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Apikalno mikropropuštanje punjenja za korijenske kanale sa silikonskom osnovom: elektrokemijsko istraživanje

Apical Microleakage of a Silicone Based Root Canal Sealer: an Electrochemical Study

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Sažetak

Svrha: Elektrokemijskom metodom procijenilo se apikalno propuštanje materijala RoekoSeal Automix (RSA) za punjenje korijenskog kanala samostalno i u kombinaciji s gutaperkom. **Materijali i metode:** Pedeset i dva prednja maksilarna zuba podijeljena su u dvije skupine. U prvoj su korijenski kanali punjeni samo RSA-om, a u drugoj gutaperkom i RSA-om (n = 24 u svakoj skupini). Preostala četiri zuba služila su kao pozitivna i negativna kontrolna skupina. Eksperimentalna jedinica konstruirana je tako da je bila neprekidno spojena na izvor struje. Jedanpostotni kalijev jodid (KI) korišten je kao elektrolit te su zubi uronjeni u otopinu. Bakrene elektrode s provodnim kapacitetom od jednoga miliampera (mA) korištene su kao anode za zatvaranje strujnog kruga. Rezultati su se očitavali ukupno tri tjedna, jedanput na dan, digitalnim voltmetrom spojenim na eksperimentalnu jedinicu. Promjene u količini propuštanja u skupini procjenjivale su se svaki dan t-testom za ovisne uzorke, a razlika između dviju skupina analizirana je t-testom za neovisne uzorke. **Rezultati:** Razlika u apikalnom propuštanju između dviju eksperimentalnih skupina nije bila statistički značajna ($p > 0,05$). U objema je zabilježeno značajno propuštanje u svim vremenskim intervalima ($p < 0,05$). **Zaključak:** RoekoSeal Automix samostalno nije se razlikovao u propuštanju od gutaperke punjene njime. Također nije bio potpuno učinkovit u sprječavanju propuštanja.

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Ključne riječi

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Uvod

Svrha endodontskog punjenja jest osigurati hermetičko brtvljenje apeksa i potpuno punjenje sustava korijenskih kanala (1). To se obično postiže kombinacijom gutaperke kao jezgre i korijenskog cementa za punjenje kao međupunila. Korijenskim cementima popunjavaju se male praznine između krutog materijala za punjenje i zida korijenskog kanala. Ako cement ne zadovoljava potrebne uvjete, može prouzročiti propuštanje koje rezultira endodontskim neuspjehom (2). Neprestance se, pa i danas, pokušavaju proizvesti bolji cementi za punjenje i krute jezgre punjenja, te se nastoji poboljšati tehnika punjenja kako bi endodontsko liječenje bilo što uspješnije. Tako se nedavno na tržištu pojavio cement za punjenje kanala RoekoSeal Automix (RSA, Roeko, Langenau, Njemačka) proizveden na osnovi polidimetilsiloksana. To je silikonski elastomer koji se sastoji od polidimetilsiloksana, silikonskog ulja, ulja na bazi parafina, heksakloroplatinatne kiseline (katalizator) i cirkonijeva dioksida za radioopacitet. Prema tvrdnjama proizvođača RSA se može koristiti u sustavu automiksa, ne sadržava eugenol, biokompatibilan je i radioopak, dobro teče, stvrdnjava se u suhom i vlažnom okruženju, dobiva mehaničku retenciju zbog ekspanzije, omogućuje reviziju i ne otapa se nakon stvrdnjavanja (3). Posljednjih je

Introduction

The purpose of endodontic filling is to provide a fluid-tight seal at the apex and a total obturation of the root canal system (1). This is commonly achieved using a combination of gutta-percha as a core material and a root canal sealer. Root canal sealers are used to fill the minor interstices between the solid filling material and the wall of the canal. Unless a root canal sealer meets the necessary requirements, it may cause an increase in leakage which leads to endodontic failure (2). To date, there have been lasting attempts to develop better sealers, core materials and obturation techniques to increase the success of root canal treatment. Recently, RoekoSeal Automix (RSA, Roeko, Langenau, Germany), which is a polydimethylsiloxane-based sealer, has been introduced to endodontics. RSA is a silicone elastomer, consisting essentially of polydimethylsiloxane, silicone oil, paraffin base oil, hexachloroplatinic acid (catalyst), zirconium dioxide for the radiopacity. According to the manufacturer, RSA is ready for use in an automix system, does not contain eugenol, biocompatible, radiopaque, well flowing, sets in dry and moist conditions, provides mechanical retention through expansion, allows retreatment and is insoluble when set (3). In recent years, interest has been shown in testing the new devel-

godina sve veće zanimanje za testiranje cemenata za punjenje korijenskih kanala kao samostalnih punjenja zahvaljujući njihovim poboljšanim svojstvima (4). Koncept jednovrznog punjenja privlačan je iz nekoliko razloga, pa i zato što je klinički jednostavan i brz. S druge strane ima i mnoge loše strane – ne može se kontrolirati radna duljina i kompaktnost punjenja te je moguća toksičnost u slučaju da se prepuni. Unatoč tomu nastavlja se razvoj takvih materijala (5). Lee EndoFill, također cement za punjenje korijenskih kanala na temelju silikona, predstavljen je i kao samostalno punilo, uz to što se može kombinirati s gutaperkom (6). Kad se razmatra slična osnova za materijale, RSA također može biti samostalni materijal za punjenje korijenskog kanala (4). Osim navedenoga i njegova netopivost podupire samostalno korištenje.

Propuštanje materijala za punjenje procjenjivalo se različitim metodologijama. Među korištenima su penetracija boje, izlazak boje, bakterijska penetracija, penetracija radioizotopa, tehnika bistenja, elektrokemijska metoda, plinska kromatografija i fluidni transport (7). Penetracija boje pritom je vjerojatno jedna od najčešće korištenih tehnika jer je jednostavna i jeftina (8). No, ima i ograničenja poput polikvantitativnih rezultata zbog visokoga stupnja varijacije (9). Druga je elektrokemijska metoda koju su prvi opisali Jacobson i von Fraunhofer, a mogla bi dati kvantitativne rezultate apikalnog propuštanja tijekom kontinuiranog razdoblja (10). Ta metoda prihvaćena je kao pouzdana tehnika za procjenu propuštanja (11).

Svrha ovog istraživanja bila je procijeniti apikalno propuštanje RoekoSeal Automixa kao samostalnog materijala za punjenje tako što se ubrizgao u kanalni prostor s pomoću automiks-sustava te usporediti njegovu mogućnost brtvljenja s kombinacijom RSA i gutaperke korištenjem elektrokemijske metode.

Materijal i postupak

Pedeset i dva zdrava ljudska prednja maksilarna zuba, ekstrahirana iz parodontalnih ili ortodontskih razloga, pohranjena su u 0,9 postotnu fiziološku otopinu. Izvana su očišćeni od mekih tkiva 24-satnim uranjanjem u otopinu 2,5-postotnog natrijeva hipoklorida (NaOCl). Svi su zubi bili tipično trepanirani. Izmjerena im je radna duljina jedan milimetar koronarno od vrška korijena. Preparacija korijenskih kanala obavljena je K-flex Filesom (Dentsply Maillefer, Ballaigues, Švicarska), a zatim su zubi dobro isprani 2,5-postotnim natrijevim hipokloridom (NaOCl). Apikalno je preparacija iznosila #40, a *step back* je završen s #60.

Punjenje korijenskih kanala

Zubi su nasumce podijeljeni u dvije skupine (u svakoj po 24). Nakon ispiranja destiliranom vodom korijenski kanali posušeni su paper pointom (Sybron Dental Specialties, Orange, Kalifornija, SAD).

Eksperimentalne skupine

Prva skupina

Roeko Seal Automix (Roeko SAD, Monrovia, Kalifornija, SAD) ubrizgan je automiks-štrcaljkom u korijenski kanal. Zatim su snimljeni bukolingvalni i meziodistalni radiogra-

oped sealers as sole filling materials because of their improved properties (4). The sole filling material concept is appealing for several reasons such as being clinically easy to use and fast. On the other hand, it has multiple disadvantages which include the lack of working length control, failure in providing a compact obturation and also possible toxicity in case of overfilling. However, it is certain that efforts to develop such a material continues (5). Lee EndoFill which is also a silicone based root canal sealer was introduced as a sole filling material together with the combined usage with gutta-percha (6). When considering the similar basis of the materials, RSA may also have a potential to be a sole material for root canal filling (4). In addition, insolubility of RSA supports the possibility of sole application.

Leakage of filling materials has been evaluated by various methodologies. Dye penetration, dye extraction, bacterial penetration, radioisotope penetration, clearing technique, electrochemical method, gas chromatography, fluid transport method are among these methodologies (7). Dye penetration is probably the most commonly used technique for this purpose because the method is simple as well as inexpensive (8). However, it has some limitations such as the semi-quantitative results and a high level of variation (9). On the other hand, the electrochemical method which was first described by Jacobson and von Fraunhofer could provide quantitative measurements of apical leakage over a continuous time period (10). This method was accepted as a reliable technique to determine the leakage (11).

The purpose of this study was to evaluate the apical leakage of RSA as a sole filling material by injecting into the canal space with an automix system and to compare its sealing ability to RSA in combination with gutta-percha using an electrochemical method.

Materials and Methods

Fifty-two sound human maxillary anterior teeth which were extracted for periodontal or orthodontic reasons were collected and stored in 0.9% saline solution. The teeth were externally cleaned of soft tissue attachments by soaking for 24 hours in a 2.5% sodium hypochloride (NaOCl) solution. Routine access cavities were prepared in all of the teeth. A working length of 1 mm coronally of the root apex was established. Canal preparation was performed by K-flex files (Dentsply Maillefer, Ballaigues, Switzerland) using copious irrigation with 2.5% NaOCl. The apical preparation was to #40 and step-back preparation was up to #60.

Root Canal Filling

Teeth were randomly divided into groups of 24. After final rinse with distilled water, root canals were dried with paper points (Sybron Dental Specialties, Orange, CA).

Experimental Groups

Group 1

RSA RoekoSeal Automix (Roeko USA, Monrovia, CA) alone was injected into the canal space with an automix syringe. Buccolingual and mesiodistal radiographs were taken

mi za procjenu kvalitete punjenja. Procjenjivale su se gustoća punjenja i udaljenost kraja punjenja od radiološkog vrška. Punjenja bez praznina uz stijenku kanala na jedan milimetar od radiološkog vrška smatrala su se prihvatljivima.

Druga skupina

Korijenski kanali punjeni su tehnikom lateralne kondenzacije *master*-gutaperkom #40 (Kerr, Romulus, Michigan, SAD), F-akcesornom gutaperkom (Kerr, Romulus, Michigan, SAD) te RSA-om. Lateralna kondenzacije nastavljena je sve dok spreder nije prestao ulaziti u apikalnu polovicu kanala. Učinjene su bukolingvalne i meziodistalne radiološke snimke radi procjene kvalitete punjenja korijenskih kanala.

Kontrolne skupine

Dva zuba korištena su kao pozitivna kontrolna skupina. Njihovi korijenski kanali nisu bili napunjeni nakon instrumentacije i nisu bili uronjeni u vrući tekući vosak kako bi se izolirali njihovi apikalni otvori.

Dva druga zuba korištena su kao negativna kontrolna skupina. Nakon preparacije pristupnog otvora korijeni su zajedno s apikalnim otvorima potpuno prekriveni vrućim tekućim voskom zbog potpune izolacije.

Procjena propuštanja

Zubni korijeni u prvoj i drugoj skupini uronjeni su u vrući tekući vosak. Taj se postupak ponavljao tri puta kako bi se postigla zadovoljavajuća izolacija. Poslije je voštani sloj uklonjen skalpelom cirkumferentno jedan milimetar od apikalnog foramena. Koronarno je gutaperka uklonjena svrdlom Gates-Glidden (Dentsply Tulsa Dental Specialties, Tulsa, Oklahoma, SAD) veličine tri, a ostavljena su samo četiri milimetra punjenja apikalno. Bakrene elektrode od jednog miliampera (anode) uronjene su u kanale u doticaju s preostalim gutaperkom. Svaki zub s projicirajućom elektrodom zabrtvljen je ljepljivim voskom zbog stabilnosti i izolacije. U pozitivnoj kontrolnoj skupini ($n = 2$), nakon punjenja i postavljanja elektroda u korijenski kanal, zubi su uronjeni u vrući vosak, uključujući i apikalni otvor. Postupak je se ponavljao tri puta. Negativna kontrolna skupina ($n = 2$) nije bila punjena i korijeni nisu bili prekriveni vrućim voskom, a elektrode su uronjene u nenapunjene korijenske kanale.

Sustav za testiranje

Sustav anodizirajućeg uređaja sastojao se od triju komponenata: (1) neprekidnog izvora struje spojenog na digitalni čitač (0-20V DC konstantni izvor struje i Digitalni Multimetar, Hacettepe University, Electrical Engineering Department, Ankara, Turska), (2) krute plastične posude s čvrsto prijanjajućim plastičnim poklopcem s 52 standardna otvora za uzorke zuba i dodatne rupe za žicu od nehrđajućeg čelika (katoda) te (3) spojenih žica (slika 1.).

Uzorci zuba i katoda postavljeni su u pripremljene rupe u poklopcu i pričvršćeni ljepljivim voskom oko pet milimetara od vrhova korijena koji su virili s donje strane poklopca.

to evaluate the quality of the root canal fillings following the obturation. The density of the filling and the distance between the end of the filling and the radiological apex were benchmarks for evaluation of the quality of root canal filling. A filling without any voids along the walls of the canal and located between 1 mm from the radiographic apex was considered to be an acceptable filling.

Group 2

Canals were filled by using the lateral condensation technique with a #40 master cone (Kerr, Romulus, MI), fine accessory points (Kerr, Romulus, MI) and RSA. Lateral condensation continued until the finger spreader no longer penetrated the apical one half.

Buccolingual and mesiodistal radiographs were taken to evaluate the quality of the root canal fillings following the obturation.

Control Groups

Two teeth were used as positive control group. Their root canals were not filled after the root canal preparation and they were not immersed to hot coating wax in liquid form to isolate them from their apical foramina.

Two teeth were used as negative control group. Following the access preparation, their roots and the apical foramina were completely coated with the liquid form hot coating wax for full isolation.

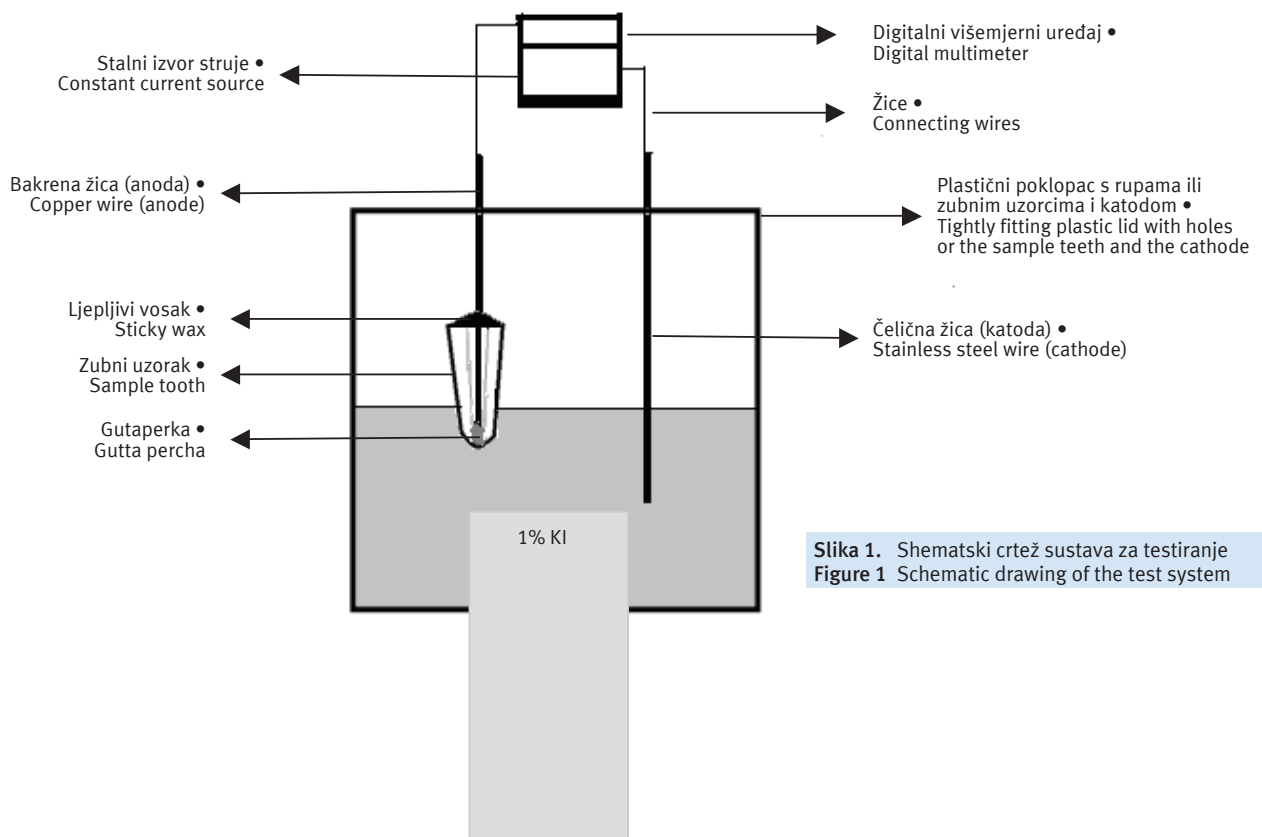
Assessment of Leakage

The roots of the teeth in group 1 and 2 were immersed in a hot coating wax in liquid form. This procedure was repeated three times to obtain a satisfactory isolation. Later, the wax coating was removed circumferentially within 1mm from the apical foramen with a scalpel. The coronal gutta-percha was removed using Gates-Glidden drills (Dentsply Tulsa Dental Specialties, Tulsa, OK) of size 3 leaving only the apical 4 mm of the root canal filling. 1 mA Cu electrodes (anodes) were inserted into the canals in contact with the remaining gutta-percha. Each tooth with the projecting electrode was sealed with sticky wax for stability and insulation. In the positive control group ($n=2$), following the obturation and electrode insertion into the canals, the roots of the teeth were immersed into the hot coating wax including the apical foramina. This procedure was repeated three times. The negative control group ($n=2$) were not obturated and the roots were not coated with hot wax; the electrodes were later applied into the unfilled canals.

Model System Design

The anodizing apparatus system consisted of three components: (1) a constant current source with a digital reader (0-20V DC Constant Current Source and Digital Multimeter, Hacettepe University, Electrical Engineering Department, Ankara, Turkey); (2) a rigid plastic cell with a tightly fitting plastic lid which has 52 standard holes for the sample teeth and another drilled hole for the stainless steel wire (cathode); (3) the connecting wires (Figure 1).

Sample teeth and the cathode were placed into their prepared holes on the lid and attached by a sticky wax about 5



Slika 1. Shematski crtež sustava za testiranje
Figure 1 Schematic drawing of the test system

Posuda je do ruba napunjena 1-postotnim kalijevim jodidom (KI) kao elektrolitom. Poklopac je postavljen na posudu tako da su vrhovi korjenova uronjeni u otopinu elektrolita. Posuda i poklopac zabrtvljeni su ljepljivim voskom radi osiguranja sustava. Pedeset i dvije elektrode spojene su na konstantan izvor struje koji je stvarao anodizirajuću struju od 20 volta. Poslije je katoda postavljena u jedanpostotni kalijev jodid i strujni krug je zatvoren. Količina prolazne struje, koja predstavlja iznos propuštanja, očitavala se tri tjedna jedanput na dan.

Statistička analiza

Rezultati su statistički analizirani unutar skupina t-testom za ovisne uzorke, a između skupina korišten je t-test za neovisne uzorke.

Rezultati

Pozitivna kontrolna skupina imala je trenutačni protok struje i najveće propuštanje među eksperimentalnim skupinama, a kod negativne nije zapaženo nikakvo propuštanje. Razlika u propuštanju između tih dviju skupina nije bila statistički značajna u svim mjerenim vremenskim razmacima korištenjem t-testa za neovisne uzorke ($p > 0,05$). S druge strane, t-test za ovisne uzorke pokazao je da RSA statistički značajno propušta od prvog do dvadesetprvog dana u svakoj eksperimentalnoj grupi i sveukupno ($p < 0,05$). Razlika u apikalnom propuštanju za eksperimentalne skupine vidi se na slici 2., a detaljni podaci nalaze se u tablici 1.

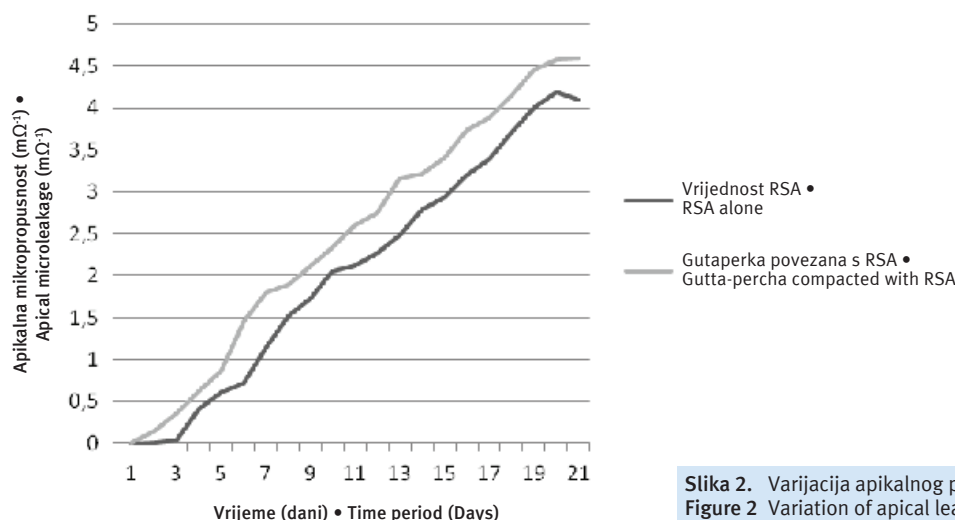
mm of their root apices projected from the underside of the lid. The cell was fully filled with 1% KI as electrolyte. Later, the lid was tightly placed on the cell to contact the apices and the electrolyte solution. The cell and the lid were sealed by sticky wax to secure the system. Fifty-two copper electrodes (anodes) were connected to the constant current source to deliver a constant 20 volts anodizing current. Later, the cathode was placed into the 1% KI and the circuit was completed. The amount of electric current, which represents the amount of the leakage, was read from the digital screen once a day for 21 days.

Statistical Analysis

The results were statistically analyzed with “t-test for independent samples” between the groups and “t-test for dependent samples” within the groups.

Results

The positive control group exhibited an immediate current flow and the highest leakage among experimental groups, whereas no leakage was seen in the negative control group. The difference of apical leakage amount between two experimental groups was not statistically significant at all time periods according to ‘t-test for independent samples’ ($p > 0,05$). On the other hand, ‘t-test for dependent samples’ showed that RSA had significant leakage statistically from day 1 to 21 in each experimental group and on the whole ($p < 0,05$). The differences in apical leakage for experimental groups can be seen in Figure 2 and the detailed data are also shown in Table 1.



Slika 2. Varijacija apikalnog propuštanja eksperimentalnih grupa
Figure 2 Variation of apical leakage of experimental groups

Tablica 1. Srednja vrijednost apikalnog propuštanja ($m\Omega^{-1}$) i standardna devijacija eksperimentalnih grupa
Table 1 Mean apical leakage ($m\Omega^{-1}$) and standard deviation of the experimental groups

Vrijeme (dani) • Time Period (Day)	Vrijednost RSA • RSA alone		Gutaperka s RSA • Gutta-percha compacted with RSA	
	Srednja vrijednost • Mean	Stand. devijacija • SD	Srednja vrijednost • Mean	Stand. devijacija • SD
1.	0.002	0.002	0.009	0.013
2.	0.007	0.003	0.14	0.242
3.	0.031	0.026	0.353	0.333
4.	0.409	0.501	0.63	0.455
5.	0.613	0.548	0.864	0.589
6.	0.719	0.711	1.452	0.757
7.	1.147	0.854	1.804	0.863
8.	1.512	1.059	1.893	1.064
9.	1.731	1.262	2.117	1.122
10.	2.056	1.481	2.333	1.179
11.	2.12	1.486	2.593	1.214
12.	2.26	1.469	2.742	1.138
13.	2.475	1.575	3.157	1.295
14.	2.78	1.502	3.22	1.313
15.	2.927	1.647	3.394	1.315
16.	3.199	1.668	3.729	1.545
17.	3.385	1.626	3.879	1.614
18.	3.712	1.515	4.143	1.644
19.	3.995	1.679	4.455	1.640
20.	4.191	1.777	4.575	1.544
21.	4.093	1.783	4.582	1.572

Rasprava

Endodontska terapija trebala bi spriječiti reinfekciju korijenskog kanalnog sustava koja se događa pri mikropropuštanju. To se može postići savršanim brtvljenjem materijala za punjenje. Za procjenu propuštanja korišteno je nekoliko metoda, ali ne postoji suglasnost o tome koja bi se trebala rabiti za najbolju procjenu (9). U mnogim istraživanjima u kojima se proučavala korelacija između različitih metodologija procjene propuštanja nisu nađene korelacije (12 – 14). To se može pripisati različitim fizikalnim mehanizmima pojedinih metodologija (15). Elektrokemijska metoda kvantificira mjerenja s pomoću protoka električne struje kroz dva komada

Discussion

Root canal treatment should prevent reinfection of the root canal system which occurs by microleakage. This can be achieved by a perfect sealing of the filling material. Several methods have been used to assess the quality of root canal filling materials. However, there is no consensus about the methods used for leakage evaluation (9). A number of studies which evaluated the correlation between various leakage methodologies found no correlation (12-14). The lack of correlation may be related to the different physical mechanisms of the methodologies (15). The electrochemical method uses quantitative measurements with the flow of an elec-

metala u elektrolitnoj otopini (16). Difuzija iona kroz materijal za punjenje i strukturu zuba procjenjuje iznos struje koja odražava stupanj propuštanja. Elektrokemijska metoda pouzdan je i učinkovit način procjene propuštanja materijala za punjenje korijenskih kanala (17). Premda ta metoda obećava u usporedbi s drugim metodama, ograničavaju je dva čimbenika. Kao prvo, djelomično propuštanje elektrolita ne može se mjeriti, te zato mogu penetrirati u punoj dužini materijala za punjenje korijenskih kanala da bi se izmjerilo propuštanje (18). Kao drugo, nakupljanje korozivnih produkata s vremenom mijenja sastav materijala za punjenje i otpuštene ionske komponente mogu utjecati na rezultate (19). U istraživanjima o propuštanju može se pratiti pad ili rast mjerenja tijekom vremena. Na to može utjecati nekoliko čimbenika povezanih s materijalom za punjenje. Primjerice, smanjenje propuštanja tijekom vremena vjerojatno je povezano s ekspanzijom materijala za punjenje. Orstavik i suradnici izvijestili su da je u četiri tjedna RoekoSeal Automix imao malu ekspanziju od 0,2 posto (20). Wu i njegovi kolege ustanovili su, pak, da RSA pokazuje minimalno propuštanje tijekom 18 mjeseci (21). Istraživanje s pomoću penetracije boje iz 2003. godine pokazalo je da RSA ima bolja svojstva brtvljenja negoli Grossmanov cement (22). S druge strane, Flores i suradnici uočili su kod RSA skupljanje od 1,33 posto (23). Svojstvo dimenzijskih promjena i otapanje cementa također mogu uzrokovati propuštanje. Unatoč tomu što je dimenzijski najstabilniji cement, RoekoSeal Automix pokazao je kontinuirani rast topivosti tijekom 28 dana kao i drugi ispitani cementi u istraživanju u kojem se proučavala topivost određenih cemenata (24). Wu i suradnici istaknuli su 2006. godine da je RoekoSeal Automix dimenzijski stabilan i spriječio je propuštanje najmanje godinu dana. Tvrdili su također da nije potreban velik omjer gutaperke/cementa ako je cement RSA (25). U jednom istraživanju *in vitro* zaključeno je da je RoekoSeal Automix, samostalno kao punilo, spriječio koronarno propuštanje bolje nego gutaperka sama ili s cementom (4). I dalje nema dovoljno istraživanja o samostalnoj primjeni RSA kao punila. Prema našim rezultatima korištenje samo RSA nije statistički značajno različito od kombinacije gutaperke s RSA-om i samog RSA, kad je riječ o propuštanju. Obje skupine pokazivale su značajno propuštanje tijekom promatranoga razdoblja. To može biti povezano sa skvrčavanjem (23) ili topivošću RSA (24). Pretpostavlja se da laboratorijska istraživanja propuštanja mogu dati različite rezultate, ovisno o vrsti istraživanja. To potiče pitanje kliničke relevantnosti procjene propuštanja *in vitro*. Sposobnost brtvljenja važno je svojstvo i taj se parametar mora i dalje primjenjivati u procjeni novih materijala (26).

Zaključak

Tijekom istraživanja nije bilo razlike između korištenja samo RSA i RSA u kombinaciji s gutaperkom, kad je riječ o apikalnom propuštanju. Korištenje RSA na oba načina pokazalo je značajno propuštanje.

tric current through two pieces of metal which are immersed in an electrolyte solution (16). Diffusion of ions through filling material and tooth structure provides an estimate of the current magnitude which reflects the degree of leakage. The electrochemical method is a reliable and effective way to evaluate the leakage of root canal filling materials (17). Although this technique is promising compared with other methods, it has two main limitations. Primarily, partial leakage of the electrolytes cannot be measured, therefore, the electrolytes must penetrate to the full length of the filling to measure the leakage (18). Secondly, accumulation of corrosion products over time or the changes in the composition of the filling materials and the released ionic compounds may have influence on the results (19). In leakage studies, a decrease or increase in measurements can be seen over time. This may occur due to a number of factors related to filling materials. For instance, the decrease in leakage over time is probably associated with the expansion of the filling material. Orstavik et al. reported that Roeko-Seal had a small expansion of 0.2% within 4 weeks (20). Wu et al. found that RSA had minimal leakage throughout 18 months (21). In 2003, a dye penetration study showed that RSA had better sealing abilities than Grossman's sealer (22). On the other hand, Flores et al. demonstrated shrinkage of 1.33% for RSA (23). Apart from the property of dimensional changes, dissolution of the sealer may also cause an increase in leakage. Despite being one of the most dimensionally stable sealers, RSA showed a continuous increase in solubility over a 28 day period similarly to the other tested sealers in a study which had compared the solubility of certain sealers (24). In 2006, Wu et al. reported that RSA was dimensionally stable and prevented leakage at least for one year. They also indicated that the high ratio of gutta-percha/sealer may not be necessary if the sealer is RSA (25). An *in vitro* study concluded that RSA alone prevented coronal leakage better than gutta-percha alone or with sealer (4). However, there are not enough studies related to the application of RSA alone. According to our results, usage of RSA alone was not statistically different from the combination of gutta-percha and RSA in terms of leakage. However, both groups showed a significant leakage at all times. This may be related to shrinkage (23) or solubility of RSA (24). It is assumed that laboratory leakage studies may provide different results according to study designs. This also raises the question of the clinical relevance of leakage evaluation *in vitro*. On the other hand, the sealing ability is an important property and this parameter should continue to be used to evaluate new materials (26).

Conclusion

The obtained results revealed that no difference was found between RSA in combination with gutta-percha and RSA alone in terms of apical sealing ability. Nevertheless, the use of both applications of RSA showed a significant leakage.

Abstract

Objectives: To evaluate the apical leakage of the root canal fillings performed with RoekoSeal Automix (RSA) alone and in combined with gutta-percha electrochemically. **Materials and methods:** Fifty two maxillary anterior teeth were divided into two groups. In group 1, the root canals were filled with RSA alone and in group 2 the root canals were filled with gutta-percha and RSA (n=24 each group). The remaining 4 teeth were used for positive and negative control groups. An experimental cell was constructed which was connected with a constant current source. 1% potassium iodide (KI) solution was added to the cell as the electrolyte and the teeth were then immersed in this solution. Copper electrodes with 1 milliampere (mA) conductance capacity were used as anodes to complete the circuit. The results were read daily, with a digital voltmeter connected to the experimental cell, for a total of 21 days. The changes in amount of leakage from day to day within the groups were evaluated by a "t-test for dependent samples" and the difference between two groups was analyzed by "t-test for independent samples". **Results:** The difference of apical leakage amount between two experimental groups was not statistically significant ($p>0.05$). Both groups showed significant leakage at all time periods ($p<0.05$). **Conclusion:** RSA alone was not different in terms of leakage from gutta-percha compacted with RSA. However, RSA was not totally effective in preventing leakage.

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Key words

Tooth Apex; Root Canal Preparation;
Dental Leakage; Root Canal Filling
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