The flow rate of endodontic sealers in various consistencies

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SUMMARY
Introduction The flow of endodontic sealer (ES) is the property that characterizes its velocity along the certain surface and depends on the friction force. The aim of this research was to measure the flow rate of three zinc oxide eugenol based ES’s in various consistencies exposed to the load of 2 kg.

Material and methods The experimental group included prepared samples of sealers protocolled by ADA specification No. 57 A) Endomethasone N in liquid:powder ratio of 1:5, 1:6, 1:7 (standard), 1:8 and 1:9 according to the manufacturer brochure depending on the clinical situation; B) Roth 801 as 1:7 (standard) and 1:8 mixtures C) Tubliseal EWT as standard preparation (base-catalyst 1:1). A volume of 0.05 ml sealer was spread on the glass plate and upon applying the load of 2 kg the diameter of sealer was measured. In the control group the sealer samples were loaded only by the weight of glass plate (0.1kg).

Results Based on measured diameters of sealers, all of them satisfied ADA requirements for the flow (d>20mm) (Endomethasone – 20.7–27.8 mm; Roth 801- 29.6–30.0 mm; Tubliseal -39.9 mm). The thin consistency of sealers (1:5, 1:6) showed significantly higher flow than standard mixture (1:7) (p < 0.05).

Conclusion Tubliseal EWT sealer showed the highest flow rate, significantly different than standard mixtures (1:7) of Endomethasone N and Roth 801.

Keywords: flow; viscosity; sealer; endodontic sealer; zinc oxide eugenol

INTRODUCTION
One of the main roles of endodontic sealer (ES) is lubricating canal instruments and gutta-percha cones during its insertion and compaction. This feature is directly dependent on its velocity over the surface (dentin). The appropriate flow of ES is important to be able to reach the most distant labyrinth spaces (apical ramification, recurrent canals, pulpoperiodontal communications, cul de sac, irregular ampular spaces and fracture gaps etc.) and hermetically seal endodontic space [1]. One study has confirmed that presence of residual irrigant could accelerate sealer’s setting time and slow down the sealer flow. Temperature rise during gutta-percha compaction has similar effect on setting time of ES resulting in slowing down the flow rate (warm compaction technique) [2]. The flow rate of ES is also dependent on material nature. In general, thinner consistency creates the higher flow rate and vice versa [3].

One study confirmed that denser ES had lower flow, where higher viscosity increased possibility of creating pools (reservoirs) within sealer itself and prevented sealer to line all canal walls affecting homogeneity of root canal filling. This study also showed that thinner ES created pores on dentinal wall-sealer junction as well as between canal wall and gutta-percha cones [4]. Sealer’s flow is also correlated to the canal shape, width and convergence where for very narrow accessory canals and dentin tubules of diameter < 500 µm capillarity rule may be applied. The flow rate is also dependent on dentin structure. It is known that dentinal tubules become narrower with age but ES flow is also affected in vital tooth (filled by tubular liquor) [5].

Some authors reported different ES flow rate of AH Plus along dentinal walls after the use of different irrigants where Chlorhexidine improved while Cetrimide decreased sealer flow. The explanation for higher flow is the presence of liquid vehicular-carrier incorporated in Chlorhexidine while powder component of Cetrimide likely caused higher friction [6]. Some authors examined different compaction forces on gutta-percha cones (3.0–24.3 kg, 8N, 10–25 N, 20 N) where higher values were attributed to the compaction techniques and lower ones to mono-cone method. Higher values of ES flow rates were to be expected with higher compaction forces [3, 7–10].

A variety of experimental models have been used to measure the ES flow rates. One of them is microscope examination of dentinal tubules and pulp-periodontal communications filled by ES of different fluidity [2, 11, 12]. Kontakiotis et al. investigated the values of contact angle for Roth 801, AH26, RSA, Gutta Flow dropped onto the dentin surface indicating inverse correlation of their flow and contact angle (higher the flow, lower the contact angle) [13]. Japanese authors compared two study models for the same sealer: flow of sealer down the vertical glass slab (time and length) and spreading the sealer drop between two horizontally pressed plates (diameter of circle). A discrepancy in obtained results with these two methods for tested sealers (Sealapex, AH26, Canals and CH61)
has been found [14]. Some authors used passive leaking through the rotational viscometer (round in shape) and examined rheological parameters: pseudoplasticity, i.e. increase of viscosity stress due to the increase of fluidity shear rate [15, 16].

The aim of this research was to evaluate the flow of three zinc oxide-eugenol endodontic sealers of different consistency (density) under the load of 2 kg. The null hypothesis was that there was no difference between the flow rates among three standardly prepared sealers and no differences in flow rate between standard mixture and mixtures with different powder to liquid ratios.

**MATERIAL AND METHOD**

**Materials**

The study included the following endodontic sealers: Endomethasone N (Septodont, St. Maur, France), Roth 801 (Roth Inter. Limit.) and Tublisel EWT (Kerr Romulus, Michigan, USA), all being zinc-oxide-eugenol based materials. The materials were mixed according to the manufacturer recommendation; eight samples of each ES were prepared. The powder to liquid ratio for standard mixture of Endomethasone N samples was 1.5 gr: 3.0 gr (standard mixture assumed one scoop powder and two oil drops that was the ratio of w/w = 1:7). The next Endomethasone N mixtures were made in very thin (1:5), thin (1:6), thick (1:8) and very thick consistency (1:9). Roth 801 sealer was prepared as standard mixture (1:7) and thicker mixture (1:8) with weight ratio powder/liquid (w/w) 0.13 gr: 0.03 gr. Tublisel EWT was prepared by mixing equal parts of base and catalyst from original tubes. This variant was chosen due to the prolonged setting time that experiment required. The accurate weights of sealers' components were measured using the digital scale (with error of ±0.0005 gr) – Mettler PE 360, Germany.

**Groups**

The experiment was done using a pair of glass plates according to ADA specification No.57. and ISO standard number 6876/2001 [17]. The sealers were aspirated by insulin-graduated syringe with barrel of 2 mL. The amount of 0.05 ± 0.025 mL sealer was immediately injected after mixing on the middle portion of glass plate and spread in circle using dental probe to the size of 10 mm in diameter. Three minutes later another glass plate (120 gr) was gently placed over sealer (Figure 1). The weight of 2 kg was then placed over second plate for each sample. Two-plates system was fixed by metal rings for the next 7 minutes.

The following experimental groups were formed: Endomethasone N: a) 1:5+2 kg; b) 1:6+2 kg; c) 1:7+2 kg; d) 1:8+2 kg; e) 1:9+2 kg; Roth 801; f) 1:7+2 kg; g) 1:8+2 kg; Tublisel EWT: h) 1:1+2 kg. In control group the samples were loaded with the weight of glass plate (120 gr). The experiment was done under the standard laboratory conditions, temperature and humidity (t = 22 ± 1°C, 60–65%).

**Measurements**

The biggest and the smallest diameter of each sample of spread sealer was measured using orthodontic ruler during 11th minute after mixing the sealer and immediately after removing the 2 kg weight. ADA standard required 10 minutes to display real flow rate. The sample that exhibited discrepancy of maximal and minimal diameter more than 1 mm was discarded. An orthodontic ruler was used to measure sealer diameters with accuracy of 0.5 mm ± 0.025 mm (error).

**Statistical calculation**

Student t-test, Boniferroni and Post-hoc test were used for statistical comparison of results within the control and experimental groups at the confidence level of 0.05.

**RESULTS**

The mean values of sealers diameters are presented in Table 1 and 2.

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**Figure 1.** Control group with sealers A) Tublisel EWT, B) Endomethasone N and C) Roth 801 without extra load

**Slika 1.** Kontrolna grupa sa silerima: A) Tublisel EWT, B) Endome-tazon N i C) cement bez opterećenja Roth 801

The obtained results of spread sealers diameter loaded by the glass plate weight only (control group) are shown in the Table 2. The mean values of sealer diameters were: Endomethasone N: 15.5 mm, Roth 801: 19.7 mm and Tublisel EWT: 19.8 mm. The statistically significant difference between the diameter values of spread sealers was noted between Endomethasone N and both, Roth 801 and Tublisel EWT (p < 0.05) while there was no significant difference between Roth 801 and Tublisel EWT.
Table 1. The mean values of spread sealers diameter under the load of 2 kg in experimental groups

| Sealers       | Endomethasone N 1:5* | Endomethasone N 1:6* | Endomethasone N Stand 1:7* | Endomethasone N 1:8* | Endomethasone N 1:9* | Roth 801 Stand 1:7* | Roth 801 1:8* | Tubliseal EWT Stand 1:1** |
|--------------|----------------------|----------------------|---------------------------|----------------------|----------------------|---------------------|------------------|-----------------------------|
| Diameter     |                      |                      |                           |                      |                      |                     |                  |                             |
| Prečnik (mm) | 27.8 ± 1.9           | 25.1 ± 3.0           | 24.1 ± 1.2                | 22.1 ± 1.7           | 22.4 ± 1.7           | 32.8 ± 1.9          | 30.0 ± 1.9      | 39.9 ± 1.3                        |
| Groups       | a                     | b                     | c                         | d                     | e                     | f                   | g                | h                           |

Table 2. The disk diameter values of spread sealers without extra load (only 100 gr weight of glass slab)

| Sealers      | Diameter values | Mean diameter |
|--------------|-----------------|---------------|
|              | Vrednosti prečnika (mm) | Prosečna vrednost prečnika (mm) ± SD |
| Endomethasone N | 15.5 ± 16.0 | 16.0 ± 2.2 |
| Roth 801      | 19.0 ± 20.0   | 19.7 ± 5.5  |
| Tubliseal EWT | 18.8 ± 20.2  | 19.8 ± 3.4  |

DISCUSSION

Our results showed the difference in the flow rate among tested sealers with the load of 2 kg, therefore, the null hypothesis can be rejected. In addition, the null hypothesis stating there was no difference in the flow rate between standard mixture and mixtures with different powder to liquid ratios was rejected due to found statistically significant difference between flow rate of 1:5 and 1:8 mixtures.

The study used protocol similar to the Grossman model [18] that is simple and allows easy comparison of results [3,19–21]. The calculated SD values were less than 30% for experimental (13.0–29.8%) and control group (15.5–19.8%). This indicates homogeneity of the results and satisfactory measuring precision.

Literature data for root canal pressure during obturation was within the span of 8 to 35 N (0.8–3.5 kg) therefore we used 2 kg weight to be comparable to the similar literature results [3,7–10]. In our study ISO protocol for the endodontic sealer flow was respected hence minimum 20 mm of diameter of spread sealer was noted [17]. Gambarini et al. results for the sealers: Roeko Seal Automix (Polyvynilsiloxan) 32.7 mm, Bioseal (ZOE sealer) 38.5 mm and Real Seal (composite resin) 37.9mm, are also in accordance to ISO requirements and similar to results in our study [19]. The differences in final results of the flow in different studies are the consequence of the experimental condition and can be correlated to the weight of cover glass plate (30-120-500 gr), additional load (1.0–3.5 kg), the amount of placed sealer on the plate (0.05 ± 0.005 – 0.5 ± 0.05ml), pressure exposure time (30 sec to 10 min) and humidity values [3,7–10].

Considering the depth of tubular penetration, Balaguer et al. using SEM analysis found deeper flow of AH Plus sealer than Acroseal, RSA, Endobtur and Ketac-Endo. The authors explained lower flow of these sealers due to warm gutta-percha that created coagulant particles in hot sealers resulting in harder penetration along the dentinal tubules [20]. Our investigation satisfied ADA Number 57 standard (d > 20 mm) for each sealer in all experimental groups (22.1–39.9 mm) with loads of 2 kg.

In vitro study of Candeiro et al. revealed better flow of calcium-silicate sealer Endosequence BC Sealer (27 mm) than AH Plus (21 mm). The authors explained superior flow of first sealer due to its smaller particles although both satisfied ISO 6876/2001 standard [21].

The different ratio of powder in tested sealers in the current study resulted in corresponding diameter values for spread sealers (flow). Endomethasone N showed significantly lower diameter (around 30%) than Roth 801 that is in accordance to the results of Camps et al. [22]. They also compared the flow of ZOE-based sealer Esthesone and Pulp Canal Sealer (thicker and thinner mixtures) and obtained higher flow rate in thinner samples. Furthermore, they found significantly lower fluidity of tested sealers (31 mm and 40 mm) than manufacturers’ referent values. Their study also showed that very fluid mixture of sealer (of low density) placed in root canal during application of mono-cone technique required around 80% lower pressure than in cases of the same sealer of higher density. This fact indicates the choice of obturation technique (that exerts different stress values to dentin canal walls) in various canal systems (wide opened apical foramen and thin root canal walls) [22].

Balaguer et al. explained high flow rate of sealer in cases of thin prepared mixture by more present liquid (oil) constituent that lowers the friction i.e. viscosity (shear stress) over the surface [20]. Analyzing the mixtures with component ratio from 1:5 to 1:9 samples where the powder percentage is different for about 50%, statistically significant difference was found in sealer’s diameters. Mendonca et al. reported similar findings in their study using comparable variations of powder and liquid components in ZOE-based sealers (Endomethasone N, Grossman sealer and Tubliseal). In low-density sealer samples they found smaller sealer penetration into dentinal tubules due to less resistance related to higher liquid percentage [23] and that was in accordance with other investigations [3,24].

Manufacturers instructions suggest using different density of sealers (thicker or thinner) (Endomethasone N, Roth 801 cement), what was included in experimental, mostly in in vitro studies [3,22,24]. To achieve more efficient and accurate dosing in standard manual mixing of ZOE-based sealers, it is mostly used as two-component paste (Tubliseal, TublisealEWT).
One of the promising calcium-silicate sealers, MTA Obtura, did not show statistically significant difference in flow rate compared to Sealer 26 although both satisfied ADA No. 57 requirements [30]. Kyung et al. found that only bio-ceramic-based sealer Endosequence BC created smaller diameter of around 18 mm, while others (AH-Plus, AD Seal, Radic-Sealer, EndoSeal MTA, MTA Fillapex, AD Seal i Radic-Sealer) showed satisfying diameters (more than 20 mm) [31]. Jeanneau C et al. investigated anti-inflammatory effect of Endomethasone N and Pulp Canal Sealer and found that only standard or thick consistency (adequate saturation of powder with eugenol) had effect on lessening the secretion of interleukine-6 [32].

Some authors analyzed the sealer flow using ISO standard and viscosity of sealers using rheometer device and found the latter one to be more accurate (p = -0.8618). The greatest flow was found for Pulp Canal Sealer EWT and then for AH Plus, Sealapex and Capsel sealer [33]. It is to note that heterogeneity of results about flow rate of various sealers indicates to follow the proposed standard protocols in order to get comparable results. As for clinical aspect, the density of ES should be in function of every single case and chosen obturation technique.

CONCLUSION

All tested sealers showed satisfactory flow level. The greatest flow was observed in Tubiseal EWT paste, then Roth 801 cement and the lowest in Endomethasone N.

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Ispitivanje fluidnosti endodontskih silera različitih konzistencija

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UVOD
Jedna od glavnih uloga endodontskog silera (ES) za opturaciju je njegovo lubrikantno (podmazujuće) svojstvo prema instrumentima i gutaperka kroz rotacioni viskometarski uređaj, tj. kroz testiranim metodama [14]. Pojedini autori su koristili pasivno istiskivanje silera kroz rotacioni viskometarski uređaj, tj. kroz testiranim metodama [14]. Pojedini autori beležile su velike fluidnosti slika kompakcionih tehnike [2]. Brzina fluidnosti ES je takođe zavisna od prirode (teksture) materijala, pa se uopšteno može reći da je ona veća kod uređa opremljenih, a manja kod gušćih preparata [3].

Jedno istraživanje je pokazalo da gušći sileri pokazuju manju fluidnost, tj. nepovoljnu viskoznost i težinu stvaranja baženica (rezervoara) unutar samog silera, koji ne doseže do svih površina kanalskog ispuna, što nepovoljno utiče na kompaktnost kanalskog ispuna. Ovo istraživanje pokazuje da redi siler stvara nepoželjne pore na spoju silera i dentinskog zida, kao i između kanalskog zida i gutaperka konusa [4]. Fluidnost silera je takođe u korelaciji sa oblikom kanala, njegovom širinom i konvergencijom, pa se za veoma uske akcesorne kanale i dentinske kanalice manjeg promjera od 500 µm na fluidnost silera može primijetiti zakon kapilariteta koji zavisi od sastava silera i širine dentinskih kanalica. Fluidnost ES takođe zavisi od strukture dentina jer se vremenom dijametar tubula smanjuje, a mogućnost prodora u tubule je otežana, naročito ako su oni ispunjeni tečnošću [5].

Neki autori beležili su različite fluidnosti, odnosno prodor AH Plus, u dentinske zidove posle tretmana dizinfičijenama, pri čemu predtretman hloreksidom poboljšava, a cetrimidom pogoršava ovu osobinu. Obaštešenje za veću fluidnost najverovatnije leži u prisustvu tečnog vehikuluma (nosioca) kod prvog kondicionera. Kao objašnjenje za manju fluidnost AH Plus kod predtretmana sa cetrimidom autori uzakrivaju na njegovu pražnalicu kastu komponentu, koja pruža veći otpor prilikom prekrivanja dentinskog zida kanalna [6]. Pojedini autori beležili su veće fluidnosti u odnosu na standardno pripremljene AH Plus silere [7–10]. Neki autori beležili su veću fluidnost es na bazi cink-oksid-eugenola različitih konzistencija pod dejstvom opterećenja od 2 kg. Cilj ovog istraživanja je bio da se ispita fluidnost tri ES na bazi cink-oksid-eugenola različitih konzistencija pod dejstvom opterećenja od 2 kg.

Materijal i metode
U eksperimentalnoj grupi su pripremljeni uzorci prema specifikaciji ADA No. 57 za ispitivanje fluidnosti zamešanih silet [7–10]. Postavljena je nulta hipoteza da ne postoji razlika u fluidnosti različitih ES na bazi cink-oksid-eugenola različitih konzistencija pod dejstvom opterećenja od 2 kg. Materijali i izrađena su tri ES na bazi cink-oksid-eugenola različitih konzistencija sa standardnim odnosom prah : tečnost 1 : 7, 1 : 8 i 1 : 9 [8, 9] (A) Endometa N 20,7–27,8 mm; B) Roth 801 29,6–30 mm; C) Tubliseal 39,9 mm). Ređe zamešani Endometa N (1 : 5, 1 : 6) pokazao je znatno veću fluidnost od standardno pripremljenog (1 : 7) (p < 0,05).

Rezultati
Posle merenja i statističke obrade rezultata svi zamešani sileri su pokazali zadovoljavajuće nivo fluidnosti – d > 20 mm (A) Endometa N 20,7–27,8 mm; B) Roth 801 29,6–30 mm; C) Tubliseal 39,9 mm). Ređe zamešan Endometa N (1 : 5, 1 : 6) pokazao je znatno veću fluidnost od standardno pripremljenog (1 : 7) (p < 0,05).

Zaključak
Najveću fluidnost pokazao je siler Tubliseal EWT, koja je bila veća veća u odnosu na standardno zamešane (1 : 7) Endometa N i Roth 801.
MATERIJAL I METOD

Materijali

U eksperimentu su ispitivani sileri Endometazon N (Septodont, St. Maur, Francuska), Roth 801, (Roth Inter. Limit.) i Tubliseal EWT (Kerr Romulus, Mičigen, USA) na bazi cink-oksid egenu-la. Materijali su zamešani prema uputstvu proizvođača, za svaku grupu po osam uzoraka. Odnos praha i ulja za standardno pri-premljen Endometazon N je bio 1,5 gr : 3,0 gr (standardna mešavina 1 : 7) i gusto zamešana masa (1 : 8) sa težinskim odnosom prah/tečnost (w/w) 0,13 gr : 0,03 gr. Tubliseal EWT je pripremljen mešanjem jednakih delova pasta baze i katalizatora istinskih zrnova iz tuba. Ova nova varijanta je izabrana za studiju zbog produženog vremena očvršćavanja. Tačna odmeravanja ura-đena su digitalnim uređajem sa greškom merenja od 0,0005 g (Mettler PE 360, Nemačka).

Grupe

Eksperiment je urađen primenom dveju staklenih pločica slično ADA specifikaciji No. 57, odnosno prema standardu ISO 6876/2001 [17]. Sileri su usisani u insulinski graduadiusn spirc (2 mL), a količina od 0,05 ± 0,025 mL odmah je posle mešanja istisnuta na sredinu staklene pločice i cirkularno pomoću sonde postavljena kružno do velicine 10 mm u prečniku. Posle tri mi-nuta druga staklena pločica težine 120 gr je nežno postavljena preko slera. Teg od 2 kg za svaki uzorak postavljen je posebno. Pomoću metalnih prstenova pločice su fiksirane sledećih 7 min. U eksperimentu je korišćen protokol sličan Grosmanovo-nom modelu zbog jednakosti izvođenja i mogućnosti po-ređenja rezultata [18]. Dobijene vrednosti SD su bile manje od 30% (13,0–29,8%) u eksperimentalnoj i kontrolnoj grupi (kompozitna smola) 37,9 mm su takođe u saglasnosti sa ISO nilsilikan) 32,7 mm, Bioseal (ZOE siler) 38,5 mm i Real Seal (kompozitna smola) 37,9 mm i tubuluseal EWT 19,8 mm. Značajna statistička razlika u veličini prečnika razlivenih slera je zabeležena poredjenjem Endometazona N prema slerima Roth 801 i Tubliseal EWT (p < 0,05), dok između slera Roth 801 i Tubliseal EWT nije zabeležena statistički značajna razlika.

DISKUSIJA

Dobijeni rezultati prikazani su u tabelama 1 i 2. Najveća proseečna vrednost prečnika razlivenih slera za Endometazon N bila je pri odnosu 1 : 6 (27,8 mm), potom pri odnosu 1 : 5 (25,1 mm), zatim pri odnosu 1 : 7 (24,1 mm), a nešto manji prečnik je uočen pri odnosu 1 : 9 (22,4 mm) i odnosu 1 : 8 (22,1 mm). Poredenjem dobijenih rezultata uočena je statistički značajna razlika između grupe sa odnosom mešavine 1 : 5 prema zamešanoj masi u odnosu 1 : 8 i 1 : 9 (p < 0,05). Kod posedte za opturaciju Roth 801 proseečna vrednost razlivenih slera posle opterećenja je iznosila 32,8 mm za odnos 1 : 7, a za odnos 1 : 8 34 mm. Proseečna vrednost prečnika kod cementa Tubliseal EWT je iznosila 39,9 mm. Poredenjem prečnika standardno zamešanih uzoraka testiranih slera uočena je statistički značajuća razlika između Endometazona N i ostala dva slera, kao i između slera Roth 801 i Tubliseal EWT (p < 0,05).

Dobijeni rezultati merenja prečnika razlivenih slera opte-rećenih samo težinom pokrovne staklene pločice u ovoj grupi prikazani su u Tabeli 2. Proseečne vrednosti prečnika razlivenih slera iznosile su za Endometazon N 15,5 mm, Roth 801 19,7 mm i Tubliseal EWT 19,8 mm. Značajna statistička razlika u veličini prečnika razlivenih slera je zabeležena poredjenjem Endometazona N prema slerima Roth 801 i Tubliseal EWT (p < 0,05), dok između slera Roth 801 i Tubliseal EWT nije zabeležena statistički značajna razlika.

Merenje

Za svaki uzorak od tri primenjena slera ortodontskim lenjirom je meren najveći i namanji dijametar u 11. minuto od početka mešanja, odnosno posle uklanjanja tegova (Slika 1), jer se prema standardu razživljanje (fluidnost) ispoljava u okviru 10 minu-ta. Ukoliko disk razlivenog slera nije bio uniformno kružan (razlika najvećeg i najmanjega prečnika je bila veća od 1 mm), formiran je novi uzorak. Ortodontski lenjir je imao veličinu ra-stereda od 0,5 mm (0,025 mm greška merenja), a posle merenja izračunavana je srednja vrednost dobijenih prečnika.

Statistička obrada

Korišćeni su Student t-test, Boniferroni i test Post-hoc za sta-tističko poredenje veličine dijametara slera kod kontrolne i eksperimentalne grupe na nivou značajnosti od 0,05.
prodir nego sileri Acroseal, RSA, Endobtur i Ketac-Endo. Ovi autori daju objašnjenje za manju fluidnost ova četiri silera, što tumači činjenicom da zagrejana gutaperka utiče na stvaranje gromuljice kod zagrejnog silera, koji teže prodire u dentinske tubule [20]. Naše istraživanje je zadovoljilo ADA no. 57 standard (d > 20 mm) kod svih silera u svim eksperimentalnim podgrupama (22,1–39,9 mm) sa korišćenjem opterećenja od 2 kg.

U in vitro studiji Candiego i sar. nalaze da kalcijskom silikatnim siler EndoSequence BC pokazuje bolju fluidnost (27 mm) nego AH Plus (21 mm). Autori ovo objašnjavaju veličinom čestica silera i potvrđuju da oba zadovoljavaju postavljen ISO 6876/2001 standard [21].

Različit ude doh pra ha u silerima u ovim istraživanjima dao je i srazmerne vrednosti prečnika različitih materijala odnosno fluidnosti. Poredenje fluidnosti standardno zamešanih silera (1 : 7) Endometa zon N i Roth 801 u našoj studiji je pokazalo značajno manje dijametre (oko 30%) kod Endometa zona N, što je u saglasnosti sa rezultatima koje su objavili Camps i sar. [22]. Ovi autori su porodili fluidnost kod ZOE silera Esthesone i silera Pulp Canal (sa gušćom i redom varijantom), pri čemu su dobili značajno veću fluidnost kod rede zamešanih uzoraka. Camps i sar. su dobili značajno manje vrednosti fluidnosti testiranih silera nego što sam proizvođač navodi u brošuri (31 mm odnosno 40 mm). Rezultati njihove studije takođe pokazuju da je jako fluidna masa (male gušćine) silera u kanalu pri aplikaciji monokonsu zahteva oko 80% manji pritisak nego primena istog silera veće gušćine. Ova činjenica ukazuje na značaj izboce sile sile i in vitro smese) ukazuju rezultati ispitivanja koji govore o većoj fluidnosti i dužim prodorom potvrđenim spiralnom kompjuterizovanim tomografijom [26].

Tivari nalazi kod uzorka AH Plus optimalne vrednosti penetracije u dentinske tubule i poboljšanu hermetičnost i antimikrobnog efekat u odnosu na pastu Perma Evolution (mešavina kalcijskom silikata i kalcijskom fosfata). Ovo studija uzima u obzir granulaciju čestica silera i zaključuje da je nivo fluidnosti obrnuto proporcionalan veličini čestica [27].

Istiskivanje silera kroz otvor kao model za merenje fluidnosti nije pokazao značajne razlike između Roth 801 i Tubliseal EWT [16], dok je eksperimentalni model sa dve staklene pločice (ISO 6876/2001) pokazao različite fluidnosti između ovih silera bez obzira na primenjenu silu od 2 kg.

Razlike u fluidnosti silera jedino se mogu objasniti različitim metodološkim postupcima u eksperimentu. Različit viskozitet sile rezultovalo je odgovarajućim veličinom dijametar različitog silera. Shodno tome, Ono i sar. ukazuju veću fluidnost silera kod gušćih silera (smolastih i glasjeronih cemenata) nego kod cink-ossid eguljenih silera. Oni zaključuju da je za kvalitetnu opturaciju bolji izbor gušćih silera jer ovde mehuriči ostaju zabijeniji i ne dosežu do kanalskog zida i time smanjuju mogućnost mikrobne perkolacije između usne dublje i kanalskih dentinskih tubula [2]. Jedno istraživanje otkriva ekspanziju gutaperka mase primenom različitih koncentracija eguljena kod ZOE-nog silera (Pulp Canal Sealer EWT), gde je porast uveličanja pružao volumetrijskom promenom gutaperke, većom fluidnošću paste, odnosno boljim tubularnim prodorom potvrđenim spiralnom kompjuterizovanim tomografijom. Oni kod fluidnih silera sa manjom gušćinom dobijaju i manji kod ZOE-nih silera Endometazon, silera Grossman i Tubliseal.

Oni kod fluidnih silera sa manjom gušćinom dobijaju i manji kod ZOE-nih silera Endometazon, silera Grossman i Tubliseal. Ovi autori daju objašnjenje za manju fluidnost ova četiri silera, što je u saglasnosti sa rezultatima koje su objavili Camps i sar. [22]. Ovi autori su porodili fluidnost kod ZOE silera Esthesone i silera Pulp Canal (sa gušćom i redom varijantom), pri čemu su dobili značajno manje dijametre (oko 30%) kod Endometazona na ADa No. 57 standard (d > 20 mm) kod svih silera u svim eksperimentalnim podgrupama (22,1–39,9 mm) sa korišćenjem opterećenja od 2 kg. U našoj studiji prisutan je bio samo faktor parametar toplote gušćine, tj. njegovim boljim razlivanjem [29].

Jedan od obećavajućih kalcijskom silikatnih silera, MTA Obtura, nije pokazao statistički značajnu razliku u fluidnosti poređenjem sa preparamet Sealer 26, iako su oba zadovoljila ADA no. 57 standard [30]. Kyung i sar. nalaze da jedino siler na bazi biokeramičkih čestica EndoSequence BC stvara nezadovoljavajuće dijametar dentinskih tubula, a shodno tome i na fluidnost silera.

Mutal i sar. naglašavaju značaj gasnih mehurića tokom opturacije, koji se više stvaraju kod silera sa nižom fluidnošću. Oni primenuju pore i vakule većine čak do 500 mikrona, koje su više zastupljene kod gušćih silera (smolastih i glasjeronih cemenata) nego kod cink-ossid eguljenih silera. Oni zaključuju da je za kvalitetnu opturaciju bolji izbor gušćih silera jer ovde mehuriči ostaju zabijeniji i ne dosežu do kanalskog zida i time smanjuju mogućnost mikrobne perkolacije između usne dublje i kanalskih dentinskih tubula. Jedno istraživanje otkriva ekspanziju gutaperka mase primenom različitih koncentracija eguljena kod ZOE-nog silera (Pulp Canal Sealer EWT), gde je porast uveličanja pružao volumetrijskom promenom gutaperke, većom fluidnošću paste, odnosno boljim tubularnim prodorom potvrđenim spiralnom kompjuterizovanim tomo grafijom.}

{
\textbf{The flow rate of endodontic sealers in various consistencies}}

U SEM studiji Mamootil i sar. uočavaju nešto slabiju ppeniciju kalcijuma i fosfata kod ZOE-nog silera (Pulp Canal Sealer EWT), gde je porast uveličanja pružao volumetrijskom promenom gutaperke, većom fluidnošću paste, odnosno boljim tubularnim prodorom potvrđenim spiralnom kompjuterizovanim tomo grafijom.}
pravilno očvršćavanje i zasićenje cink-oksida eugenolom i na taj način ispoljava i svoje antiinflamatorno dejstvo smanjenjem lučenja interleukina-6 [32].

Grupa autora poredi i fluidnosti ISO standardom i viskozitet silera uz pomoću reometra, označava ovu drugu metodu kao precizniju ($\rho = -0.8618$) i ističe najveću fluidnost za Pulp Canal Sealer EWT, potom kod silera AH Plus, Sealapex i Capseala [33].

Može se primetiti da heterogenost rezultata o nivou fluidnosti ES u bogatoj literaturi iz ove problematike ukazuje na potrebu pridržavanja standardno propisanih protokola, kako bi rezultati mnogobrojnih studija bili verodostojno uporedivi.

Što se tiče kliničkog aspekta, gustina zamešanog silera treba da je u funkciji svakog pojedinačnog slučaja i naravno u funkciji izabrane tehnike opturacije.

**ZAKLJUČAK**

Na osnovu rezultata ovih istraživanja može se zaključiti da svi testirani sileri pokazuju zadovoljavajući nivo fluidnosti. Najveću fluidnost pokazala je pasta Tubliseal EWT, potom Roth 801 cement, a najmanju Endometazon N.