ORIGINAL ARTICLE
ORIGINALNI RAD
https://doi.org/10.2298/SGS2104189D
UDC: 615.463:616.314-7

Radiopacity of calcium silicate-based endodontic sealers using digital imaging

Bojan Dželetović, Ivana Bošnjak, Đorđe Antonijević, Jovan Badnjar, Zoran Petrov, Vanja Opačić-Galić

University of Belgrade, School of Dental Medicine, Department for Restorative Dentistry and Endodntics, Belgrade, Serbia

SUMMARY

Introduction Adequate radiopacity of endodontic sealers allows radiographic visualization, assessment of root canal filling quality and its clinical follow-up after obturation. The aim of our study was to evaluate the radiopacity of Bio-Root RCS, MTA Fillapex, Bioceramic Root Canal Sealer, GuttaFlow Bioseal in comparison to AH Plus sealer, as a gold standard in clinical practice.

Material and methods Sealer specimens, 2 mm thick and 5 mm in diameter, were radiographed with an aluminum stepwedge using digital imaging system. Radiographic densities of the specimens were shown as mean greyscale values (Adobe Photoshop CS4 software) and expressed as mmAl/mm of the material. ANOVA with a post hoc Tukey test was used, significance was set at 0.05.

Results Differences in radiopacity between tested endodontic sealers were statistically significant except the difference between BioRoot RCS and GuttaFlow Bioseal.

Conclusion Radiopacities of all evaluated calcium silicate-based sealers were higher than minimal values recommended by standards. AH Plus sealer had the highest radiopacity, while calcium silicate-based sealers showed lower values, from BioRoot RCS, followed by GuttaFlow Bioseal, to MTA Fillapex, in descending order, and Bioceramic Root Canal Sealer with the lowest values.

Keywords: radiopacity; calcium silicate; root canal sealer

INTRODUCTION

Obturation, that follows adequate cleaning and shaping of the root canal, should seal the canal apically and laterally and prevent potentional microleakage, avoiding possible reinfection. Root canal filling consists of solid gutta-percha cone and endodontic sealer that fills spaces between gutta-percha and dentin walls of the root canal [1].

Since root canal sealer is in contact with periapical tissues its biological properties should be favorable for reparation/regeneration proceses in alveolar bone, cementum or periodontal ligament. Calcium silicate-based sealers have bioactive properties related to ions release and hydroxyapatite crystals formation on their surface after contact with phosphate containing body fluids [2]. Calcium hydroxide formed during calcium silicate materials hydration results in high pH that changes alkalinity in the adjacent promoting healing, hard tissue formation and interference with osteoclastic activity [3]. These materials show antimicrobial activity through neutralization of lipopolysaccharides that are present in the membrane of gram-negative bacteria and through irreversible reaction with bacterial enzymes [4, 5].

In order to assess endodontic filling quality and follow-up its long-term efficiency, endodontic materials should have sufficient radiopacity. Namely, radiopacity enables clear distinction between endodontic filling and surrounding dental and periapical tissues [6]. Adequate radiopacity of endodontic materials allows radiographic visualization of voids in the canal obturation that can be formed by air bubbles entrapment during the mixing of two-component sealers or during gutta-percha cones insertion in the canal [7]. On the other hand, empty spaces in endodontic filling cause inadequate seal and could be created by sealer dissolution. These voids are difficult to spot and could, particularly, be masked by strong radiopacity of obturation materials [8].

New calcium silicate-based sealers became available on the market but independent research on some of their physical properties are still lacking. On the other hand, there are discrepancies in results of studies examining radiopacity of calcium silicate-based sealers that probably could be explained by differences in experimental designs used [9, 10]. In order to obtain evidence-based recomendations for clinical practice it is important to perform scientific research on newly developed sealers and compare them with currently widely used materials.

The aim of our study was to evaluate radiopacities of calcium silicate-based sealers BioRoot RCS, MTA Fillapex, Bioceramic Root Canal Sealer and GuttaFlow Bioseal in comparison to AH Plus sealer that is a gold standard in clinical practice.

Address for correspondence: Bojan DŽELETOVIĆ, Rankeova 4, 11000 Belgrade, Serbia; *dzeletovicbojan6@gmail.com*

Table 1. Sealers, manufacturers and composition of the tested materials
Tabela 1. Naziv paste, proizvođač i sastav

Sealer	Manufacturer	Composition
BioRoot RCS	Septodont, Saint Maur-des-Fosses, France	**Powder:** tricalcium silicate, zirconium oxide and excipients **Liquid:** aqueous solution of calcium chloride and excipients **Prašak:** trikalcijum-silikat, cirkonijum-oksid i pomoćne supstance **Tečnost:** vodeni rastvor kalcijum-hlorida i pomoćnih supstanci
MTA Fillapex	Angelus, Londrina, Brazil	**Base paste:** salicylate resin, natural resin, calcium tungstate, nanoparticulated silica, pigments **Catalyst paste:** diluting resin, mineral trioxide aggregate, nanoparticulated silica, pigments **Osnovna pasta:** salicilatna smola, prirodna smola, kalcijum-volframat, nanočestice silicijum-dioksida, pigmenti **Katalizatorska pasta:** smola za razređivanje, mineralni trioksid
Bioceramic Root Canal Sealer	SSWhite, Lakewood, New Jersey, USA	**Base paste:** salicylate resin, natural resin, calcium tungstate, nanoparticulated silica, pigments **Catalyst paste:** diluting resin, mineral trioxide aggregate, nanoparticulated silica, pigments **Osnovna pasta:** salicilatna smola, prirodna smola, kalcijum-volframat, nanočestice silicijum-dioksida, pigmenti **Katalizatorska pasta:** smola za razređivanje, mineralni trioksid
GuttaFlow Bioseal	Coltène/Whaledent, Langenau, Germany	Gutta-percha powder, polydimethylsiloxane, platinum catalyst, zirconium dioxide, silver (preservative), coloring, bioactive glass ceramic Prah gutaperke, polidimetilsiloksan, katalizator platine, cirkonijum-dioksid, srebro (konzervans), boje, bioaktivna staklokeramika
AH Plus	Dentsply, DeTrey GmbH, Konstanz, Germany	**Paste A:** Bisphenol epoxy resin–A, Bisphenol epoxy resin–F, calcium tungstate, zirconium oxide, silica, iron oxide pigments **Paste B:** Dibenzyldiamine, aminodiamantana, tricyclodecane–diamine, calcium tungstate, zirconium oxide, silica, silicone oil **Pasta A:** bisfenol-epoksidna smola-A, bisfenol-epoksidna smola-F, kalcijum-volframat, cirkonijum-oksid, silicijumdioksid, gvožđe-oksidni pigmenti **Pasta B:** dibenzildiamin, aminodiamantana, triciklodekan-diamin, kalcijum-volframat, cirkonijum-oksid, silicijum-dioksid, silikonsko ulje

MATERIAL AND METHODS

The following materials were evaluated in the study: BioRoot RCS (Septodont, St Maur-des-Fosses, France), MTA Fillapex (Angelus, Londrina, Brazil), Bioceramic Root Canal Sealer (SS White, New Jersey, USA), GuttaFlow Bioseal (Coltene Whaledent, Langenau, Germany) and AH Plus (Dentsply DeTrey Gmbh, Konstanz, Germany) (Table 1). Endodontic sealers were mixed according to the manufacturers instructions and placed in teflon molds, 2 mm thick and 5 mm in diameter. Specimens were placed in an incubator at 37°C and 95% relative humidity and following complete setting, thickness of the specimens was checked using a digital caliper. If necessary, specimens were ground wet with carbide paper (P600) to reach the thickness of 2±0.1 mm.

Three specimens of each sealer were radiographed with an aluminum stepwedge (99.6 % pure, 10 mm thickness, in steps of 1 mm each) using a Radiovisiography (RVG-4) CCD-based digital sensor (Trophy Radiology, Cedex, France). X-ray generator (Trophy Radiology) operating at 70 kVp and 7 mA was used with a source-to-object distance of 30 cm and exposure of 0.07 s. Radiographic densities of the specimens were expressed as mean greyscale values using Adobe Photoshop CS4 software (Adobe Systems, San Hose, CA). Each sealer specimen was read three times as well as each step of the aluminum stepwedge. Regions containing iregularities such as air bubbles were avoided. For radiopacity determination, graph for the logarithm of aluminum thickness versus the corresponding radiographic density was plotted with the best-fitting logarithmic trend line. After that, the radiographic density of the material was used to calculate the radiopacity from the graph. Radiopacities were expressed as mmAl/mm of the material (mmAl).

The normality of data distribution was tested by Kolmogorov–Smirnov test. Analysis of variance (ANOVA) with a post hoc Tukey test was used for comparison of the differences between the sealers. We used SPSS 16.0 for Windows (SPSS Inc., Chiago, IL, USA) statistical program for all analyzes and significance was set at 0.05.

RESULTS

Figure 1 shows digital radiograph of GuttaFlow Bioseal and aluminium stepwedge. Table 2 shows mean values and standard deviations of the radiopacities of investigated endodontic sealers in millimetres of aluminium (mm Al). The highest average radiopacity was observed for AH Plus paste (11.22 mmAl), followed by decreasing values: BioRoot RCS (8.32 mmAl), GuttaFlow Bioseal (7.64 mmAl), MTA Fillapex (5.58 mmAl), while the lowest values were shown for Bioceramic Root Canal Sealer paste (3.4 mmAl). The statistical analysis revealed significant difference in mean radiopacity between MTA Fillapex and all other sealers, Bioceramic Root Canal Sealer and all other sealers, as well as GuttaFlow Bioseal and all other sealers. There was no significant difference only between BioRoot RCS and GuttaFlow Bioseal.

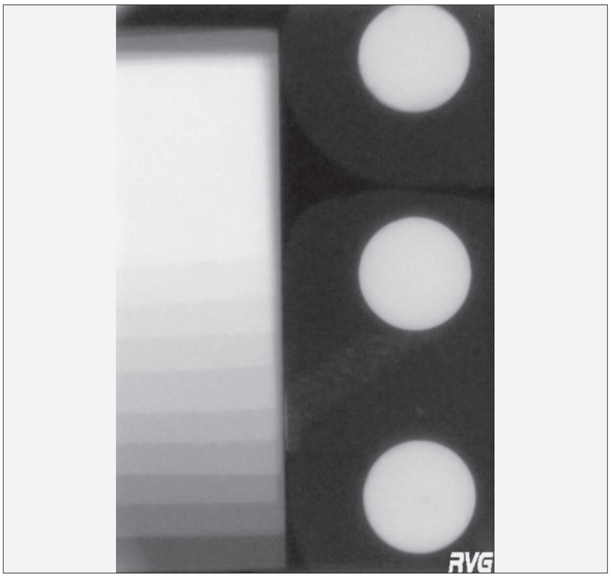

Figure 1. Digital radiographic image of GuttaFlow Bioseal and aluminium stepwedge
Slika 1. Digitalni radiogram paste GuttaFlow Bioseal i aluminijumskog etalona

Table 2. Radiopacity values of calcium silicate-based endodontic sealers, expressed in millimetres of aluminium equivalent
Tabela 2. Vrednosti rendgenkontrastnosti kalcijum-silikatnih pasta izražene u ekvivalentnim milimetrima aluminijuma

Calcium silicate-based sealers Kalcijum silikatne paste	Radiopacity (mmAl) (mean ± SD) Rendgenokontrast (mmAl) (srednja vrednost ± SD)
BioRoot RCS	8.32 ± 0.7
MTA Fillapex	5.58 ± 0.37
Bioceramic Root Canal Sealer	3.4 ± 0.25
GuttaFlow Bioseal	7.64 ± 0.5
AH Plus	11.22 ± 0.43

DISCUSSION

It is established by International Organization for Standardization (ISO) that the root canal sealers, at a thickness of 1 mm, should have a radiopacity equivalent to at least 3 mm of aluminum. All endodontic sealers evaluated in our study had a greater radiopacity than the minimum recommended by the ISO specified standards. Although the examined sealers are calcium silicate-based, significant differences in radiopacity, observed in this study, could be the consequence of type and percentage of radiopacifying agents in these materials.

Namelly, it was found by Duarte et al. in 2009 that different radiopacifiers had decreasing radiopacity: bismuth oxide, lead oxide, bismuth subnitrate, iodoform, zirconium oxide, bismuth carbonate, calcium tungstate, barium sulphate, and zinc oxide [11]. Bioceramic Root Canal Sealer and MTA Fillapex have calcium tungstate as opacifying agent and that could be the reason for their lower radiopacity in comparison to other sealers [11].On the other hand, BioRoot RCS and AH plus contain zirconium oxide in its composition that increases their radiopacity more [11]. GuttaFlow Bioseal has several components that increase its radiopacity: zirconium dioxide, silver and gutta-percha [12]. Beside zirconium oxide, AH plus contains calcium tungstate and iron oxide which contribute to the highest raiopacity value obsearved for this sealer [13].

Scientific literature showed large variety of radiopacity values reported for calcium silicate-based sealers evaluated in the present study. Radiopacity of BioRoot RCS ranged from 5.2 to 8.3 mmAl [14, 13], while values reported for GuttaFlow Bioseal were between 3.94 and 7.44 mmAl [15, 16]. Results for MTA Fillapex reported in previous studies ranged from 3.01 to 9.4 mmAl [17, 18]. It is important that the composition of MTA Fillapex was changed by the manufacturer and instead of bismuth oxide calcium tungstate was added as radiopacifying agent which further complicated comparisons between studies [19]. Bioceramic Root Canal Sealer is a product relatively recently introduced and we found no data in literature regarding its radiopacity, so it was not possible to compare our results with the ones from previous examinations. Epoxy-based sealer AH Plus was a control material in the majority of studies on sealers and showed significant variability in radiopacity values, from 5.9 to 18.4 mmAl [13, 20].

This diversity in experimental results could partially be explained by various methodological approaches and different radiographic systems, conventional or digital, used in mentioned studies [9]. Namelly, according to international standards for radiopacity of endodontic sealers radiographic visualization must be obtained through chemical processes of conventional radiographic film developing, fixation, rinsing and drying. All these procedures may negatively interfere with radiographic image quality and are time consuming [21]. In order to minimize the influence of radiographic film processing and X-ray exposure conditions on measurement accuracy, aluminium wedge, which is chosen as a reference since aluminum roentgenographic contrast is very similar to dentin, is radiographed on the same film with examined samples [22]. After film processing, the amount of light transmitted by the sample image should be measured using an optical densitometer and translated in thickness of aluminum step-wedge image that transmits equivalent amount of light. On the other hand, as digital radiography became more widely used in dental practice, this motivated new examinations on radiopacity of dental materials based on digital systems [23].

Wide adoption of digital radiography systems made them more clinically relevant than conventional film radiography. As well, computer-based digital image processing and analysis make data acquisition easier, excludes errors with film processing and uses lower radiation dose since digital sensors are more sensitive than conventional films [24]. Having in mind widespread usage and advantages of digital radiography over film some authors proposed that new, modified protocols should be revised by standardization organizations [25, 26].

Different examinations on radiopacity of endodontic materials comparing conventional and digital radiography demonstrated that the choice of imaging system might significantly affect radiopacity measurements [27, 28]. In these studies, the authors concluded that it is difficult to compare their results with the results of other studies due to different methodological approaches to radiopacity measurement. This suggests that when obtaining radiopacity values for different endodontic sealers it would be important to use the same experimental design and radiographic system in order to reliably compare them. It is interesting that radiopacity values for BioRoot RCS were very close to our results in previous studies (7.96 and 8.3 mmAl) which, similarly to our study, used digital radiography systems [13, 29]. Likewise, our findings for GuttaFlow Bioseal were quite consistent with radiopacities reported in two studies (7.02 and 7.44 mmAl) that also used similar digital radiography systems [15, 30].

Another possible cause for various radiopacity values of endodontic sealers reported in literature could be the variations in the ratio of components of two-component endodontic sealers, during its preparation, that could substantially alter materials properties [31]. This was shown for different physicochemical properties such as setting time, flow, solubility or radiopacity values, even when used methodology was the same [31]. Similarly, the authors who evaluated radiopacity of endodontic materials assumed that the manipulation with the material during the mixing process could be the reason for observed diversity of results [32]. Additionally, it was shown that the quantity of radio-opacifiers could be different in two ends of the packing tube, and that the radiopacifying agent could be deposited at the lower end, while the upper portions of the tube could present lower quantity of radio-opacifier [33].

CONCLUSION

Endodontic sealers examined in the present study showed different radiopacity values that could be the consequence of type and amount of radiopacifying agents in its composition. AH Plus sealer had the highest radiopacity, while calcium silicate-based sealers showed lower values, from BioRoot RCS, followed by GuttaFlow Bioseal, to MTA Fillapex, in descending order, and Bioceramic Root Canal Sealer with the lowest values.

ACKNOWLEDGES

This study was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, record number: 451-03-9/2021-14/ 200129.

REFERENCES

1. Chen B, Haapasalo M, Mobuchon C, Li X, Ma J, Shen Y. 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(4):531–8. [DOI: 10.1016/j.joen.2019.12.009] [PMID: 32081458]
2. Kaup M, Schäfer E, Dammaschke T. An *in vitro* study of different material properties of Biodentine compared to ProRoot MTA. Head Face Med. 2015;11:6. [DOI: 10.1186/s13005-015-0074-9] [PMID: 25934270]
3. Guo J, Yang D, Okamura H, Teramachi J, Ochiai K, Qiu L, Haneji T. Calcium hydroxide suppresses *Porphyromonas endodontalis* lipopolysaccharide-induced bone destruction. J Dent Res. 2014;93(5):508–13. [DOI: 10.1177/0022034514526886] [PMID: 24603641]
4. Tanomaru JM, Leonardo MR, Tanomaru Filho M, Bonetti Filho I, Silva LA. Effect of different irrigation solutions and calcium hydroxide on bacterial LPS. Int Endod J. 2003;36(11):733–9. [DOI: 10.1046/j.1365-2591.2003.00717.x] [PMID: 14641436]
5. Estrela C, Sydney GB, Bammann LL, Felippe Júnior O. Mechanism of action of calcium and hydroxyl ions of calcium hydroxide on tissue and bacteria. Braz Dent J. 1995;6(2):85–90 [PMID: 8688662]
6. Katz A, Kaffe I, Littner M, Tagger M, Tamse A. Densitometric measurement of radiopacity of Gutta-percha cones and root dentin. J Endod. 1990;16(5):211–3. [DOI: 10.1016/S0099-2399(06)81671-7] [PMID: 2074412]
7. Tagger M, Katz A. Radiopacity of endodontic sealers: development of a new method for direct measurement. J Endod. 2003;29(11):751–5. [DOI: 10.1097/00004770-200311000-00016] [PMID: 14651284]
8. Gambarini G, Testarelli L, Pongione G, Gerosa R, Gagliani M. Radiographic and rheological properties of a new endodontic sealer. Aust Endod J. 2006;32(1):31–4. [DOI: 10.1111/j.1747-4477.2006.00005.x] [PMID: 16603043]
9. Zamparini F, Siboni F, Prati C, Taddei P, Gandolfi MG. Properties of calcium silicate-monobasic calcium phosphate materials for endodontics containing tantalum pentoxide and zirconium oxide. Clin Oral Investig. 2019;23(1):445–57. [DOI: 10.1007/s00784-018-2453-7] [PMID: 29737429]
10. Prüllage RK, Urban K, Schäfer E, Dammaschke T. Material Properties of a Tricalcium Silicate-containing, a Mineral Trioxide Aggregate-containing, and an Epoxy Resin-based Root Canal Sealer. J Endod. 2016;42(12):1784–8. [DOI: 10.1016/j.joen.2016.09.018] [PMID: 27769676]
11. Húngaro Duarte MA, de Oliveira El Kadre GD, Vivan RR, Guerreiro Tanomaru JM, Tanomaru Filho M, de Moraes IG. Radiopacity of portland cement associated with different radiopacifying agents. J Endod. 2009;35(5):737–40. [DOI: 10.1016/j.joen.2009.02.006] [PMID: 19410095]
12. Camargo RV, Silva-Sousa YTC, Rosa RPFD, Mazzi-Chaves JF, Lopes FC, Steier L, et al. Evaluation of the physicochemical properties of silicone- and epoxy resin-based root canal sealers. Braz Oral Res. 2017;31:e72. [DOI: 10.1590/1807-3107BOR-2017.vol31.0072] [PMID: 28832718]
13. Khalil I, Naaman A, Camilleri J. Properties of Tricalcium Silicate Sealers. J Endod. 2016;42(10):1529–35. [DOI: 10.1016/j.joen.2016.06.002] [PMID: 27523906]
14. Siboni F, Taddei P, Zamparini F, Prati C, Gandolfi MG. Properties of BioRoot RCS, a tricalcium silicate endodontic sealer modified with povidone and polycarboxylate. Int Endod J. 2017;50 Suppl 2:e120–e136. [DOI: 10.1111/iej.12856] [PMID: 28881478]
15. Tanomaru-Filho M, Torres FFE, Chávez-Andrade GM, de Almeida M, Navarro LG, Steier L, et al. Physicochemical Properties and Volumetric Change of Silicone/Bioactive Glass and Calcium Silicate-based Endodontic Sealers. J Endod. 2017;43(12):2097–101. [DOI: 10.1016/j.joen.2017.07.005] [PMID: 29032816]
16. Lopes FC, Zangirolami C, Mazzi-Chaves JF, Silva-Sousa AC, Crozeta BM, Silva-Sousa YTC, et al. Effect of sonic and ultrasonic activation on physicochemical properties of root canal sealers. J Appl Oral Sci. 2019;27:e20180556. [DOI: 10.1590/1678-7757-2018-0556] [PMID: 31508791]
17. Lee JK, Kwak SW, Ha JH, Lee W, Kim HC. Physicochemical Properties of Epoxy Resin-Based and Bioceramic-Based Root Canal Sealers. Bioinorg Chem Appl. 2017;2017:2582849. [DOI: 10.1155/2017/2582849] [PMID: 28210204]
18. Marciano MA, Duarte MA, Camilleri J. Calcium silicate-based sealers: Assessment of physicochemical properties, porosity and hydration. Dent Mater. 2016;32(2):e30–40. [DOI: 10.1016/j.dental.2015.11.008] [PMID: 26727694]
19. Kebudi Benezra M, Schembri Wismayer P, Camilleri J. Interfacial Characteristics and Cytocompatibility of Hydraulic Sealer Cements.

J Endod. 2018;44(6):1007–17. [DOI: 10.1016/j.joen.2017.11.011] [PMID: 29398087]
20. Almeida LHS, Moraes RR, Morgental RD, Cava SS, Rosa WLO, Rodrigues P, et al. Synthesis of silver-containing calcium aluminate particles and their effects on a MTA-based endodontic sealer. Dent Mater. 2018;34(8):e214–e223. [DOI: 10.1016/j.dental.2018.05.011] [PMID: 29789161]
21. Syriopoulos K, Sanderink GC, Velders XL, van der Stelt PF. Radiographic detection of approximal caries: a comparison of dental films and digital imaging systems. Dentomaxillofac Radiol. 2000;29(5):312–8. [DOI: 10.1038/sj/dmfr/4600553] [PMID: 10980568]
22. Antonijevic D, Jevremovic D, Jovanovic S, Obradovic-Djuricic K. An *in vitro* radiographic analysis of the density of dental luting cements as measured by CCD-based digital radiography. Quintessence Int. 2012;43(5):421–8. [PMID: 22536594]
23. Rasimick BJ, Shah RP, Musikant BL, Deutsch AS. Radiopacity of endodontic materials on film and a digital sensor. J Endod. 2007;33(9):1098–101. [DOI: 10.1016/j.joen.2007.05.005] [PMID: 17931942]
24. Cutajar A, Mallia B, Abela S, Camilleri J. Replacement of radiopacifier in mineral trioxide aggregate; characterization and determination of physical properties. Dent Mater. 2011;27(9):879–91. [DOI: 10.1016/j.dental.2011.04.012] [PMID: 21571361]
25. Carvalho-Junior JR, Correr-Sobrinho L, Correr AB, Sinhoreti MA, Consani S, Sousa-Neto MD. Radiopacity of root filling materials using digital radiography. Int Endod J. 2007;40(7):514–20. [DOI: 10.1111/j.1365-2591.2007.01246.x] [PMID: 17511790]
26. Baksi BG, Sen BH, Eyuboglu TF. Differences in aluminum equivalent values of endodontic sealers: conventional versus digital radiography. J Endod. 2008;34(9):1101–4. [DOI: 10.1016/j.joen.2008.06.004] [PMID: 18718374]
27. Akcay I, Ilhan B, Dundar N. Comparison of conventional and digital radiography systems with regard to radiopacity of root canal filling materials. Int Endod J. 2012;45(8):730–6. [DOI: 10.1111/j.1365-2591.2012.02026.x] [PMID: 22458866]
28. Antonijević D, Ilić D, Medić V, Dodić S, Obradović-Djuričić K, Rakočević Z. Evaluation of conventional and digital radiography capacities for distinguishing dental materials on radiograms depending on the present radiopacifying agent. Vojnosanit Pregl. 2014;71(11):1006–12. [DOI: 10.2298/vsp1411006a] [PMID: 25536802]
29. Antunes TBM, Janini ACP, Pelepenko LE, Abuna GF, Paiva EM, Sinhoreti MAC, et al. Heating stability, physical and chemical analysis of calcium silicate-based endodontic sealers. Int Endod J. 2021;54(7):1175–88. [DOI: 10.1111/iej.13496] [PMID: 33577106]
30. Camargo RV, Silva-Sousa YTC, Rosa RPFD, Mazzi-Chaves JF, Lopes FC, Steier L, et al. Evaluation of the physicochemical properties of silicone- and epoxy resin-based root canal sealers. Braz Oral Res. 2017;31:e72. [DOI: 10.1590/1807-3107BOR-2017.vol31.0072] [PMID: 28832718]
31. Camps J, Pommel L, Bukiet F, About I. Influence of the powder/liquid ratio on the properties of zinc oxide-eugenol-based root canal sealers. Dent Mater. 2004;20(10):915–23. [DOI: 10.1016/j.dental.2004.02.002] [PMID: 15501319]
32. Vivan RR, Ordinola-Zapata R, Bramante CM et al. Evaluation of the radiopacity of some commercial and experimental root-end filling materials. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009;108(6):e35–8. [DOI: 10.1016/j.tripleo.2009.07.037] [PMID: 19913718]
33. Baldi JV, Bernardes RA, Duarte MA, Ordinola-Zapata R, Cavenago BC, Moraes JC, et al. Variability of physicochemical properties of an epoxy resin sealer taken from different parts of the same tube. Int Endod J. 2012;45(10):915–20. [DOI: 10.1111/j.1365-2591.2012.02049.x] [PMID: 22486920]

Received: 08.09.2021 • Accepted: 09.11.2021

Ispitivanje rendgenkontrastnosti kalcijum-silikatnih pasta digitalnim radiografisanjem

Bojan Dželetović, Ivana Bošnjak, Đorđe Antonijević, Jovan Badnjar, Zoran Petrov, Vanja Opačić-Galić

Univerzitet u Beogradu, Stomatološki fakultet, Klinika za bolesti zuba i endodonciju, Beograd, Srbija

KRATAK SADRŽAJ

Uvod Adekvatna rendgenkontrastnost pasta za punjenje kanala korena omogućava radiografsku vizuelizaciju, procenu kvaliteta kanalnog punjenja i kliničko praćenje nakon opturacije.

Cilj ovog rada je bio da se ispita rendgenkontrastnost pasta BioRoot RCS, MTA Fillapex, Bioceramic Root Canal Sealer, GuttaFlow Bioseal i da se uporede sa rendgenkontrastnošću paste AH Plus, koja se smatra zlatnim standardom u kliničkoj praksi.

Materijal i metode Uzorci pasta promera 5 mm i debljine 2 mm radiografisani su, zajedno sa stepeničastim etalonom, digitalnim radiografskim sistemom. Radiografske gustine uzoraka, prikazane kao srednje vrednosti tona sivo-bele skale (Adobe Photoshop CS4), izražene su u mm Al/mm materijala. Korišćena je jednofaktorska analiza varijanse sa testom Tukey post hoc i nivoom značajnosti od 0,05.

Rezultati Razlike u rendgenkontrastnosti su bile statistički značajne između svih ispitivanih pasta osim između BioRoot RCS i GuttaFlow Bioseal.

Zaključak Rendgenkontrastnost svih ispitivanih pasta je bila veća od minimuma propisanog standardom. Najveću rendgenkontrastnost imala je pasta AH Plus, dok su kalcijum-silikatne paste pokazale manje vrednosti, po opadajućem redosledu od BioRoot RCS, preko GuttaFlow Bioseal, zatim MTA Fillapex i Bioceramic Root Canal Sealer, kod koje su uočene najmanje vrednosti.

Ključne reči: rendgenkontrastnost; kalcijum-silikati; pasta za punjenje kanala

UVOD

Opturacija, koja sledi posle adekvatnog čišćenja i oblikovanja kanala korena, treba da omogući apeksno i lateralno zaptivanje kanala i prevenciju mogućeg mikrocurenja, čime bi se sprečila moguća reinfekcija. Kanalno punjenje se sastoji od gutaperka poena i paste za punjenje kanala, koja popunjava prostor između gutaperke i dentinskog zida kanala korena [1].

S obzirom na to da je pasta za punjenje kanala u kontaktu sa periapikalnim tkivom, njegova biološka svojstva bi trebalo da omoguće stimulaciju reparatornih/regeneracionih procesa u alveolarnoj kosti, cementu i periodontalnom ligamentu. Kalcijum-silikatne paste imaju bioaktivna svojstva koja se vezuju za oslobađanje jona i formiranje kristala hidroksiapatita na njihovoj površini nakon kontakta sa tkivnim tečnostima bogatim fosfatima [2]. Kalcijum-hidroksid, koji nastaje hidratacijom kalcijum-silikatnih materijala, dovodi do povećanja pH vrednosti, čime se povećava alkalnost u okolnim tkivima, što stimuliše zarastanje, formaciju tvrdih tkiva i smanjenje osteoklastne aktivnosti [3]. Antimikrobna aktivnost ovih materijala se ostvaruje neutralizacijom lipopolisaharida prisutnih u membrani gram-negativnih bakterija i ireverzibilnom reakcijom sa bakterijskim enzimima [4, 5].

Da bi se procenio kvalitet kanalnog punjenja i pratio uspeh endodontske terapije, endodontski materijali bi trebalo da imaju odgovarajuću rendgenkontrastnost. Naime, rendgenkontrastnost omogućava jasno razlikovanje endodontskog materijala od okolnih zubnih i periapikalnih tkiva [6]. Adekvatna rendgenkontrastnost endodontskih materijala omogućava vizuelizaciju pora u kanalnom punjenju, koje mogu nastati kao posledica mešanja dvokomponentnih pasta ili tokom unošenja gutaperka poena u kanal [7]. Sa druge strane, nepopunjeni prostori unutar kanalnog punjenja uzrokuju neadekvatnu hermetičnost i mogu biti posledica rastvaranja paste. Ovi prostori se teško uočavaju i mogu biti zamaskirani naročito kod pasta sa izrazitom rendgenkontrastnošću [8].

Na tržištu su se pojavile nove kalcijum-silikatne paste, ali u literaturi još uvek nedostaju nezavisna istraživanja o svim njihovim fizičkim svojstvima. Takođe, postoji neusaglašenost u rezultatima studija koje su ispitivale rendgenkontrastnost kalcijum-silikatnih pasta, što je najverovatnije posledica korišćenja različitih eksperimentalnih modela [9, 10]. Da bismo dobili, na dokazima zasnovane, preporuke za kliničku praksu, važno je sprovesti naučna ispitivanja novih endodontskih pasta i uporediti ih sa materijalima koji su već u širokoj upotrebi.

Cilj ovog rada je bio da se ispita rendgenkontrastnost kalcijum-silikatnih pasta BioRoot RCS, MTA Fillapex, Bioceramic Root Canal Sealer i GuttaFlow Bioseal i uporedi sa rendgenkontrastnošću paste AH Plus, koja je zlatni standard u kliničkoj praksi.

MATERIJAL I METOD

U ovoj studiji su korišćene sledeće paste: BioRoot RCS (Septodont, St Maur-des-Fosses, Francuska), MTA Fillapex (Angelus, Londrina, Brazil), Bioceramic Root Canal Sealer (SS White, Nju Džerzi, SAD), GuttaFlow Bioseal (Coltene Whaledent, Langenau, Nemačka) i AH Plus (Dentsply DeTrey Gmbh, Konstanz, Nemačka) (Tabela 1). Paste su zamešane prema uputstvu proizvođača i ulivene u teflonske kalupe debljine 2 mm, promera 5 mm. Uzorci su inkubirani na 37° C i 95% relativne vlažnosti do potpunog vezivanja pasta. Debljina uzoraka je proverena digitalnim mikrometrom i ukoliko je bilo potrebno, oni su polirani abrazivnim papirom (P600) da bi se osigurala ujednačena debljina od 2 ± 0,1 mm.

Od svake paste napravljena su po tri uzorka koji su radiografisani zajedno sa aluminijumskim etalonom (čistoće 99,6%, 10 stepenika debljine od po 1 mm) radiovizijskim sistemom (RVG-4) sa CCD digitalnim senzorom (Trophy Radiology, Cedex, Francuska). Korišćen je radiografski aparat (Trophy Radiology) koji je radio na 70 kVp i 7 mA, sa rastojanjem od objekta radiografisanja 30 cm i vremenom ekspozicije od 0,07 s. Radiografska gustina uzoraka je izražena srednjim vrednostima tona sivo-bele skale korišćenjem programskog paketa Adobe Photoshop CS4 (Adobe Systems, San Hose, Kalifornija). Merenja su ponavljana tri puta za svaki uzorak i za svaki stepenik aluminijumskog etalona. Delovi uzoraka na kojima su uočene nepravilnosti, kao što su mehurići vazduha, nisu bili podvrgnuti merenju. Za određivanje rendgenkontrastnosti napravljen je grafikon logaritamske zavisnosti debljine aluminijuma od tona sivo-bele skale. Zatim su radiografske gustine materijala korišćene za određivanje rendgenkontrastnosti sa grafikona. Rendgenkontrastnost je bila izražena u mmAl/mm materijala (mmAl).

Normalnost distribucije podataka ispitana je testom Kolmogorov–Smirnov. Urađena je jednofaktorska analiza varijanse sa testom Tukey post hoc za poređenje razlika među silerima. Statistička analiza je urađena u programskom paketu SPSS 16.0 za Windows (SPSS Inc., Chiago, IL, SAD), nivo značajnosti je bio α = 0,05.

REZULTATI

Na Slici 1 prikazan je digitalni radiogaram paste GuttaFlow Bioseal i stepeničastog etalona. U Tabeli 2 su prikazane srednje vrednosti i standardne devijacije rendgenkontrastnosti ispitivanih pasta u milimetrima aluminijuma (mm Al). Najveća prosečna rendgenkontrastnost uočena je kod AH Plus paste (11,22 mmAl), a zatim, po opadajućim vrednostima: BioRoot RCS (8,32 mmAl), GuttaFlow Bioseal (7,64 mmAl), MTA Fillapex (5,58 mmAl), dok je najmanje vrednosti pokazala pasta Bioceramic Root Canal Sealer (3,4 mmAl). Statistička analiza je pokazala značajne razlike u vrednostima rendgenkontrastnosti između MTA Fillapex i svih ostalih pasta, zatim Bioceramic Root Canal Sealer i svih ostalih pasta, kao i GuttaFlow Bioseal i svih ostalih pasta. Jedino između pasta BioRoot RCS i GuttaFlow Bioseal nije bilo značajne razlike.

DISKUSIJA

Međunarodna organizacija za standardizaciju (ISO) propisala je da bi paste za punjenje kanala korena, pri debljini od 1 mm, trebalo da imaju rendgenkontrastnost ekvivalentnu debljini od minimalno 3 mm aluminijuma. Sve paste testirane u ovoj studiji ostvarile su rendgenkontrastnost veću od standardom propisane. Iako su sve ispitivane paste na bazi kalcijum-silikata, značajne međusobne razlike u rendgenkontrastnosti uočene u ovoj studiji mogu biti posledica vrste i procentualne zastupljenosti rendgenkontrastnog sredstva u ovim materijalima.

Naime, Duarte i sar. 2009. su utvrdili da različita rendgenkontrastna sredstva imaju opadajuću rendgenkontrastnost: bizmut-oksid, olovo-oksid, bizmut-subnitrat, jodoform, cirkonijum-oksid, bizmut-karbonat, kalcijum-tungstat, barijum-sulfat i cink-oksid [11]. Bioceramic Root Canal Sealer i MTA Fillapex kao rendgenkontrastna sredstva imaju kalcijum-tungstat, što može biti uzrok njihove niže rendgenkontrastnosti u odnosu na ostale paste [11]. Sa druge strane, BioRoot RCS i AH Plus sadrže cirkonijum- oksid u svom sastavu, koji uslovljava veću rendgenkontrastnost [11]. Pasta GuttaFlow Bioseal ima više komponenti koje povećavaju njenu rendgenkontrastnost: cirkonijum- dioksid, srebro i gutaperka [12]. AH Plus, pored cirkonijum-oksida, sadrži i kalcijum- tungstat i fero-oksid, koji dodatno doprinose najvećoj rendgenkontrastnosti zabeleženoj kod ove paste [13].

U literaturi se nailazi na različite vrednosti rendgenkontrastnosti za kalcijum-silikatne paste koje su predmet ovog istraživanja. Rendgenkontrastnost BioRoot RCS varira od 5,2 do 8,3 mmAl [14, 13], dok se vrednosti zabeležene za GuttaFlow Bioseal kreću od 3,94 do 7,44 mmAl [15, 16]. Vrednosti za pastu MTA Fillapex u prethodnim studijama kreću se od 3,01 do 9,4 mmAl [17, 18]. Važno je naglasiti da je proizvođač menjao sastav paste MTA Fillapex, tako što je bizmut-oksid zamenjen kacijum-tungstatom, što dodatno usložnjava poređenje među studijama [19]. Kako je Bioceramic Root Canal Sealer relativno nov proizvod na tržištu, u literaturi nismo pronašli podatke koji se tiču njegove rendgenkontrastnosti, pa nije bilo moguće uporediti naše sa rezultatima drugih istraživanja. U većini studija o endodontskim pastama, AH Plus pasta, na bazi epoksi smole, bila je kontrolni materijal i pokazala izraženu varijabilnost u vrednostima rendgenkontrastnosti od 5,9 do 18,4 mmAl [20, 13].

Varijabilnost navedenih rezultata se delimično može objasniti različitim metodološkim pristupima i različitim radiografskim sistemima, konvencionalnim ili digitalnim, koji su korišćeni u pomenutim studijama [9]. Naime, prema međunarodnom standardu za rendgenkontrastnost pasta za punjenje kanala, ispitivanje radiografske vizuelizacije ostvaruje se hemijskim procesom razvijanja, fiksacije, ispiranja i sušenja konvencionalnog rendgen filma. Sve ove procedure mogu negativno uticati na kvalitet rendgen filma i vremenski su zahtevne [21]. Da bi se umanjio uticaj procesa razvijanja filma i uslova radiografisanja na preciznost merenja, na istom filmu sa uzorkom radiografiše se i aluminijumski etalon, koji je izabran kao referentan jer aluminijum ima sličnu rendgenkontrastnost kao dentin [22]. Nakon razvijanja filma potrebno je optičkim denzitometrom meriti količinu svetlosti koju propusti film i prevesti je u debljinu aluminijuma koja na filmu propusti istu količinu svetlosti. Sa druge strane, sve veća upotreba digitalne radiografije u kliničkoj praksi pokrenula je nova istraživanja rendgenkontrastnosti stomatoloških materijala uz upotrebu digitalizovanih sistema [23].

Široka upotreba ovih sistema ih je načinila i klinički relevantnijim u odnosu na konvencionalnu radiografiju. Takođe, kompjuterska obrada i analiza digitalne slike omogućavaju da se lakše dođe do podataka, isključuje greške koje se vezuju za razvijanje filmova i koristi manje doze zračenja, s obzirom na to da su digitalni senzori osetljiviji od konvencionalnih filmova [24]. Imajući u vidu široku rasprostranjenost i prednosti digitalne radiografije u odnosu na konvencionalnu, neki autori su smatrali da bi trebalo usvojiti nove, modifikovane protokole od strane organizacija za standardizaciju [25, 26].

Različita istraživanja o rendgenkontrastnosti endodontskih materijala, poredeći konvencionalnu i digitalnu metodu, pokazala su da izbor metode za radiografisanje može značajno uticati na dobijene vrednosti rendgenkontrastnosti [27, 28]. U ovim istraživanjima autori su zaključili da je teško porediti njihove rezultate sa rezultatima drugih studija zbog različitih metodoloških pristupa merenju rendgenkontrastnosti. Ovo dalje implicira da je pri određivanju rendgenkontrastnosti različitih pasta za punjenje kanala važno da se primeni isti eksperimentalni dizajn studije i isti radiografski sistem da bi rezultati bili uporedivi. Interesantno je što je u prethodnim studijama koje su, slično našoj, koristile digitalne radiografske sisteme, BioRoot RCS pasta imala slične vrednosti rendgenkontrastnosti (7,96 i 8,3 mmAl) [29, 13]. Takođe su rezultati rendgenkontrastnosti za GuttaFlow Bioseal u našem istraživanju saglasni sa rezultatima iz dve studije (7,02 i 7,44 mmAl) koje su koristile digitalne radiografske sisteme slične našim [30, 15].

Drugi mogući uzrok za veliki raspon u vrednostima rendgenkontrastnosti pasta za punjenje kanala korena opisan u literaturi mogle bi biti varijacije u odnosu pojedinačnih komponenti dvokomponentnih pasta, tokom njihove pripreme, koje mogu značajno da promene svojstva materijala [31]. Ovo je pokazano za različita fizičko-hemijska svojstva, kao što su vreme vezivanja, tečljivost, rastvorljivost ili rendgenkontrastnost, čak i kada je korišćena ista metodologija [30, 32]. Isto tako, autori koji su ispitivali rendgenkontrastnost endodontskih materijala smatrali su da manipulacija materijalom tokom procesa mešanja može uzrokovati razlike u rezultatima [33]. Takođe je pokazano da količina rendgenkontrastnog sredstva može biti različita na dva kraja tube sa endodontskom pastom, kao i da se rendgenkontrastno sredstvo može nataložiti na donjem kraju tube, dok gornji delovi mogu sadržati manju količinu rendgenkontrastnog sredstva [32].

ZAKLJUČAK

Paste za punjenje kanala korena ispitane u ovoj studiji pokazale su različite vrednosti rendgenkontrastnosti, koje mogu biti posledica vrste i količine rendgenkontrastnih sredstava u njihovom sastavu. Najveću rendgenkontrastnost imala je pasta AH Plus, dok su kalcijum-silikatne paste pokazale manje vrednosti, po opadajućem redosledu, od BioRoot RCS, preko GuttaFlow Bioseal, zatim MTA Fillapex i Bioceramic Root Canal Sealer, kod koje su uočene najmanje vrednosti.

ZAHVALNICA

Istraživanje je podržano od strane Ministarstva prosvete, nauke i tehnološkog razvoja Republike Srbije, evidencioni broj: 451-03-9/2021-14/200129.