results of the current investigation should be clinically taken with caution as dentinal structure, tubular fluids, odontoblastic projections, smear layer, dentin nature, and bonding agents may influence an outcome. The effects of different concentrations of NaOCl and MTAD, and PDT photosensitizers on radicular dentin need to be investigated further. Scanning electron microscopy (SEM) along with atomic force microscopy (AFM) of debonded samples needs additional examination. This should be supported by clinical trials, as well as *in vivo* research, to implement the findings of the present study.

Conclusions

CP and MTAD and RBP and MTAD for canal disinfection and bonding of glass fiber post to radicular dentin demonstrated comparable bond values at all three root levels and can be recommended in clinical settings after further investigations.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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Authors' Contribution

Conceptualization, M.S.; Methodology, A.B. and R.J.A.; Software, M.S. and R.J.A.; Validation, Z.Q., R.J.A., and A.B.; Formal analysis, R.J.A.; Investigation, A.M.A., Z.Q., R.J.A.; Resources, A.B.; data curation, R.J.A.; writing – original draft preparation, Z.Q., and R.J.A.; writing – review and editing, M.N.; visualization, F.N.; supervision, R.J.A., Z.Q. and M.N.; project administration, M.N.; funding acquisition, F.N. All authors have read and agreed to the published the version of the manuscript.

References

- 1) Shuruthi J, Malarvizhi D, Mitthra S, Subbiya A. Role of photodynamic therapy in endodontics—a review. *Indian J Public Heal Res Dev* 2019; 10: 2192-2195.
- 2) Sin JH, Walsh LJ, Figueredo CM, George R. Evaluation of effectiveness of photosensitizers used in laser endodontics disinfection: A systematic review. *Transl Biophotonics* 2021; 3: e202000007.
- 3) Gillen BM, Looney SW, Gu LS, Loushine BA, Weller RN, Loushine RJ, Pashley DH, Tay FR. Impact of the quality of coronal restoration versus the quality of root canal fillings on success of root canal treatment: A systematic review and meta-analysis. *J Endod* 2011; 37: 895-902.
- 4) Vohra F, Bukhari IA, Sheikh SA, Naseem M, Husain M. Photodynamic activation of irrigation (using different laser prototypes) on pushout bond strength of fiber posts. *Photodiagnosis Photodyn Ther* 2020; 30: 101716.
- 5) Santos JN, de Oliveira Carrilho MR, De Goes MF, Zaia AA, de Almeida Gomes BP, de Souza-Filho FJ, Ferraz CC. Effect of Chemical Irrigants on the Bond Strength of a Self-Etching Adhesive to Pulp Chamber Dentin. *J Endod* 2006; 32: 1088-1090.
- 6) Al-Qahtani AS, AlZain SA, AlHamdan EM, Tulbah HI, Al Alsheikh HM, Naseem M, Vohra F. A comparative evaluation of the effect of phototherapy of fiber post on its bond strength to dental composite. *Photodiagnosis Photodyn Ther* 2018; 24: 228-231.
- 7) Al Jeaidi ZA. Influence of resin cements and root canal disinfection techniques on the adhesive bond strength of fibre reinforced composite post to radicular dentin. *Photodiagnosis Photodyn Ther* 2021; 33: 102108.
- 8) Keskin G, Çiloğlu M. Efficacy of antimicrobial photodynamic therapy and Er,Cr:YSGG laser-activated irrigation on dentinal tubule penetration of MTA-based root canal sealer: a confocal microscopy study. *Photodiagnosis Photodyn Ther* 2021; 36: 102584.
- 9) Vaziri S, Kangarlou A, Shahbazi R, Nazari Nasab A, Naseri M. Comparison of the bactericidal efficacy of photodynamic therapy, 2.5% sodium hypochlorite, and 2% chlorhexidine against *Enterococcus faecalis* in root canals; an in vitro study. *Dent Res J (Isfahan)* 2012; 9: 613-617
- 10) Pérez C, Zúñiga T, Palavecino CE. Photodynamic therapy for treatment of *Staphylococcus aureus* infections. *Photodiagnosis Photodyn Ther* 2021; 34: 102285.
- 11) Abrar E, Naseem M, Baig QA, Vohra F, Maawadh AM, Almohareb T, AlRifaiy MQ, Abduljabbar T. Antimicrobial efficacy of silver diamine fluoride in comparison to photodynamic therapy and chlorhexidine on canal disinfection and bond strength to radicular dentin. *Photodiagnosis Photodyn Ther* 2020; 32:102066.
- 12) Martins CR, de Andrade MV, Carvalho AP, Pereira RM, Bresolin CR, Mello-Moura AC, Imparato JC. Photodynamic therapy associated final irrigation in root canals of the primary teeth. *Photodiagnosis Photodyn Ther* 2021; 33: 102182.
- 13) Banci HA, Strazzi-Sahyon HB, Duarte MA, Cintra LT, Gomes-Filho JE, Chalub LO, Berton SA, de Oliveira VH, Dos Santos PH, Sivieri-Araujo G. Influence of photodynamic therapy on bond strength and adhesive interface morphology of MTA based root canal sealer to different thirds of intraradicular dentin. *Photodiagnosis Photodyn Ther* 2020; 32: 102031.
- 14) Dunavant TR, Regan JD, Glickman GN, Solomon ES, Honeyman AL. Comparative Evaluation of Endodontic Irrigants against *Enterococcus faecalis* Biofilms. *J Endod* 2006; 32: 527-531.
- 15) Torabinejad M, Shabahang S, Apécio RM, Kettering JD. The antimicrobial effect of MTAD: An in vitro investigation. *J Endod* 2003; 29: 400-403.
- 16) Mortazavi V, Khademi A, Khosravi K. Effect of MTAD on the shear bond strength of self-etch adhesives to dentin. *Dent Res J (Isfahan)* 2012; 9: 24-30.
- 17) Alrahlah A, Naseem M, Tanveer SA, Abrar E, Charania A, AlRifaiy MQ, Vohra F. Influence of disinfection of caries affected dentin with different concentrations of silver diamine fluoride, curcumin and Er,Cr:YSGG on adhesive bond strength to resin composite. *Photodiagnosis Photodyn Ther* 2020; 32: 102065.
- 18) Al Deeb L, Bin-Shuwaish MS, Abrar E, Naseem M, Al-Hamdan RS, Maawadh AM, Al Deeb M, Almohareb T, Al Ahdal K, Vohra F, Abduljabbar T. Efficacy of chlorhexidine, Er Cr YSGG laser and photodynamic therapy on the adhesive bond integrity of caries affected dentin. An in-vitro study. *Photodiagnosis Photodyn Ther* 2020; 31: 101875.
- 19) Alkhudhairy F, Naseem M, Ahmad ZH, Alnooh AN, Vohra F. Efficacy of phototherapy with different conventional surface treatments on adhesive quality of lithium disilicate ceramics. *Photodiagnosis Photodyn Ther* 2019; 25: 292-295.
- 20) Aljamhan AS, Alrefeai MH, Alhabdan A, Alkhudhairy F, Abrar E, Alhuseini SA. Push out bond strength of glass fiber post to radicular dentin irrigated with Nisin and MTAD compared to methylene blue photodynamic therapy. *Photodiagnosis Photodyn Ther* 2021; 34: 102304.
- 21) Abrar E, Baig QA, Afaq A, Anzar W. Efficacy of different endodontic procedures with post-operative pain and Quality of Life (QoL) using (OHIP-14). *Prof Med J* 2021; 28: 218-223.
- 22) Alshahrani A, Abrar E, Maawadh AM, Al-Hamdan RS, Almohareb T, AlFawaz Y, Naseem M, Vohra F, Abduljabbar T. Management of caries affected dentin (CAD) with resin-modified glass ionomer cement (RMGIC) in the presence of different caries disinfectants and photosensitizers. *Photodiagnosis Photodyn Ther* 2020; 32: 101978.
- 23) Maawadh AM, Almohareb T, Al-Hamdan RS, Al Deeb M, Naseem M, Alhenaki AM, Vohra F, Ab-

- duljabbar T. Repair strength and surface topography of lithium disilicate and hybrid resin ceramics with LLLT and photodynamic therapy in comparison to hydrofluoric acid. *J Appl Biomater Funct Mater* 2020; 18: 228-231.
- 24) Chiniforush N, Pourhajbagher M, Parker S, Benedicenti S, Bahador A, Sălăgean T, Bordea IR. The effect of antimicrobial photodynamic therapy using chlorophyllin-phycoerythrin mixture on enterococcus faecalis: The influence of different light sources. *Appl Sci* 2020; 10: 10124290.
 - 25) Vohra F, Bukhari IA, Sheikh SA, Naseem M, Husain M. Photodynamic activation of irrigation (using different laser prototypes) on push-out bond strength of fiber posts. *Photodiagnosis Photodyn Ther* 2020; 30: 101716.
 - 26) Al Ahdal K, Al Deeb L, Al-Hamdan RS, Bin-Shuwaish MS, Al Deeb M, Maawadh AM, AlHelal A, Vohra F, Abduljabbar T. Influence of different photosensitizers on push-out bond strength of fiber post to radicular dentin. *Photodiagnosis Photodyn Ther* 2020; 31: 101805.
 - 27) Stájer A, Kajári S, Gajdács M, Musah-Eroje A, Baráth Z. Utility of photodynamic therapy in dentistry: Current concepts. *Dent J* 2020; 8: 43-47.
 - 28) Alkudhairy F, Vohra F, Naseem M, Ahmad ZH. Adhesive bond integrity of dentin conditioned by photobiomodulation and bonded to bioactive restorative material. *Photodiagnosis Photodyn Ther* 2019; 28: 110-113.
 - 29) Alkudhairy F, Al-Johany SS, Naseem M, Bin-Shuwaish M, Vohra F. Dentin bond strength of bioactive cement in comparison to conventional resin cement when photosensitized with Er,Cr:YSGG laser. *Pakistan J Med Sci* 2020; 36: 85-90.
 - 30) Çökük N, Kara E, Kaki D, Aydođdu M, Sarida S. Influence of the Er, Cr: YSGG laser and different irrigation methods on push-out bond strength of fiber post. *J Adhes Sci Technol* 2016; 30: 1178-1188.
 - 31) Çetinkaya Í, Bodrumlu E, Kocak MM, Kocak S, Sađlam BC, Türker SA. Effect of modified NaOCl irrigation solution on bond strength of bioceramic-based root canal sealer to dentin. *Indian J Dent Res* 2020; 31: 574-578.
 - 32) Mohammadi Z, Yaripour S, Shalavi S, Palazzi F, Asgary S. Root Canal Irrigants and Dentin Bonding: An Update. *IEJ Iran Endod J* 2017; 12: 131-136.
 - 33) Strazzi-Sahyon HB, de Oliveira MS, da Silva PP, Banci HA, de Melo FS, Martinez CM, Cintra LT, Gomes-Filho JE, Dezan-Junior E, Dos Santos PH, Sivieri-Araujo G. Does photodynamic therapy with methylene blue affect the mechanical properties and bond strength of glass-fiber posts in different thirds of intraarticular dentin? *Photodiagnosis Photodyn Ther* 2020; 30: 101673.
 - 34) Strazzi-Sahyon HB, da Silva PP, Nakao JM, da Silva PZ, Nunes LP, Seron MA, Cintra LT, Dos Santos PH, Sivieri-Araujo G. Influence of two photodynamic therapy sessions and different photosensitizers on the bond strength of glass-fiber posts in different regions of intraarticular dentin. *Photodiagnosis Photodyn Ther* 2021; 33: 102193.
 - 35) Sahyon HB, da Silva PP, de Oliveira MS, Cintra LT, Dezan-Júnior E, Gomes-Filho JE, de Castilho Jacinto R, Dos Santos PH, Sivieri-Araujo G. Influence of curcumin photosensitizer in photodynamic therapy on the mechanical properties and push-out bond strength of glass-fiber posts to intraarticular dentin. *Photodiagnosis Photodyn Ther* 2019; 25: 376-381.
 - 36) Alrahlah A, Naseem M, Tanveer SA, Abrar E, Charania A, AlRifaay MQ, Vohra F. Influence of disinfection of caries affected dentin with different concentration of silver diamine fluoride, curcumin, and Er,Cr:YSGG on adhesive bond strength to resin composite. *Photodiagnosis Photodyn Ther* 2020; 32: 102065
 - 37) Alrahlah A, Niaz MO, Abrar E, Vohra F, Rashid H. Treatment of caries affected dentin with different photosensitizers and its effect on adhesive bond integrity to resin composite. *Photodiagnosis Photodyn Ther* 2020; 31: 101865.