

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

Biocompatibility / Cytotoxicity

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. *JOE*. 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 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. 2014 (online June 7th 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.

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. *JOE*. 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. *JOE* 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)”).

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. *JOE* 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.



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. IEJ 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.

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. IEJ 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.

Siyi Liu, MD, Sainan Wang, PhD, and Yanmei Dong, PhD; Evaluation of a Bioceramic as a Pulp Capping Agent In Vitro and In Vivo. JOE. 2015 (In press)

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).

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. JOE. 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.



Ian Chen, DDS, MS, Bekir Karabucak, DMD, MS, CongWang, DDS, Han-GuoWang, 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 a New Calcium Silicate-based Bioceramic Material as Root-end Filling Materials in Dogs. *JOE*. 2015 (in press).

Subject: The purpose of this study was to 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 (dogs).

Significance/Conclusion: Like MTA, RRM is a biocompatible material with good sealing ability. However, in this animal model 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 CBCT and micro CT but not periapical radiography.

Wafaa K, Siham A *JOE* 2015 April (Online) Can Mineral Trioxide Aggregate and Nanoparticulate EndoSequence Root Repair Material Produce Injurious Effects to Rat Subcutaneous Tissues?

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 more friendly with the tissue than MTA (within the parameters of this study).

Mineralization / Osteogenic / Pulp Cells / Pulp Capping

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. *JOE*. 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).

Yuqing Jiang et al. A Comparative Study on Root Canal Repair Materials: A Cytocompatibility Assessment in L929 and MG63 Cells. *The Scientific World Journal* Volume 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 cells 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®.

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. *IEJ* 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.

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. *IEJ* 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.

Siyi Liu, MD, Sainan Wang, PhD, and Yanmei Dong, PhD; Evaluation of a Bioceramic as a Pulp Capping Agent In Vitro and In Vivo. *JOE*. 2015 (In press)

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

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.

Antibacterial Properties

Zhang H, Shen Y, Ruse ND, Haapasalo M. Antibacterial activity of endodontic sealers by modified direct contact test against *enterococcus faecalis*. *JOE*. 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 killed all bacterial within 2 min of contact (fastest), had the strongest antibacterial activity and continued to be effective at killing bacteria for 7 days after mixing/setting. The high pH of BC Sealer makes it extremely effective at killing bacteria.

Lovato, K, Sedgley, M. Antibacterial Activity of EndoSequence Root Repair Material and ProRoot MTA against Clinical Isolates of *Enterococcus faecalis* *JOE*. 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.

Leakage/ Bond Strength/ Sealing Ability / Fracture Resistance

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). 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. *JOE*. 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.

Ersahan S, Aydin C. Dislocation Resistance of iRootSP (aka BC Sealer), a Calcium Silicate- based Sealer, from Radicular Dentine. *JOE*. 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.



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Ghoneim AG, Lutfy RA, Sabet NE, Fayyad DM. Resistance to fracture of roots obturated with novel canal-filling systems. *JOE*. 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* Volume 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 cellsmodels. Furthermore, the time-course in vitro cytotoxicity of these materials was accessed.

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®.

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. *JOE*. 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 effect 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.

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*. *JOE*. 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".

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. *JOE*. 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. *JOE*. 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.

Significant 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. *JOE*. 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.
