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# RENDGENKONTRASTNOST JEDNOKOMPONENTNIH KALCIJUM SILIKATNIH ENDODONTSKIH PASTA RADIOCAPACITY OF PREMIXED CALCIUM SILICATE- BASED ENDODONTIC SEALERS

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## Sažetak

**Uvod:** Jednokomponentne kalcijum-silikatne endodontske paste su injektabilni materijali, spremni za upotrebu bez prethodne pripreme, sa dobrim biološkim osobinama koji stvaraju povoljne uslove za reparaciju i očuvanje periapikalnih tkiva.

**Cilj** našeg rada bio je da ispitamo rendgenkontrastnost jednokomponentnih kalcijum silikatnih endodontskih pasta: TotalFill BC Sealer, EndoSequence BC Sealer, Ceraseal, Bio-C Sealer i da ih uporedimo sa pastom na bazi epoksi smola, AH Plus.

**Materijal i metode:** Po tri uzorka (2 mm debljine i 5 mm u prečniku) svake paste su radiografsana sa referentnim aluminijumskim etalonom koristeći CCD (charge-coupled device) digitalni senzor (Trophy Radiology, Cedex, France). Za određivanje rendgenkontrastnosti pravljen je grafikon logaritamske zavisnosti debljine aluminijuma od radiografske gustine sa kalibracionom krivom. Rendgenkontrastnost je očitavana sa grafika i predstavljena u milimetrima debljine aluminijuma po milimetru debljine materijala (mmAl). Jednofaktorska analiza varijanse sa Tukey post hoc testom je korišćena za statističku analizu i nivo značajnosti je bio postavljen na 0,05.

**Rezultati:** Rendgenkontrastnost EndoSequence BC Sealer i Bio-C Sealer bila je značajno manja od rendgenkontrastnosti Ceraseal i AH Plus paste. Razlike među vrednostima za EndoSequence BC Sealer i Bio-C Sealer kao i među vrednostima za Ceraseal i AH Plus nisu bile značajne. TotalFill BC Sealer pasta nije bila značajno različita od ostalih pasta.

**Zaključak:** Jednokomponentne kalcijum silikatne endodontske paste ispitivane u našem istraživanju imale su rendgenkontrastnost veću od 9 mm, po rastućim vrednostima od Bio-C Sealer, EndoSequence BC Sealer, TotalFill BC Sealer do Ceraseal.

**Ključne reči:** rendgenkontrastnost, kalcijum-silikati, endodontska pasta

## Abstract

**Background:** Premixed calcium silicate-based sealers are ready-to-use, injectable materials with advantageous biological properties that create environment favorable for periapical tissues repair and health.

**The aim** of our study was to examine the radiopacities of premixed calcium silicate-based sealers: TotalFill BC Sealer, EndoSequence BC Sealer, Ceraseal, Bio-C Sealer and to compare them with epoxy-based sealer, AH Plus.

**Material and methods:** Three specimens (2 mm thick and 5 mm in diameter) of each sealer were radiographed using charge-coupled device-based digital sensor (Trophy Radiology, Cedex, France) along with an aluminum stepwedge reference. For radiopacity determination, a graph of the logarithm of aluminum thickness versus radiographic density was plotted and a calibration curve was generated. Radiopacities were assessed from the graph and presented as millimeters of aluminum per millimeter of material (mmAl). ANOVA with a post hoc Tukey test was used for statistical analysis and significance was set at 0.05.

**Results:** Radiopacity values of EndoSequence BC Sealer and Bio-C Sealer were significantly lower than radiopacities of Ceraseal and AH Plus. Differences in values between EndoSequence BC Sealer and Bio-C Sealer as well as between Ceraseal and AH Plus were nonsignificant. TotalFill BC Sealer was nonsignificantly different from all other sealers.

**Conclusion:** Premixed calcium silicate-based endodontic sealers evaluated in our study had radiopacity values higher than 9 mmAl, in ascending order, from Bio-C Sealer, EndoSequence BC Sealer, TotalFill BC Sealer to Ceraseal.

**Key words:** radiopacity calcium silicate, endodontic sealer

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## Uvod

Jedan od glavnih ciljeva endodontske terapije je trodimenzionalno, hermetično punjenje kanalnog sistema koristeći gutaperka poene i endodontsku pastu kao sredstvo za ostvarivanje veze sa dentinom kanala korena. Kanalne paste dolaze u direktni kontakt sa okolnim periapikalnim tkivima i trebalo bi da imaju odgovarajuća biološka svojstva. Biokompatibilni endodontski materijal trebalo bi da stvori sredinu povoljnu za reparaciju i očuvanje periapikalnih tkiva<sup>1</sup>. Kalcijum-silikatni materijali imaju poželjna bioaktivna svojstva jer stimulišu biološke signale i interakciju sa susednim tkivima<sup>2</sup>. To može biti korisno za reparaciju/regeneraciju potencijalno oštećenog periodontalnog ligamenta, cementa ili tkiva alveolarne kosti. Naime, dokazano je da kalcijum-silikatni materijali mogu da pokrenu regeneraciju i da ne ometaju zarastanje periapikalnih tkiva čak i kada se prebace, nenamerno, preko otvora na vrhu korena<sup>3</sup>.

Kalcijum-silikatne paste su trenutno dostupne kao dvokomponentni i jedno-komponentni materijali spremni za upotrebu bez prethodne pripreme. Kod dvokomponentnih pasta reakcija vezivanja/hidratacije se pokreće posle mešanja komponenti, pre unošenja u kanal korena. Sa druge strane, jedno-komponentne paste vodu neophodnu za hidrataciju i vezivanje dobijaju apsorpcijom vlage zaostale u kanalu, dentinskim tubulima ili iz tkiva oko korena<sup>4</sup>. Jednokomponentne paste se isporučuju kao unapred pripremljeni, injektabilni materijali u špricima sa kanalnim kanilama. To omogućava lakšu i efikasniju aplikaciju i potencijalno može imati kliničke prednosti zbog olakšavanja rada stomatologa. Lakša aplikacija može biti naročito korisna u kompleksnim endodontskim slučajevima kao što su perforacije korena, apikotomije ili široki otvori na vrhu korena. Sa druge strane, injektabilni materijal se može lako prebaciti i trebalo bi paziti da se pastom, pri injektiranju, ne ispuni potpuno kanalni prostor.

Pored povoljnih bioloških osobina, materijali za punjenje kanala korena bi trebalo da obezbede dugotrajno zaptivanje i odgovarajuće fizičko-hemijske osobine, kao što su, rastvorljivost, vreme vezivanja, tečljivost i sorpcija. Važna osobina endodontskih pasta je rendgenkontrastnost koja im omogućava jasno razlikovanje od susednih anatomskih struktura kao što su kost i zubi<sup>5</sup>.

## Introduction

One of the main goals of endodontic treatment is hermetic three-dimensional obturation of root canal system that requires gutta-percha cones and endodontic sealer as a binding agent to the root dentin. Root canal sealers come into direct contact with the surrounding periapical tissues and should have suitable biological behavior. Biocompatible endodontic material should create environment favorable for periapical tissues repair and health<sup>1</sup>. Calcium silicate-based materials have favorable bioactive properties to provide biological signals and interact with adjacent tissues<sup>2</sup>. This could be beneficial for the reparation/regeneration of potentially damaged periodontal ligament, cementum or alveolar bone tissues. Namely, it was proposed that calcium silicate-based materials could induce tissue regeneration and that they do not act as a hindrance for periapical healing even when extruded, unintentionally, beyond the apical foramen<sup>3</sup>.

Calcium silicate-based sealers are currently available as two-component and premixed ready-to-use materials. In two-component sealers setting, reaction/hydration is initiated after components mixing, before their insertion into the root canal. On the other hand, premixed sealers obtain the water necessary for hydration and setting by absorption of the residual moisture present in the root canal, dentinal tubules or periradicular area<sup>4</sup>. Premixed sealers are supplied as ready-to-use, injectable materials in syringes with intracanal tips. This offers easier delivery approach, efficient application and potential clinical advantage due to dentist-friendly manipulation. Easier material application may be additionally favorable in complex endodontic situations like root perforations, apicoectomy or wide apices. Conversely, injectable material may be susceptible to extrusion and care should be taken to try not to fill the whole canal space with the sealer.

Beside advantageous biological properties, root filling materials should have a long-lasting sealing ability and adequate physicochemical properties, such as solubility, setting time, flow or water sorption. Important characteristic of endodontic sealer is radiopacity that allows it to be distinguished from adjacent anatomic structures such as bone and tooth<sup>5</sup>. Adequate sealer radiopacity enhances the evaluation of the root fillings quality and diagnostic procedures in endodontics<sup>6</sup>. Radiopacity could be helpful in revealing of possible empty spaces or voids in the obturation as well as in inappropriate contours or overtreatment.

Odgovarajuća rendgenkontrastnost doprinosi boljoj proceni kvaliteta kanalnog punjenja i kvalitetnijim dijagnostičkim procedurama u endodonciji<sup>6</sup>. Rendgenkontrastnost olakšava uočavanje praznih prostora ili pukotina kao i neodgovarajućih oblika ili prebacivanja punjenja. Sa druge strane, postoji i zabrinutost da previše kontrastna pasta može zamaskirati nesavršenosti u samom punjenju<sup>7</sup>.

Minimalni zahtevi za rendgenkontrastnost endodontske paste, utvrđeni od strane Međunarodne organizacije za standardizaciju (ISO), su nivo kontrastnosti ne manji od vrednosti koju ima 3 mm aluminijuma, pri debljini od 1mm<sup>8</sup>. Prema ISO standardima rendgenkontrastnost se mora utvrđivati korišćenjem konvencionalnih dental filmova i njihove hemijske obrade rastvorima razvijajuća/fiksira, ispiranjem i sušenjem. Rendgenkontrastnost se procenjuje pomoću optičkog denzitometra kojim se meri količina svetla propuštenog kroz rendgen film, a koja se potom prevodi u odgovarajuću debljinu aluminijuma poređenjem sa aluminijumskim etalomom radiografisanim zajedno sa ispitivanim uzorkom<sup>8</sup>. Međutim, usvajanje digitalnih metoda radiografisanja u kliničkoj praksi, pokrenulo je upotrebu takvih radiografskih sistema i u istraživanjima rendgenkontrastnosti<sup>9-11</sup>. Digitalne metode mogu ukinuti potrebu za hemijskim razvijanjem filmova i merenjima denzitometrom, dajući konzistentnije rezultate uz vremenski manje zahtevne postupke<sup>12</sup>. Prednost ovih metoda je i mogućnost merenja na dobijenim slikama pri velikom uveličanju, direktno na ekranu, čime je moguće odabrati zonu reprezentativnu za merenje<sup>9</sup>. Sagledavajući činjenicu da digitalni radiografski sistemi koriste različite tehnologije digitalnih senzora pokazano je da izbor sistema radiografisanja može uticati na merenja rendgenkontrastnosti<sup>11,13</sup>. Slično tome, pretpostavlja se da razlike u eksperimentalnim metodologijama korišćenim u studijama koje su ispitivale rendgenkontrastnost endodontskih pasta mogu biti uzrok razlika među njihovim rezultatima<sup>14,15</sup>.

Kako se nove jednokomponentne kalcijum-silikatne paste pojavljuju u kliničkoj praksi, postaje sve značajnije uporediti ih sa materijalima koji su trenutno u širokoj upotrebi kako bi se kliničarima omogućio izbor materijala zasnovan na dokazima.

**Cilj** ove studije bio je da ispitamo rendgenkontrastnost jednokomponentnih kalcijum silikatnih endodontskih pasta: *TotalFill BC Sealer*, *EndoSequence BC Sealer*, *Ceraseal*, *Bio-C Sealer* i da ih uporedimo sa zlatnim standardom u endodontskoj praksi, AH Plus pastom.

On the other hand, worry has been expressed that a too opaque sealer may mask imperfections in filling material<sup>7</sup>.

The minimal requirement for the radiopacity of endodontic sealer established by International Organization for Standardization (ISO) is a radiopacity value equivalent to not less than 3 mm Al, at a thickness of 1 mm<sup>8</sup>. According to the ISO standards, radiopacity must be determined using conventional dental films and their chemical processing by developing/fixation solutions, rinsing, and drying. The radiopacity must be evaluated with the aid of an optical densitometer measuring the amount of light transmitted through the film image that is then translated into equivalent thickness of aluminum by comparing it with an aluminum stepwedge standard radiographed alongside the test specimens<sup>8</sup>. However, as digital imaging systems have been adopted in clinical practice, this has motivated the use of these radiographic systems in radiopacity research<sup>9-11</sup>. Digital methods could eliminate the need for chemical processing of radiographic film and optical densitometer measuring, thus providing more consistent results and less time-consuming procedure<sup>12</sup>. Further advantage of these methods is that the image can be measured at great magnification directly on the screen enabling selection of a representative measurement area<sup>9</sup>. Considering that digital radiography systems use different technologies of digital sensors, it was shown that the choice of imaging system may affect radiopacity measurements<sup>11,13</sup>. In a similar way, it was proposed that the differences in experimental methodology used in the studies examining radiopacity of endodontic sealers could be the reason for discrepancies in the obtained results<sup>14,15</sup>.

As new premixed calcium silicate-based sealers emerge for clinical application, it became more important to compare them with the currently widely used materials in order to enable evidence-based selection by clinicians.

**The aim** of present study was to examine the radiopacity of premixed calcium silicate-based sealers: *TotalFill BC Sealer*, *EndoSequence BC Sealer*, *Ceraseal*, *Bio-C Sealer* and to compare them with gold standard in endodontic practice AH Plus sealer.

## ***Materijalii metode***

U istraživanju smo ispitivali sledeće materijale: *TotalFill BCSealer*, *EndoSequence BC Sealer*, *Ceraseal*, *Bio-C Sealer* i *AH Plus* (Tabela 1). Paste su zamešane po uputstvu proizvođača i postavljene u 2 mm duboke i 5 mm široke kalupe. Posle kompletnog vezivanja, u inkubatoru pri 95% vlažnosti i temperaturi od 37°C, debljina uzoraka je merena digitalnim meračem. Ukoliko je bilo potrebno, a kako bi imali debljinu od  $2\pm 0.1$  mm, uzorci su bili tanjeni vodenim šmirglanjem. Pripremljena su po tri uzorka svake paste.

Svi uzorci su bili radiografisani sa aluminijumskim stepeničastim etalonom (99,6 % čistoće, 1-10 mm debljine, 1 mm svaki stepenik) koristeći CCD (charge-coupled device) digitalni senzor (Trophy Radiology, Cedex, France), Radiovisiography (RVG-4). Korišćen je rendgen aparat (Trophy Radiology) sa naponom cevi od 70 kVp, strujom 7 mA, vremenom ekspozicije 0.07 s i rastojanjem od cevi do uzorka od 30 cm. Svaki uzorak materijala i svaki stepenik aluminijumskog etalona očitavan je tri puta i radiografska gustina uzoraka izražena srednjim vrednostima tona sivo-bele skale koristeći program Adobe Photoshop CS4 (Adobe Systems, San Hose, Kalifornija). Pažljivo su izbegavani delovi uzoraka koji su sadržavali mehuriće vazduha ili druge nepravilnosti. Za određivanje rendgenkontrastnosti nacrtan je grafikon logaritamske zavisnosti debljine aluminijuma od radiografske gustine sa kalibracionom krivom. Radiografska gustina svakog uzorka na snimku je korišćena za očitavanje rendgenkontrastnosti sa grafika. Rendgenkontrastnost je predstavljena u milimetrima debljine aluminijuma po milimetru debljine materijala (mmAl).

Kolmogorov–Smirnov test korišćen je za proveru normalnosti raspodele podataka, a jednofaktorska analiza varijanse (ANOVA) sa *Tukey post hoc* testom za poređenja među grupama. Nivo statističke značajnosti je bio postavljen na 0,05. Podatke smo analizirali SPSS 16.0 for Windows (SPSS Inc., Chiago, IL, USA) statističkim programom.

## ***Materials and methods***

Materials evaluated in the study were: *TotalFill BCSealer*, *EndoSequence BC Sealer*, *Ceraseal*, *Bio-C Sealer* and *AH Plus* (Table 1). Sealers were mixed, according to the manufacturers' instructions and placed in 2 mm thick and 5 mm wide molds. After complete setting, in an incubator at 95% humidity and 37°C temperature, the thickness of specimens was measured using a digital caliper. Specimens were ground wet if it was necessary to ensure a thickness of  $2\pm 0.1$  mm. Three specimens of each sealer were prepared.

All specimens of each sealer were radiographed with an aluminum stepwedge (99.6 % pure, 1-10 mm thickness, 1 mm each step) using charge-coupled device-based digital sensor (Trophy Radiology, Cedex, France), Radiovisiography (RVG-4). X-ray machine (Trophy Radiology) was used, with a tube voltage at 70 kVp, current 7 mA, exposure time 0.07 s and focus-to-target distance of 30 cm. Each sealer specimen and step of the aluminum stepwedge was read three times and radiographic densities were expressed as an average greyscale values using the Adobe Photoshop CS4 software (Adobe Systems, San Hose, CA). Care was taken to avoid regions containing air bubbles or other imperfections. For radiopacity determination, a graph of the logarithm of aluminum thickness versus radiographic density was plotted and a calibration curve was generated. Radiographic density of each specimen on the image was used to assess the radiopacity from the graph. Radiopacities were presented as millimeters of aluminum per millimeter of material (mmAl).

Kolmogorov–Smirnov test was used to check normality of data distribution and analysis of variance (ANOVA) with a Tukey post hoc test for between groups' comparisons. Statistical significance was set at 0.05. We evaluated data using SPSS 16.0 for Windows (SPSS Inc., Chiago, IL, USA) statistical program.

**Tabela 1:** Paste, proizvođači i sastavi ispitivnih endodontskih materijala  
**Table 1:** Sealers, producers and composition of the tested endodontic materials

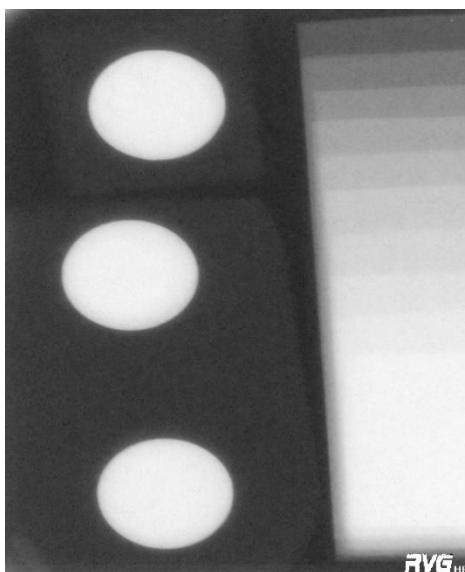
Pasta Sealer	Proizvođač Producer	Sastav Composition
TotalFill BCSealer	FKG Dentaire SA, La Chaux-de-Fonds, Switzerland	Zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, filler and thickening agents
EndoSequence BC Sealer	Brasseler USA Savannah, Georgia, USA	Zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, filler and thickening agents
Ceraseal	Meta Biomed Co., Cheongju-si, Chungcheongbuk-do, South Korea	Calcium silicates, zirconium oxide, thickening agent
Bio-C Sealer	Angelus, Londrina, PR, Brazil	Calcium silicates, calcium aluminate, calcium oxide, zirconium oxide, iron oxide, silicon dioxide, dispersing agent
AH Plus	Dentsply, DeTrey GmbH, Konstanz, Germany	<b>Paste A:</b> Bisphenol epoxy resin–A, Bisphenol epoxy resin–F, calcium tungstate, zirconium oxide, silica, iron oxide pigments. <b>Paste B:</b> Dibenzylidiamine, aminodiamantana, tricyclodecane–diamine, calcium tungstate, zirconium oxide, silica, silicone oil.

## Rezultati

Na Slici 1 prikazan je digitalni radiogram Bio-C Sealer paste i aluminijumski etalon. Srednje vrednosti i standardne devijacije rendgenkontrastnosti ispitivanih jedno-komponentnih kalcijum-silikatnih pasta predstavljene u milimetrima aluminijuma (mmAl) prikazani su na grafiku 1. EndoSequence BC Sealer ( $9.21 \pm 0.51$ ) i Bio-C Sealer ( $9.08 \pm 0.01$ ) imali su slične vrednosti rendgenkontrastnosti koje su bile značajno niže od rendgenkontrastnosti AH Plus ( $10.48 \pm 0.54$ ) i Ceraseal ( $10.41 \pm 0.33$ ) paste. AH Plus pasta je pokazala najveću rendgenkontrastnost ali razlika nije bila značajna u odnosu na Ceraseal i TotalFill BC Sealer ( $9.63 \pm 0.32$ ) paste. Razlike između TotalFill BC Sealer i svih ostalih pastanisu bile značajne.

## Results

Figure 1 shows a digital radiographic image of Bio-C Sealer and aluminium stepwedge. Graph 1 shows the mean and standard deviations of the radiopacity values of investigated premixed calcium silicate-based sealers in millimetres of aluminum (mmAl). EndoSequence BC Sealer ( $9.21 \pm 0.51$ ) and Bio-C Sealer ( $9.08 \pm 0.01$ ) had close radiopacity values that were significantly lower than radiopacities of AH Plus ( $10.48 \pm 0.54$ ) and Ceraseal ( $10.41 \pm 0.33$ ). AH Plus had the highest radiopacity but the difference was nonsignificant in comparison to Ceraseal and TotalFill BC Sealer ( $9.63 \pm 0.32$ ). Differences between TotalFill BC Sealer and all other sealers were statistically nonsignificant.



**Slika 1:** Digitalni radiogram Bio-C paste i aluminijumskog etalona  
**Figure 1:** Digital radiographic image of Bio-C Sealer and aluminum stepwedge

### *Diskusija*

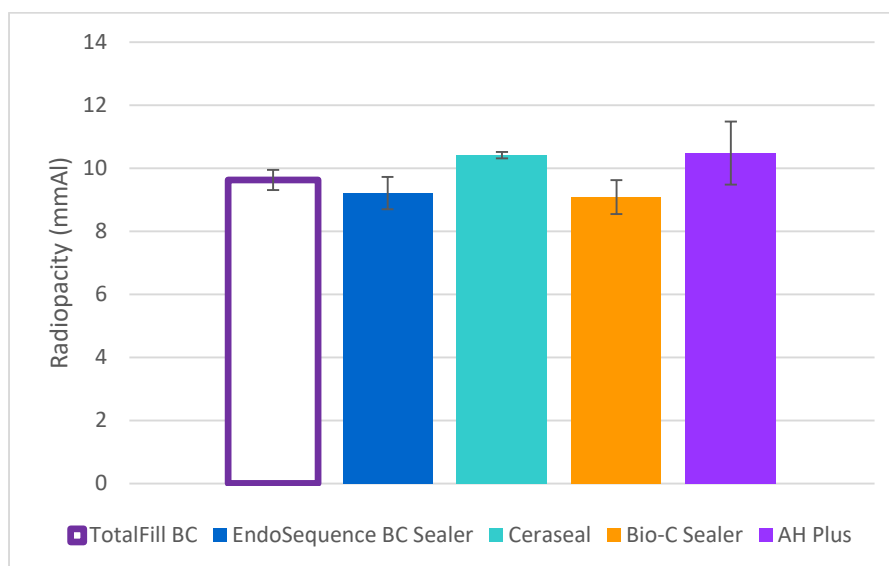
Kako bi postigle optimalnu rendgenkontrastnost, endodontskim pastama je potrebno dodati rendgenkontrastna sredstva. Nivo rendgenkontrastnosti materijala prevashodno zavisi od molekularne strukture i količine rendgenkontrastnih sredstava u njihovom sastavu<sup>16</sup>. Analizom sastava ispitivanih pasta videli smo da je glavno rendgenkontrastno sredstvo u svim materijalima cirkonijum oksid (Tabela 1).

Cirkonijum oksid se koristi u oblastima stomatologije i ortopedije kao biomaterijal i rendgenkontrastno sredstvo<sup>17</sup>. Kao rendgenkontrastno sredstvo korišćen je takođe i u endodontskim materijalima kao što je Portland cement<sup>18</sup>. Pored rendgenkontrastnosti on može uticati na i druge osobine paste kao što su vreme vezivanja, sorpcija, rastvorljivost ili kompresivna čvrstoća<sup>17</sup>. Takođe, cirkonijum oksid ne utiče na mehanizme hidratacije kalcijum-silikata<sup>19</sup> ali može poboljšati in vitro biokompatibilnost materijala<sup>20</sup>. Cutajar i sar. su pokazali da je dodatak cirkonijum oksida redukovao poroznost materijala, a da sama poroznost može uticati na rendgenkontrastnost paste<sup>17</sup>. Naime, autori su objasnili da prazni prostori u materijalu (poroznost) mogu smanjiti broj atoma koji mogu reagovati sa X zracima<sup>17</sup>. Dodatno, Marciano i sar. su prepostavili da povećanje količine rendgenkontrastnih sredstava u kalcijum-silikatnim pastama može smanjiti poroznost usled relativno manje količine kalcijum-silikatne komponente što rezultira manjim brojem pora<sup>21</sup>.

### *Discussion*

Endodontic sealers require an addition of radiopacifying agents in order to optimize their radiographic visualization. Radiopacity level of the material primarily depends on molecular structure and quantity of the radiopacifiers in its composition<sup>16</sup>. Analyzing the composition of the examined sealers, we saw that the main radiopacifying agent in all materials was zirconium oxide (Table 1).

Zirconium oxide is used in dental and orthopedic fields as a biomaterial and radiopacifier<sup>17</sup>. As a radiopacifying agent, it was used also in endodontic materials such as Portland cement<sup>18</sup>. Besides radiopacity, it could influence other sealers properties such as setting time, sorption, solubility or compressive strength<sup>17</sup>. Also, zirconium oxide does not affect the hydration mechanisms of the calcium silicate<sup>19</sup> but can improve in vitro biocompatibility of the material<sup>20</sup>. Cutajar et al. showed that the addition of zirconium oxide reduced the porosity of the material and that porosity, for itself, can affect radiopacity of the sealer<sup>17</sup>. Namely, authors explained that voids in the material (porosity) could reduce the number of atoms available for interaction with the X-rays<sup>17</sup>. In addition, Marciano et al. proposed that the increased amount of radiopacifier in calcium silicate-based sealer would reduce the porosity due to relatively less presence of the calcium silicate component, which results in fewer pores<sup>21</sup>.



**Grafik 1:** Rendgenkontrastnost jednokomponentnih kalcijum-silikatnih endodontskih pasta (u ekvivalentnim milimetrima aluminijuma)

**Graph 1:** Radiopacity of premixed calcium silicate-based endodontic sealers (in millimetres of aluminium equivalent).

Još uvek su retki podaci nezavisnih istraživanja fizičko-hemijskih osobina jednokomponentnih kalcijum-silikatnih pasta, kao grupe endodontskih pasta koja se poslednja pojavila, a naročito nekih od novijih formulacija. Uzimajući u obzir rendgenkontrastnost, većina podataka dostupnih u naučnoj literaturi odnosi se na EndoSequence BC Sealer sa vrednostima između 3,8 i 10,8 mmAl (16,4). Naši rezultati koji se odnose na ovu pastu (9,21 mmAl) bili su na nivou viših vrednosti opisanih u literaturi. To može biti objašnjeno razlikama među radiografskim tehnikama korišćenim u ranijim studijama. U istraživanjima u kojima su dobijene više vrednosti rendgenkontrastnosti korišćeni su, kao i u našem istraživanju, digitalni radiografski sistemi, dok su u istraživanjima u kojima su dobijene niže vrednosti za EndoSequence BC Sealer korišćeni konvencionalni filmovi za radiografisanje<sup>22,4</sup>. Pretpostavlja se da ova razlika verovatno može biti posledica sastava materijala i veće osetljivosti digitalnih senzora na fotone visokih energija<sup>10,13</sup>. To znači da se hemijski elementi koji filtriraju više fotona visokih energija, u poređenju sa aluminijumskim etalomom, mogu činiti više rendgenkontrastnim na snimku načinjenom digitalnim senzorom nego rendgen filmom<sup>10,13</sup>. U tom smislu, Baksi i sar. pokazali su da se rendgenkontrastnost endodontskih pasta razlikovala oko 7%-20% na snimcima dobijenim konvencionalnim filmovima u odnosu na one dobijene digitalnim sistemima baziranim na fosfornim pločama<sup>23</sup>.

Data from an independent investigation of physico-chemical properties of premixed calcium silicate-based endodontic sealers, as the most recently introduced group of endodontic sealers, and especially some of the new formulations, are still limited. Considering radiopacity, majority of the data in scientific literature refers to EndoSequence BC Sealer with reported values between 3.8 and 10.8 mmAl (16.4). Our results for this sealer (9.21 mmAl) were consistent with higher values from the range reported in the literature. This could be explained by the differences related to radiographic technologies used in previous studies. Studies that reported higher radiopacity values, as ours, used digital radiographic imaging systems, while studies that presented lower values for EndoSequence BC Sealer used conventional x-ray film for radiographic imaging<sup>22,4</sup>. It was suggested that this difference possibly could be a consequence of the material's composition and greater sensitivity of the digital sensors to high-energy photons<sup>10,13</sup>. This means that elements that filter out more high-energy photons, in comparison with aluminum reference, could appear more radiopaque on the sensor than on radiographic film<sup>10,13</sup>. In this regard, Baksi et al. showed that radiopacity of endodontic sealers were by 7%–20% different when comparing images obtained using conventional dental x-ray film and images obtained using a digital system based on storage phosphor plate technology<sup>23</sup>.

Oni su sugerisali da, pored osetljivosti senzora, uočene razlike takođe mogu biti posledica činjenice da digitalni sistemi imaju konverziju podataka analogno-u-digitalno i ograničenu mogućnost predstavljanja nijansi sive (od 0 do 255) za razliku od konvencionalnih radiograma koji se sastoje od zrna srebra i koji mogu predstaviti skoro neograničen broj nivoa ozračenosti<sup>23</sup>. Slično tome, Akcay i sar. su poredeći konvencionalni i dva digitalna sistema radiografisanja (fosforne ploče i CCD-senzor) pokazali da je pet endodontskih pasta imalo veću rendgenkontrastnost na digitalnim slikama<sup>11</sup>. Ovi autori su takođe zapazili da na očitavanja rendgenkontrastnosti pri digitalizaciji filmova utiču i osobine skenera i da bi i oni trebalo da imaju svoju referentnu skalu sive boje<sup>11</sup>.

Rezultati koje smo dobili za TotalFill BC Sealer pastu nisu bili značajno različiti od vrednosti za EndoSequence BC Sealer. Ovo je verovatno uzrokovano činjenicom da su sastavi ovih pasta bazirani na istom patentu<sup>14</sup>. Ceraseal je nedavno razvijena pasta i postoji samo jedna studija o njenim fizičko-hemijskim osobinama. U toj studiji autori su pokazali da je rendgenkontrastnost Ceraseal paste ekvivalentna debljini od 5,94 mm aluminijumskog etalona<sup>3</sup>. Značajna razlika u odnosu na vrednosti koje smo mi dobili, 10,41 mmAl, može se pripisati razlikama u ekspozicionim parametrima ili razlikama u osetljivosti korišćenih digitalnih senzora<sup>13</sup>. Naime, u pomenutoj studiji autori su koristili napon cevi od 60 kV, struju od 2 mA, vreme ekspozicije od 0,08 s i rastojanje cevi od objekta od 10 cm za razliku od parametara koje smo mi koristili: 70 kV, 7 mA, 0,07 s i 30 cm. Slično prethodnoj, *Bio-C Sealer* pasta je relativno nov materijal na tržištu tako da ima malo podataka u literaturi koji se odnose na njenu rendgenkontrastnost. Samo jedna skorašnja studija je ispitivala rendgenkontrastnost koristeći digitalni sistem i pokazala malo niže vrednosti od naših, 7,11 mmAl, ali koristeći drugačije parametre ekspozicije<sup>22</sup>.

Nivoi rendgenkontrastnosti svih ispitivanih jednokomponentnih kalcijum-silikatnih pasta bili su relativno visoki, najmanje tri puta viši od onih zahtevanih standardom. To verovatno može da doprinese boljoj proceni endodontskih punjenja u slučaju prebacivanja preko vrha korena, posebno imajući u vidu da su ove paste injektabilne i da lako mogu biti prebačene periapikalno.

They suggested that, beside sensors sensitivity, the observed difference also may be a consequence of the fact that digital systems have analogue-to-digital data conversion and a limited number of available grey shades (from 0 to 255) in contrast to conventional radiographic image which consists of silver grains that could display almost continuous radiation intensities<sup>24</sup>. Likewise, Akcay et al., using a conventional and two digital-radiography systems (storage phosphor plate and charge-coupled device sensor), showed that five different endodontic sealers had higher radiopacities on digital images<sup>11</sup>. These authors also noted that read-out of radiopacity-measurements with film digitalization depends on characteristics of the scanner and they proposed that they should have their own grey scale references<sup>11</sup>.

Our results for TotalFill BC Sealer were not significantly different from the values observed for EndoSequence BC Sealer. This is probably due to the fact that the compositions of these two sealers are based on the same patent<sup>14</sup>. Ceraseal is a recently developed sealer and there is just one research report about its physicochemical properties. In this study, the authors reported that radiopacity of Ceraseal was equivalent to 5.94 mm thick aluminium step wedge<sup>3</sup>. Quite a difference from the value obtained in our study, 10.41 mmAl, could be related to different exposure parameters or sensitivity of the digital sensor used<sup>13</sup>. Namely, in the mentioned study, the authors used a tube voltage at 60 kV, 2 mA current, 0.08 s exposure time and focus-to-target distance of 10 cm unlike parameters used in our study: 70 kV, 7 mA, 0.07 s and 30 cm, respectively. Likewise, Bio-C Sealer is a relatively new material on the market and there are limited data in the literature concerning its radiopacity levels. Only one current study evaluated its radiopacity using digital imaging system, but different exposure parameters showed the results slightly lower than ours, 7.11 mmAl<sup>22</sup>.

Radiopacity values of all examined premixed calcium silicate-based sealers were relatively high, three times higher than the value required by standards, at least. This possibly could facilitate the better evaluation of endodontic filling in case of the extrusion over the root apex, especially having in mind that these sealers are injectable materials and could easily be extruded periapically.



## ***Zaključak***

Ispitivane jednokomponentne kalcijum-silikatne endodontske paste imale su rendgenkontrastnost preko 9 mmAl, od Bio-C Sealer, EndoSequence BC Sealer, TotalFill BC Sealer do Ceraseal, po rastućim vrednostima. Pasta na bazi epoksi smola, AH Plus, kao kontrolni materijal, imala je najveću rendgenkontrastnost ali mislimo da uočene razlike, u odnosu na druge paste, verovatno klinički nisu dovoljno značajne da bi uticale na odabir paste u svakodnevnoj praksi, prema nivou rendgenkontrastnosti.

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## ***Conclusion***

Premixed calcium silicate-based endodontic sealers evaluated in our study had radiopacity values higher than 9 mmAl, in ascending order, from Bio-C Sealer, EndoSequence BC Sealer, TotalFill BC Sealer to Ceraseal. Epoxy-based sealer, AH Plus, as a control material, had the highest radiopacity but we think that the differences observed are probably not clinically significant and relevant to influence the choice of sealer in everyday practice, based on radiopacity level.

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