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## EndoSequence® BC Sealer™ and Root Repair Material (RRM™) Research Bibliography

### Biocompatibility/Cytotoxicity

Liu Y, Liu XM, Bi J, Yu S, Yang N, Song B, Chen X. Cell migration and osteo/odontogenesis stimulation of iRoot FS as a potential apical barrier material in apexification. *International Endodontic Journal*, 2020; 53(4):467-477.

Subject: To investigate the in-vitro biological effects of root repair materials on the proliferation, migration and osteo/odontogenic differentiation of human stem cells from the apical papilla and the mechanism of induction.

**Significance/Conclusion:** *IRoot FS promoted the cell migration of apical papilla stem cells without cytotoxicity*

Giacomino CM, Wealleans JA, Kuhn N, Diogenes A. Comparative Biocompatibility and Osteogenic Potential of Two Bioceramic Sealers. *Journal of Endodontics*, 2019; 45(1):51-56.

Subject: A murine osteoblast precursor cell line was exposed to a wide range of concentrations of classical and two bioceramic sealers for 7 days.

**Significance/Conclusion:** *EndoSequence BC Sealer and ProRoot ES were significantly more biocompatible and promoted osteoblastic differentiation, a bioactivity not found in AH Plus and Roth sealers.*

Natália Gomes de Oliveira, Pollyana Rodrigues de Souza Araújo, Marina Torreão da Silveira, Ana Paula Veras Sobral, and Marianne de Vasconcelos Carvalho. Comparison of the biocompatibility of calcium silicate-based materials to mineral trioxide aggregate: Systematic review. *European Journal of Dentistry*, 2018 April; 12(2).

Subject: 18 studies qualified to compare the newer bioceramic materials to MTA

**Significance/Conclusion:** *The results showed that bioceramic materials have biological properties similar to those of MTA, including low cytotoxicity as well as promoting cell proliferation and adhesion, low expression of inflammatory cytokines, and reduced pulp inflammation.*

G.T.M Candeiro, C. Moura-Netto, R.S. D'Almeida-Couto, N. Azambuja-Junior, M. M. Marques, s. Cai, G. Gavini. Cytotoxicity, genotoxicity and antibacterial effectiveness of a bioceramic endodontic sealer. *International Endodontic Journal*, 2015 Aug; doi: <https://doi.org/10.1111/iej.12523>.

Subject: Compared these characteristics of bioceramic endodontic sealer Endosequence BC sealer with those of AH Plus sealer.

**Significance/Conclusion:** *Bioceramic-based sealer had less cytotoxicity and genotoxicity and similar antibacterial effect against E. faecalis in comparison with AH Plus sealer.*

Zhang W, Li Z, Peng. Ex vivo cytotoxicity of a new calcium silicate-based canal filling material.

*International Endodontic Journal*, 2010; 43(9):769. doi:10.1111/j.1365-2591.2010.01733.

Subject: BC Sealer Cytotoxicity vs. AH Plus and MTA

**Significance/Conclusion: Concluded that BC Sealer is highly biocompatible and that it is significantly less cytotoxic than AH Plus.**

Jingzhi M, Shen Y, Stojicic S, Haapasalo M. Biocompatibility of Two Novel Root Repair Materials. *Journal of Endodontics*, 2011; 37(6):793-8.

Subject: Biocompatibility of RRM (Syringable Paste and Putty)

**Significance/Conclusion: Concluded that both versions of RRM are highly biocompatible and comparable to MTA.**

AlAnezi AZ, Jiang J, Safavi KE, Spangberg LSW, Zhu Q. Cytotoxicity evaluation of EndoSequence Root Repair Material. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*, 2010; 109(3): 122-5. DOI:10.1016/j.tripleo.2009.11.028. Subject: Cytotoxicity/Biocompatibility of RRM compared to MTA (gray and white).

**Significance/Conclusion: Concluded that cell viability is similar to both gray and white MTA in fresh and set conditions.**

Ruparel, Ruparel, Chen, Ishikawa, Diogenes. Direct Effect of Endodontic Sealers on Trigeminal Neuronal Activity. *Journal of Endodontics*, 2014 May;

40(5):638-687. Published Online: March 20, 2014 doi: <http://dx.doi.org/10.1016/j.joen.2014.01.030>

Subject: Evaluation of the effect of sealers on peripheral nociceptors. A post-operative sensitivity study.

**Significance/Conclusion: Concluded that ZOE and AH Plus in their fresh form evoked greater CGRP release than the control groups. Conversely, EndoSequence BC Sealer reduced basal CGRP release at all concentrations tested.**

Chang, Lee, Kang, Kum, Kim. In Vitro Biocompatibility, Inflammatory Response, and Osteogenic Potential of 4 Root Canal Sealers: Sealapex, Sankin Apatite Root Sealer, MTA Fillapex, and iRoot SP Root Canal Sealer. *Journal of Endodontics*, 2014 (online June 7<sup>th</sup> 2014); doi: <http://dx.doi.org/10.1016/j.joen.2014.04.006>

Subject: Comparison of the cytotoxicity, inflammatory response, osteogenic effect and the signaling mechanisms of the sealers tested.

**Significance/Conclusion: iRoot SP (aka BC Sealer) showed lower expression of inflammatory mediators and enhanced osteoblastic differentiation of PDLCS.**

Hui-min Zhou, PhD, Tian-feng Du, DDS, PhD, Ya Shen, DDS, PhD, Zhe-jun Wang, DDS, PhD, Yu-feng Zheng, PhD, and Markus Haapasalo, DDS, PhD. In Vitro Cytotoxicity of Calcium Silicate-containing Endodontic Sealers. *Journal of Endodontics*, 2015; (41(1));56-61.

Subject: Cytotoxicity evaluation of bioceramic sealers vs. AH Plus (control).

**Significance/Conclusion: Concluded that BC Sealer was significantly less cytotoxic than MTA- Fillapex and AH Plus.**

Ciasca M, Aminoshariae A, Jin G, Montagnese T, Mickel A. A Comparison of the Cytotoxicity and Proinflammatory Cytokine Production of EndoSequence Root Repair Material and ProRoot MTA in Human Osteoblast Cell Culture Using Reverse-Transcriptase Polymerase Chain Reaction. *Journal of Endodontics*, 2012; 38(6); 486-9. Subject: Cytotoxicity and Proinflammatory Cytokine Production of RRM™ compared to MTA. **Significance/Conclusion: Concluded that RRM and MTA showed similar Cytotoxicity and Cytokine Production.**

Hirschman W, Wheeler M, Bringas J, Hoen M. Cytotoxicity Comparison of Three Current Direct Pulp-capping Agents with a New Bioceramic Root Repair Putty. *Journal of Endodontic*, 2012; 38(3);385-8. Subject: Cytotoxicity comparison of RRM vs. popular pulp capping agents (White MTA, Dycal and UltraBlend Plus). **Significance/Conclusion: Concluded that RRM was the most biocompatible of the group (“after exposure to the 8-day elutes, the respective percentage of cell survivability was 91% (Brasseler), 88% (MTA-Angelus), 76% (UltrablendPlus), and 37% (Dycal)”).**

Yuqing Jiang et al. A Comparative Study on Root Canal Repair Materials: A Cytocompatibility Assessment in L929 and MG63 Cells. *The Scientific World Journal*; vol. 2014, Article ID 463826. Subject: The aim of this study was to conduct a comparative assessment on the surface morphology and the cell adhesion capacity of iRoot BP Plus (aka BC RRM Putty), iRoot FS (aka BC RRM Fast Set Putty), ProRoot MTA, and Super-EBA on both fibroblast and osteoblast-like cell models. Furthermore, the time-course in vitro cytotoxicity of these materials was assessed. **Significance/Conclusion: Concluded that BC RRM-Fast Set Putty is extremely biocompatible and non-cytotoxic. Furthermore, BC RRM exhibited the fastest set time and the best cell adhesion capacity of all the materials tested including ProRoot.**

Nicole Shinbori, DDS, Ana Maria Grama, DDS, Yogesh Patel, DDS, Karl Woodmansey, DDS, Jianing He, DMD, Clinical Outcome of Endodontic Microsurgery That Uses EndoSequence BC Root Repair Material as the Root-end Filling Material. *Journal of Endodontics*, 2015 February (online). Subject: Clinical outcome study of BC RRM Putty for apical surgery and evaluation of prognostic factors influence on the success/performance of BC RRM Putty. **Significance/Conclusion: Concluded that BC RRM is suitable for root end filling (92% success rate) and that none of the prognostic factors affected the success.**

Wafaa K, Siham. Can Mineral Trioxide Aggregate and Nanoparticulate EndoSequence Root Repair Material Produce Injurious Effects to Rat Subcutaneous Tissues? *Journal of Endodontics*, 2015 April; 41(7), doi:10.1016/j.joes.2015.02.034. Subject: Evaluation of effect of implantation of MTA and BC RRM into Rats. **Significance/Conclusion: Concluded that MTA and BC RRM caused an inflammatory effect. The MTA group was significantly more injurious. Given the long term research on the excellent biocompatibility of MTA this study shows that BC RRM is even friendlier with the tissue than MTA (within the parameters of this study).**

## Mineralization/Osteogenic/Pulp Cells/Pulp Capping

Wu X, Yan M, Lu J, Ge Z, Li Y, Bian M, Fu L, Yu J. iRoot SP Promotes Osteo/Odontogenesis of Bone Marrow Mesenchymal Stem Cells via Activation of NF- $\kappa$ B and MAPK Signaling Pathways. *Stem Cells International*, 2020 December.

Subject: To assess the effect of BC sealer on the biological features of Bone Marrow mesenchymal stem cells (BMSCs).

Significance/Conclusion: *iRoot SP BC sealer promotes osteo/odontogenic differentiation of BMSC's possibly provided a clinical application for the regeneration of bone and tooth tissue in the future.*

Von Arx T, Janner SFM, Haenni S, Bornstein MM. Bioceramic root repair material (BCRRM) for root-end obturation in apical surgery. An analysis of 174 teeth after 1 year. *Swiss Dental Journal*, 2020 May; 130(5):390-396.

Subject: To evaluate the 1 year outcome of 174 consecutively treated apicoectomies using bioceramic root repair material (BCRRM) as the retrograde filling material.

Significance/Conclusion: *94.1% were successful, 4.1% uncertain and 1.8% failed. BCRRM is a biocompatible root-end filling material showing excellent one year results.*

Lee B-N, Hong J-U, Kim S-M, Jang J-H, Chang H-S, Hwang Y-C, Hwang I-N, Oh W-M. Anti-inflammatory and Osteogenic Effects of Calcium Silicate-based Root Canal Sealers. *Journal of Endodontics*, 2019; 45(1):73-78.

Subject: To assess the effects of 3 root canal sealers on cell viability, inflammatory response, and osteogenic potential in MC3T3-E1 cells.

Solution/Conclusion: *Calcium silicate-based sealers exhibit anti-inflammatory effects and induce osteogenic differentiation in MC3T3-E1 cells.*

Lopez-Garcia S, Pecci -Lloret MR, Guerrero-Girones J, Pecci-Lloret MP, Lozano A, Llana C, Rodriguez-Lozano JJ, Forner L.; Comparative Cytocompatibility and Mineralization Potential of Bio-C Sealer and TotalFill BC Sealer. *Materials (Basel)*, 2019; 12(19):3087

Subject: To investigate cytocompatibility and mineralization potential of two bioceramic sealers compared to AH Plus.

Significance/Conclusion: *Bioceramic sealers demonstrated better cytocompatibility in terms of cell viability, migration, cell morphology, cell attachment and mineralization capacity than AH Plus.*

Mahgoub N, Alqadasi B, Aldhorae K, Assiry A, Altawili ZA, Hong T. Comparison between iRoot BP Plus (EndoSequence Root Repair Material) and Mineral Trioxide Aggregate as Pulp-capping Agents: A Systematic Review. *Journal of International Society of Preventive & Community Dentistry*, 2019 Nov; 9(6):542-552.

Subject: Systematic review to evaluate BC putty materials used as pulp capping agents.

Significance/Conclusion: *Materials are biocompatible that enhance hDPCs and other variant human cells proliferation, migration, attachment adhesion, mineralization, and dentinal bridge formation.*

Edrees HY, Abu Zeid STH, Atta HM, AlQriqri MA. Induction of Osteogenic Differentiation of Mesenchymal Stem Cells by Bioceramic Root Repair Material. *Materials (Basel)*, 2019; 12(14):2311.

Subject: evaluate the osteogenic activity of Endosequence Root Repair Material (ERRM) putty using rat mesenchymal stem cells (MSCs).

Significance/Conclusion: *ERRM enhances the osteogenic differentiation of MSCs.*

Lei Y, Yang YT, Zhan Y. Evaluation of bioceramic putty repairment in primary molars pulpotomy. *Beijing Da Xue XUE Bao Yi Xue Ban*, 2019 Feb; 51(1):70-74.

Subject: To evaluate the clinical characteristics of BC putty used as a pulp capping agent in primary molars.

Significance/Conclusion: *One year success rate was 95% in maintaining vitality with no periapical disease.*

E. P. Güven , P. N. Taşlı , M. E. Yalvac , N. Sofiev, M. B. Kayahan , F. Sahin. *In vitro* comparison of induction capacity and biomineralization ability of mineral trioxide aggregate and a bioceramic root canal sealer. *International Endodontic Journal*, 2013.

Subject: In vitro evaluation of the capacity of these materials to induce biomineralization

Significance/Conclusion: *MTA and iRoot SP induced hTGSC differentiation into odontoblast-like cells.*

Z. € Oncel Torun, D. Torun, K. Demirkaya, S. T. Yavuz, M. P. Elc, M. Sarper & F. Avcu. Effects of BC RRM Putty and white mineral trioxide aggregate on cell viability and the expression of genes associated with mineralization. *International Endodontic Journal*, 2014 October. doi:10.1111/iej.12393.

Subject: Cytotoxicity and mineralization evaluation of BC RRM Putty and white MTA on human dental pulp cells (hDPCs).

Significance/Conclusion: *Concluded that both BC RRM Putty and White MTA were highly biocompatible and facilitated odontoblastic differentiation of hDPCs at a similar and favorable level.*

Zhang S., Yang X., Fan M. Bioaggregate and iRoot BP Plus (RRM™ Putty) optimizes the proliferation and mineralization ability of human dental pulp cells. *International Endodontic Journal*, 2013.

Subject: Evaluation of the mineralization ability of BC RRM Putty compared to MTA.

Significance/Conclusion: *Concluded that RRM Putty outperformed MTA in terms of ALP activity and odontoblastic-differentiation associated gene expressions (mineralization). Given RRM Putty's favorable handling and mineralization performance in this study it can be concluded that RRM Putty is an excellent pulp capping material.*

Zhang W, Li Zhi, Peng, B. Effects of iRootSP (aka BC Sealer™) on Mineralization-related Genes Expression in MG63 Cells. *Journal of Endodontics*, 2010; 36(12):1978-1982

Subject: Cytotoxicity and Osteoconductivity of BC Sealer vs. AH Plus

Significance/Conclusion: Concluded that BC Sealer was nontoxic and able to induce mineralization and odontoblastic cell differentiation in hDPCs (human dental pulp cells) at a higher level than mineral trioxide aggregate (MTA).

S. Shi, Z. F. Bao, Y. Liu, D. D. Zhang, X. Chen L. M. Jiang & M. Zhong Comparison of in vivo dental pulp responses to capping with iRoot BP Plus and mineral trioxide Aggregate. *International Endodontic Journal*, 2015 February. doi:10.1111/iej.12439.

Subject: Direct pulp cap performance comparison (healing and bridge formation) of MTA vs. RRM Putty in dogs.

Significance/Conclusion: Concluded that BC RRM Putty performed favorably and as good as MTA. Both MTA and RRM performed excellent. Both groups exhibited bridge formation and an absence of pulpal inflammation.

Siyi Liu, MD, Sainan Wang, PhD, and Yanmei Dong, PhD. Evaluation of a Bioceramic as a Pulp Capping Agent In Vitro and In Vivo. *Journal of Endodontics*, 2015 May; 41(5):652-7. doi:10.1016/j.joen.2014.12.009. Epub 2015 Jan.

Subject: In Vitro and In Vivo evaluation of BC RRM Putty as a pulp capping agent using hDPCs as compared to MTA.

Significance/Conclusion: Concluded that BC RRM Putty is an excellent pulp capping material and exhibited favorable results for biocompatibility, hDPCs proliferation and mineralization (bridge formation).

## Retreatability

Garrib M, Camilleri J. Retreatment efficacy of hydraulic calcium silicate sealers used in single cone obturation. *Journal of Dentistry*, 2020 July; 98.

Subject: to assess the efficacy of mechanical instrumentation aided by targeted chemical means for the removal of bioceramic sealers.

Significance/Conclusion: 17% EDTA and 10% formic acid applied for 5 minutes used in conjunction with mechanical instrumentation achieved over 95% removal of GP and sealer and also achieved patency and reestablishment of the working length while not damaging the dentin.

Romeiro K, de Almeida A, Cassimiro M, Gominho L, Dantas E, Chagas N, Volozo C, Freire L, Albuquerque. Reciproc and Reciproc Blue in the removal of bioceramic and resin-based sealers in retreatment procedures. *Clinical Oral Investigations*, 2020; 24(1):405-416.

Subject: Compare remaining root canal material, dentin removal, apical transportation and apical extrusion of debris after retreatment of bioceramic sealer of resin-based sealers.

Significance/Conclusion: All tests resulted in similar results. Retreatment of BC sealer may be more time consuming.

Eymirli A, Sungur DD, Uyanik O, Purali N, Naggas E, Cehreli ZC. Dentinal Tubule Penetration and Retreatability of a Calcium Silicate-based Sealer Tested in Bulk or with Different Main Core Material. *Journal of Endodontics*, 2019 Aug; 45(8)1036-1040.

Subject: Tubular penetration of Endosequence BC sealer with or without Gutta percha and to compare the removal of the sealer.

Significance/Conclusion: The best sealer penetration was achieved with the use of 0.04 tapered GP points. Removal of the sealer was easier when it was accompanied by GP points.

KyungJae K, Kim DV, Kim S-yYang SE. A micro-computed tomographic study of remaining filling materials of two bioceramic sealers and epoxy resin sealer after retreatment. *Restorative Dentistry & Endodontics*, 2019 April; vol. 44.

Subject: To evaluate the residual root canal filling material after retreatment (EndoSeal MTA, BC sealer and AH Plus) using micro-computed tomography (micro CT).

Significance/Conclusion: EndoSeal MTA had large amounts of sealer remaining while there was no difference between the BC sealer and AH Plus.

Kakoura F, Pantelidou O. Retreatability of root canals filled with Gutta percha and a novel bioceramic sealer: A scanning electron microscopy study. *Journal of Conservative Dentistry*, 2018; 21(6):632-636.

Subject: To evaluate residual filling material and re-establishment of working length and apical patency after retreatment of BioRoot RCS, versus TotalFill BC Sealer and AH26 used in single cone obturation.

Significance/Conclusion: All the sealers were removed to a similar extent. The working length and patency were reestablished sufficiently in all groups.

H. Ersev, B. Yilmaz, M.E. Dincol & R. Daglaroglu. The efficacy of ProTaper University rotary retreatment instrumentation to remove single gutta-percha cones cemented with several endodontic sealers. *International Endodontic Journal*, 2012; DOI:10.1111/j.1365-2591.2012.02032.x.

Subject: Evaluation of the retreatability of BC Sealer vs. AH Plus and other sealers.

Significance/Conclusion: Both BC Sealer and AH Plus were readily retreated using conventional retreatment methods with the ProTaper retreatment instruments.

Kim, Hyunsuk, et al. "Comparisons of the Retreatment Efficacy of Calcium Silicate-Based Sealers and Residual Sealer in Dentinal Tubules." *Journal of Endodontics*, 2015; 41(12):2025-2030., doi:10.1016/j.joen.2015.08.030.

Subject: The aim of this study was to evaluate the retreatment efficacy and amount of residual sealer in a single canal filled with either EndoSequence BC (Brasseler, Savannah, GA) or AH Plus (Dentsply DeTrey, Konstanz, Germany).

Significance/Conclusion: The present study shows that EndoSequence BC Sealer and AH Plus sealer have similar efficacy in dentin penetration and retreatment efficacy.

## Antibacterial Properties

Katakidis A, Sidiropoulos K, Koulaouzidou E, Gogos C, Economides N. Flow characteristics and alkalinity of novel bioceramic root canal sealers. *Restorative Dentistry & Endodontics*, 2020; 45(4).

Subject: PH and flow characteristics were tested for Sealapex (calcium hydroxide sealer) and TotalFill BC sealer and BioRoot RCS sealer.

Significance/Conclusion: *The TotalFill BC Sealer demonstrated the highest flow. The bioceramic sealers initially presented higher alkaline activity than the polymeric calcium hydroxide sealer. However, at 3 and 4 weeks post-immersion (i.e. when the sealers had fully set), all sealers had similar pH values.*

Fausto Zamparini, Francesco Siboni, Carlo Prati, Paola Taddei, Maria Giovanna Gandolfi. Properties of calcium silicate-monobasic calcium phosphate materials for endodontics containing tantalum pentoxide and zirconium oxide. *Clinical Oral Investigations*, 2019; vol.23: 445-457

Subject: Evaluate chemical-physical properties and apatite-forming ability of three pre-mixed calcium silicate materials containing monobasic calcium phosphate (CaH<sub>4</sub>P<sub>2</sub>O<sub>8</sub>) bioceramic, tantalum pentoxide and zirconium oxide, recently marketed for endodontics (TotalFill BC-Sealer, BC-RRM-Paste, BC-RRM-Putty).

Significance/Conclusion: *These materials met the required chemical and physical standards and released biologically relevant ions. The CaSi-CaH<sub>4</sub>P<sub>2</sub>O<sub>8</sub> system present in the materials provided Ca and OH ions release with marked abilities to nucleate a layer of B-type carbonated apatite favoured/accelerated by the bioceramic presence. They therefore offer many biological advantages over materials used for similar indications.*

Bukhari S, Karabucak B. The Antimicrobial Effect of Bioceramic Sealer on an 8-week Matured Enterococcus faecalis Biofilm Attached to Root Canal Dentinal Surface. *Journal of Endodontics*, 2019; 45(8):1047-1052.

Subject: Test the antibacterial activity of bioceramic sealer vs. AH Plus on 8-week-old Enterococcus faecalis biofilms attached to root canal surfaces using a dentine infection model.

Significance/Conclusion: *EndoSequence BC Sealer exhibited significant antimicrobial capacity in the presence of dentin for up to 2 weeks on an 8-week-old E. faecalis biofilm in comparison with AH Plus sealer.*

Marija Šimundić Munitić, Tina Poklepović Peričić, Ana Utrobičić, Ivona Bago, Livia Puljak. Antimicrobial efficacy of commercially available endodontic bioceramic root canal sealers: A systematic review. *PLoS ONE*, 2019; 14(10).

Subject: Evaluate the antimicrobial effects of various bioceramic sealers

Significance/Conclusion: *All sealers were antibacterial. However the different methods of evaluation did not allow for comparison between the sealers.*



Gurpreet Singh, Iti Gupta, Faheim M. M. Elshamy, Nezar Boreak, and Husham Elraih Homeida. In vitro comparison of antibacterial properties of bioceramic-based sealer, resin-based sealer and zinc oxide eugenol based sealer and two mineral trioxide aggregates. *European Journal of Dentistry*, 2016; 10(3):366-369. doi:10.4103/1305-7456.184145  
Subject: Antibacterial properties of bioceramic sealers, two MTA aggregates, resin-based sealers and zinc oxide sealers.  
Significance/Conclusion: All bioceramic materials (Bc Sealer and MTA aggregates were antibacterial. Resin based sealers were not.

Lovato, K, Sedgley, M. Antibacterial Activity of EndoSequence Root Repair Material and ProRoot MTA against Clinical Isolates of Enterococcus faecalis. *Journal of Endodontics*, 2011; 37(11):1542-6. Subject: Evaluation of the antibacterial properties RRM™ (Syringable and Putty) vs. MTA.  
Significance/Conclusion: RRM and MTA both effectively killed E. faecalis. There was no statistical difference between their effectiveness.

Wang, Zhejun, et al. “Dentin Extends the Antibacterial Effect of Endodontic Sealers against Enterococcus Faecalis Biofilms.” *Journal of Endodontics*, 2014; 40(4):505–508., doi:10.1016/j.joen.2013.10.042.  
Subject: The purpose of this study was to evaluate the antimicrobial effects of root canal sealers on Enterococcus faecalis biofilms in dentinal tubules by using a novel dentin infection model.  
Significance/Conclusion: The 3 endodontic root canal sealers had antibacterial effects against E. faecalis in the dentinal tubules. BC sealer and AH Plus had superior antibacterial effects compared with PCEWT. The antibacterial effects of sealers in dentinal tubules continued after setting.

## Leakage/Bond Strength/Sealing Ability/Fracture Resistance

Penha da Silva PJ, Marceliano-Alves MF, Provenzano JC, DellazariRLA, Goncalves LS, Alves FRF. Quality of Root Canal Filling Using a Bioceramic Sealer in Oval Canals: A Three-Dimensional Analysis. *European Journal of Dentistry*, 2021 Feb. doi: 10.1055/s-0040-1722095.  
Subject: to compare the quality of oval canal filling with EndoSequence BC sealer using a single-cone technique compared to lateral condensation.  
Significance/Conclusion: There was no difference between the techniques for the total canal and for the apical third.

Khalil WA, Alghamdi F, Aljahdali E. Strengthening effect of bioceramic cement when used to repair simulated internal resorption cavities in endodontically treated teeth. *Dental and Medical Problems*, 2020; 57(2):165-169  
Subject: To assess fracture resistance of premolar teeth with internal resorption cavities repaired with glass-ionomer cement (GIC), Gutta-percha (GP) or Endosequence Root Repair Material (RRM).  
Significance/Conclusion: GIC and RRM provided similar strength and both were superior to GP.

Chu JH, Chia KY, Qui AL, Moule A, Na WH. The effects of sodium hypochlorite and ethylenediaminetetraacetic acid on the microhardness of Mineral Trioxide Aggregate and TotalFill Bioceramic Putty. *Australian Endodontic Journal*, 2020 Apr; 46(1):33-39.

Subject: Evaluate the effect of 5% NaOCl and 17% EDTA on the microhardness of MTA Angelus (MTAA) and TotalFill Bioceramic Putty (BCP) after 24hrs and 8 days.

Significance/Conclusion: Allowing the materials to set for a week before exposing them to the irrigants improves their microhardness. Significant for perforation repair

Patri G, Agrawal P, Anushree N, Arora S, Kunjappu JJ, Shamsuddin SV. A Scanning Electron Microscope Analysis of Sealing Potential and Marginal Adaptation of Different Root Canal Sealers to Dentin: An *In Vitro* study. *The Journal of Contemporary Dental Practice*, 2020 Jan; 21(1):73-77

Subject: evaluate the sealing potential and marginal adaptation of different root canal sealers (ProRoot MTA, EndoREZ, Endosequence BC) to dentin.

Significance/Conclusion: Significantly better sealing ability and marginal adaptation was demonstrated by Endosequence BC sealer

Asawaworarit W, Pinyosopon T, Kijssamanmith K. Comparison of apical sealing ability of bioceramic sealer and epoxy resin-based sealer using the fluid filtration technique and scanning electron microscopy. *Journal of Dental Sciences*, 2020; 15(2):186-192.

Subject: To evaluate the apical sealing ability of bioceramic (Endosequence BC sealer) and epoxy resin-based (AH Plus) sealers at 24 h, 7 days and 4 weeks.

Significance/Conclusion: BC sealer had significantly better sealing ability than AH Plus at all test periods. SEM showed BC sealer had better penetration into dentinal tubules.

Mohammed YT, Al-Zaka IM., Fracture Resistance of Endodontically Treated Teeth Obturated with Different Root Canal Sealers (A Comparative Study). *The Journal of Contemporary Dental Practice*, 2020 Jan; 21(5):490-493.

Subject: to compare the effect of different root canal sealers on fracture resistance of endodontically treated teeth using AH Plus, GuttaFlow 2, MTA- Fillapex and TotalFill BC Sealers

Significance/Conclusion: BC sealer with BC cones enhanced the in-vitro fracture resistance of endodontically treated teeth compared to the other sealers tested.

Almohaimede A, Almanie D, Alaathy S, Almadi E. Fracture Resistance of Roots Filled With Bio-Ceramic and Epoxy Resin-Based Sealers: *In Vitro* Study. *European Endodontic Journal*, 2020; 5(2):134-137.

Subject: To assess the resistance to fracture after root filling with TotalFill BC Sealer or epoxy-resin (AH Plus) sealer.

Significance/Conclusion: BC sealer showed better fracture resistance but in this study it was not significantly different.

Roizenbilt RN, Soares FO, Lopes RT, Dos Santos BC, Gusman H. Root canal filling quality of mandibular molars with EndoSequence BC and AH Plus sealers: A micro-CT study. *Australian Endodontic Journal*, 2020; 46(1):82-87

Subject: Compare obturation quality using Micro CT of Single Cone with BC Sealer vs AH Plus with a continuous wave technique.

Significance/Conclusion: *There was no significant difference between groups for filling volume, voids and gaps ( $P > 0.05$ ). Using two filling methods, EndoSequence BC and AH Plus promoted a similar root filling quality in mesial roots of mandibular molars.*

Silva EJNL, Ehrhardt IC, Sampaio GC, Cardoso ML, da Silva Oliveira D, Uzeda MJ, Calasans-Maia MD, Cavalcante DM, Zuolo ML, De-Deus G. Determining the setting of root canal sealers using an in vivo animal experimental model. *Clinical Oral Investigations*, 2020 Aug.

Subject: Compare in-vitro vs.in-vivo methods to test the setting time of different sealers

Significance/Conclusion: *Setting times were different in-vitro and in-vivo. AH Plus, BioC sealer and TotalFill BC sealer had set at 7 and 14 days in-vivo.*

Lertmalapong P, Jantarat J, Srisatjaluk RL, Komoltri C. Bacterial leakage and marginal adaptation of various bioceramics as apical plug in open apex model. *Journal of Investigative and Clinical Dentistry*, 2019 Feb; 10(1):12371.

Subject: To investigate bacterial leakage and marginal adaptation of bioceramic apical plugs.

Significance/Conclusion: *3- and 4 mm Biodentine and TotalFill BC RRM putty groups and 4mm ProRoot MTA group showed the best sealing ability and marginal adaptation of apical plugs.*

M Juez, ML Ballester, and E Berástegui. In vitro comparison of apical microleakage by spectrophotometry in simulated apexification using White Mineral Trioxide Aggregate, TotalFill Bioceramic Root Repair material, and BioDentine. *Journal of Conservative Dentistry*, 2019; 22(3): 237-240.

Subject: to compare the sealing ability of White MTA, BioDentine and TotalFill Root Repair Materials with a glucose leakage model after orthograde obturation using an open apex model.

Significance/Conclusion: *There was no statistical difference in leakage between the groups.*

Note: Different methods of placement of the materials add variables to the study.

Ersahan S, Aydin C. Dislocation Resistance of iRootSP (aka BC Sealer), a Calcium Silicate-based Sealer, from Radicular Dentine. *Journal of Endodontics*, 2010; 36(12):2001-2.

Subject: Comparison of the push out bond strength (and the assumed sealability) of BC Sealer™ vs. AH Plus and Sealapex and EndoRez.

Significance/Conclusion: *BC Sealer and AH Plus both exhibited high bond strengths which were significantly higher than Sealapex and EndoRez.*

Ceci Nunes Carvalho, Renata Grazziotin-Soares, George Táccio de Miranda Candeiro, Luis Gallego Martinez, Juliana Pereira de Souza, Patrícia Santos Oliveira, José Bauer, and Giulio Gavini. Micro Push-out Bond Strength and Bioactivity Analysis of a Bioceramic Root Canal Sealer. *Iranian Endodontic Journal*, 2017; 12(3):343-348.

Subject: Compare Endosequence BC Sealer to AH plus for Push Out Bond Strength and Bioactivity.

Significance/Conclusion: *AH Plus showed superior bond strength. BC sealer showed indications of bioactivity.*

*Note: Moisture use to store the materials would result in a "soft set: of the Bioceramic and less push out strength. However as shown even with this soft set bioactivity remains and important property of these materials.*

Zhang W, Zhi L, Peng B. Assessment of a new root canal sealer's apical sealing ability. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*, 2009; 107; e79- e82.

Subject: Comparison of sealability of BC Sealer with a single cone technique vs AH Plus with a warm vertical technique (continuous wave)

Significance/Conclusion: The study concluded that there was no statistical difference in the sealing ability of each material with the associated technique used. Warm vertical is considered by many to be the standard of care because it minimizes the sealer layer and fills the majority of the canal 3 dimensionally with a relatively stable filling material (gutta percha does shrink upon cooling). The warm techniques were developed to overcome the limitations of the sealers at our disposal (prior to BC Sealer, sealers have been known to shrink significantly).

Significance/Conclusion: *This study showed that BC Sealer used with a single cone technique, can provided the same sealability as the more time consuming and technique sensitive continuous wave technique with AH Plus*

Nagas E, Uyanik MO, Eymirli A, Cehreli ZC, Vallittu PK, Lassila LVJ, Durmaz V. Dentin moisture conditions affect the adhesion of root canal sealers. *Journal of Endodontics*, 2011; 38(2): 240-4.

Subject: Comparison of the push out bond strength (and the assumed sealability) of BC Sealer™ + Gutta Percha vs. AH Plus + Gutta, MTA Fillapex + Gutta and Epiphany + Resilon in a full range of moisture conditions (artificially dry, normal, moist and wet).

Significance/Conclusion: *BC Sealer exhibited, by far, the highest bond strength in all moisture conditions. Many sealers are negatively affected if water or bleach remains in the canal when the sealer is applied. BC Sealer is hydrophilic and achieves its set by utilizing the moisture naturally present in the dentinal tubules. This study proves that regardless of moisture level in the canal, BC Sealer will achieve its set and it exhibits excellent bonding to the canal walls.*

Fernanda Leal, Gustavo De-Deus, Claudia Brandao, Aderval Luna, Erick Souza, Sandra Fidel. Similar Sealability Between Bioceramic Putty Ready-To-Use Repair Cement and White MTA. *Brazilian Dental Journal*, 2013; 24(4): 362-366 ISSN 0103-6440 <http://dx.doi.org/10.1590/0103-6440201302051>.

Subject: BC RRM Putty Sealability vs. White MTA.

Significance/Conclusion: *Concluded that BC RRM Putty (aka. iRootBP Plus) has a similar ability to that of white MTA in preventing glucose leakage as a root end filling material.*

Zhou, Hui-Min, et al. "Physical Properties of 5 Root Canal Sealers." *Journal of Endodontics*, 2013; 39(10):1281-1286. Doi:10.1016/j.joen.2013.03.012.

Subject: The aim of this study was to evaluate the pH change, viscosity and other physical properties of 2 novel root canal sealers (MTA Fillapex and Endosequence BC) in comparison with 2 epoxy resin-based sealers (AH Plus and ThermaSeal), a silicone-based sealer (GuttaFlow), and a zinc oxide-eugenol-based sealer (Pulp Canal Sealer).

Significance/Conclusion: *The tested sealers were pseudoplastic according to their viscosities as determined in this study. The MTA Fillapex and Endosequence BC Sealer each possessed comparable flow and dimensional stability but higher film thickness and solubility than the other sealers tested.*

Ghoneim AG, Lutfy RA, Sabet NE, Fayyad DM. Resistance to fracture of roots obturated with novel canal-filling systems. *Journal of Endodontics*, 2011; 37(11):1590-2.

Subject: Evaluation of the fracture resistance of teeth obturated with BC Sealer™ + gutta percha and BC Sealer™ + Silicate Coated Points.

Significance/Conclusion: *The negative control for this study was tooth that had not undergone root canal therapy. The study concluded that BC Sealer used in conjunction with Brasseler's coated/impregnated cones (originally ActivGP Point but later updated to BC Points) actually increased the fracture resistance of the root to a level comparable of the negative control. This type of restorative obturation could represent a significant advancement in root canal therapy.*

Yuqing Jiang et al. A Comparative Study on Root Canal Repair Materials: A Cytocompatibility Assessment in L929 and MG63 Cells. *The Scientific World Journal*; vol. 2014, Article ID 463826.

Subject: The aim of this study was to conduct a comparative assessment on the surface morphology and the cell adhesion capacity of iRoot BP Plus (aka BC RRM Putty), iRoot FS (aka BC RRM Fast Set Putty), ProRoot MTA, and Super-EBA on both fibroblast and osteoblast-like cell models. Furthermore, the time-course in vitro cytotoxicity of these materials was assessed.

Significance/Conclusion: *Concluded that BC RRM-Fast Set Putty is extremely biocompatible and non-cytotoxic. Furthermore, BC RRM exhibited the fastest set time and the best cell adhesion capacity of all the materials tested including ProRoot.*

Hegde, Vibha, and Shashank Arora. "Sealing Ability of Three Hydrophilic Single-Cone Obturation Systems: An in Vitro Glucose Leakage Study." *Contemporary Clinical Dentistry*, 2015; 6(5):1–8.

**Subject:** The aim of this study is to compare the coronal-apical sealing ability of three single-

cone obturation systems using a glucose leakage model.

**Significance/Conclusion:** Hydrophilic groups have shown significantly lesser leakage as compared to the gold standard hydrophobic gutta-percha obturation system. Furthermore, studies would be required to assess the hydrophilic nature of the recent obturation systems.

Christopher DeLong, DDS, Jianing He, DMD, PhD, and Karl F. Woodmansey, DDS: The Effect of Obturation Technique on the Push-out Bond Strength of Calcium Silicate Sealers. *Journal of Endodontics*, 2015; 41:385–388. [http://www.jendodon.com/article/S0099-2399\(14\)01043-7/pdf](http://www.jendodon.com/article/S0099-2399(14)01043-7/pdf). **Subject:** The purpose of this study was to evaluate the push-out bond strengths of MTA Plus Sealer, AH Plus and EndoSequence BC Sealer when they were used in cold single cone technique (SC) and a thermoplastic technique (CW).

**Significance/Conclusion:** BC Sealer showed significantly higher bond strengths than AH Plus and MTA Plus sealer in both cold and warm techniques. The CW obturation technique decreased the bond strengths of both MTA Plus and BC Sealer but BC Sealer (cold and warm) was still higher than AH Plus with warm vertical.

**Note:** This study confirmed that heating bioceramic sealers can affect their bond strength. For non-premixed bioceramics (MTA Plus) the negative effect was shown to be more significant. For premixed bioceramic sealers (BC Sealer) heat did not have a major effect (BC Sealer CW warm still outperformed AH Plus with CW). Furthermore, it is now suggested by Brasseler that BC Sealer be used with a warm vertical technique only at 150C. This study utilized 200C which is warmer than what Brasseler now recommends. For clarification, none of the groups utilized Brasseler's BC Points which are bioceramic coated and impregnated and have been shown to increase the bond strength when used with BC Sealer.

McMichael, G E, et al. "Dentinal Tubule Penetration of Tricalcium Silicate Sealers." *Journal of Endodontics*, U.S. National Library of Medicine, Apr. 2016. [www.ncbi.nlm.nih.gov/pubmed/26898564](http://www.ncbi.nlm.nih.gov/pubmed/26898564). Accessed 28 June 2017.

**Subject:** The treatments for which mineral trioxide aggregate (MTA)-based materials can be used in dentistry are expanding. Smaller particle size and easier handling properties have allowed the advent of tricalcium silicate sealers including EndoSequence BC Sealer (Brasseler USA, Savannah, GA), QuickSet2 (Avalon Biomed, Bradenton, FL), NeoMTA Plus (Avalon Biomed), and MTA Fillapex (Angelus, Londrina, Brazil). The objective of this study was to measure the tubule penetration with these sealers using continuous wave (CW) and

single-cone (SC) obturation techniques.

**Significance/Conclusion:** Within the limitations of this study, the CW and SC techniques produced similar tubule penetration at both the 1-mm and the 5-mm level with the tricalcium silicate sealers BC Sealer, QuickSet2, and NeoMTA Plus.

Topçuoğlu, Hüseyin Sinan, et al. “*In Vitro* Fracture Resistance of Roots Obturated with Epoxy Resin–based, Mineral Trioxide Aggregate–based, and Bioceramic Root Canal Sealers.” *Journal of Endodontics*, 2013; 39(12):1630–1633., doi:10.1016/j.joen.2013.07.034.

Subject: The aim of this study was to evaluate the fracture resistance of teeth filled with 3 different endodontic sealers.

Significance/Conclusion: *In contrast to Tech Biosealer Endo, Endosequence BC and AH Plus Jet sealer increased the force to fracture in root-filled single-rooted premolar teeth.*

## Hydrophilicity, Low Contact Angle, Calcium Hydroxide diffusion & Release of Calcium Ions

Zhang H, Shen Y, Ruse ND, Haapasalo M. Antibacterial activity of endodontic sealers by modified direct contact test against enterococcus faecalis. *Journal of Endodontics*, 2009; 35(7): 1051-5.

Subject: Evaluation of the antibacterial properties of BC Sealer vs. AH Plus, Apexit Plus, TubliSeal, Sealapex, Epiphany SE and Endo Rez.

Significance/Conclusion: *“BC Sealer, by far had the lowest contact angle/wetting ability”. The authors attribute the favorable sealing properties of BC Sealer to its “combination of high pH, hydrophilicity, and active calcium hydroxide diffusion”.*

Carvalho, C. N., et al. “Comparative Analyses of Ion Release, PH and Multispecies Biofilm Formation between Conventional and Bioactive Gutta-Percha.” *International Endodontic Journal*, 2015 April; 49(11): 1048–1056., doi:10.1111/iej.12558.

Subject: To analyse the effect of commercial and experimental gutta-percha with the addition of niobium phosphate glass on biofilm formation by oral bacteria from human dental plaque. Additional pH and elemental release of the materials were analysed.

Significance/Conclusion: *GNB and GBC reduced biofilm formation. GNB had the lowest amount of viable bacteria in biofilms with the highest pH, and high Zn and Na release values after 30 days.*

Candeiro, George Táccio De Miranda, et al. “Evaluation of Radiopacity, PH, Release of Calcium Ions, and Flow of a Bioceramic Root Canal Sealer.” *Journal of Endodontics*, 2012; 38(6): 842–845., doi:10.1016/j.joen.2012.02.029.

Subject: The aim of the present study was to evaluate the physicochemical properties of a bioceramic root canal sealer, Endosequence BC Sealer. Radiopacity, pH, release of calcium ions (Ca<sup>2+</sup>), and flow were analyzed, and the results were compared with AH Plus cement.

Significance/Conclusion: *Endosequence BC Sealer showed radiopacity and flow according to ISO 6876/2001 recommendations. The other physicochemical properties analyzed demonstrated favorable values for a root canal sealer.*

## Healing

Ian Chen, DDS, MS, Bekir Karabucak, DMD, MS, Cong Wang, DDS, Han-Guo Wang, DDS, PhD, Eiki Koyama, DDS, PhD, Meetu r. Kohli, BDS, DMD, Hyun-Duck Nah, DMD, PhD, and Syngcuk Kim, DDS, PhD. Healing after Root-end Microsurgery by Using Mineral Trioxide Aggregate and New Calcium silicate-based Bioceramic Material as Root-end Filling Materials in Dogs. *Journal of Endodontics*, 2015; 41:389–399.

[http://www.jendodon.com/article/S0099-2399\(14\)01046-2/pdf](http://www.jendodon.com/article/S0099-2399(14)01046-2/pdf)

Subject: Compare healing after root-end surgery by using grey mineral trioxide aggregate (MTA) and EndoSequence Root Repair Material (RRM) as root end-filling material in an animal model

Significance/Conclusion: *RRM achieved a better tissue healing response adjacent to the resected root-end surface histologically. The superior healing tendency associated with RRM could be detected by CBT and micro CT but not periapical radiography.*

Nicole Shinbori, DDS, Anna Maria Grama, DDS, Yogesh Patel, DDS, Karl Woodmansey, DDS, and Jianing He, DMD, PhD: Clinical Outcome of Endodontic Microsurgery That Uses EndoSequence BC Root Repair Material as the Root-end Filling Material. *Journal of Endodontics*; Published Online February 18th, 2015. [http://www.jendodon.com/article/S0099-2399\(15\)00008-4/pdf](http://www.jendodon.com/article/S0099-2399(15)00008-4/pdf)

Subject: The purpose of this retrospective study was to determine the clinical and radiographic outcome of root-end surgery when EndoSequence BC Root Repair (ES-BCRR) was used as the root-end filling material and to identify any possible prognostic factors that may have affected the healing outcome.

Significance/Conclusion: *This current study suggests that ES-BCRR is a suitable root-end filling material to be used in endodontic surgery.*

## Color Stability

Cangul Keskin, DDS, Ebru Ozsezer Demiryurek, PhD, DDS, and Taha Ozyurek, DDS: Color Stabilities of Calcium Silicate-based Materials in Contact with Different Irrigation Solutions. *Journal of Endodontics*, 2015; 41:409–411.

[http://www.jendodon.com/article/S0099-2399\(14\)01129-7/pdf](http://www.jendodon.com/article/S0099-2399(14)01129-7/pdf).

Subject: Mineral trioxide aggregate (MTA) has been reported to cause tooth discoloration when applied with the esthetic zone. A previous study has shown discoloration of MTA in contact with root canal irrigation solutions. Moreover, there are limited data on color stability of novel calcium silicate-based materials. This study aimed to evaluate color changes of 4 calcium silicate based materials in contact with different irrigation solutions.

Significance/Conclusion: *All materials exhibited clinically perceptible discoloration when immersed in sodium hypochlorite and chlorhexidine gluconate. ProRoot White MTA showed a statistically significant difference from Bioaggregate, Biodentine, and white MTA Angelus.*

Distilled water did not cause any clinically perceptible discoloration of any material. In esthetically critical regions compounds free of bismuth oxide, Biodentine, and BioAggregate can be considered as alternatives to MTA. However, all calcium silicate based materials exhibited clinically perceptible color changes.