

EVALUATION OF PUSH-OUT BOND STRENGTH
OF BIOCERAMIC ROOT CANAL SEALERS WITH
DIFFERENT FINAL IRRIGATION PROTOCOLS

Bilge Özcan, Burcu Biçer*, Feridun Şaklar**,
Lena Bal***,#

Received on August 7, 2023

Presented by D. Damianov, Member of BAS, on October 31, 2023

Abstract

This study aims to evaluate the bond strength of bioceramic root canal sealers, with different final irrigation protocols. A total of 104 human upper incisor teeth were selected for applying four different irrigation solutions (Ethylene diamine tetraacetic acid (EDTA), Chlorine Hexidine Gluconate (CHX), Sodium Hypochlorite (NaOCl), and Distilled Water (D.W)) and two root canal sealer protocols (Endosequence BC (BC), Well-Root ST (ST)), in this in vitro study. After root canal treatment specimens were sectioned to three parts (coronal, middle, and apical). Push-out bond strength test was performed in a universal testing machine (Zwick-Roel, Germany) at a crosshead speed of 1 mm/min. Regardless of the irrigation protocol and sealer used, the highest bond strength values were obtained from the apical section ($p < 0.05$). 5.25% NaOCl + 17% EDTA + 5.25% NaOCl and 2% CHX + 17% EDTA + D.W statistically showed the highest bond strength value and 2% CHX + 17% EDTA + 2% CHX group showed the lowest value in this study ($p < 0.05$). The bond strength values of Endosequence BC Sealer were statistically higher than the bond strength values of Well Root ST ($p < 0.05$). According to the final irrigation, Endosequence BC Sealer and Well Root ST root canal sealers showed the highest bonding strength in CHX+EDTA+D.W and NaOCl+EDTA+NaOCl groups.

Key words: bond strength, endosequence BC sealer, irrigation protocol, well root ST

#Corresponding author.

DOI:10.7546/CRABS.2023.12.15

Introduction. Microorganisms are the most important etiological factor in the pathogenesis of pulp and periapical tissue diseases [1]. Many studies reported that mechanical preparation does not completely remove the root canal walls and leaves untouched areas, and concomitant canal irrigation to mechanical preparation is important [2]. In evaluating the effect of different final irrigation protocols on the bond strength of root canal sealers, studies have shown that the root canal sealer affects the adhesion to the root dentin tissue. Leakage in the canals after root canal treatment reduces the success of the endodontics treatment [3,4]. Researchers have tried different root canal-filling sealers to overcome this problem. Bioceramic-based root canal sealers, which have bioactivity and hermetically seal well, have become widespread. Calcium silicate and hydroxyapatite components of bioceramic sealers give the material biocompatibility and bioactive properties. Due to its small particle structure and fluidity, hydroxyapatite penetrates the lateral canal and dentinal tubules well and can increase the bonding between dentin and filling materials. Additionally, the basic PH during the setting process increases its antimicrobial properties. Prominent sealers in this group are Bioseal, Endosequence BC Sealer, Smartpaste Bio, iRoot SP, Appetite root canal filling sealer, and Well Root ST [5]. In the literature reviews, microbiological studies evaluate the physical properties of Endosequence BC Sealer and Well-Root ST Sealer. However, no study has been found on evaluating the physical properties of these two sealers with irrigation protocols. This study aims to reveal the varying dentin bond strengths in the root's apical, middle, and coronal regions, according to different irrigation protocols of bioceramic root canal sealers with two different contents.

Materials and methods. Sample preparation. This in vitro study was approved by the Ankara University Faculty of Dentistry ethics committee with a reference number of 36290600. The study used the power analysis method and push-out universal bond strength test. One hundred and four non-caries upper central teeth of similar length (± 2 mm) with no restorations, and fractures in the crown and root, extracted for periodontal, and orthodontic reasons were used in this study. The apexification was finished in all teeth. Buccolingual and mesiodistal radiographs of teeth were evaluated. Root canal resorption or calcification teeth were excluded from the study. For root length standardization, the teeth were cut with a diamond fissure bur (ISO 806314, 014, Meisinger, Germany) under cooling water, 13 mm upper from the apex. 10 K-file was inserted into the canal until the tip appeared from the apical foramen, and the working length was determined to be 1 mm shorter than the canal length. According to the final irrigation protocol, the samples were divided into 8 groups and 13 specimens were in each group. In all samples, not stuck in the canal a 27 gauge needle, 2 mm shorter than the working length was used for irrigation protocol. Root canals were shaped with the ProTaper NiTi rotary file system (Dentsply Maillefer, Ballaigues, Switzerland), with an apical width of #40.06 up to the F4 file.

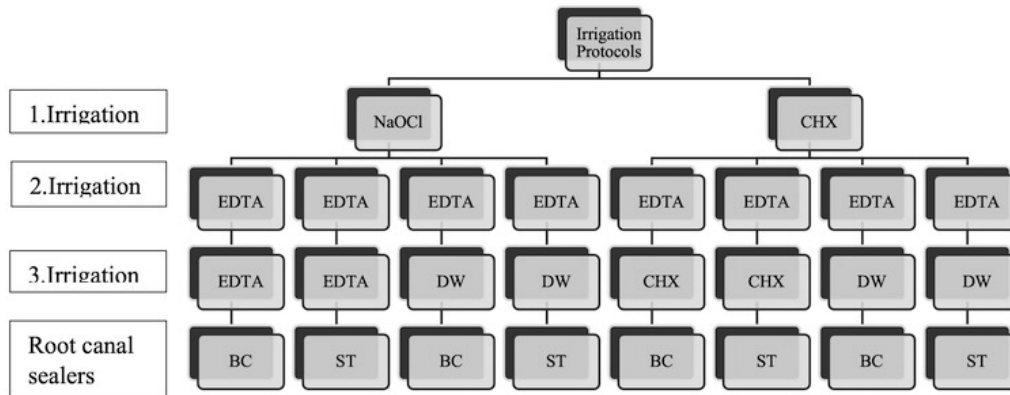


Fig. 1. Treatment procedure

Treatment procedure. Four different irrigation solutions (17% Ethylene diamine tetraacetic acid (EDTA) (Werax, Spot Dent. San., Izmir, Turkey), 2% Chlorine Hexidine Gluconate (CHX) (Werax, Spot Dent. San., Izmir, Turkey), 5.25% Sodium Hypochlorite (NaOCl) (Sultan Chemist Inc., Englewood, New Jersey, USA), and Distilled Water (D.W)), and two different root canal sealers (Endosequence BC (Brasseler, Savannah, USA), Well-Root ST (Vericom Dental, Korea)) were used for treatment procedure in this study. The irrigation procedures and root canal sealers are shown in Fig. 1. To complete the setting of the root canal seal, the samples were kept in an oven at 37 °C, 100% humidity with no light for 7 days. Then the roots were embedded in acrylic resin in plastic molds. The specimens were sectioned horizontally from the coronal to apical in 2 mm thicknesses with a 0.3 mm diamond disc on the IsoMet device (IsoMet5000, Buehler, IL, USA). The thicknesses of the samples were measured using a digital caliper (Electronic Digital Caliper; Shan, China) (± 0.1 mm). Three samples were randomly selected from each tooth's coronal, middle, and apical third. The samples' bond strength was tested using a Push-out Universal machine (Zwick-Roel, Germany). Three different tips (0.3, 0.5, and 0.8 mm) were used to match with the canal sealer. Tips were positioned in such a way that they did touch the root canal sealers only. With the Instron device, a force was applied with a constant speed of 1 mm/min. Due to the increasing angle of the root sections from the apical to the coronal, the force was applied from the apical to the coronal face of the seal. The splitting strength was recorded by using the Nexygen data analysis program (Lloyd LRX, Fareham, UK), and the bond strength was calculated by converting Newtons (N) to megapascals (MPa) by the following formula [6]:

$$\text{Bonding area of root canal filling} = \pi(R + r)[h^2 + (R - r)^2]^{1/2},$$

where R is the coronal radius of the canal, r is the apical radius, h is the thickness of the section, and π value is referenced as 3.14.

Statistical analysis. The data were analyzed with the SPSS 20.00 program. The Kruskal–Wallis test was used for comparisons between groups and the Dunn test was used for pairwise comparisons. The significance level was determined as 0.05.

Result. According to the results of this study, the highest bond strength values of BC root canal sealer belong to CHX + EDTA + D.W irrigation protocol at the coronal (4.92) and middle (5.2) section, and NaOCl + EDTA + NaOCl irrigation protocol in the apical (13.03) section.

The lowest bond strength of BC Sealer was observed in the coronal (0.88) and middle section (1.97) in the CHX+EDTA+CHX irrigation protocol, while in the apical (6.69) section it was observed in the NaOCl + EDTA + D.W irrigation protocol (Table 1).

The highest bond strength of Well-Root ST root canal sealer belongs to CHX + EDTA + D.W irrigation protocol in the coronal (3.16) section, while in the middle (3.42) and apical (7.93) sections, it was observed in NaOCl + EDTA + D.W irrigation protocol. The lowest bond strength was observed in the NaOCl + EDTA + NaOCl protocol in the coronal (1.34) section, while it was observed in the CHX + EDTA + CHX protocol in the middle (2.53) and apical (5.77) sections (Table 1).

In terms of bond strength in the same irrigation protocols with different canal sealers, there was no statistically significant difference in the coronal and middle thirds of the Group 1 and Group 2 samples, whereas a statistical difference was found in the bond strength of the apical triple section ($p < 0.05$).

There was no statistically significant difference between Group 3 and Group 4 and also between Group 7 and Group 8 samples, whereas a statistically significant difference was found in the bond strength values of the coronal section in Group 5 and Group 6 samples ($p < 0.05$). In comparing the bond strength values of all specimens, coronal, middle triple, and apical sections, Endosequence BC Sealer was statistically higher than the Well Root ST root canal sealer ($p < 0.05$) (Table 1).

T a b l e 1

Bond strength of Endosequence BC and Well-Root ST root canal sealer after different irrigation procedures (SD: standard deviation)

BC Sealer	Bond Strength (MPa)	NaOCl		NaOCl		CHX		CHX	
		EDTA	SD	EDTA	SD	EDTA	SD	EDTA	SD
		NaOCl		D.W		CHX		D. W	
BC Sealer	Coronal	2.93	2.1	1.72	0.99	0.88	0.53	4.92	2.02
BC Sealer	Middle	4.8	2.6	3.36	1.56	1.97	0.95	5.2	2.79
BC Sealer	Apical	13.03	5.1	6.69	1.78	6.73	1.45	10.81	3.70
Well-Root ST	Coronal	1.34	0.41	2.22	1.17	1.94	0.86	3.16	1.44
Well-Root ST	Middle	2.61	1.11	3.42	2.22	2.53	1.25	3.46	2.28
Well-Root ST	Apical	6.19	2.04	7.93	2.06	5.77	1.87	7.65	2.13

Discussion. The success rate of root canal treatment depends on the irrigation, disinfection, and preparation of the root canal system. For this reason, different chemical agents are used during and after instrumentation [7]. Three-dimensional sealing of the root canal cavity ensures the long-term success of treatment. Root canal sealers with bioceramic content provide advantages in root canal treatment such as set by the presence of tissue fluids, long-term antibacterial properties, impermeability, long working time, and expansion while setting and penetrating the root canal without gaps [8]. Calcium silicate containing bioceramic properties; Endosequence BC Sealer and Well Root ST root canal sealer were used in this study. The sealers are presented ready for application in injectors. The problems such as disproportionate mixing of the sealers and air bubbles during the preparation are eliminated and the sealer can apply to the cavity with the same pressure. According to the studies, the bioceramic sealer setting time was stated as one week [6,9]. For the sealer set, the samples were kept at 37 °C and 100% humidity for 7 days in this study. For the evaluation of shear bond strength Push-out test method was used. Samples were prepared with a thickness of 2 mm to prevent bonding breakage that may occur in the testing. In the bonding tensile testing system, the application tip forced gutta-percha surface only and tip thicknesses were 0.8 mm for coronal and 0.3 mm for apical.

According to the conical shape of the root canal, and the canal's diameter which is reduced from coronal to apex, to avoid erroneous results by contacting the tip with the dentin, a vertical force was applied to the specimens in the apical-coronal direction. Since EDTA only affects the inorganic structure of the smear layer, it has been suggested to use EDTA in combination with 0.5–5.25% NaOCl to remove organic residues [10]. By this combination, effective removal of the smear layer happens and more dentinal tubules appear. With the successful penetration of the root canal sealer into the tubules the bond strength increases. In this study, the bond strength values of the groups using NaOCl + EDTA + NaOCl as the final irrigation protocol were found to be higher than the groups using NaOCl + EDTA + D.W, which is consistent with other studies [11]. In the groups using CHX as an irrigation solution, the bond strength in the groups with CHX + EDTA + D.W protocol was found to be higher than the groups using CHX + EDTA + CHX solutions. Tissue dissolution properties of CHX and the absence of proteolytic effects make the tooth surface more hydrophilic.

Root canal sealers with bioceramic content are highly hydrophilic. This material absorbs the fluid in the root canal and dentin tubules, and forms hydroxyapatite crystals which chemically bond to dentin [8]. Dentin tubule penetration and bond strength of bioceramic sealers can be increased in root canals using CHX. In this study, it can be explained that the bond strength was higher in the groups using CHX + EDTA + D.W. According to the results of an in vitro study on molars, the interaction between 2% CHX and 17% EDTA white precipitate salt was formed by two solutions mixture [12]. The studies investigate the effect of

different final irrigation solutions on the bond strength of sealers, it was reported that the bond strength of BC Sealer was significantly reduced when CHX was used as the final irrigation protocol compared to the groups using NaOCl [13]. The groups using the CHX + EDTA + CHX protocol in this study show the lowest bond strength of root canal sealers in all the groups and it is supported by the studies above.

The dentinal tubule diameter increases from apex to coronal. Based on this information, and the result of this study, bond strength increased from coronal to apical in all groups.

GOVINDARAJAN et al. [14] evaluate tubular penetration and bond strength bioceramic and resin-based sealers on root canal treatment. They used two different collagen materials (Cashew nut shell liquid and Epigallocatechin-3-gallate) before sealer application. The results showed that push-out bond strength was the highest rate in the apical section. In support of our findings, the apical third section showed the least penetration of sealers into the tubules, and the highest bond strength was shown in the apical third section. So proper sealers usage increases the success of root canal treatment and bond strength and diminishes leakage-related issues. The studies show that bioceramic-based root canal sealers constitute more successful bond strength to dentin tissue than methacrylate resin-based ones [15,16].

Endosequence BC Sealer and Well Root ST root canal sealer's high apical bond strength can be explained by the good penetration of sealers to the apical small-diameter dentinal tubules, so that the bond strength is not affected by the decreasing dentinal tubule diameter.

FRASQUETTI et al. [17] assess the effect of two different bioceramic sealers and drying protocols on dentin bond strength. They used two different bioceramic sealers (Sealer Plus BC, Bio C Sealer). Similar bond strength values were shown regardless of the drying-irrigation protocols and sealers.

Although both sealers used in this study, have bioceramic properties, they contain various materials at different rates. Endosequence BC Sealer contains calcium silicate, monophasic calcium phosphate, zirconium oxide, tantalum oxide, and thickening agents, while Well Root ST contains calcium alumina silicate, zirconium oxide, filling, and thickening agents [18]. Endosequence BC root canal sealer showed significantly higher values of bonding strength than Well Root ST root canal sealer in the coronal (4.92), middle third (5.2), and apical third (13.03) sections. So bond strength values of BC Sealer root canal are thought to be due to the different contents of the sealers. No study was found comparing the bond strength of Well Root ST and Endosequence BC root canal sealers.

Conclusion. The effect of root canal filling materials containing calcium silicate applied after different final irrigation procedures on bond strength to the root canal was evaluated in this in vitro study. Endosequence BC Sealer showed higher bond strength than Well Root ST root canal sealer. Final irrigation proto-

cols affect the bond strength of calcium silicate sealers. According to the results, with a bioceramic sealer containing calcium silicate, 5.25% NaOCl + 17% EDTA + 5.25% NaOCl protocol or 2% CHX + 17% EDTA + D.W can be considered the satisfactory choice in final irrigation solution for endodontic treatment.

This study proposes using calcium silicate-containing Endosequence BC Sealer and Well Root ST root canal sealers as an alternative to conventional sealants used in the clinic, due to their superior physical properties, ease of application, and good bonding results with dentin. This research was carried out under in vitro conditions, and further studies on the subject are needed in vivo.

REFERENCES

- [1] SUNDQVIST G., D. FIGDOR, S. PERSSON, U. SJÖGREN (1998) Microbiologic analysis of teeth with failed endodontic treatment and the outcome of conservative re-treatment, *Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod.*, **85**(1), 86–93.
- [2] MOHAMMADI Z., P. V. ABBOTT (2009) The properties and applications of chlorhexidine in endodontics, *Int. Endod. J.*, **42**, 288–302.
- [3] VILANOVA W. V., J. R. CARVALHO-JUNIOR, E. ALFREDO, M. D. SOUSA-NETO, Y. T. C. SILVA-SOUSA (2012) Effect of intracanal irrigants on the bond strength of epoxy resin-based and methacrylate resin-based sealers to root canal walls, *Int. Endod. J.*, **45**, 42–48.
- [4] BALLAL N. V., A. TWEENY, K. KHECHEN, K. N. PRABHU, F. R. SATYANARAYAN TAY (2013) Wettability of root canal sealers on intraarticular dentine treated with different irrigating solutions, *J. Dent.*, **41**, 556–560.
- [5] ZOUFAN K., J. JIANG, T. KOBAYASHI, Y.-H. WANG, K. E. SAFAVI et al. (2011) Cytotoxicity evaluation of Gutta flow and endo sequence BC sealers, *Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod.*, **112**(5), 657–661.
- [6] LEAL F., R. A. SIMÃO, S. R. FIDEL, R. A. S. FIDEL, M. DO PRADO (2015) Effect of final irrigation protocols on push-out bond strength of an epoxy resin root canal sealer to dentin, *Aust. Endod. J.*, **41**(3), 135–139.
- [7] PRADO M., R. A. SIMÃO, B. P. F. A. GOMES (2013) Effect of different irrigation protocols on resin sealer bond strength to dentin, *J. Endod.*, **39**(5), 689–692.
- [8] BILGIÇ A., E. BODRUMLU (2016) Bioceramic based root canal sealer: Review, *Ataturk Univ. Dentistry Fac. J.*, **14**, 111–117 (in Turkish).
- [9] ÖZLEK E., M. G. EROPLU (2016) In-vitro investigation of the effect of different irrigation systems on the bond strength of the canal filling material to the root canal, *Van Med. J.*, **23**(3), 252–258 (in Turkish).
- [10] TATSUTA C. T., L. A. MORGAN, J. C. BAUMGARTNER, J. D. ADEY (1999) Effect of calcium hydroxide and four irrigation regimens on instrumented and uninstrumented canal wall topography, *J. Endod.*, **25**(2), 93–98.
- [11] SHOKOUHINEJAD N., M. R. SHARIFIAN, M. JAFARI, M. A. SABETI (2010) Push-out bond strength of Resilon/Epiphany self-etch and gutta-percha/AH26 after different irrigation protocols, *Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod.*, **110**(5), 88–92.

- [12] RASIMICK B. J., M. NEKICH, M. M. HLADEK, B. L. MUSIKANT, A. S. DEUTSCH (2008) Interaction between chlorhexidine digluconate and EDTA, *J. Endod.*, **34**(12), 1521–1523.
- [13] RAZMI H., B. BOLHARI, N. K. DASHTI, M. FAZLYAB (2016) The effect of canal dryness on bond strength of bioceramic and epoxy-resin sealers after irrigation with sodium hypochlorite or chlorhexidine, *Iran. Endod. J.*, **11**(2), 129–133.
- [14] GOVINDARAJAN J., B. A. HEMASATHYA, B. N. REDDY, S. NATHAN, S. SANKAR et al. (2022) Comparative assessment of novel collagen cross-linking agents on push-out bond strength of two different sealers: An in vitro study, *J. Contemp. Dent. Pract.*, **23**(11), 1122–1127, <https://doi.org/10.5005/jp-journals-10024-3439>.
- [15] CIMPEAN S. I., A. L. C. BURTEA, R. S. CHIOREAN, M. C. DUDESCU, A. ANTONIAC et al. (2022) Evaluation of bond strength of four different root canal sealers, *Materials (Basel, Switzerland)*, **15**(14), <https://doi.org/10.3390/ma15144966>.
- [16] FERREIRA M. M., J. P. MARTINHO, I. DUARTE, D. MENDONÇA, A. C. CRAVEIRO et al. (2022) Evaluation of the sealing ability and bond strength of two endodontic root canal sealers: An in vitro study, *Dent. J. (Basel)*, **10**(11), <https://doi.org/10.3390/dj10110201>.
- [17] FRASQUETTI K. S., L. PIASECKI, A. KOWALCZUCK, E. CARNEIRO, V. P. D. WESTPHALEN et al. (2022) Effect of different root canal drying protocols on the bond strength of two bioceramic sealers, *Eur. J. Dent.*, <https://doi.org/10.1055/s-0042-1758807>.
- [18] YANG D.-K., S. KIM, J.-W. PARK, E. KIM, S.-J. SHIN (2018) Different setting conditions affect the surface characteristics and microhardness of calcium silicate-based sealers, *Hindawi, Scanning*, **2018**, Art. 7136345, 11 pp, <https://doi.org/10.1155/2018/7136345>.

*Department of Endodontics
Ankara Medipol University
Celal Bayar Blvd
06050 Cankaya, Ankara*

e-mail: bilge.ozcan@ankaramedipol.edu.tr

**Private practitioner
Ankara, Turkey
e-mail: bicerburcu539@gmail.com*

***Department of Endodontics
Ankara University
19/1 Mevlana Blvd
06560 Yenimahalle, Ankara
e-mail: saklar@gmail.com*

****Department of Restorative Dentistry
Ankara Medipol University
Celal Bayar Blvd
06050 Cankaya, Ankara
e-mail: lena.almasifar@ankaramedipol.edu.tr*