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KALCIJUM-SILIKATNI CEMENTI U ENDODONCIJI

CALCIUM SILICATE SEALERS IN ENDODONTICS

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Sažetak

Uvod: Endodontske paste za punjenje kanala korena služe da obezbede opturaciju nepropusnu za tečnost, opturaciju pomoćnih kanala i multiplih foramina, potpuno ograničavajući prodor bakterija. U poslednje vreme, umesto potrebe za hermetičkim zatvaranjem kanala korena, veći značaj daje se biološkoj strani, pri čemu se paste za punjenje kanala korena razlažu, kako bi stvorile interakciju sa dentinom korena, što aktivira njihovu bioaktivnost. Trikalcijum-silikatne paste pokreću bioaktivnost na površini materijala nakon kontakta sa tkivnim tečnostima.

Cilj ovog rada jeste da sagleda svojstva kalcijum-silikatnih pasta za punjenje kanala korena i njihovu kliničku primenu.

Rezultati: Nasuprot cementima na bazi smole, cementi na bazi kalcijum-silikata poseduju slabu i, ispod standarda, fizička svojstva, ali pokazuju obećavajuća svojstva – biokompatibilnost, antimikrobni potencijal zajedno sa sklonošću ka biološkoj aktivnosti.

Zaključak: Korisna svojstva cementa na bazi kalcijum-silikata čine ih pogodnim za dugoročni uspeh u lečenju kanala korena. S obzirom na to da se noviji kompetentni cementi redovno pojavljuju na tržištu, neophodno je proučiti njihova svojstva, kako bi se pojednostavio izbor endodontskih cementa stomatolozima, u slučaju da je indicirana upotreba cementa.

Ključne reči: antimikrobna aktivnost, bioaktivnost, biokompatibilnost, kalcijum-fosfat, kalcijum-silikat, jačina veze, dentin kanala korena, cement

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Abstract

Introduction: Endodontic root canal sealers serve the purpose of providing a fluid-tight seal, sealing off accessory canals and multiple foramina, while comprehensively confining the bacteria. Of late, rather than seeking a hermetic seal of the root canal, a more biological perspective is being tackled in which, sealers resolve to interact with root dentin, resulting in bioactivity. Tricalcium silicate sealers set the bioactivity in motion on the material surface after contacting the tissue fluids.

The Aim: The purpose of this paper is to review the properties of calcium silicate sealers in addition to the recent advances of the same and their clinical applications.

Results: Although calcium silicate sealers possess subpar physical properties in comparison to resin-based sealers, they manifest promising properties like biocompatibility, antimicrobial potential along with their propensity for bioactivity.

Conclusion: Beneficial properties of calcium silicate sealers render these sealers beneficial in the long-term success of root canal treatment. With newer competent sealers being put forth in the market on a regular basis, it is imperative to study their properties to simplify the clinician's selection of sealer, where indicated.

Key words: antimicrobial activity, bioactivity, biocompatibility, calcium phosphate, calcium silicate, push-out bond strength, root canal dentin, sealers.

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Uvod

Prednost upotrebe osnovnih materijala i endodontske paste igra ključnu ulogu u konkretnom ostvarivanju hermetičke opturacije nakon terapije kanala korena, pored toga što eliminišu mogućnost prodora bakterija koje uzrokuju oboljenje.

Značajnost endodontskih cemenata za punjenje kanala pripisuje se njihovoj sklonosti da obezbede opturaciju nepropusnu za tečnost, kao i formiranje veze između materijala za opturaciju i zidova kanala korena dok potpuno ograničavaju prodor bakterija¹. Od samog početka, endodontski cementi poboljšani su tako da odgovaraju zahtevima koje je naveo Grossman. Napredak u ovom pravcu delovanja doveo je do najsavremenijih kalcijum-silikatnih cemenata².

Ovaj pregledni rad zasnovan je na istraživanju pomenutih pasta kako bi se procenila njihova različita svojstva.

Pregled literature

Kalcijum-silikatne paste se u širem smislu dele na paste na bazi kalcijum-fosfata, paste na bazi MTA i paste na bazi kalcijum-silikata. Sastav pomenutih pasta naveden je u Tabeli 1.

Cementi na bazi kalcijum-fosfata

Apatitni cementi kanala korena (ARCS - tip I, II i III)

Proučavajući jedan od štetnih efekata cemenata kanala korena, Partovi i sar. zaključili su da je ARCS tip III izazvao najmanje prebojavanja u poređenju sa drugim testiranim cementima³.

Ne samo da je utvrđeno da ARCS nije citotoksičan zajedno sa drugim kalcijum-silikatnim cementima kao što su iRoot SP i MTA Fillapex, već je, takođe, efikasno indukovao aktivnost alkalne fosfataze (ALP) i povećanje osteoblastnih markera i faktora transkripcije⁴.

Capseal I i II

U poređenja sa ARCS i Sealapex⁵, Capseal I i II cementi pokazali su najveći alkalizirajući potencijal, kao i poboljšano otpuštanje jona kalcijuma.

Bae i sar. zaključili su da su od svih testiranih endodontskih pasta Capseal I i II bili najmanje citotoksični; osim toga, pojačali su bioaktivnost povećanjem lučenja osteokalcina (OCN) i ALP⁶.

Introduction

The preference of core material and endodontic sealer plays a pivotal role in concretizing the attainment of a hermetic seal following root canal therapy Besides erasure of disease-causing bacteria.

The momentousness of endodontic sealers is attributed to their propensity for engineering a fluid-tight seal also bond formation between the obturation material and root canal while comprehensively confining bacteria¹. From the outset, sealers have been ameliorated to match the requirements connoted by Grossman. A furtherance following this course of action led to the state-of-the-art Calcium silicate sealers².

This review is based on the exploration of these sealers for assessing different properties.

Review of Literature

Calcium silicate sealers are broadly divided into calcium phosphate-based, MTA-based and calcium silicate-based sealers. The compositions of these sealers are listed in Table 1.

Calcium Phosphate-based Sealers

Apatite Root Canal Sealer (ARCS- Type I, II and III)

While studying one of the adverse effects of root canal sealers, Partovi et al. concluded that ARCS Type III caused the least amount of discoloration in comparison to the other sealers tested³.

Not only was ARCS found to be non-cytotoxic along with other calcium silicate sealers like iRoot SP and MTA Fillapex, but it also efficiently induced alkaline phosphatase (ALP) activity and the upregulation of osteoblastic markers and transcription factors⁴.

Capseal I and II

Both, Capseal I and II sealers showed the highest alkalizing potential in addition to enhanced calcium ion leaching when compared to ARCS and Sealapex⁵.

Bae et al. concluded that of all the sealers tested, Capseal I and II were least cytotoxic, additionally, boosted bioactivity by increasing the expression of Osteocalcin (OCN) and ALP⁶.

Tabela 1: Klasifikacija i sastav kalcijum-silikatnih cementa
Table 1: Classification and composition of calcium silicate sealers

OSNOVA MATERIJALA MATERIAL BASE	PROIZVOD PRODUCT	PROIZVOĐAČ MANUFACTURER	SASTAV COMPOSITION
Na bazi kalcijum fosfata/ Calcium phosphate-based	Apatitni cement kanala korena Tip I / Apatite Root Canal Sealer Type-I	Sankin Kogyo, Tokyo, Japan	Prah: 80% Alfa trikalcijum fosfat, 20% Hidroksiapatit; Powder: 80% Alpha tricalcium phosphate, 20% Hydroxyapatite; Tečnost: : 25% Poliakrilna kiselina, 75% Voda 25% Liquid: Polyacrylic acid, 75% Water.
	Apatitni cement kanala korena Tip II / Apatite Root Canal Sealer Type-II		Prah: 56% Alfa trikalcijum fosfat/ 14% Hidroksiapatit, 30% jodoform; Powder: 56% Alpha tricalcium phosphate, 14% Hydroxyapatite, 30% Iodoform; Tečnost: 25% Poliakrilna kiselina, 75% Voda Liquid: : 25% Polyacrylic acid, 75% Water.
	Apatitni cement kanala korena Tip III/ Apatite Root Canal Sealer Type-III		Prah: 80% Alfa trikalcijum fosfat, 14% Hidroksiapatit, 5% Jodoform, 1% Bizmut subkarbonat; Powder: : 80% Alpha tricalcium phosphate, 14% Hydroxyapatite, 5% Iodoform, 1% Bismuth subcarbonate; Tečnost: : 25% Poliakrilna kiselina, 75% Voda. Liquid: : 25% Polyacrylic acid, 75% Water.
	Capseal I	-	Prah: Tetrakalcijum fosfat (TKF) i dikalcijum fosfat dehidrirani/ (DKFD) Portland cement, cirkonijum oksid Powder: Tetracalcium phosphate (TTCP) and dicalcium phosphate anhydrous (DCPA), Portland cement, zirconium oxide Tečnost: Hidroksi apatit metal celuloza u rastvoru natrijum sulfata Liquid: :Hydroxypropyl methyl cellulose in sodium phosphate solution.
	Capseal II		Prah: Tetrakalcijum fosfat (TKF) i dikalcijum fosfat dehidrirani/ (DKFD), beli Portland cement i cirkonijum oksid Powder: Tetracalcium phosphate (TTCP) i Tetracalcium phosphate (TTCP) and dicalcium phosphate anhydrous (DCPA), white Portland cement, zirconium oxide; Tečnost: Hidroksilapatit metal celuloza u rastvoru natrijum fosfata Liquid: Hydroxypropyl methyl cellulose in sodium phosphate solution.
Na bazi mineral-trioksida (MTA) /MTA based	MTA Fillapex	Angelus, Londrina, PR, Brazil	Pasta A: Silikatna smola, bizmut trioksid, silikatni dim Paste A: Salicylate resin, bismuth trioxide, fumed silica; Pasta B: Silikatni dim, titanijum dioksid, MTA(40% trikalcijum silikat, dikalcijum silikat, kalcijum oksid, trikalcijum aluminat), baza od smole (pentaerititol, rozinat, p-toluensulfonamida) Paste B: Fumed silica titanium dioxide, MTA (40%, tricalcium silicate, dicalcium silicate, calcium oxide, tricalcium aluminate), base resin (pentaerythritol, rosinat, p-toluenesulfonamide).
	Endo CPM	EGEO S.R.L., Buenos Aires, Argentina	Silicijum dioksid, kalcijum karbonat, bizmut trioksid, barijum sulfat, propilen glikol alginat, natrijum citrat, kalcijum hlorid, aktivni sastojci. Silicon dioxide, calcium carbonate, bismuth trioxide, barium sulfate, propylene glycol alginate, sodium citrate, calcium chloride, active ingredients.
	MTA-Angelus	Angelus, Londrina, PR, Brazil	Trioksid, bizmut oksid, gvožđe oksid, kalcijum karbonat, magnezijum oksid, kristalni silicijum dioksid i ostaci Tricalcium silicate, dicalcium silicate, tricalcium aluminate, tetracalcium aluminoferrite, bismuth oxide, iron oxide, calcium carbonate, magnesium oxide, crystalline silica, and residues.
	ProRoot Endo	Dentsply, Tulsa Dental, Tulsa, OK, USA	Prah: Trioksid, bizmut oksid, gvožđe oksid, kalcijum karbonat, magnezijum oksid, kristalni silicijum dioksid i ostaci Powder: Tricalcium silicate, dicalcium silicate, calcium sulfate, bismuth oxide, and a small amount of tricalcium aluminate; Tečnost: Viskozni vodeni rastvor polimera rastvorljivog u vodi Liquid: Viscous aqueous solution of a water-soluble polymer.
	ProRoot MTA	Dentsply Maillefer, Ballaigues, Switzerland	Trioksid, bizmut oksid, gvožđe oksid, kalcijum karbonat, magnezijum oksid, kristalni silicijum dioksid i ostaci Tricalcium silicate, dicalcium silicate, calcium sulfate, bismuth oxide, and a small amount of tricalcium aluminate.
	EndoSeal MTA	Maruchi, Wonju, Korea	Kalcijum silikat, kalcijum aluminat, kalcijum aluminoferrit, kalcijum sulfati, radiopacifikator, sredstvo za zgušnjavanje. Calcium silicate, calcium aluminates, calcium aluminoferrite, calcium sulfates, radiopacifier, thickening agent.
	MTA Plus	Avalon Biomed Inc., Bradenton, Florida, USA	Trioksid, bizmut oksid, gvožđe oksid, kalcijum karbonat, magnezijum oksid, kristalni silicijum dioksid i ostaci Tricalcium silicate, dicalcium silicate, tricalcium aluminate, bismuth oxide, calcium sulphate, silica
	Na bazi kalcijum silikata/ Calcium silicate-based	iRoot SP	Innovative Bioceramix, Vancouver, BC, Canada
EndoSequence BC		Brasseler, Savannah, GA, USA	Cirkonijum oksid 35%-45%, Dikalcijum silikat 7%-15%, Trikalcijum silikat 20%-35%, Kalcijum hidroksid 1%-4%, punila. Zirconium oxide 35%-45%, Dicalcium silicate 7%-15%, Tricalcium silicate 20%-35%, Calcium hydroxide 1%-4%, fillers.
TotalFill BC		FKG Dentaire, La Chaux-deFonds,	Cirkonijum oksid 35%-45%, Dikalcijum silikat 7%-15%, Trikalcijum silikat 20%-35%, Kalcijum hidroksid 1%-4%, punila

		Switzerland	Zirconium oxide 35%–45%, Dicalcium silicate 7%–15%, Tricalcium silicate 20%–35%, Calcium hydroxide 1%–4%, fillers.
	BioRoot RCS	Septodont, Saint-Maur-desFossés, France	Prah: Trikalcijum silikat, cirkonijum oksid i ekscipijenti; Powder: Tricalcium silicate, zirconium oxide and excipients; Vodeni rastvor: Kalcijum hlorid i pomoćne supstance. Aqueous solution: Calcium chloride and excipients.
	Sealer Plus BC	MK Life, Porto Alegre, Brazil	Kalcijum disilikat, nanočestica kalcijum trisilikat, cirkonijum oksid. Calcium disilicate, nanoparticulate calcium trisilicate, zirconium oxide.
	CeraSeal	Meta Biomed, South Korea	Kalcijum silikati, cirkonijum oksid, sredstvo za zgušnjavanje. Calcium silicates, zirconium oxide, thickening agent.
	Bio-C Sealer	Angelus, Londrina, PR, Brazil	Trikalcijum silikat, dikalcijum silikat, trikalcijum aluminat, kalcijum oksid, cirkonijum oksid, silicijum oksid, polietilen glikol, gvožđe oksid. Tricalcium silicate, dicalcium silicate, tricalcium aluminate, calcium oxide, zirconia oxide, silicon oxide, polyethylene glycol, iron oxide.

Cementi na bazi mineralnog trioksida agregata

Mineral trioksid agregat (MTA) Filappex

Kalcijum-silikatnim cementima generalno nedostaju fizička svojstva dobrog zaptivanja, tako da ne ispunjavaju ISO specifikacije. MTA Fillapex pokazao je svojstva apsorpcije vode, rastvorljivost i vreme vezivanja niže od onog kod BioRoot RCS, ali veće od onog kod cemenata na bazi smole⁷. Suprotno tome, MTA Fillapex pokazao je veću rendgenkontrastnost od drugih kalcijum-silikatnih cemenata^{7,8}. Iako je pokazao najveću fluidnost⁹, debljina filma bila je najmanja u poređenju sa ostalim testiranim kalcijum-silikatnim cementima¹⁰. U poređenju sa AH Plus i drugim testiranim pastama, MTA Fillapex pokazao je najveći protok^{9,11}, iako je imao veću debljinu filma od AH plus¹⁰. Ovaj endodontski cement pokazao je najniži kapacitet alkalizacije među ostalim testiranim cementima na bazi kalcijum-silikata, nakon dvadeset-osmodnevnog potapanja u destilovanu vodu, Hankov balansirani rastvor soli (HBSS) i Dulbeccoov modifikovani medijum Eagle (DMEM; Gibco, SAD)¹⁰. Osim toga, MTA Fillapex cement pokazao je najveće otpuštanje jona kalcijuma u poređenju sa cementima na bazi smole¹², ali najniže među cementima na bazi kalcijum-silikata¹³. Pored jona kalcijuma, MTA Fillapex takođe je pokazao oslobađanje jona bizmut-oksida¹³, natrijuma i kalijuma¹⁴, kao i apsorpciju jona fosfora¹³. Kada je potopljen u fiziološki rastvor sa fosfatnim puferom (PBS), MTA Fillapex demonstrirao je najveći gubitak zapremine i procentualne zapreminske širine¹⁵.

Nakon tople vertikalne kompakcije posle sedam dana, MTA Fillapex pokazao je veće mikrocurenje od cemenata na bazi smole: međutim, nakon četiri nedelje, rezultati su bili obrnuti¹⁶. MTA Fillapex takođe je pokazao manje prebojavanje u poređenju sa cementom na bazi cink-oksida-eugenola (ZOE)¹⁷.

Mineral Trioxide Aggregate-based Sealers

MTA Fillapex

Calcium silicate sealers in general lack physical properties of a good sealer thus not meeting the ISO specifications. MTA Fillapex has been reported to have water sorption, solubility, and setting time lower than that of BioRoot RCS but higher than that of resin-based sealers⁷. Contrastingly, MTA Fillapex showed greater radiopacity than other calcium silicate sealers^{7,8}. Though it showed the highest flow⁹, it had the lowest film thickness amongst other calcium silicate sealers tested¹⁰. Similarly, as opposed to AH Plus and other sealers tested, MTA Fillapex showed the highest flow^{9,11}, albeit had a greater film thickness than the former¹⁰. This sealer demonstrated the lowest alkalizing capacity amongst the other tested calcium silicate sealers, following a 28-day immersion period into distilled water, Hank's Balanced Salt Solution (HBSS) and Dulbecco's Modified Eagle Medium (DMEM; Gibco, USA)¹⁰. Moreover, MTA Fillapex has shown the highest calcium ion release when compared with resin-based sealers¹², but the lowest amongst calcium silicate sealers¹³. In addition to calcium ions, MTA Fillapex has also displayed the leaching of bismuth¹³, sodium and potassium ions¹⁴, and uptake of phosphorus ions¹³. When immersed into Phosphate Buffered Saline (PBS), MTA Fillapex showed the highest volume loss and percentage volume of extrusion¹⁵.

Following warm vertical compaction after seven days, MTA Fillapex demonstrated greater microleakage than a resin-based sealer, however at 4 weeks, the results were vice-versa¹⁶. MTA Fillapex also reported lower discoloration in comparison to a Zinc Oxide Eugenol-based (ZOE) sealer¹⁷.

MTA Fillapex demonstrated thrice the cytotoxicity of iRoot SP and BioRoot RCS but lower than that of resin-based sealers¹⁸.

MTA Fillapex je pokazao tri puta veću citotoksičnost od iRoot SP i BioRoot RCS, ali nižu od cemenata na bazi smole¹⁸. Antimikrobni efekat i bioaktivnost koje ima MTA Fillapex inferiorni su kada se uporede sa BioRoot RCS^{7,19}. Siboni i sar. naveli su da su površine i MTA Fillapex i BioRoot RCS cementi izazivaju taloženje sloja kalcijum-fosfata i kalcijum-apatita nakon potapanja u HBSS⁷. DCT je zaključio da TotalFill BC i EasySeal imaju bolji antimikrobni potencijal nego MTA Fillapex¹⁹.

Endo CPM

Endo CPM pokazao je rastvorljivost sličnu rastvorljivosti AH Plus (Dentsply, Nemačka) i nižu rendgenkontrastnost, iako je njegova alkalizirajuća sposobnost bila veća od one koju ima AH Plus²⁰. Takođe, Endo CPM pokazao je veći alkalni pH i oslobađanje iona kalcijuma u poređenju sa MTA i ZOE²¹.

Za razliku od MTA Fillapex, Endo CPM pokazao je znatan prodor boje apikalno²², iako ima veću jačinu veze otpornosti (POBS) nakon monokonusne tehnike i lateralne kondenzacije²³. Pored toga, Endo CPM pokazao je lošiju adaptaciju na zidove kanala od AH Plus nakon lateralne kondenzacije²⁰.

Endo CPM nije, za razliku od MTA Fillapex²⁴ pokazao zonu inhibicije prilikom testiranja antimikrobne aktivnosti, bez obzira na primenjenu metodu testiranja.

MTA Angelus

Ispostavilo se da je rastvorljivost MTA Angelus najmanja među testiranim kalcijum-silikatnim endodontskim cementima, bez statističke razlike u odnosu na AH Plus¹⁴. Bez obzira na blagu citotoksičnost nakon 24 sata, MTA Angelus nije imao nikakve štetne efekte na vijabilnost ćelija²⁵.

ProRoot MTA

U poređenju sa EndoSeal MTA i AH Plus, ProRoot MTA pokazao je nisku rastvorljivost²⁶, rendgenkontrastnost²⁶ i povećanje zapremine²⁶, a veći potencijal alkalizacije²⁶ i potencijal za promenu boje od AH Plus²⁷. ProRoot MTA pokazao je veće oslobađanje iona kalcijuma nego EndoSequence BC, ali manje nego Biodentine²⁸. Za ProRoot MTA utvrđeno je da je najmanje citotoksični endodontski cement u poređenju sa iRoot SP i AH Plus²⁹.

The antimicrobial effect and bioactivity of MTA Fillapex was reported to be inferior to BioRoot RCS^{7,19}. Siboni et al. stated that both, MTA Fillapex and BioRoot RCS sealer surfaces had deposition of calcium phosphate and apatite layer following HBSS immersion⁷. DCT concluded that TotalFill BC and EasySeal have better antimicrobial potential than MTA Fillapex¹⁹.

Endo CPM

Endo CPM displayed solubility similar to that of AH Plus (Dentsply, Germany) and radiopacity lower than the latter, although its alkalizing ability was reported greater than that of AH Plus²⁰. Also, Endo CPM displayed a higher alkaline pH and calcium ion release when compared to MTA and ZOE²¹.

As opposed to MTA Fillapex, Endo CPM has reported significantly greater apical dye leakage²², albeit has a higher push-out bond strength (POBS) following single cone and lateral compaction techniques²³. Additionally, Endo CPM demonstrated poor adaptation to the canal walls compared to AH Plus following lateral compaction²⁰.

No inhibition zone was produced by Endo CPM when its antimicrobial effect was tested, regardless of the test method implemented, unlike MTA Fillapex²⁴.

MTA Angelus

The solubility of MTA Angelus was reported to be the least amongst the calcium silicate sealers tested, with no statistical difference to that of AH Plus¹⁴. Regardless of being slightly cytotoxic after 24 hours, MTA Angelus did not have any adverse effects on the cell viability²⁵.

ProRoot MTA

In comparison to EndoSeal MTA and AH Plus, ProRoot MTA has demonstrated low solubility²⁶, radiopacity²⁶, and volume gain²⁶, albeit, a higher alkalizing²⁶, and discoloration potential than the latter²⁷. ProRoot MTA showed a greater calcium ion release than EndoSequence BC but lower than that of Biodentine²⁸. ProRoot MTA was reported to be the least cytotoxic sealer when compared to iRoot SP and AH Plus²⁹.

EndoSeal MTA

U pogledu apsorpcije vode i rendgenkontrastnosti, EndoSeal MTA pokazao je veće vrednosti od BioRoot RCS¹⁰. U pogledu rastvorljivosti, rezultati EndoSeal MTA bili su uporedivi sa BioRoot RCS, iako su bili veći od AH Plus¹⁰. Međutim, EndoSeal MTA demonstrirao je kraće vreme vezivanja od BioRoot RCS nakon potapanja u HBSS i DMEM⁹. EndoSeal MTA pokazao je otpuštanje jona aluminijuma i bizmuta zajedno sa jonima kalcijuma i fosfora¹⁰. Kada je testiran na 37 °C, EndoSeal MTA pokazao je veću fluidnost nego ProRoot MTA²⁶. Pored toga, ovaj endodontski cement pokazao je veće povećanje zapremine od AH Plus nakon tridesetodnevno perioda potapanja u destilovanu vodu⁹.

Rezultati prodora bakterija pri korišćenju EndoSeal MTA i AH Plus podudarali su se kada su mereni na jedan, dva i tri mm od apeksa³⁰. Studija koja je upoređivala jačinu veze otpornosti EndoSeal MTA i MTA Fillapek zaključila je da je prvi imao veću jačinu (i POBS)³¹. Pored toga, zapreminski procenat praznine EndoSeal MTA primenom monokone tehnike obturacije bio je uporediv sa onim kod AH Plus sa toplom vertikalnom kompaktijom³².

Što se biokompatibilnosti tiče, EndoSeal MTA i ProRoot MTA pokazali su veću vijabilnost ćelija i niži inflamatorni odgovor u poređenju sa AH Plus²⁶. DCT rezultati ukazali su na visoku antimikrobnu aktivnost EndoSeal MTA pre postavljanja endodontske paste, premda su pokazali smanjenu aktivnost nakon postavljanja cementa³³. Yoo i sar. proučavajući bioaktivni potencijal EndoSeal MTA i ProRoot MTA, zaključili su da sam EndoSeal MTA dovodi do niže intratubularne kristalizacije apatita i kalcijum-fosfata³⁴.

MTA Plus

Nakon lateralne kompaktije, kod MTA Plus primećeno je manje otpuštanje boje nego kod AH Plus, ali veće od onog kod EndoSequence BC³⁵. Kada je u pitanju POBS, MTA Plus pokazao je niži POBS od oba gore navedena, bez obzira na korišćeni metod opturacije³⁶.

Endodontski cementi na bazi kalcijum-silikata **iRoot SP**

iRoot SP pokazao je veću stopu apsorpcije vode od AH Plus, a njihova rastvorljivost u destilovanoj vodi bila je komparabilna³⁷.

EndoSeal MTA

In terms of water sorption and radiopacity, EndoSeal MTA has displayed higher values than those by BioRoot RCS¹⁰. In terms of solubility, the results of EndoSeal MTA were comparable to BioRoot RCS, albeit, were greater than AH Plus¹⁰. However, EndoSeal MTA displayed a lower setting time as opposed to BioRoot RCS, following immersion into HBSS and DMEM⁹. EndoSeal MTA demonstrated the leaching of aluminium and bismuth ions along with calcium and phosphorus ions.¹⁰ When tested at 37°C, EndoSeal MTA reported a greater flow than ProRoot MTA²⁶. In addition, this sealer displayed a volume gain greater than AH Plus, following a 30-day immersion period into distilled water⁹.

The results of bacterial leakage of EndoSeal MTA and AH Plus were analogous when measured at one, two and three mm from the apex³⁰. Comparing the push-out bond strengths of EndoSeal MTA and MTA Fillapex, the study concluded that the former had a greater POBS³¹. In addition, the void volume percentage of EndoSeal MTA using single-cone obturation technique was comparable to that of AH Plus with warm vertical compaction³².

In terms of biocompatibility, EndoSeal MTA and ProRoot MTA demonstrated higher cell viability and lower inflammatory response in comparison to AH Plus²⁶. DCT results showed a high antimicrobial activity of EndoSeal MTA prior to sealer setting, albeit demonstrated a diminished activity after the sealer set³³. On studying the bioactive potential of EndoSeal MTA and ProRoot MTA, Yoo et al. concluded that EndoSeal MTA alone resulted in a lower intratubular crystallization of apatite and calcium phosphate³⁴.

MTA Plus

Following lateral compaction, MTA Plus has demonstrated a lower dye leakage than AH Plus, but higher than that of EndoSequence BC³⁵, whereas in terms of POBS, MTA Plus displayed a lower POBS than both, regardless of the obturation method utilized³⁶.

Calcium Silicate-based Sealers **iRoot SP**

While iRoot SP showed a higher water sorption rate than AH Plus, their solubility in distilled water was comparable³⁷.

Kada je podvrgnut temperaturi od 140°C, iRoot SP pokazao je smanjenu fluidnost u poređenju sa AH Plus, dok su u pogledu vremena vezivanja rezultati bili obrnuti³⁸. iRoot SP pokazao je manji kapacitet alkalizacije od MTA Fillapex, ali veći od ostalih testiranih cemenata na bazi smole³⁹. Otpuštanje iona kalcijuma nakon potapanja u destilovanu vodu⁴⁰ bilo je pak veće sa iRoot SP nego sa MTA Fillapex.

Za iRoot SP uočena su inferiorna svojstva prodora paste, uz neadekvatnu opturaciju lateralnih kanala, u poređenju sa cementima na bazi smole, bez obzira na primenjenu tehniku obturacije⁴¹. Međutim, u drugoj studiji iRoot SP i AH Plus imali su iste rezultate u pogledu mikrocurenja, odnosno znatno niže u odnosu na Sealapex (Sibron-Kerr, SAD) i EndoREZ (Ultradent Products Inc., SAD)³⁷. iRoot SP i MTA Fillapex pokazali su manje prebojavanje strukture zuba nego AH Plus nakon tri meseca; rezultati nakon šest meseci bili su pak obrnuti⁴².

Ne samo da je iRoot SP bio necitotoksičan, već je takođe pokazao bioaktivnost, evidentno na ekspresiju mRNA dentin sialofosfoproteina (DSPP), COL1A i ekspresije ALP⁴³. Sveže zamešan iRoot SP pokazao je antimikrobnu efikasnost veću nego kod drugih cemenata na bazi smole i dao je sličan rezultat nakon tri dana, mada je pokazao samo blagu antimikrobnu aktivnost nakon šest dana³⁹.

EndoSequence BC

EndoSequence BC je, u poređenju sa MTA Fillapex i drugim proučavanim cementima, pokazao slabe fizičke osobine – visoka rastvorljivost⁴⁴, niska rendgenkontrastnost⁹ i vreme vezivanja⁴⁴. Pored toga, ovaj cement je pokazao duže vreme vezivanja od AH Plus⁴⁵. Uprkos tome, u pogledu fluidnosti EndoSequence BC ispunjava ISO zahteve, iako ima manju fluidnost nego MTA Fillapex⁴⁴. EndoSequence BC nadmašuje EndoSeal MTA i MTA Fillapex, pokazujući veći alkalizirajući potencijal⁹. Ovaj cement ima manju debljinu filma od MTA Fillapex, ali veću od AH Plus i Pulp Canal Sealer⁴⁴. Lopez-Garcia i sar. otkrili su da EndoSequence BC pokazuje veće otpuštanje iona kalcijuma nego EndoSeal MTA, ali manje nego CeraSeal⁴⁶.

Pri poređenju sa cementima na bazi smole EndoSequence BC je pokazao izvesna štetna svojstva (niži POBS⁴⁷ i veće curenje endotoksina⁴⁸), bez obzira na korišćene tehnike obturacije.

When subjected to 140°C, iRoot SP displayed decreased flow in comparison to AH Plus, but in terms of setting time, the results were vice-versa³⁸. iRoot SP exhibited a reduced alkalizing capacity as opposed to MTA Fillapex but higher than the other resin-based sealers tested³⁹. Contrastingly, the leaching of calcium ions was higher with iRoot SP than MTA Fillapex following immersion into distilled water⁴⁰.

iRoot SP displayed inferior sealer penetration properties along with inadequately obturated lateral canals when compared to a resin-based sealer, regardless of the obturation technique employed⁴¹. Whereas, in another study, iRoot SP and AH Plus had analogous results in terms of microleakage, significant lower as opposed to Sealapex (Sybron-Kerr, USA) and EndoREZ (Ultradent Products Inc., USA)³⁷. Both, iRoot SP and MTA Fillapex showed discoloration of tooth structure, lesser than AH Plus after three months but vice-versa after six months⁴².

Not only was iRoot SP non-cytotoxic, but also exhibited bioactivity, evident on mRNA expression of Dentin Sialophosphoprotein (DSPP), COL1A and ALP expression⁴³. Freshly mixed iRoot SP displayed highest antimicrobial efficacy in comparison to other resin-based sealers, and had similar results after three days, albeit showed only slight antimicrobial activity after six days³⁹.

EndoSequence BC

EndoSequence BC has exhibited subpar physical properties like high solubility⁴⁴, low radiopacity⁹, and setting time⁴⁴, in comparison to MTA Fillapex and other sealers studied. Additionally, this sealer has demonstrated a greater setting time than AH Plus⁴⁵. Even so, in terms of flow, EndoSequence BC meets the ISO requirements, albeit has a decreased flow compared to MTA Fillapex⁴⁴. EndoSequence BC surpasses EndoSeal MTA and MTA Fillapex by demonstrating a greater alkalizing potential⁹. This sealer has a lesser film thickness than MTA Fillapex but greater than AH Plus and Pulp Canal Sealer⁴⁴. López-García et al. found that EndoSequence BC showed a higher calcium ion release as opposed to EndoSeal MTA but lesser than that of CeraSeal⁴⁶.

EndoSequence BC displayed detrimental properties like lower POBS⁴⁷, and higher endotoxin leakage⁴⁸, in comparison to resin-based sealers, regardless of the obturation techniques used.

Broj otvorenih pora koji je nakon monokonusne obturacije imao EndoSequence BC bio je veći nego kod AH Plus⁴⁹. Ipak, oba cementa su pokazala analogne rezultate u pogledu izmerenih zatvorenih pora⁴⁹.

Studija o biokompatibilnosti EndoSequence BC otkrila je da je blago citotoksičan, ali manje nego AH Plus⁵⁰. Međutim, dve druge studije o istom zaključile su da je EndoSequence bio najkompatibilniji cement među svim testiranim cementima^{45,51}. Antimikrobnim testiranjem sa Agar Diffusion Testom (ADT) zaključeno je da EndoSequence BC ima veću antimikrobnu aktivnost nego AH Plus, dok je test direktnog kontakta (DCT) dao komparabilne rezultate za oba cementa. Dokazano je da je ekspresija⁵⁰ mRNA ALP i OCN veća kod EndoSequence nego kod MTA Fillapex i AH Plus⁵¹.

TotalFill BC

U poređenju sa AH Plus, TotalFill BC pokazao je veću stopu rastvorljivosti, povećanje zapremine za sedam dana i gubitak zapremine za 30 dana¹⁹. Pored toga, ovaj cement imao je veću rastvorljivost od BioRoot RCS i MTA Fillapex¹⁹. Što se tiče fluidnosti, TotalFill BC pokazao je najveću fluidnost kada se upoređivao sa AH Plus i GuttaFlow Bioseal (Coltene Whaledent, Švajcarska)⁵². TotalFill BC bio je manje rendgenkontrastan od AH Plus, ali više nego GuttaFlow Bioseal⁵². Kada je testiran u odnosu na BC-RRM-Putty (FGK, Švajcarska), TotalFill BC pokazao je nižu rendgenkontrastnost, ali duže vreme vezivanja, uporedo⁵³. U drugoj studiji zabeležen je veći potencijal alkalizacije kod TotalFill BC i BioRoot RCS nego kod MTA Fillapex, AH Plus i Sealapex¹⁹.

TotalFill BC pokazao je veći POBS nego AH Plus i EndoREZ⁵⁴, imao je i veći broj pora između cementa i gutaperke nego AH Plus⁵⁵.

Među testiranim cementima na bazi biokeramike i smole, biokompatibilnost TotalFill BC bila je uporediva sa BioRoot RCS, iako su imali blage citotoksične efekte; s druge strane, MTA Fillapex bio je visoko citotoksičan¹⁹.

BioRoot RCS

Kada je potopljen u destilovanu vodu, BioRoot RCS je imao nižu stopu rastvorljivosti od MTA Fillapex, iako je imao suprotne rezultate pri potapanju u PBS⁵⁶.

The number of open pores reported by EndoSequence BC, following single cone obturation, were higher than those of AH Plus⁴⁹. However, both sealers displayed analogous results in case of closed pores measured⁴⁹.

The study of biocompatibility of EndoSequence BC revealed it to be slightly cytotoxic, however, lesser in comparison to AH Plus⁵⁰. Whereas, two other studies on the same concluded EndoSequence to be the most biocompatible sealer amongst all sealers tested^{45,51}. Antimicrobial testing with Agar Diffusion Test (ADT) concluded AH Plus to have a higher antimicrobial ability as opposed to AH Plus, while Direct Contact Test (DCT) gave comparable results of both sealers⁵⁰. mRNA expression of ALP and OCN have been proved to be higher with EndoSequence when compared to MTA Fillapex and AH Plus⁵¹.

TotalFill BC

In comparison to AH Plus, TotalFill BC demonstrated a higher rate of solubility, volume gain at 7 days and volume loss at 30 days¹⁹. Additionally, this sealer had higher solubility than BioRoot RCS and MTA Fillapex¹⁹. In terms of flow, TotalFill BC recorded the highest flow rate as opposed to AH Plus and GuttaFlow Bioseal (Coltene Whaledent, Switzerland)⁵². TotalFill BC was less radiopaque than AH Plus, but more than GuttaFlow Bioseal⁵². When tested in relation to BC-RRM-Putty (FGK, Switzerland), TotalFill BC displayed lower radiopacity but a higher setting time, comparatively⁵³. In another study, TotalFill BC and BioRoot RCS recorded the highest alkalizing potential in comparison to MTA Fillapex, AH Plus and Sealapex¹⁹.

TotalFill BC demonstrated a higher POBS as opposed to AH Plus and EndoREZ⁵⁴, but reported the highest number of gaps between the sealer and gutta percha than AH Plus⁵⁵.

Amongst the bioceramic sealers and resin sealers tested, the biocompatibility of TotalFill BC was comparable to BioRoot RCS, although they had mild cytotoxic effects, whereas MTA Fillapex was highly cytotoxic¹⁹.

BioRoot RCS

When immersed into distilled water, BioRoot RCS showed a lower rate of

Rendgenkontrasnost koju je pokazao BioRoot RCS bila je niža od one kod AH Plus⁵⁷; međutim, Prüllage i sar. naveli su drugačije rezultate, prema kojima je rendgenkontrasnost ovog endodontskog cementa komparabilna sa AH Plus i MTA Fillapex⁵⁶. Na 37 °C, BioRoot RCS pokazao je brzinu protoka analognu onoj koju ima EndoSeal MTA, ali nižu od one koju poseduje MTA Fillapex⁵⁷. Benezra i sar. objavili su da je BioRoot RCS imao veći protok nego AH Plus¹⁰, dok su Khalil i sar. došli do suprotnog zaključka – AH Plus pokazao je veći protok od BioRoot RCS⁵⁷. Zapaženo je da je BioRoot RCS imao nižu debljinu filma od Bio MM, a višu od AH Plus⁵⁷. Ova studija je pokazala da BioRoot RCS ima duže vreme vezivanja od AH Plus⁵⁶; u drugoj studiji, međutim, došlo se do drugačijeg zaključka⁵⁷. Kada je potopljen u HBSS, BioRoot RCS je pokazao veći kapacitet alkalizacije⁵⁷, otpuštanje jona kalcijuma^{7,57} i uzimanje jona fosfora od AH Plus⁵⁷.

Prodor ovog endodontskog cementa u dentin kanala korena bila je najveća u srednjoj trećini korena, što je komparabilno sa AH Plus, manja u koronarnom delu, za razliku od AH Plus, a najmanja u apikalnom delu, što se podudara sa EndoSeal MTA⁵⁸. BioRoot RCS pokazao je niži POBS nego TotalFill BC i AH Plus, ali viši od Endo CPM⁵⁹. Kada je podvrgnut temperaturi od 250°C, sa ciljem stimulisanja efekta vertikalne kompakcije, BioRoot RCS pokazao je gubitak težine od 15%⁶⁰.

U studijama koje su procenjivale biokompatibilnost BioRoot RCS, zajedno sa drugim endodontskim cementima na bazi kalcijum-silikata i smole, zaključeno je da je ovaj cement citotoksičan i bez štetnog uticaja na vijabilnost i morfologiju humanih PDL ćelija^{61,62}. ADT nakon kontakta sa EDTA dokazao je da je antimikrobni potencijal BioRoot RCS i AH Plus analogan, ali veći od onog koji ima MTA Fillapex⁶³. Međutim, nakon upotrebe destilovane vode i PBS, ovi endodontski cementi nisu uspeli da proizvedu zonu inhibicije⁶³. Test intratubularne infekcije, izveden nakon kontakta sa svim rastvorima, pokazao je da je, u poređenju sa MTA Filapek i AH Plus⁶³, BioRoot RCS imao najveću antimikrobnu aktivnost. Delotvorna bioaktivnost BioRoot RCS dokazana je u studiji Camps i sar.; tu je ekspresija koštanog morfogenog proteina-2 i transformišućeg faktora rasta-2 bila veća sa BioRoot RCS nego sa Pulp Canal Sealer, iako su oni pokazali komparabilne rezultate u ekspresiji vaskularnog endotelnog faktora rasta⁶¹.

solubility than MTA Fillapex, albeit had contrasting results on immersion into PBS⁵⁶. Radiopacity displayed by BioRoot RCS was lower than that of AH Plus⁵⁷, but Prüllage et al. reported dissimilar results that this sealer's radiopacity was comparable to AH Plus and MTA Fillapex⁵⁶. At 37°C, BioRoot RCS demonstrated a flow rate analogous with EndoSeal MTA but lower than that of MTA Fillapex⁵⁷. Benezra et al. reported that BioRoot RCS had a higher flow than AH Plus¹⁰, whereas Khalil et al. had a contrasting conclusion, that AH Plus displayed a higher flow than BioRoot RCS⁵⁷. In case of film thickness, BioRoot RCS had a lower film thickness than Bio MM but greater than that of AH Plus⁵⁷. A study reported BioRoot RCS to have a greater setting time than AH Plus⁵⁶, while another study concluded vice versa⁵⁷. When immersed in HBSS, BioRoot RCS showed the greatest alkalizing capacity⁵⁷, leaching of calcium ions^{7,57}, and phosphorus ions uptake than AH Plus⁵⁷.

Dentinal penetration of this sealer was highest in the middle third portion of the root, comparable to AH Plus, lesser in the coronal portion as opposed to AH Plus, and the least in the apical portion, matching EndoSeal MTA⁵⁸. BioRoot RCS demonstrated the lowest POBS amongst TotalFill BC and AH Plus but higher than that of Endo CPM⁵⁹. When subjected to a temperature of 250°C to stimulate the effect of vertical compaction, BioRoot RCS showed a 15% loss of weight⁶⁰.

Studies evaluating the biocompatibility of BioRoot RCS along with other calcium silicate and resin-based sealers, concluded this sealer to be the cytotoxic with no detrimental effect on human PDL cell viability and morphology^{61,62}. ADT following contact with EDTA proved the antimicrobial potential of BioRoot RCS and AH Plus to be analogous, but greater than MTA Fillapex⁶³. However, after using distilled water and PBS, these sealers failed to produce an inhibition zone⁶³. Intratubular Infection Test performed after contact with all the solutions, concluded BioRoot RCS to have the highest antimicrobial activity as opposed to MTA Fillapex and AH Plus⁶³. The beneficial bioactivity of BioRoot RCS was proved in a study by Camps et al., where the expression of Bone Morphogenic Protein-2 and Transforming Growth Factor-2 was higher with BioRoot RCS than Pulp Canal Sealer, although they showed comparable results in expression of Vascular Endothelial Growth Factor⁶¹.

Sealer Plus BC

Ispostavilo se da je Sealer Plus BC, jedan od novijih endodontskih cemenata na bazi kalcijum-silikata, imao rastvorljivost veću nego AH Plus^{64,65}, sličnu sa TotalFill BC i nižu od Bio-C Sealer⁶⁵. Ovaj endodontski cement je manje rendgenkontrastan i ima nižu brzinu protoka od AH Plus⁶⁴. Sealer Plus BC je takođe pokazao veće vreme vezivanja, sposobnost alkalizacije i otpuštanje jona kalcijuma od poslednjeg pomenutog⁶⁴. Međutim, Sealer Plus BC nije pokazao nikakvo povećanje zapremine pri potapanju u PBS i destilovanu vodu, za razliku od AH Plus⁶⁵. Pored toga, njegov zapreminski gubitak bio je uporediv sa TotalFill BC i Bio-C Sealer⁶⁵.

Analizom intratubularne penetracije endodontskog cementa korišćenjem fluorofora, Sealer Plus BC pokazao je komparabilne rezultate sa EndoSequence BC i AH Plus, bez obzira na metodu obturacije^{66,67}.

Silva i sar. naveli su da Sealer Plus BC i Bio-C Sealer nisu pokazali inhibiciju vijabilnosti ćelija, pa su zato bili biokompatibilni⁶⁸. Bioaktivnost ovog endodontskog cementa potvrđena je prisustvom naslaga kalcijuma i nepravilnih struktura nakon bojenja po Von Kossi⁶⁸.

CeraSeal

Prilikom procene fizičkih osobina, CeraSeal je pokazao veću stopu rastvorljivosti i fluidnosti nego BioRoot RCS⁶⁹. Nasuprot tome, ovaj endodontski cement pokazao je manju apsorpciju vode i otpuštanje jona kalcijuma, nakon potapanja u destilovanu vodu⁶⁹. Lopez-Garcia i sar. zaključili su da je nakon uranjanja u Milli-Q vodu pH koji ima CeraSeal alkalniji nego pH EndoSequence BC, a niži kada se uporedi sa EndoSeal MTA⁴⁶. Slično tome, Kharouf i sar. naveli su da je BioRoot RCS imao alkalniji pH od CeraSeal kada je potopljen u destilovanu vodu⁶⁹.

Kombinacija CeraSeal sa gutaperka poenima obloženim biokeramikom doprinela je većim vrednostima POBS od monokone obturacije sa AH Plus u svim delovima kanala korena⁷⁰. Nakon monokone obturacije, CeraSeal je imao manji procenat praznine na 2 mm i 8 mm od apeksa, pri čemu su rezultati bili analogni sa BioRoot RCS, 5 mm od vrha⁶⁹.

Utvrđeno je da su CeraSeal i EndoSequence BC biokompatibilniji od

Sealer Plus BC

One of the newer calcium silicate sealers, Sealer Plus BC has been reported to have a higher solubility in comparison to AH Plus^{64,65}, but analogous with TotalFill BC and lower than that of Bio-C Sealer⁶⁵. This sealer is less radiopaque and has a lower flow rate than AH Plus⁶⁴. Contrastingly, Sealer Plus BC displayed a higher setting time, alkalizing ability, and calcium ion release than the latter⁶⁴. However, Sealer Plus BC did not display any volume gain on immersion into PBS and distilled water, unlike AH Plus⁶⁵. Additionally, its volumetric loss was comparable to TotalFill BC and Bio-C Sealer⁶⁵.

On analysis of intratubular sealer penetration using fluorophore, Sealer Plus BC demonstrated comparable results with EndoSequence BC and AH Plus, regardless of the method of obturation^{66,67}.

Silva et al. stated that Sealer Plus BC and Bio-C Sealer did not show inhibition of cellular viability, hence were biocompatible⁶⁸. This sealer's bioactivity was confirmed on presence of calcium deposits and irregular structures following von Kossa staining⁶⁸.

CeraSeal

On evaluation of physical properties, CeraSeal demonstrated a higher rate of solubility and flow in comparison to BioRoot RCS⁶⁹. Contrastingly, this sealer showed lesser water sorption and calcium ion leaching, after being immersed into distilled water⁶⁹. López-García et al. concluded that, when subjected to immersion into Milli-Q water, the pH of CeraSeal is more alkaline than that of EndoSequence BC but lesser in comparison to EndoSeal MTA⁴⁶. Similarly, Kharouf et al. stated that the BioRoot RCS had a higher alkaline pH than CeraSeal when immersed into distilled water⁶⁹.

The combination of CeraSeal with bioceramic-coated gutta percha points yielded higher POBS values than single-cone obturation with AH Plus in all portions of the root canal⁷⁰. Following single cone obturation, CeraSeal reported a lower percentage of voids at 2 and 8 mm from the apex, whereas the results were analogous with BioRoot RCS, 5 mm from the apex⁶⁹.

CeraSeal and EndoSequence BC were found to be more biocompatible than EndoSeal MTA, which was reported to be slightly cytotoxic to human periodontal

EndoSeal MTA, za koji se navodi da je blago citotoksičan za matične ćelije humanog parodontalnog ligamenta (hPDLSC) od prethodnih endodontskih pasta⁴⁶. Oh i sar. su zaključili da je CeraSeal najbiokompatibilniji endodontski cement kada se upoređi sa AH Plus i EndoSeal TCS (Maruchi, Koreja)⁷¹. Tokom procene antimikrobne aktivnosti, ADT nije pokazao formiranje zona inhibicije od strane CeraSeal i BioRoot RCS, iako je DCT pokazao iste rezultate za oba⁶⁹. CeraSeal, EndoSequence BC su pokazali veću ekspresiju ALP, katabolitnog aktivatorskog proteina, proteina-1 iz cementoblastoma nego EndoSeal MTA, tokom procene njihove bioaktivnosti⁴⁶. U drugoj studiji u vezi sa ispitivanjem bioaktivnosti, koju ima CeraSeal navedeno je da ima bolji osteogeni potencijal nego AH Plus, ali manji od EndoSeal TCS⁷¹.

Bio-C Sealer

Bio-C Sealer je, u odnosu na TotalFill BC i AH Plus⁷², zabeležio najveću stopu rastvorljivosti i protoka, premda je u pogledu rendgenkontrasnosti ovaj endodontski cement pokazao iste rezultate kao TotalFill BC, ali niže u odnosu na AH Plus⁷². U istoj studiji, Bio-C endodontski cement pokazao je najbrže vreme vezivanja među testiranim endodontskim cementima⁷². Kada je potopljen u dejonizovanu vodu i DMEM, alkalizirajući potencijal Bio-C endodontskog cementa bio je komparabilan sa TotalFill BC i Bio-C Repair (Angelus, Brazil), ali značajno veći od AH Plus^{72,73}. Bio-C endodontski cement pokazao je veću stopu otpuštanja jona kalcijuma nego Bio-C Repair, nakon potapanja u DMEM⁷³. Slično drugim endodontskim pastama na bazi kalcijum-silikata, Bio-C endodontski cement pokazao je veći gubitak zapremine od AH Plus, nakon stavljanja u destilovanu vodu⁷².

Procenom sposobnosti zaptivanja, Bio-C Sealer pokazao je najmanju penetraciju boje u poređenju sa AH Plus i MTA Fillapex⁷⁴. Pored toga, Bio-C Sealer i AH Plus pokazali su sličan procenat praznina kao u srednjem i apikalnim delovima kanala korena, nakon monokone opturacije⁷⁵.

Bio-C Repair pokazao je bolju biokompatibilnost nego Bio-C Sealer, mada nije prijavljena citotoksičnost ni za jedan materijal prema Lopez-Garcia i sar⁷³. Sveže zamešani Bio-C Sealer pokazao je antimikrobni efekat na sve bakterije, izuzev na bakteriju *S. mutans*, premda su, nakon vezivanja, svi testirani endodontski cementi pokazali analogne rezultate na bakteriju *E. faecalis*⁷⁶.

ligament stem cells (hPDLSCs) than the former sealers⁴⁶. Oh et al. concluded CeraSeal to be the most biocompatible sealer as opposed to AH Plus and EndoSeal TCS (Maruchi, Korea)⁷¹. During evaluation of antimicrobial ability, ADT revealed no formation of inhibition zones by CeraSeal and BioRoot RCS, although, DCT reported analogous results with both⁶⁹. CeraSeal, EndoSequence BC demonstrated an increased expression of ALP, Catabolite Activator Protein, Cementoblastoma-derived Protein-1 than EndoSeal MTA, during the evaluation of their bioactivity⁴⁶. In another study evaluating bioactivity of CeraSeal stated that it had a better osteogenic potential than AH Plus but lesser than EndoSeal TCS⁷¹.

Bio-C Sealer

Bio-C Sealer recorded the highest rate of solubility and flow, when evaluated against TotalFill BC and AH Plus⁷². Although, in terms of radiopacity, this sealer showed results analogous with TotalFill BC, but lower than AH Plus⁷². In the same study, Bio-C sealer demonstrated the fastest set, amongst the sealers tested⁷². When immersed into deionized water and DMEM, the alkalizing potential of Bio-C sealer is comparable with TotalFill BC and Bio-C Repair (Angelus, Brazil), but significantly greater than AH Plus^{72,73}. Bio-C Sealer when subjected to DMEM immersion, displayed a higher rate of calcium ion release as opposed to Bio-C Repair⁷³. Mimicking other calcium silicate sealers, Bio-C sealer has also demonstrated a higher volume loss than AH Plus, after being placed into distilled water⁷².

On evaluation of sealing ability, Bio-C Sealer showed the least dye penetration in comparison to AH Plus and MTA Fillapex⁷⁴. Additionally, Bio-C Sealer and AH Plus demonstrated similar percentage of voids in the middle and apical portions of root canal, following single-cone obturation⁷⁵.

Bio-C Repair displayed better biocompatibility than Bio-C Sealer, although, no cytotoxicity was reported by any of the materials according to López-García et al.⁷³ Freshly mixed Bio-C Sealer, exhibited an antimicrobial effect against all bacteria, excluding *S. mutans*, although, following setting, all the tested sealers displayed analogous results against *E. faecalis*⁷⁶.

Zaključak

Endodontske paste za punjenje kanala korena služe da obezbede zaptivanje koje je nepropusno za tečnost, prilagođeno tako da fizička blokada koju stvaraju ne ometa komunikaciju između prostora kanala korena i okolnih tkiva, istovremeno sprečavajući rast mikroorganizama. Stoga, ishod obturacije kanala korena u velikoj meri zavisi od fizičkih i bioloških karakteristika materijala za opturaciju kanala korena.

Na stabilnost dimenzija endodontskih cemenata utiče hidrofilno okruženje, što zauzvrat utiče na njihova fizička svojstva. Iako endodontski cementi na bazi kalcijum-silikata pokazuju fizička svojstva koja su inferiorna ili analogna svojstvima cementa na bazi smole, zaključeno je da su biokompatibilni i bez ikakvih citotoksičnih ili genotoksičnih efekata. Bioaktivni potencijal endodontskih pasta na bazi kalcijum-silikata, zajedno sa njihovim antimikrobnim svojstvima, pojačava njihovu sposobnost da formiraju jaču fizičku barijeru koja zatvara bakterije, čime se sprečava ponovna infekcija, što je prednost njihovog korišćenja.

U suštini, upotreba cemenata na bazi kalcijum-silikata u endodontici izuzetno je poboljšana nakon decenija razvoja, sve do sadašnjeg vremena. Ovi endodontski cementi su procvetali, pokazujući niz korisnih svojstava; s pravom su bili odskočna daska u budućnost endodontije, čekajući da budu dalje istraženi.

Zahvalnica: Nema

Sukob interesa: Nema

Conclusion

Endodontic root canal sealers serve the purpose of providing a fluid-tight seal, tailored such that the physical blockade imparted by them hampers the communication between the root canal space and surrounding tissues simultaneously impeding growth of micro-organisms. Hence, the outcome of a root canal obturation is significantly dependent on the physical and biological characteristics of a root canal sealer.

The dimensional stability of sealers is affected by the hydrophilic surroundings which in turn affect their physical properties. Even though calcium silicate sealers display physical properties that are inferior or analogous to those of resin-based cements, they have been concluded as biocompatible without any cytotoxic or genotoxic effects. The bioactive potentiality of calcium silicate sealers along with their antimicrobial properties amplify their ability to form a stronger physical barrier entombing the bacteria, thus preventing re-infection, adding to their advantages.

Essentially, the use of calcium silicate sealers in endodontics is at a high state of refinement, having had decades of development, up to the present time. These sealers have blossomed to display an array of advantageous properties, and rightfully, have been the stepping-stone into the future of endodontics, waiting to be explored.

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