Available online at www.giornaleitalianoendodonzia.it

ORIGINAL ARTICLE

Evaluation of the push out of bond strength of different bioceramic root canal sealers with different obturation techniques

ABSTRACT

Aim: *This study aims to evaluate the effect of different obturation techniques [single cone (SC) and warm vertical compaction (WVC)] on the push-out bond strength (PBS) of gutta-percha (GP) with three calcium silicate-based sealers (CSBSs).*
Methodology: *Sixty single-rooted mandibular premolars were selected and decoronated to obtain a standardized root length of 16 mm. The canals were instrumented using VDW. Rotate system and were assigned into six equal Groups based upon the CSBS and obturation technique used following; Group 1 and Group 2; BC Sealer HiFlow (HiFlow; Brasseler USA) with SC and WVC, Group 3 and Group 4; CeraSeal (Meta Biomed Co., Cheongju, Korea) with SC and WVC, Group 5 and Group 6; BioRoot RCS (Septodont, Saint-Maur-des-Fosses Cedex, France) with SC and WVC. Roots were sectioned transversally at the thickness of 1±0.1 mm in thickness at 5 and 10 mm from the apex. The specimens were subjected to PBS test using a universal test machine at a loading speed of 0.5 mm/ min examined for their failure modes. Statistical analysis was performed using Kruskal-Wallis and multiple comparison tests.*
Results: *BioRoot-WVC Group was a significantly lower PBS value than other Groups at 5 and 10 mm from the apex ($p<0.05$). At 5 and 10 mm from the apex, no significant difference in PBS was found among the BC Sealer HiFlow and CeraSeal sealers obturated using two different techniques ($P>0.05$). The most common failure mode found in all Groups was a mixed failure.*
Conclusions: *WVC significantly reduced the PBS of the BioRoot RCS sealer compared to SC technique, but this was not significant with the BC Sealer HiFlow and CeraSeal.*

Seda Falakaloğlu[1*]
Mustafa Gündoğar[2]

[1]*Department of Endodontics, Afyonkarahisar Health Sciences University, School of Dentistry, Afyonkarahisar, Turkey*

[2]*Department of Endodontics, İstanbul Medipol University, School of Dentistry, İstanbul, Turkey*

Received 2022, January 30
Accepted 2022, March 3

KEYWORDS *BioRoot RCS, calcium silicate-base sealer, CeraSeal, EndoSequence BC sealer Hiflow, push-out bond strengh*

Corresponding Author
Asst. Prof. Seda Falakaloğlu | Department of Endodontics, School of Dentistry, Afyonkarahisar Health Sciences University, Afyonkarahisar | Turkey.
Tel: +90 546 560 6614 | Email: sedafalakaloglu@gmail.com

Peer review under responsibility of Società Italiana di Endodonzia
10.32067/GIE.2021.35.02.54

Introduction

Root canal filling is one of the crucial factors for successful endodontic treatment. Using a root canal sealer with gutta-percha (GP) is the most widely accepted obturation technique. The root canal sealer establishes a good connection between the root canal wall and the GP, preventing microleakage causing re-infection (1, 2). In recent years, calcium silicate-based sealers (CSBSs) have been widely used in endodontics. CSBSs are biocompatible and bioactive, thanks to their calcium silicate formulation. CSBSs form an apatite layer in contact with tissue and chemically bond to dentin. Micromechanical interlocking between CSBS and root dentin helps maintain the integrity of the sealer-dentin interface during a function (3, 4).

The EndoSequence BC Sealer HiFlow (BCH; HiFlow; Brasseler USA) exhibits a lower viscosity when heated and is more radiopaque, making it optimized for warm obturation techniques compared to standard BC Sealer (5). BioRoot RCS (BR; Septodont, Saint-Maur-des-Fosses Cedex, France) sealer induces hard tissue barrier formation in the presence of a physiologic solution (6). CeraSeal (CS; Meta Biomed Co., Cheongju, Korea) has an antibacterial effect, high volumetric stability, and high flowability according to manufacturer (Meta Biomed. CeraSeal Brochure [Internet]. 2022. Available from: https://www.meta-europe.com/en/produkt/ceraseal/) (7). The composition of the three CSBSs is represented in Table 1.

The single-cone technique (SC) has become very popular because of is easy and fast. CSBSs should be used with the SC technique, as recommended in the manufacturer's manual (8). The warm vertical compaction technique (WVC) might be the best to fill the pulp space in three dimensions (9). Because, in WVC technique, plasticized GP with heat can adapt well to the root canal geometry and achieve a good seal at all root canals (10). However, in WVC, using heat leads to changing the physical properties of CBCSs and this may affect the quality of the root canal filling (11, 12). The adhesion of endodontic sealer to root canal dentine has been reported to be affected by the obturation technique (12, 13).

The push-out of bond strength (PBS) tests are used as a measure of the bond strength of root canal filling materials to the root dentin. PBS results in shear stress at the dentin-cement interface, comparable with the stress in clinical conditions (14). The ability of the PBS test to evaluate adhesion is superior to other tests, as it creates parallel fractures in the interfacial area of the dentin bond (15). There are a few studies about the PBS of BCH, BR and CS (3,5,16,17). However, no data is available for comparing these CSBSs with each other in terms of PBS with SC and WVC techniques. Therefore, this study aimed to evaluate the PBS of BCH, BR, and CS with different obturation techniques. The null hypothesis was that there are no differences between these CSBSs regarding PBS and failure mode with varying obturation techniques.

Materials and Methods

The sample size calculation was performed with G Power software (Heinrich Heine University, Dusseldorf, Germany) with α=0.05 and ß=0.95, and each Group must be a minimum of nine samples (13). Sixty human mandibular premolars with only one straight root canal (curvature <5°) and a single apical foramen were included. The teeth were decoronated to achieve a standardize length of 16 mm. After determining the working length (WL), 1 mm short of the apex, the root canals were instrumented with a series of VDW.Rotate rotary file system (VDW GmbH, Munich, Germany) to #40/04. 10 ml of 2.5% NaOCl was used with a 30-G IrriFlex needle (Produits Dentaires SA, Switzerland) inserted to 1 mm short of the WL during instrumentation. Following mechanical instrumentation, each root canal was irrigated using 2 ml of 17% ethylenediaminetetraacetic acid (EDTA) solution for 1 min and 5 ml distilled water. The canals were dried using paper points.

Table 1
Composition of the sealers used

Material	Manufacturer	Type	Composition
EndoSequence BC Sealer HiFlow	HiFlow; Brasseler USA	Premixed	Zirconium oxide, calcium silicates, calcium phosphate, calcium hydroxide, filler, and thickening agents
BioRoot RCS	Septodont; Saint-Maur-des-Fosses Cedex, France	Powder-Liquid	Powder: tricalcium silicate, zirconium oxide, and povidone Liquid: aqueous solution of calcium chloride and polycarboxylate
CeraSeal	Meta Biomed Co.; Cheongju, Korea	Premixed	Calcium silicates, zirconium oxide, and thickening agent.

Prepared roots were randomly assigned to six Groups (n=10) for testing the obturation technique with different CBCSs.

Group 1 (BCH-SC)

According to the manufacturer's instruction, the canals were obturated with a size 40/0.04 BC point (Brasseler USA) sealed with a HiFlow sealer using the SC obturation technique. Before the sealer was placed into the coronal one-third of the canal with an intracanal tip, the tug back was evaluated with a master gutta-percha cone.

The master cone was coated with a thin layer of sealer and slowly inserted to the full WL, cut at the orifice level, and plugged.

Group 2 (BCH-WVC)

Same with the previous method, the master cone 40/0.04 BC point was inserted into the canal. The down pack (EQ-V Endodontic Obturation System, MetaBiomed, Cheongju, Korea) was 5 mm from the WL. Then, the hot GP was condensed with a hand plugger to achieve complete obturation of the root canal.

Group 3 (CS-SC)

Root canal obturation was used using the SC technique with a 40/0.04 GP cone (VDW GmbH, Munich, Germany) and the CeraSeal described in Group 1.

Group 4 (CS-WVC)

Root canal obturation was used using the WVC technique with a 40/0.04 GP cone and the CeraSeal described in Group 2.

Group 5 (BR-SC)

Root canal obturation was used using the SC technique with a 40/0.04 GP cone (VDW GmbH, Munich, Germany) and the BioRoot described in Group 1.

Group 6 (BR-WVC)

Root canal obturation was used using the WVC technique with a 40/0.04 GP cone and the BioRoot described in Group 2.

The radiographs were taken in the buccolingual, mesiodistal directions to ensure that the canals were without voids, the temporary filling material (Cavit G; 3 M ESPE, Seefeld, Germany) was placed. Then, the roots were kept in normal saline at 37 °C and 100% humidity for two weeks to set the fillings.

The roots were embedded into acrylic resin vertically and sectioned horizontally to obtain two slices 1±0.1 mm in thickness at 5 and 10 mm from the apex using a rotating diamond disk under water-cooling. Each slice was subjected to PBS test in a universal testing machine (Shimadzu, Kyoto, Japan) using a metallic indentor with a round cross-section and diameter of 0.5 mm and a crosshead speed of 0.5 mm/min was used. The load applied at the time of displacement was recorded in Newton. The bond strength was calculated in MPa according to the formula: Load/Adhesion surface area. The adhesion (bonding) surface area of each section was calculated as: $[(r^1+r^2) / 2]\times\pi\times h$, where π is the constant 3.14, r^1 and r^2 are the smaller and larger radii, respectively, and h is the thickness of the section in mm. After the test, samples were examined under a stereomicroscope at ×40 magnification.

The failure mode was determined into three categories; adhesive, cohesive, and mixed.
-Adhesive: the failure is between the sealer and root canal dentin;
-cohesive: the failure is between the GP cone and the sealer,
-mixed: the failure is between both interfaces (12).
The PBS from samples of the six Groups was statistically analyzed. Shapiro Wilk test indicated that the data showed non-normal distribution ($p<0.05$) and compared using Kruskal–Wallis and multiple comparison tests using SPSS 17.0 (SPSS software, SPSS Inc., Chicago, IL, USA).

Results

The descriptive statistics of all specimens had median PBS values in Table 2. BR-WVC Group was a significantly lower PBS value than other Groups at 5 and 10 mm from the apex ($p<0.05$). At 5 and 10 mm from the apex, no significant difference in PBS was found among the BCH and CS sealers obturated using two different techniques ($P>0.05$). The results of the mode of failure analysis are shown in Table 3 and the most common failure mode found in all Groups was mixed failure.

Discussion

Adhesive root canal sealers enhance resistance to fracture and minimize microleakage of canal obturation (18). CBCSs are hydrophilic materials with a low contact angle and good flowability, helping them bond to the root canal wall (19). The penetration of endodontic sealers into the dentinal tubules reduces the core material and dentin interface. Therefore, mechanical locking may improve the retention of the core material. The PBS test provides valuable information about the retention of sealers on root canal walls (20). The present study used PBS test to evaluate the adhesion of BR, BCH, and CS are reportedly efficient, practical, and reliable (20).
To the best of our knowledge, no other study assessing the PBS of BR, BCH, and CS with different obturation techniques is yet available. A measurable adhesive property was seen in all the Groups in this study. The lowest PBS value was observed in the BR-WVC Group. The null hypothesis was rejected. The reason for that could be the high temperature helps push GP to the root canal dentin wall; there have been concerns about the potential adverse effects of the heat on sealer characteristics (21-24). Chen et al. (11) reported that the GP and root canal are likely to modify the effects of heat on the physicochemical properties of the sealer and the interaction between the viscosity and the shear rates. Also, heat may accelerate hydration and hydroxyapatite formation in CBCSs (25). However, the WVC technique demonstrated the same bond strength values in BCH, and CS Groups. Atmeh et al. (26) reported that in the WVC technique, the amount of heat transmitted to the root canal filling may not cause a crucial change to the properties of CBCSs and does not affect the setting reaction of the CBCSs. Also, Dewi et al. (5) reported that WVC method did not affect the PBS of the BCH. It is consistent with the data obtained in our study about BCH. According to Abdelwahed et al. (16), CS showed higher PBS values when used in the WVC technique compared to SC and lateral compaction techniques. This contradictory result could be attributed to different methodology according to our study.
In our opinion, the PBS results of sealers with the WVC technique may be due to the physicochemical properties.
Kharouf et al. (27) compared the physicochemical properties, filling ability of CS and BR sealers. They reported that CS might have the superior filling ability and lower solubility than the BR sealer due to its specific chemical composition and mixing method. These physical properties of the sealer used with the warm technique may affect the quality of the root canal obturation (12).
Additionally, López-García et al. (28) reported that CS and EndoSequence BC Sealer displayed high cell viability, cell attachment, cell migration rates, and ion release rates. BCH has similar physicochemical and biological properties with

Table 2

Mean of the push-out bond strength (MPa) of specimens obtained from different distances from the working length

Sealers and Obturation Technique						
	BC HiFlow		CeraSeal		BioRoot	
	SC	WVC	SC	WVC	SC	WVC
5 mm	5.28^{A}	5.43^{A}	5.24^{A}	5.17^{A}	5.18^{A}	3.32^{B}
10 mm	2.34^{a}	2.25^{a}	2.17^{a}	2.24^{a}	2.26^{a}	1.28^{b}

Kruskal Wallis H-test. Different superscript letters indicate a statistically significant difference between the mean value of PBS of specimens obtained from the same distance from the WL (P<0.05). SC, single-cone obturation technique; WVC, warm vertical compaction obturation technique.

Table 3

Failure pattern distribution (n)

	BC HiFlow		CeraSeal		BioRoot	
	SC	WVC	SC	WVC	SC	WVC
5 mm						
Adhesive	0	0	0	0	0	0
Cohesive	2	1	3	2	3	2
Mixed	8	9	7	8	7	8
Total	10	10	10	10	10	10
10 mm						
Adhesive	0	0	0	0	0	0
Cohesive	4	2	4	3	5	4
Mixed	6	8	6	7	5	6
Total	10	10	10	10	10	10

SC, single-cone obturation technique; WVC, warm vertical compaction obturation technique.

EndoSequence BC Sealer (29). In the present study, the CS-WVC Group showed higher PBS values than the BR-WVC values and had no significant difference with the BCH-WVC Group. CBCSs are used with the SC technique to the manufacturer's instructions (8).

Our study found no differences between the three CBCSs with the SC technique. Previous studies reported that use of the SC to obturate root canals with an irregular shape results in formation of bubbles (30,31) and an increase in the volume of sealer in the root canal obturation (32). Retana-Lobo et al. (33) showed that the different CSBSs values for PBS observed in their study, were higher when the root canal was obturated with just the sealer. We think the difference between BR Groups might be because the amount of sealer increases in SC, and the interaction of BR with WVC is not fully known.

In a previous study comparing the physical properties of different premixed formulation CBCSs and BR, the physical properties of BR were affected by thermal treatment. They explained that different behavior of formulations (premixed and powder-liquid) could be due to the momentum of water uptake and the beginning of the setting reaction (34).

Also, the thermoplastic GP shrinks on cooling; shrinkage may lead to stress concentration on the sealer, affecting its bond

to the root dentine surface (35). Furthermore, when using a coated GP cone with CBCS, a chemical bond could help reduce leakage and reinforce the monoblock obturation concept (5). However, Eltair et al. (36) reported that an interfacial gap could be between BC sealer and coated GP. Therefore, although standard GP cone with BR and CS, there was no significant difference between all SC Groups.

Our study's most common failure mode is a mixed failure, followed by cohesive failure. These results were consistent with studies about CBCSs that also showed the dominance of mixed or cohesive failure (12,35,37). That may be, CBCSs have more potent chemical, physical bonds to radicular dentin than to the GP (33). Also, the plastic deformation of the GP may negatively affect the PBS (14).

One of the limitations of this study was to investigate the PBS of three CBCSs after two weeks following obturation, and saline was used to give the humidity to the samples. However, the phosphate-buffered saline (PBS) or Hank's balanced salt solution (HBSS) may enhance the bond strength of CBCSs (38,39). For this reason, comparing different filling techniques with CBCSs in PBS or HBSS should be considered in future research.

Conclusions

Within the limitation of this in vitro study, the following was concluded the WVC method did not affect the PBS of the premixed CS and BCH. However, the heat-based root canal obturation method negatively impacted the BR's PBS.

Concerning this study's results, CS can be used with standard GP since the PBS of the SC technique was equal to the WVC. Therefore, further clinical investigations are required to evaluate the PBS of BCH, BR, and CS with different obturation techniques.

Clinical Relevance

The present study results suggest that BC Sealer HiFlow and CeraSeal are suitable calcium silicate-based sealers with warm vertical compaction for root canal treatment.

Conflict of Interest

The authors declare that they have no confict of interest.

Acknowledgements

The authors would like to thank Asst. Prof. Merve Yeniçeri Özata for statistical analysis.

Ethical approval

Ethical approval was obtained from the research ethics committee of İstanbul Medipol University (Ref. Number: 137).

References

1 *Whitworth J. Methods of filling root canals: principles and practices. Endod Top. 2005;12:2-24.*
2 *Stoll R, Kirsten B, Stachniss V. The influence of different factors on the survival of root canal fillings: a 10-year retrospective study. J Endod. 2005;31(11):783-90.*
3 *Donnermeyer D, Dornseifer P, Schäfer E et al. The push-out bond strength of calcium silicate-based endodontic sealers. Head Face Med. 2018;14:13.*
4 *Donnermeyer D, Vahdat-Pajouh N, Schäfer E et al. Influence of the final irrigation solution on the push-out bond strength of calcium silicate-based, epoxy resin-based and silicone-based endodontic sealers. Odontology. 2019;107:231-236.*
5 *Dewi A, Upara C, Sastraruji T et al. Effect of a heat-based root canal obturation technique on push-out bond strength of the classical bioceramic and new HiFlow sealer. Aust Endod J. 2021;*
6 *Siboni F, Taddei P, Zamparini F et al. Properties of bioRoot RCS, a tricalcium silicate endodontic sealer modified with povidone and polycarboxylate. Int Endod J. 2017;50(2):120-136.*
7 *Muedra, P., Forner, L., Lozano, A., Sanz, J. L., Rodríguez-Lozano, F. J., Guerrero-Gironés, J., Riccitiello, F., Spagnuolo, G., & Llena, C. (2021). Could the Calcium Silicate-Based Sealer Presentation Form Influence Dentinal Sealing? An In Vitro Confocal Laser Study on Tubular Penetration. Materials, 14(3), 659. https://doi.org/10.3390/ma14030659.*
8 *Lim M, Jung C, Shin DH et al. Calcium silicate-based root canal sealers: a literature review. Restor Dent Endod. 2020;45(3):e35.*
9 *Schilder H. Filling root canals in three dimensions. J Endod. 2006;32:281-290.*
10 *Aminsobhani M, Ghorbanzadeh A, Sharifian M et al. Comparison of obturation quality in modified continuous wave compaction, continuous wave compaction, lateral compaction and warm vertical compaction techniques. J Dent. 2015;12:99-108.*

11 Chen B, Haapasalo M, Mobuchon C et al. Cytotoxicity and the effect of temperature on physical properties and chemical composition of a New Calcium Silicate-based root canal sealer. J Endod. 2020;46:531-538.
12 DeLong C, He J, Woodmansey K. The effect of obturation technique on the push-out bond strength of calcium silicate sealers. J Endod. 2015;41(3):385-388.
13 Gade VJ, Belsare LD, Patil S et al. Evaluation of push-out bond strength of endosequence BC sealer with lateral condensation and thermoplasticized technique: an in vitro study. J Conserv Dent. 2015;18:124-127.
14 Pane ES, Palamara JE, Messer H. Critical evaluation of the push-out test for root canal filling materials. J Endod. 2013;39:669-673.
15 Sudsangiam S, van Noort R. Do dentin bond strength tests serve a useful purpose? J Adhes Dent. 1999;1:57-67.
16 Abdelwahed A., Roshdy N, Elbanna A. Evaluation of Push-out Bond Strength of CeraSeal Bioceramic sealer with Different Obturation Techniques. Egypt Dent J. 2021;67(3):2655-2662.
17 Aly Y, El Shershaby S. Evaluation of Push out Bond Strength of Different Endodontic Sealers with Different Obturation Techniques. Curr Sci Int. 2020;9(3):455-461.
18 Poggio C, Dagna A, Ceci M et al. Solubility and pH of bioceramic root canal sealers: A comparative study. J Clin Exp Dent. 2017;9:1189-94.
19 de Candeiro GTM, Correia FC, Duarte MAH et al. Evaluation of radiopacity, pH, release of calcium ions, and flow of a bioceramic root canal sealer. J Endod. 2012;38(6):842-845.
20 Goracci C, Tavares AU, Fabianelli A 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(4):353-61.
21 Viapiana R, Guerreiro-Tanomaru JM, Tanomaru-Filho M et al. Investigation of the effect of sealer use on the heat generated at the external root surface during root canal obturation using warm vertical compaction technique with System B heat source. J Endod. 2014;40:555-561.
22 Viapiana R, Baluci CA, Tanomaru-Filho M et al. Investigation of chemical changes in sealers during application of the warm vertical compaction technique. Int Endod J. 2015;48:16-27.
23 Camilleri J. Sealers and warm gutta-percha obturation techniques. J Endod. 2015;41:72-78.
24 Qu W, Bai W, Liang YH et al. Influence of warm vertical compaction technique on physical properties of root canal sealers. J Endod. 2016;42:1829-33.
25 Dabaj P, Kalender A, Unverdi Eldeniz A. Push-out bond strength and SEM evaluation in roots filled with two different techniques using new and conventional sealers. Mater. 2018;11:E1620.
26 Atmeh AR, AlShwaimi E. The effect of heating time and temperature on epoxy resin and calcium silicate-based endodontic sealers. J Endod. 2017;43:2112-2118.
27 Kharouf N, Arntz Y, Eid A et al.. Physicochemical and Antibacterial Properties of Novel, Premixed Calcium Silicate-Based Sealer Compared to Powder–Liquid Bioceramic Sealer. J Clin Med. 2020;9(10):3096.
28 López-García S, Myong-Hyun B, Lozano A et al. Cytocompatibility, bioactivity potential, and ion release of three premixed calcium silicate-based sealers. Clin Oral Investig. 2020;24:1749-1759.
29 Mann A, Zeng Y, Kirkpatrick T et al. Evaluation of the physicochemical and biological properties of EndoSequence BC Sealer HiFlow. J Endod. 2022;48:123-131.
30 Marciano MA, Ordinola-Zapata R, Cunha TV et al. Analysis of four gutta-percha techniques used to fill mesial root canals of mandibu-lar molars. Int Endod J. 2011;44:321-329.
31 Weis MV, Parashos P, Messer HH. Effect of obturation technique on sealer cement thickness and dentinal tubule penetration. Int Endod J. 2004;37:653-663.
32 Somma F, Cretella G, Carotenuto M et al. Quality of thermoplasticized and single point root fillings assessed by micro-computed tomography. Int Endod J. 2011;44:362-369.
33 Retana-Lobo C, Tanomaru-Filho M, Guerreiro-Tanomaru JM et al. Push-Out Bond Strength, Characterization, and Ion Release of Premixed and Powder-Liquid Bioceramic Sealers with or without Gutta-Percha. Scanning. 2021;p12.
34 Donnermeyer D, Ibing M BS et al. Physico-chemical investigation of endodontic sealers exposed to simulated intracanal heat application: hydraulic calcium silicate-based sealers. Materials (Basel). 2021;14:728.
35 Al-Hiyasat AS, Alfirjani SA. The effect of obturation techniques on the push-out bond strength of a premixed bioceramic root canal sealer. J Dent. 2019;89:103169.
36 Eltair M, Pitchika V, Hickel R et al. Evaluation of the interface between gutta-percha and two types of sealers using scanning electron microscopy (SEM). Clin Oral Investig. 2018;22:1631-1639.
37 Shokouhinejad N, Gorjestani H, Nasseh AA et al. Push-out bond strength of gutta-percha with a new bioceramic sealer in the presence or absence of smear layer. Aust Endod J. 2013;39:102-106.
38 Huffman BP, Mai S, Pinna L et al. "Dislocation resistance of ProRoot Endo Sealer, a calcium silicate-based root canal sealer from radicular dentine. Int Endod J. 2009;42(1):34-46.
39 Reyes-Carmona JF, Felippe MS, Felippe WT. The biomineralization ability of mineral trioxide aggregate and Portland cement on dentin enhances the push-out strength. J Endod. 2010;36(2):286-291.