CLINICAL DENTISTRY AND RESEARCH 2013; 37(3): 32-37 Original Research Article

RADIOPACITY EVALUATION OF THREE CALCIUM SILICATE-BASED MATERIALS BY DIGITAL RADIOGRAPHY

Fuat Ahmetoğlu, DDS, PhD
Assistant Professor, Department of Endodontics, Faculty of Dentistry, İnönü University, Malatya, Turkey

Neslihan Şimsek, DDS, PhD,
Assistant Professor, Department of Endodontics, Faculty of Dentistry, İnönü University, Malatya, Turkey

Ali Keleş, DDS, PhD,
Assistant Professor, Department of Endodontics, Faculty of Dentistry, İnönü University, Malatya, Turkey

M. Sinan Ocak, DDS,
Research Assistant, Department of Endodontics, Faculty of Dentistry, İnönü University, Malatya, Turkey

Oğuzhan Altun, DDS, PhD,
Assistant Professor, Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, İnönü University, Malatya, Turkey

ABSTRACT

Background and Aim: The aim of present study was to evaluate the radiopacity of BioAggregate, MM-MTA and Biodentine by means of direct digital radiography.

Materials and Methods: Five circular specimens, 5 mm in diameter and 1 mm high, were prepared for each material tested. After the material set, radiographs were made by using a phosphor plate and graduated aluminum stepwedge varying in thickness from 1 to 12 mm. The images were viewed using Digora for Windows software and were compared with the aluminum stepwedge. Data was analyzed using Kruskal Wallis analysis of variance and Post-Hoc Connover test.

Results: MM-MTA was the most radiopaque materials (5.90 mm of aluminum), followed by BioAggregate and Biodentine presented the lowest radiopacity values (3.78, 3.42 mm of aluminum, respectively).

Conclusion: Although the materials evaluated demonstrated different radiopacities, all three materials had radiographic values above the minimum recommended by the International Organization of Standardization. This study shown that these materials are suitable for endodontic use in terms of radiographic assessment.

Correspondence

Fuat Ahmetoğlu, DDS, PhD
Departments of Endodontics, Faculty of Dentistry, İnönü University, 44280, Malatya, Turkey
Phone: +90 422 341 11 06
Fax: +90 422 341 11 07
E-mail: fuat.ahmetoglu@inonu.edu.tr

Key words: BioAggregate, Biodentine, Digital Radiography, MM-MTA, Radiopacity

Submitted for Publication : 05.28.2013
Accepted for Publication : 09.05.2013

CLINICAL DENTISTRY AND RESEARCH 2013; 37(3): 32-37 Orjinal Araştırma

ÜÇ KALSİYUM SİLİKAT KÖKENLİ MATERYALİN DİJİTAL RADYOGRAFLA RADYO-OPASİTELERİNİN DEĞERLENDİRİLMESİ

Fuat Ahmetoğlu,
Yar. Doç. Dr., İnönü Üniversitesi, Diş Hekimliği Fakültesi, Endodonti Anabilim Dalı, Malatya, Türkiye

Neslihan Şimsek,
Yar. Doç. Dr., İnönü Üniversitesi, Diş Hekimliği Fakültesi, Endodonti Anabilim Dalı, Malatya, Türkiye

Ali Keleş,
Yar. Doç. Dr., İnönü Üniversitesi, Diş Hekimliği Fakültesi, Endodonti Anabilim Dalı, Malatya, Türkiye

M. Sinan Ocak,
Araştırma Görevlisi, İnönü Üniversitesi, Diş Hekimliği Fakültesi, Endodonti Anabilim Dalı, Malatya ,Türkiye

Oğuzhan Altun,
Yar. Doç. Dr., İnönü Üniversitesi Diş Hekimliği Fakültesi, Ağız, Diş ve Çene Radyolojisi Anabilim Dalı, Malatya, Türkiye

ÖZET

Amaç: Bu çalışmanın amacı BioAggregate, MM-MTA ve Biodentine'in radio-opasitelerinin direct dijital radyografla değerlendirilmesidir.

Gereç ve Yöntem: 5 mm çapında ve 1 mm yüksekliğinde olan beş dairesel örnek her bit materyalin test edilmesi için hazırlanmıştır. Materyaller hazırlandıktan sonra fosfor plak ve 1 ile 12 mm arasında kalınlıkları değişen derecelendirilmiş alüminyum stepwedgeler ile radyograflar alınmıştır. Görüntüler Windows'un Digora yazılımıyla görüntülenmiş ve alüminyum stepwedgelerle kıyaslanmıştır. Sonuçlar Kruskal Wallis analizi ve Post-Hoc Connover testleri ile analiz edilmiştir.

Bulgular: MM-MTA en radio-opak materyalken (5.90 mm alimünyum), diğerleri sırasıyla azalan radio-opasiteye gore BioAggregate ve Biodontine olmuştur (3.78, 3.42 mm alüminyum).

Sonuç: Materyallerin değerlendirilmesi ile farklı radio-opasite oluşturmalarına rağmen her üç material de Uluslararası Standardizasyon kurumu'nun önerdiği minimum değerlerin üzerinde değer göstermişlerdir. Bu çalışma ile bu materyallerin endodontic kullanımda radyografik değerlendirme açısından uygun oldukları gösterlmiştir.

Sorumlu Yazar

Fuat Ahmetoğlu
İnönü Üniversitesi, Diş Hekimliği Fakültesi, Endodonti Anabilim Dalı
44280, Malatya, Türkiye
Telefon: +90 422 341 11 06
Faks: +90 422 341 11 07
E-mail: fuat.ahmetoglu@inonu.edu.tr

Anahtar Kelimeler: BioAggregate, Biodentine, Dijital Radyograf, MM-MTA, Radyopasite

Yayın Başvuru Tarihi : 28.05.2013
Yayına Kabul Tarihi : 05.09.2013

INTRODUCTION

Perforations are undesirable incident that can occur at any stage of root canal therapy or during restorative procedures in Endodontics.[1] Perforation defects is repaired by non-surgical or surgical techniques.[2] Surgical repair is indicated when access through the canal is impossible.[3] Among physical and chemical properties, the ideal material for treating endodontic perforations should have a sufficient degree of radiopacity to allow for a clear distinction between the material and surrounding anatomic structures and to determine the quality of the filling.[4] Therefore, newly developed root filling materials should be investigated in this respect.

BioAggregate (Innovative BioCeramix, Vancouver, BC, Canada) endodontic cement has been introduced as a new generation of root canal repair material. It is being used for a variety of applications in endodontics such as direct pulp capping, apical pluging, root-end filling, external root resorption repair and partial pulpotomy.[5] This material is a fine, white, hydraulic powder cement mixture for endodontic applications. It utilizes the advanced science of nanotechnology to produce ceramic particles that, upon reaction with water, produce biocompatible and aluminum-free ceramic material. Some of the advantages of this new repair material are its high pH (pH> 12.8), resistance to washout, no-shrinkage upon setting, exceeding biocompatibility (nontoxic), and chemical stability within the biological environment, excellent sealing ability and superb physical properties. Furthermore, bioceramics will not result in a significant inflammatory response even though an overfill occurs during the obturation process or in a root repair.[6] The current bioceramic materials might also provide a useful alternative to mineral trioxide aggregate (MTA).[7] MTA possesses several advantageous properties and has been recommended as a repair material for root perforations.[8] MTA has been biological properties,[9,10] low solubility, good marginal adaptation and sealing ability.[11-13] However, one of the limitations of MTA is its extended setting time of 2 hours and 45 minutes[13] and the difficulty in its handling. Currently, clinically approved MTA products are available within the dental marketplace. MM-MTA (MicroMega, Besançon Cedex, France) incorporates a faster set time of 20 minutes with a pasty consistency for easy handling and placement. The MM-MTA powder and liquid are directly contained in the cap, which insures the correct powder-to-liquid quantity for optimal consistency. This eliminates the need for a practitioner to prepare MTA paste by mixing the powder and liquid on a mixing plate, which may result in a grainy consistency. Therefore, MM-MTA, once mixed, is extremely homogenous with properties and blend, which are always optimal and reproducible. Recently, marketed Biodentine (Septodent, Saint Maur des Fosse´s, France) was claimed to be used as a dentine restorative material in addition to endodontic indications similar to those of MTA. This bioactive cement has dentin-like mechanical properties and can be used as a root end filling material as well as a repair material for root perforations and resorptions.[14]

The International Organization for Standardization (ISO)[15] establishes that root canal sealing materials should have a radiopacity equivalent to no less than 3 mm of aluminum. Several studies evaluating radiopacity[16-18] employ an aluminum step-wedge, and digital methods that determine gray values have also been proposed.[19] Digital radiography offers many software packages for the quantitative analysis of radiographs, enabling improvements both in diagnosis and treatment decisions.[20]

Our aim in this study was to evaluate the radiographic properties of the three current root repair materials — BioAggregate, MM-MTA and Biodentine — with direct digital radiography.

MATERIALS AND METHODS

The major chemical compounds and manufacturers are listed in Table 1. Five specimens were prepared from each material tested. Five plastic plates, containing 3 wells measuring 1 mm in depth and 5 mm in diameter, were utilized. The test materials were manipulated according to the manufacturers' instructions, and the prepared materials were poured immediately into the wells. The specimens were stored in a moist chamber (incubator) at 37°C for 48 h. Then, the plates were removed, and the specimen thickness was checked with a digital caliper (Guilin Guanglu Measuring Instument Co. Ltd., Chine) and those with unsuitable thickness, voids, bubbles, or cracks were discarded and replaced.

The plastic plate filling test materials and an aluminum step-wedge were positioned on radiographic film. Standardized radiographic images of the specimens were obtained by using a size 2 Digora phosphor plate (31 x 41mm, Digora™ system, Soredex Orion Corporation, Helsinki, Finland) alongside an aluminum step-wedge that was used for reference. The step-wedge was made of ≥98% pure aluminum with uniform steps of 1 mm, from 1 mm to 12 mm. The radiographs were taken by using a radiographic unit

Table 1. Root repair materials, compositions and manufacturers used in this study

Product	Composition*	Manufacturer
BioAggregate	Tricalcium silicate, dicalcium silicate, calcium phosphate, amorphous silicon oxide, tantalum oxide**	Innovative BioCeramix, Vancouver, BC, Canada
MM-MTA	Tricalcium silicate, dicalcium silicate, tricalcium aluminates, calcium sulphate dihydrate, magnesium oxide, bismuth oxide**	MicroMega, Besançon Cedex, France
Biodentine	Tricalcium silicate, dicalcium silicate, calcium carbonate and oxide, iron oxide, zirconium oxide**	Septodont, Saint Maur des Fossés, France

*Information according to the manufacturers, ** Radiopacifier

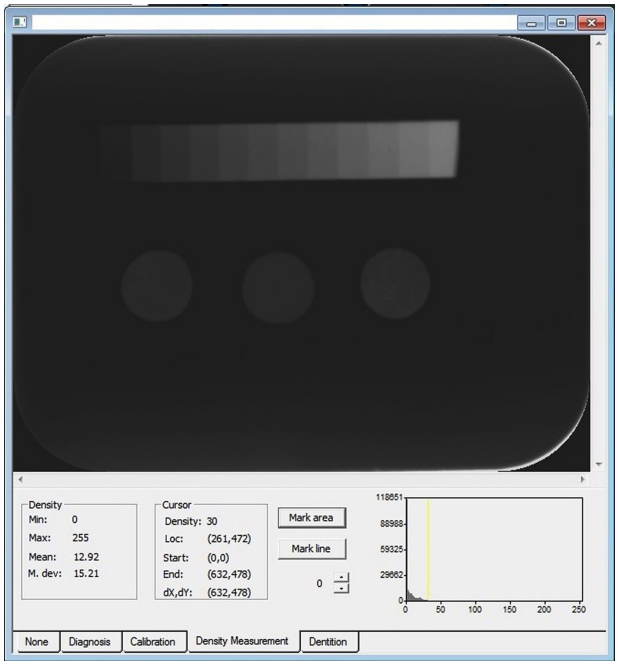

Figure 1. Computer screen during the quantification of the radiopacity of materials by Digora for windows software

(Belmont Photo-X II DC, Somerset, NJ 08873) operating at 60 kV, 7mA, with exposure set at 0.20 seconds. The object-to-focus distance was 30 cm. Exposed-imaging plates of the test samples and step-wedge were scanned immediately after exposure using the Digora Optime Radiolasergraphy (RLG) following the manufacturer's standard instructions to provide the gold standard images. The images were viewed using Digora for Windows 5.1 software (Figure 1). The same protocol was used for all phosphor plates exposed to radiation. Radiographic values were taken on five different points of each material and the average was then calculated. The mean gray value of each material was then converted to equivalent millimeters of aluminum, permitting the measurement of the studied materials. Two evaluators took the measurements. Both evaluators were blinded to the identity of materials. The radiopacity value was determined according to the radiographic density, which was also converted into millimeters of aluminum.

Data were statistically analyzed by means of Kruskal Wallis analysis of variance and Post - Hoc Connover test using MedCalc Statistical Software Manual 2007 (MedCalc Software bvba, Ostend, Belgium). The level of statistical significance was set at $p < 0.05$.

RESULTS

The radiopacity values are presented in Table 2. All materials exhibited a radiopacity above the 3 mm of aluminum recommended by ISO 6786.[15] The median values of radiopacity ranged from 3.42 to 5.90 mm of aluminum per millimeter of material. MM-MTA showed the highest radiopacity of all materials ($p < 0.05$) followed by BioAggregate and Biodentine. BioAggregate and Biodentine were similar in radiographic value ($p > 0.05$).

DISCUSSION

Radiopacity of endodontic materials is an essential physical property that distinguishes the adjacent anatomical structures, such as bone and teeth[21-23] and checks the obturation quality.[17] Thus; an endodontic filling material should be radiopaque.[15] The radiopacity properties of every new material should be investigated. In this study, we compared the radiopacities of three current root repair materials—BioAggregate, MM-MTA and Biodentine—with different thicknesses of pure aluminum step-wedge by means of direct digital radiography.

Tagger and Katz[24] developed a method for analysis of the radiopacity of endodontic sealers using standardized samples radiographed next to an aluminum step-wedge by specialized radiographic software and hardware, eliminating

Table 2. Radiopacity values of the tested materials

Tested Materials	Median	Min. - Max.
BioAggregate	3.78	3.08 - 4.56
MM-MTA	5.90	4.48 - 6.34
Biodentine	3.42	3.06 - 3.92

the need for an optical densitometer. The aluminum step-wedge with varying thicknesses was chosen as the standard for measuring radiopacity because it allows comparison of specific sample thicknesses of aluminum step-wedge under typical radiographic conditions.[25,26] The radiographs are digitized and the specimens' radiopacity is compared to that of the aluminum step-wedge using image-analysis computer software. The radiographic software allows for a more detailed analysis of the digital image, which is shown on a computer screen and can be evaluated graphically or by the grey-pixel value.[4,27] Digital x-ray systems have been used previously to evaluate the radiopacity of dental materials.[4,17,18,25]

The ISO 6876/2001[15] requires a minimal radiopacity equivalent to 3 mm of aluminum for the root canal sealers. According to the present results, all materials evaluated in the present investigation proved to be sufficiently radiopaque. Although each of the three materials tested were similar in their main composition of tricalcium silicate, each item had different substances conferring radiopacity. These substances are shown in Table 1.

There was no literature about the radiopacity of MM-MTA, which is a new root repair material, when this study was performed. The radiopacity value of MM-MTA showed an average 5.90 mm thick aluminum. The present result is in agreement with previous reports,[13,21,28,29] which evaluated the radiopacity of the previous formulation of MTA. These studies have shown a radiodensity range of 3 to 7.2 mm of aluminum for MTA; MM-MTA has a similar value within this range in this study (5.90 mm). The formation of this range can be connected to the choice of imaging device, which can affect the measured radiopacity of a material.[25] In this study, phosphor plates and a digital scanner and its software were used.

While MM-MTA exhibited 5.90 mm thick aluminum, BioAggregate and Biodentine showed values similar to each other in radiopacity, at 3.78 and 3.42 mm thick aluminum, respectively. However, there is very little published literature on BioAggregate and Biodentine, which may be due to the novelty of these materials. In a study conducted only recently, Grech et al.[30] investigated the physical properties of BioAggregate and Biodentine and found that both materials exhibited a radiopacity value higher than 3 mm aluminum; although BioAggregate was the most radiopaque material tested, the difference was not statistically significant. We found similar results in the present study. However, in the present study, radiographic values are lower than in the mentioned study, because we evaluated the materials at the end of the second day, while they evaluated the materials within the first day. The same study showed that radiopacity value decreases over time.[30]

CONCLUSION

This study concluded that radiopacity measurements for BioAggregate, MM-MTA and Biodentine exceeded the minimum standard for root canal sealers according to the ISO. Therefore, these materials are suitable for endodontic use in terms of radiographic assessment.

ACKNOWLEDGMENT

The authors acknowledge this study was supported by the Department of Scientific Research Projects, The University of Inonu, Malatya, Turkey.

REFERENCES

1. Main C, Mirzayan N, Shabahang S, Torabinejad M. Repair of root perforations using mineral trioxide aggregate: a long-term study. J Endod 2004; 30: 80-83.

2. Breault LG, Fowler EB, Primack PD. Endodontic perforation repair with resin-ionomer: a case report. J Contemp Dent Pract 2000: 1; 48-59.

3. Carrotte P. Surgical endodontics. Br Dent J 2005: 2; 71-79.

4. 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: 514-520.

5. Tuna EB, Dincol ME, Gencay K, Aktoren O. Fracture resistance of immature teeth filled with BioAggregate, mineral trioxide aggregate and calcium hydroxide. Dent Traumatol 2011; 27: 174-178.

6. Koch KA, Brave DG. Bioceramics, Part 2: The clinician's viewpoint. Dent Today 2012; 31: 118,120,122-125.

7. Lovato KF, Sedgley CM. Antibacterial activity of endosequence root repair material and proroot MTA against clinical isolates of Enterococcus faecalis. J Endod 2011; 37: 1542-1546.

8. Ford TR, Torabinejad M, McKendry DJ, Hong CU, Kariyawasam SP. Use of mineral trioxide aggregate for repair of furcal perforations. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995; 79: 756-763.

9. Torabinejad M, Hong CU, Lee SJ, Monsef M, Pitt Ford TR. Investigation of mineral trioxide aggregate for root-end filling in dogs. J Endod 1995; 21: 603-608.

10. Torabinejad M, Pitt Ford TR, McKendry DJ, Abedi HR, Miller DA, Kariyawasam SP. Histologic assessment of mineral trioxide aggregate as a root-end filling in monkeys. J Endod 1997; 23: 225-228.

11. Torabinejad M, Watson TF, Pitt Ford TR. Sealing ability of a mineral trioxide aggregate when used as a root end filling material. J Endod 1993; 19: 591-595.

12. Torabinejad M, Smith PW, Kettering JD, Pitt Ford TR. Comparative investigation of marginal adaptation of mineral trioxide aggregate and other commonly used root-end filling materials. J Endod 1995; 21: 295-299.

13. Torabinejad M, Hong CU, McDonald F, Pitt Ford TR. Physical and chemical properties of a new root-end filling material. J Endod 1995; 21: 349-353.

14. Han L, Okiji T. Uptake of calcium and silicon released from calcium silicate-based endodontic materials into root canal dentine. Int Endod J 2001; 44: 1081-1087.

15. International Organization for Standardization. ISO 6876, Dental Root Canal Sealing Materials. 2nd ed. Geneva, Switzerland, 2001.

16. Rasimick BJ, Shah RP, Musikant BL, Deutsch AS. Radiopacity of endodontic materials on film and a digital sensor. J Endod 2007; 33: 1098-1101.

17. Candeiro GT, Correia FC, Duarte MA, Ribeiro-Siqueira DC, Gavini G. Evaluation of radiopacity, pH, release of calcium ions, and flow of a bioceramic root canal sealer. J Endod 2012; 38: 842-845.

18. Altintas SH, Yildirim T, Kayipmaz S, Usumez A. Evaluation of the Radiopacity of Luting Cements by Digital Radiography. J Prosthodont 2013; 22: 282-286.

19. Baksi BG, Sen BH, Eyuboglu TF. Differences in aluminum equivalent values of endodontic sealers: conventional versus digital radiography. J Endod 2008; 34: 1101-1104.

20. Baksi Akdeniz BG, Eyuboglu TF, Sen BH, Erdilek N. The effect of three different sealers on the radiopacity of root fillings in simulated canals. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007; 103: 138-141.

21. Tanomaru-Filho M, da Silva GF, Duarte MA, Goncalves M, Tanomaru JM. Radiopacity evaluation of root-end filling materials by digitization of images. J Appl Oral Sci 2008; 16: 376-379.

22. Candeiro GT, Correia FC, Duarte MA, Ribeiro-Siqueira DC, Gavini G. Evaluation of radiopacity, pH, release of calcium ions, and flow of a bioceramic root canal sealer. J Endod 2012; 38: 842-845.

23. Gambarini G, Testarelli L, Pongione G, Gerosa R, Gagliani M. Radiographic and rheological properties of a new endodontic sealer. Aust Endod J 2006; 32: 31-34.

24. Tagger M, Katz A. Radiopacity of endodontic sealers: development of a new method for direct measurement. J Endod 2003; 29: 751-755.

25. Tasdemir T, Yesilyurt C, Yildirim T, Er K. Evaluation of the radiopacity of new root canal paste/sealers by digital radiography. J Endod 2008; 34: 1388-1390.

26. Bodrumlu E, Sumer AP, Gungor K. Radiopacity of a new root canal sealer, Epiphany. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007; 104: e59-61.

27. Tanomaru-Filho M, Jorge EG, Guerreiro Tanomaru JM, Goncalves M. Radiopacity evaluation of new root canal filling materials by digitalization of images. J Endod 2007; 33: 249-251.

28. Chng HK, Islam I, Yap AU, Tong YW, Koh ET. Properties of a new root-end filling material. J Endod 2005; 31: 665-668.

29. Islam I, Chng HK, Yap AU. Comparison of the physical and mechanical properties of MTA and portland cement. J Endod 2006; 32: 193-197.

30. Grech L, Mallia B, Camilleri J. Investigation of the physical properties of tricalcium silicate cement-based root-end filling materials. Dent Mater 2013; 29: e20-28.