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Effect of photodynamic therapy and ErCrYSGG laser irradiation on the push-out bond strength between fiber post and root dentin

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A R T I C L E I N F O

Keywords:
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Fiber post
Push-Out bond strength

A B S T R A C T

Background: To evaluate the push out bond strength and modes of failure of fiber post by using photodynamic therapy (PDT), Er,Cr:YSGG laser and conventional cleaning and shaping (CCS).
Methods: Sixty maxillary anterior teeth were sectioned horizontaly 2 mm incisal to the cemento-enamel junction, and root canal were prepared for post space. Tapered fiber posts were placed inside the root canal after post space was made. The fiber posts were subjected to PDT, Er,Cr:YSGG laser and CSS with 20 specimens in each group. The specimens obtained were sectioned in cervical and apical sections. A universal testing machine was used to perform the push out test and the push out bond strength was formulated by $\sigma = C/A$, expressed in megapascals (MPa).
Results: The highest mean push out bond strength was achieved by PDT group (8.08 ± 2.73 MPa) and the lowest was shown by specimens in CCS group (7.45 ± 1.04 MPa). ANOVA showed no statistical difference among the experimental groups ($p = 0.481$). In the cervical segments, the mean push-out bond strength was found to be slightly higher for all three groups compared to apical segments ($P < 0.05$). The independent t-tests results showed that the mean push-out bond strength values of the cervical segments were slightly higher than the apical segments in PDT, Er,Cr:YSGG and CSS groups ($P < 0.05$). Significant differences were observed when mean push-out bond strengths were compared for both cervical ($p = 0.037$) and apical ($p = 0.019$) segments between all the groups. Twenty-one failures were found at the interface between the adhesive and the dentin surface, 6 failures were observed at the interface between the adhesive and post, whereas 5 failures were mixed.
Conclusion: Push-out bond strength to root canal dentin were not affected by Er,Cr:YSGG compared with conventional cleaning and shaping. However, PDT produced the smallest number of failure modes and slightly higher push-out bond strength to root dentin.

1. Introduction

Root canal treatment is comprised of the proper instrumentation, shaping, complete disinfection, and obturation of the root canal system. The main purpose of endodontic therapy is based on the eradication of bacterial load from the root canal, or maximum decrease in bacterial count to the levels compatible with the periradicular tissue healing [1,2]. Although the conventional treatment procedures assist in decreasing the bacterial influx, however proper and complete disinfection of the root canal system is difficult to achieve [3]. The primary reasons include endodontic bacterial resistance and anatomical complexity of root canal system that allows incomplete bacterial disinfection through instrumentation/irrigation especially at the apical level of the root that results in endodontic treatment failure [4,5].

Posts have been commonly recommended in order to increase the structural integrity of an endodontically treated tooth. Fiber reinforced

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posts are considered to be better than their counterpart as they have superior physical properties like aesthetics, resilience and modulus of elasticity which is similar to root dentin [6,7]. With the advancement in dentistry, new and innovative methods are being introduced in order to reduce the treatment failures in endodontics and increase the bond strength of posts. Comparisons have been drawn in between pressure alterations device ultrasonic systems, and laser devices for cleaning and disinfection of root canal [8–10]. In recent years, laser application namely photodynamic therapy (PDT) and laser irradiation has become common in dentistry especially in endodontics [11–13].

Photodynamic therapy (PDT) is an antimicrobial mode of treatment which is based on the chemical amalgamation of low intensity laser of precise wavelength and a nontoxic photosensitive agent. The mechanism of action is based on the reaction of the excited photosensitizer with the molecular oxygen from the environment in order to produce highly reactive oxygen species (ROS), which leads to damage of the membrane and intracellular molecules including the proteins and the nucleic acids [14]. The photosensitizers having a strong cationic charge binds and then penetrates into the bacterial cell, without causing any particular damage to the viability of the host cell [14,15]. Research suggests that retaining smear layer for adaptation of the materials to root surface may have an impact on the overall efficacy of PDT on bond strength [16]. For instance, Souza et al. [17] have showed the presence of photosensitizer in the root canal walls after final irrigation protocols. Other studies performed by Souza et al [18,19] revealed low bond strength values when the photosensitizer removal is not performed by final irrigants and ultrasonic activation [18,19].

Laser irradiation uses laser light which on application is absorbed by the bacterial cells. After absorption by the bacterial pigments and substrate, the bactericidal effect of laser irradiation occurs due to local heating, resulting in increased temperatures which serve to be lethal [20]. Besides having a direct bactericidal effect, lasers could assist and improve root canal disinfection and removal of smear layer by initiating powerful streaming within an irrigant, resulting in dispersion of irrigant into apical ramification. Different lasers including Erbium yttrium scandium gallium garnet (Er:Cr,YSGG), Erbium doped yttrium aluminium garnet (Er:YAG) and neodymium-doped yttrium aluminium garnet (Nd:YAG) have been used in different endodontic and periodontal procedures which have resulted in better outcomes. Er:Cr,YSGG being a middle infrared laser with a wavelength of 2790 nm is hydroxilapatite and is very well absorbed in water, which results in heating of the bacterial surroundings inside the root canal system [20–22].

It is therefore, hypothesized that application of PDT and Er:Cr,YSGG may increase the push-out bond strength compared to conventional cleaning and shaping (CCS) between fiber post and root dentin. The aim of the present study was to evaluate the push out bond strength and modes of failure of fiber posts among aPDT, Er:Cr,YSGG and CCS.

2. Materials and methods

The present study was approved by the Research Center Ethics Committee (UDRC-09-2018/44). Sixty single rooted extracted maxillary teeth obtained from clinical practice were selected for the study. The teeth were chosen due to their external root anatomy, avoiding roots with flattened areas, curvatures, cracks, fractures and teeth with similar root lengths, in order to ease biomechanical preparation as well as canal preparation for post cementation. Disinfection was done by placing the teeth in a 0.5% chloramine solution at a temperature of 4 °C for 48 h. To eliminate traces of the chloramine solution, the teeth were washed for 24 h under running water. The soft tissue ligaments and calculus was removed from the teeth and stored in physiologic saline before going forward with any further procedures. The crown of each tooth was decoronated in the bucco-lingual direction at the cementoenamel junction with a low-speed diamond bur in order to obtain a uniform root measurement of 19 mm.

The step-back technique was incorporated to shape and prepare the canals 1 mm short of the apex of the root. K-files (MANI, Tochigi, Japan), no. 4, no. 3 and no. 2 Gates Glidden drills (MANI) were the instruments used. Rinsing was done with the help of 10 mL of 2.5% sodium hypochlorite done with the help of 10-mL BD disposable syringe. File no. 35 was chosen as the master apical file. Drying of the root canals were done with paper points (GapaDent, Zhengzhou Smile Dental Equipment, Henan, PRC). The shaped and prepared canals were obturated with Gutta-percha (Gapa Dent) and AH26 sealer (Dentsply DeTrey, Konstanz, Germany) using a lateral compaction technique. After 24 h of obturation, 10 mm of each canal length was prepared using no. 4, no. 3 and no. 2 Peeso reamers (MANI). Special drills were also provided by the manufacturer of no. 100 fiber posts (Endolight Post; RTD, St. Egerve, France). Before the insertion of fiber posts, the cleaning and drying of the posts were done with 70% ethanol and compressed air respectively. The post space were cleaned with 5 mL EDTA with a disposable syringe for 1 min. A mold of condensation silicone material with a putty consistency (Speedex; Coltene/Whaledent, Altstatten, Switzerland) was made into which the specimens were thoroughly embedded. The samples were randomly divided into three groups, based on PDT, Er,Cr:YSGG and CCS groups, respectively.

Photodynamic therapy method was used in one of the test groups. The canals were filled with a filter-sterilized solution of photosensitizer methylene blue (2% aq. solution) for 5 min. Light was introduced on the canals by using a diode laser (Handy laser sprint dental, RJ-laser, Winden, Germany). Wavelength of the light was 638 nm and output power was 150 mW. According to the instruction of the manufacturer the light was applied as follows: 2.5 min of irradiation, 2.5 min of stop and 2.5 min of re-radiation was done to initiate free radicals formation without increasing the destructive temperature. For a 360° uniform radiation, an optical fiber (PACT, Cumdente, Tübingen, Germany) having a diameter of 200 μm and taper of 0.03 mm was used, respectively. The optical fiber was placed inside the canal and it was made sure that the guiding light reached the entire length of the canal included the inaccessible areas such as fins and branches. After irradiation, canals were rinsed with 10 ml of normal saline.

The Er,Cr:YSGG diode laser Opus 10 (OpusDent, Yokneam–Israel) with a wavelength of 830 nm was used. Irradiation of the root canal was done either by continuous wave mode (CW) or pulsed mode (PL) employing a 300 μm optical fiber. The laser optical fiber was inserted into the entire structure of the root canal and irradiated from apical to cervical axis in a spiral fashion at a ratio of 2 mm/sec, with 2.5% NaOCl being used for irrigation. Irradiation was performed in five cycles with time intervals of 20 s between cycles, with roots being cooled in between the cycles. The average power density of the laser at CW and PL was 1989 W/cm^2 and 1200 W/cm^2 respectively. The power was set to 1.25 W, frequency 15 Hz, with 34% of air and 24% water levels.

The roots with cemented posts were sectioned perpendicularly to the long axis. Six serial perpendicular slices 0.05 mm thickness, three slices representing the coronal and apical region of the post space) were obtained from each specimen using a low-speed diamond saw (Micracut; Metkon, Bursa, Turkey) under water cooling. The slices were attached individually to a universal testing machine (Lloyd Instruments, UK), and loading was applied to the apical side of the discs facing a cylindrical plunger with a metal rod (0.8 and 1.2 mm in diameter for the apical and coronal slices, respectively) at a crosshead speed of 0.5 mm/min until failure occurred. In total, push-out tests were carried out on 24 slices for each group (12 coronal, 12 apical). The push-out bond strength (MPa) was calculated by dividing the maximum failure load value (N) by the bonding area of post segments (mm2). Diameter of coronal and apical post segments and thickness of the slice were measured using digital calipers and bonding surface area was calculated using the following formula:

Bonding surface area: $\pi\ (r_1 + r_2)\ x\ (\sqrt{}(r_1 - r_2)^2 + h^2)$, where $\pi = 3.14$, r_1 represents the coronal post radius, r_2 is the apical post radius, and h is the thickness of the slice. Failure types of 192 (24 slices × 8 groups) post segments were examined by two independent

Table 1
Push-out bond strength values of the different groups MPa (± SD).

Groups (n = 20)	*Mean*	*SD*	*P value*
PDT	8.08	2.73	0.481
Er,Cr:YSGG	7.83	1.22	
CCS	7.45	1.04	

PDT – photodynamic therapy; Er,Cr:YSGG – erbium yttrium scandium gallium garnet; CCS – conventional cleaning and shaping; SD – standard deviation.

operators under a stereomicroscope (Stemi 2000-C; Carl Zeiss, Göttingen, Germany) at x40 magnification. Failure modes were classified into three categories, as adhesive failure between cement and dentine (C/D), cohesive failure between cement and post (C/P), or mixed failure (M) in both dentine and cement.

3. Results

The highest mean push out bond strength was achieved by PDT group (8.08 ± 2.73 MPa) and the lowest was shown by specimens in CCS group (7.45 ± 1.04 MPa). ANOVA showed no statistical difference between the groups (PDT, Er,Cr:YSGG and CCS) ($p = 0.481$) (Tables 1 and 2). Table 2 presents the comparison of push out bond strength values among the groups based on the cervical and apical segments. In the cervical segments, the mean push-out bond strength was found to be slightly higher for all three experimental groups compared to apical segments ($P < 0.05$). The independent t-tests results showed that the mean push-out bond strength values of the cervical segments were slightly higher than the apical segments in PDT, Er,Cr:YSGG and CSS groups ($P < 0.05$). Moreover, significant differences were observed when mean push-out bond strengths were compared for both cervical ($p = 0.037$) and apical ($p = 0.019$) segments between all the groups. Twenty-one failures were found at the interface between the adhesive and the dentin surface, 6 failures were observed at the interface between the adhesive and post, whereas, 5 failures were mixed. A total of 4 failures (9.7%) and 3 failures (7.3%) and 7 (17%) failures and 8 failures (19.5%) were found in the cervical and apical segments in the PDT and Er,Cr:YSGG groups, respectively, while a total of 4 failures (9.7%) and 6 (14.6%) failures were found in the cervical and apical segments in the CCS groups. Overall, the group with the smallest total number of failure modes were found in the PDT group, while the group with the largest number of failure modes were found in the CCS group (Table 3).

4. Discussion

In the present study the push out bond strength of fiber posts to root dentin using PDT and Er,Cr:YSGG laser were investigated. In addition, and modes of failure in the cervical and apical region of the root dentin were compared among the different groups PDT, Er,Cr:YSGG laser and CCS. The outcome of the present study suggests that PDT or laser irradiation showed no effect on the overall mean push-out bond strength. Moreover, the group with the smallest total number of failure modes were found in the PDT group, while the group with the largest number of failure modes were found in the CCS group.

Table 2
Push-out bond strength values of the cervical and apical segments MPa (± SD).

Groups (n = 20)	*Cervical segment (n = 10 each)*	*Apical segment (n = 10 each)*	*P value*
PDT	9.23 (1.94)	7.76 (2.00)	0.042*
Er,Cr:YSGG	8.18 (1.85)	6.92 (2.96)	0.048*
CCS	8.01 (1.73)	5.44 (3.77)	0.002*
P-value	0.037*	0.019*	

PDT – photodynamic therapy; Er,Cr:YSGG – erbium yttrium scandium gallium garnet; CCS – conventional cleaning and shaping; SD – standard deviation.

* Statistically significant results obtained by *t*-test at $p < 0.05$.

Table 3
Type of failure modes in each group.

Groups (n = 20 each)	*Root segment*	*Type of failure*			
		Adhesive-post	*Adhesive-dentin*	*Mixed*	Total
PDT	CERVICAL	0	3	1	4
	APICAL	1	2	0	3
Er,Cr:YSGG	CERVICAL	2	4	1	7
	APICAL	1	3	0	4
CCS	CERVICAL	1	5	2	8
	APICAL	1	4	1	6

PDT – photodynamic therapy; Er,Cr:YSGG – erbium yttrium scandium gallium garnet; CCS – conventional cleaning and shaping.

The assessment of the bond strength in the present study was done by using the push out test method. This test employs the process of applying shear forces at the root-post interface which show similarity to stresses under clinical conditions [23]. The push out testing regimen is a comprehensive and advantageous approach as it allows for homogenous stress distribution throughout the structure of root dentin, lower failure rates are observed as compared to tensile test and provides numerous testing samples from a one root [24]. It is also the most reliable method in testing the push out bond strength in fiber posts [25].

A slightly greater push-out bond strength was observed for PDT group. However, the use of 17% EDTA can promote the erosion of peritubular and intertubular dentin, which can compromise the fracture strength of the tooth [26,27]. These findings are not in accordance with an earlier study by Prado et al. [28]. In the present study, the value for the push out bond strength for fiber posts is significantly higher at the cervical portion as compared to the apical portion of the root in all of the studied groups. With regards to the action of PDT, it may therefore be proposed that such technique achieved higher degree of photosensitizer removal in the cervical as compared to apical regions. Furthermore, numerous reasons have been proposed by the authors in this regard that the bond strength being lower at the apical root area may be due to poor conditioning of dentin, inability to adhesively bond to the gutta percha at the apical level of the root and improper distribution of the dentinal tubules at the apical area [29].

For Er,Cr:YSGG it has been proposed by the authors that due to use of high pulse energy, a slight amount of thermal effect might have been observed at the dentine walls, hence leading to decreased bond strength at different levels [30]. Partial vaporization of the smear layer is another factor which can alter the bond strength levels [31]. As far as PDT is concerned, the activation of the photosensitizer allows the release of ROS mainly singlet oxygen which happens to damage the hybrid layer formation [32]. It also has a negative effect on the adhesive interface between the root dentin and fiber post system, hence leading to decreased bond strength in the specimens [33].

Collectively, a total of 21 failures were reported at the dentin-root interface from the studied groups. The adhesive failure observed at the dentin presents as a question mark at the validity of push out bond strength, hence indicating the adhesive and bonding interface as the weakest combination in the bonded post tooth structure. Residual sodium hypochlorite (NaOCl) in the root dentin can be a hypothetical reason for the predominant failures being observed at the adhesive-dentin interface as it tends to form an oxygen layer which compromises the polymerization of the resin being used [34].

Less number of sample size can be considered as a limitation of the present study. Another limitation can be the assessment of the modes of the type of failures at only the cervical and apical areas of the root and not including them middle section of the root dentin. Furthermore, scanning electron microscopy and optical microscopy have been used to evaluate the cleaning of the root canals in several studies [35,36]. The advantage of using scanning electron microscopy is attributed to the fact that it allows observers to evaluate the presence of debris and the smear layer, unlike optical microscopy [37]. However, the present study did not evaluate using such laboratory techniques. The results of this study provide us with new knowledge regarding the efficacy of photodynamic therapy, Er,Cr:YSGG laser and conventional cleaning and shaping on the push out bond strength of fiber posts. However, more studies are required to evaluate the effect of different type of lasers on the push out bond strength of fiber posts with the root dentin interface.

5. Conclusion

Push-out bond strength to root canal dentin were not affected by Er,Cr:YSGG compared with conventional cleaning and shaping. However, PDT produced the smallest number of failure modes and slightly higher push-out bond strength to root dentin.

Declaration of Competing Interest

None declared.

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