Original Article

DOI: 10.7860/JCDR/2017/21420.9256

Dentistry Section

A Comparative Study of the Quality of Apical Seal in Resilon/Epiphany SE Following Intra canal Irrigation With 17% EDTA, 10% Citric Acid, And MTAD as Final Irrigants – A Dye Leakage Study Under Vacuum

SARAVANA KARTHIKEYAN BALASUBRAMANIAN[1], VIDYA SARASWATHI[2], NIDAMBUR VASUDEV BALLAL[3], SHASHI RASHMI ACHARYA[4], J. SIVAKUMAR SAMPATH[5], SANDEEP SINGH[6]

ABSTRACT

Introduction: Adequate apical sealing ability of the root canal filling material is an essential requisite for a successful endodontic therapy. Various endodontic irrigants are used for the removal of smear layer before obturating with a solid core material, thereby, reducing microleakage and improving apical seal. Resilon, a synthetic material was developed as an alternative to replace the conventional gutta-percha (standard root canal filling material) and traditional sealers for the obturation of endodontically treated teeth.

Aim: To evaluate and compare in-vitro, the post obturation apical seal obtained with Resilon /Epiphany SE (Self Etch) sealer following irrigation with 17% Ethylenediamine Tetra-Acetic Acid (EDTA), 10% citric acid, and MTAD (a mixture of doxycycline, citric acid, and a detergent, Tween 80), as final irrigants in combination with Sodium hypochlorite (NaOCl) using dye leakage under vacuum method.

Materials and Methods: Fifty five single rooted human maxillary central incisors were subjected to root canal instrumentation. Based on the final irrigation solution, samples were divided into three experimental groups (n=15); (I) 17% EDTA + 1.3% NaOCl, (II) 10% citric acid + 1.3% NaOCl, (III) MTAD + 1.3% NaOCl and two control groups (positive and negative) with 0.9% normal saline as a final irrigant. The samples were obturated with resilon/epiphany SE sealer according to manufacturer instructions and placed in 2% rhodamine B dye solution under vacuum pressure for 30 minutes and allowed to remain in the dye for seven days. All samples were then longitudinally split and examined for dye leakage under stereomicroscope and the data were statistically analysed using one-way ANOVA and post hoc tukey test.

Results: Statistically significant difference (p=0.001) was observed in the mean apical leakage between the experimental and the control groups. However, there was no significant difference (p>0.05) observed in the mean apical leakage amongst the three experimental groups.

Conclusion: 17% EDTA, 10% citric acid, and MTAD were equally effective in achieving the post-obturation apical seal with resilon/epiphany SE sealer when used as a final irrigant in combination with NaOCl.

Keywords: Dye penetration, Microleakage, Root canal filling, Secondary monoblock, Smear layer, Sodium hypochlorite

INTRODUCTION

The main rationale of endodontic therapy is to eliminate microorganisms and their toxic products from the root canal system [1]. One of the major reasons attributed for the clinical failure of endodontic therapy, is apical microleakage [2]. In a root canal filled teeth, this leakage can occur at the various interfaces like endodontic sealer and dentin or sealer and canal filling material (gutta-percha) or through voids within the sealer [3]. Smear layer removal is considered one of the methods for improving the apical seal and for reducing micro leakage before root canal filling [4]. This is due to the fact that, smear layer removal allows better sealer penetration into the dentinal tubules and therein increases the bond strength of resin-based sealers to dentin [5].

For effective removal of the smear layer, combined application of sodium hypochlorite (NaOCl) and a chelating agent, such as Ethylenediamine Tetra-Acetic Acid (EDTA), is commonly recommended [6]. Organic acids such as citric acid may also be used for smear layer removal [7]. It has been suggested that the combined use of 10% citric acid and 2.5% NaOCl is a very effective approach for the smear layer removal [7]. MTAD, which is a mixture of a tetracycline isomer, citric acid, and a detergent, is also effective as a final rinse to remove the smear layer with minimal erosive changes to the surface dentin compared with EDTA [8].

The most commonly used material for root canal obturation is gutta-percha combined with a sealer; however, this standard approach does not provide a completely fluid-tight seal of the root canal system [4]. Resilon (Resilon Research LLC, Madison, Connecticut), a synthetic material was developed as an alternative to replace gutta-percha and traditional sealers for the obturation of endodontically treated teeth. The Epiphany obturation system comprises of three substances: the core material, the sealer, and its bonding agent [9]. Later, Epiphany Self-Etch (SE) resin endodontic obturation system (Pentron Clinical Technologies, Wallingford, Connecticut) has been marketed which consists of two components namely: Epiphany SE sealer and Resilon, the core material. The manufacturer states that with the addition of Epiphany SE sealer, no change in technique is required when transferring from conventional gutta-percha to the Epiphany system. Such resin-based adhesive material may have

the potential to reduce the apical leakage of micro-organisms into the root canal system because of its significant dentinal tubule penetration, in addition to its adhesive nature.

It has also been suggested that, intra-canal irrigation with citric acid rather EDTA is recommended for achieving improved apical seal, in particular, when a resin-based sealer is employed for root canal obturation [10].

Until date, there are no published articles related to the effect of citric acid on the apical sealing ability of Resilon/Epiphany SE sealer. Hence, the purpose of the present study was to evaluate and compare the apical sealing ability of Resilon/Epiphany SE sealer following intra-canal irrigation with 17% EDTA, 10% citric acid, and MTAD as final irrigants in combination with NaOCl, using the dye leakage under vacuum method.

MATERIALS AND METHODS

This was an in vitro, comparative, experimental study in which 55 human single rooted maxillary central incisors, along with straight roots extracted for periodontal reasons within the age group of 45-55 years were selected. Ethical clearance was obtained from the institutional review board of Manipal University, India. Radiographs of each specimen were obtained to confirm the presence of a single canal, mature root apex, resorptive defects (if any) or previous root canal filling. Teeth with caries, cracks, fractures, resorption, previous restorations and root dilacerations were excluded from this study. All specimens were cleaned carefully of debris and calculus with curettes and were stored in 0.2% sodium azide solution (Sigma Chemical Co, St. Louis, Missouri) at 4°C until their use. All the teeth were then decoronated at or near the cemento-enamel junction using a high speed diamond disc (Horico, Berlin, Germany) with an adequate cooling system and were standardized to the root length of 13 mm. The pulp tissue was removed using a barbed broach and the working length was established by placing a No. 15 size K-file (Mani Inc, Tochigi Ken, Japan) into each root canal until it was just visible at the apical foramen and by subtracting 1 mm from this estimated length. Cleaning and shaping was done using K-files (Mani Inc. Japan) by step back technique. Apically canals were enlarged up to size 40 and gates glidden drills (Mani Inc) No. 2-4 were used to enlarge the coronal third of the root canals. All canals were irrigated with 2 ml of 1.3% NaOCl (KMC Pharmacy, Manipal, India) between the uses of each file. Based on the final irrigation sequence, the samples were then divided randomly into three experimental groups of 15 each and two control groups of five each as follows:

Experimental Groups

Group I: 5 ml of 17% EDTA (Merck, Darmstadt, Germany) for 1 minute followed by 5 ml of 1.3% NaOCl for 1 minute.

Group II: 5 ml of 10% citric acid (KMC Pharmacy, Manipal, India) for 1 minute followed by 5 ml of 1.3 % NaOCl for 1 minute.

Group III: Biopure MTAD (Dentsply Tulsa Dental, Tulsa, Oklahoma) was used according to manufacturer's instructions. 1.3% NaOCl followed by 1 ml of MTAD was placed in each canal for 5 minutes and then each canal was rinsed with 4 ml of MTAD.

The above mentioned irrigating solutions were introduced into the root canals by means of a 27-gauge stainless steel beveled needle. The needle was placed within 1 to 2 mm of working length in each canal. The root canals were finally rinsed with 5 ml of distilled water (KMC Pharmacy, Manipal, India) to terminate the action of irrigants and to remove any precipitate that might have been formed. The root canals in the experimental groups were then dried with sterile absorbent paper points (Dentsply-Maillefer, Ballaigues, Switzerland) and obturated with Resilon/Epiphany SE sealer (Pentron Clinical Technologies, LLC, Wallingford, Connecticut) using the following technique. Epiphany SE sealer was mixed on a mixing pad, and then a Resilon master cone (size 40/0.02) was lightly coated and placed into the canal to the working length. Lateral compaction with accessory Resilon cones was performed until the entire root canal was filled. Following removal of the excess obturating material with a heated instrument and vertical condensation using a plugger, the coronal surface was light-cured for 40-60 seconds to aid in adequate immediate seal.

Control Groups

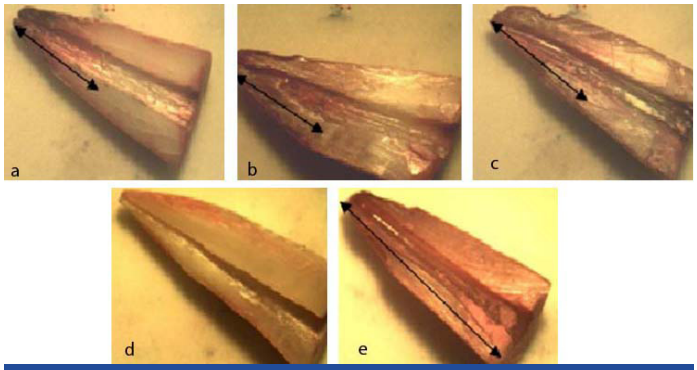
Positive control group: Five roots were filled only with a single Resilon cone (size 35) without Epiphany SE sealer.

Negative control group: Five root canals were obturated using laterally compacted Resilon/Epiphany SE sealer.

Radiographs of all specimens were taken in buccolingual and mesiodistal directions to evaluate the quality of the root canal fillings. The root canal orifice was sealed with Fuji II glass ionomer cement (GC Corporation, Tokyo, Japan). All specimens were left to set in an incubator for seven days at 37°C and 100% humidity. The external surfaces of the experimental specimens and the samples from the positive control group were covered by two layers of nail varnish apart from the apical 3 mm around the foramen. The samples in the negative control group were entirely covered with two layers of nail varnish, including the apical 3 mm. The samples were immersed in 2% rhodamine B dye solution and placed under vacuum pressure of 75 Torr for 30 minutes and allowed to remain in the dye for seven days. This extremely versatile vacuum machine (Bright Line Vacuum Chamber Multiple 315n, Orved China) measuring size of 450x440x340 mm, was made up of stainless steel with an individual nozzle for containers, along with a pump dehumidification cycle H_2Out, and an accessory easy vacuum pump (8 m^3/h) which works under sensory system for creating the external vacuum. After exposure to the dye, samples were rinsed with running water to remove the dye and the nail varnish was gently removed with a #15 disposable scalpel blade (Lister, Kanpur, India). The roots were then longitudinally grooved using a diamond disc and split into halves using a chisel. Following the separation of the roots, the Resilon/Epiphany filling was removed. The sectioned halves of each root specimen in the respective experimental and control groups were labelled as follows: Group I – A; Group II – B; Group III – C; positive control – D for easy identification and better differentiation which were then subjected to linear dye penetration. The dye leakage was measured by an examiner who was unaware of the experimental groups using a x10 stereomicroscope (Zeiss, Thornwood, New York) from the apex to the coronal extent with an ocular built micrometer scale and the images were captured with a charged couple device camera. Then, the obtained results were statistically analyzed using a SPSS software (SPSS 11.5). Data were analysed by one-way ANOVA to determine whether there were significant differences between the experimental and control groups and pairs of groups were compared using the post hoc tukey test. The level of significance was set at $p<0.05$.

RESULTS

Stereomicroscopic images of dye penetration in the respective experimental and control groups were represented in [Table/Fig-1]. In the positive control group, dye leakage was observed through the entire length of the root canal whereas in the negative control group, no leakage was observed through the canal [Table/Fig-1]. The descriptive statistics of linear dye penetration values for all the groups are illustrated in [Table/Fig-2]. One-way ANOVA test revealed that there was a high significant difference observed in the mean apical leakage between the various experimental groups and control group i.e., between Group I (17% EDTA), Group II (10% citric acid), Group III (MTAD), and positive control group with corresponding F-value = 8.70 and p-value=0.005 (as displayed in [Table/Fig-3,4]. But there was no statistically significant difference ($p>0.05$) observed in the mean apical leakage among the three experimental groups [Table/Fig-4].



[Table/Fig-1]: Extent of dye leakage observed in the root canals of various experimental and control groups: (a) Group I (EDTA + NaOCl); (b) Group II (Citric acid + NaOCl); (c) Group III (MTAD + NaOCl); (d) Negative control with no dye penetration; (e) Positive control with complete dye penetration.

GROUPS	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	BCC subtype
Group –I :17 % EDTA	15	50.6667	16.13190	4.16524	41.7331	59.6002
Group – II: 10 % Citric acid	15	43.3333	11.44344	2.95468	36.9962	49.6705
Group – III:MTAD	15	42.0000	8.82367	2.27826	37.1136	46.8864
Control group: (positive)	5	100.0000	3.53553	1.58114	95.6101	104.3899
Total	4	50.8000	20.56250	2.90798	44.9562	56.6438

[Table/Fig-2]: Descriptive data of the experimental and control groups.

Dye leakage	(DF)	(SS)	(MS)	F-ratio	p-value
Between groups	3	14101.333	4700.444	32.678	.0005
Within groups	46	6616.667	143.841		
Total	49	20718.000			

[Table/Fig-3]: One-way ANOVA: Analysis of variance for leakage (leakage versus various groups).
DF : Degree of freedom, SS : Sum of square, MS : Mean square.

Groups of material (A)	Groups of material (B)	Mean Difference (A-B)	Std. Error	Level of Signif-icance	95% Confidence Interval	
					Lower Bound	Upper Bound
10 % Citric acid	17% EDTA	-7.3333	4.37935	.349 >	-19.0065	4.3398
	MTAD	1.3333	4.37935	.990 >	-10.3398	13.0065
Control group: (positive)	EDTA	49.3333(*)	6.19334	.0005***	32.8250	65.8417
	Citric acid	56.6667(*)	6.19334	.0005***	40.1583	73.1750
	MTAD	58.0000(*)	6.19334	.0005***	41.4917	74.5083

[Table/Fig-4]: Post hoc tukey tests depicting multiple intergroup comparisons of dye leakage (x 10 1 um).
(*) - significant mean difference at the 0.05 level.
(***) - very highly significant
(>) - no significance

DISCUSSION

Citric acid as an intra canal irrigant, was investigated in concentrations ranging from 1-50% in endodontics [6]. It has been suggested that the combined use of 10% citric acid and 2.5% NaOCl was an effective approach for the smear layer removal [6]. However, there are no reports in the literature till date related to the effect of 10% citric acid in the apical sealing ability of Resilon/ Epiphany SE sealer. Hence, the present study was carried out in an attempt to study the effect of the same.

MTAD has been reported to be effective in smear layer removal [8], in addition to the elimination of microorganisms that are resistant to conventional endodontic irrigants and medications [11] and providing sustained antimicrobial activity through the binding affinity of doxycycline for dental hard tissues [12]. However, the effectiveness of MTAD in complete removal of smear layer is enhanced when low concentrations of NaOCl (1.3%) was used as an intra canal irrigant before the final rinse of MTAD [8]. Therefore, in the present study, 1.3% NaOCl was employed in between the instrumentation as well as in combination with EDTA, citric acid, and MTAD as a final rinse.

According to the results obtained in the present study, there were no statistically significant differences in the mean apical leakage observed between the three experimental groups. These results can be attributed to the smear layer removal abilities of these three agents when used as a final irrigant [13]. The results obtained with Group I and Group II in this study were concomitant with that of other studies that reported a minor or no difference in smear layer removal with EDTA and citric acid [14,15]. This was well documented in a study conducted by Khedmat and Shoukouhinejad et al., [15] who reported no significant differences in the efficacy of smear clear [17% EDTA including a cationic (cetrimide) and an anionic surfactant], EDTA and citric acid in smear layer removal at the coronal, middle and apical thirds of the root canal. On the contrary, Reis et al., [16] showed that the chelating effect of 1, 5, and 10% citric acid is significantly more than 17% EDTA which is in accordance with Machado-Silveiro et al., [17] who showed that the decalcifying effect of 10% citric acid on dentin is more than 17% EDTA. The results obtained in this study with reference to Groups I and II were in contrast to the results of the study conducted by Yamada et al., who reported that EDTA is more effective in removing the smear layer than citric acid [18].

The results of the present study also demonstrated that there was no significant difference between Group I and Group III when used as a final irrigant, which is concomitant with the results of other studies [19,20]. These findings were in contrast to the results of other studies which have been shown that MTAD was superior to EDTA in removing the smear layer in the apical third of the canals [21]. The factors to be considered in obtaining these conflicting results in various studies where different irrigation regimens of EDTA, citric acid, and MTAD were used can be attributed to: the type of teeth used, the concentration of irrigation solutions, the order of irrigation solutions used, time span of irrigation, and the criteria considered by the investigators as being effective and successful in addition to the diversity of methodologies used to assess leakage.

In the present study, the validity of experimental model was justified, since positive control specimens revealed complete dye penetration of the root canal whereas the negative control teeth demonstrated no dye penetration. Hence, there was a high significant difference observed in the mean apical leakage between the experimental groups and the positive control group.

The results of the present study were concomitant with the results of previous studies which have proved that smear layer removal improves the apical seal [22,23]. It has been suggested that resin–based sealers have superior apical sealing ability with the removal of the smear layer [22]. Economides et al., in a study compared the microleakage of two sealers, Fibrefill (resin-based sealer) and calciobiotic root canal sealer (CRCS; calcium hydroxide-based sealer), with and without the presence of smear layer and reported that microleakage values were less when the smear layer was removed [23]. Farhad et al., in a bacterial leakage study, compared the coronal sealing ability of three sealers such as, AH26, Roth's 801, pure Zinc oxide eugenol (ZOE) sealer and concluded that these sealers exhibited better coronal seal against bacterial ingress following smear layer removal [24]. The advantage of resin-based sealers like AH26, Epiphany SE over ZOE-based sealers is that they cannot only lock into open dentinal tubules but also exhibit adhesion to the exposed dentinal surfaces.

However, a perfect seal is difficult to achieve with bonded root fillings for a number of reasons. This was also evident in the present

study, where all the roots obturated with Resilon/Epiphany SE sealer (except that of the negative control group) showed leakage. The extremely high configuration factor (C-factor) of the root canals might have resulted in maximizing the polymerization shrinkage stress of adhesive systems [25]. Another possible explanation that can be attributed to the leakage in the experimental groups might be due to the collapse of demineralized collagen matrices left in the root canal walls following irrigation with various chelating agents which might have prevented sealer infiltration and formation of high quality layer bonding [26]. In addition, polycaprolactone (the raw material of Resilon) is biodegradable under microbial attack [27] in contrast to gutta-percha which is relatively an inert material. These factors are to be considered while employing Resilon/Epiphany SE sealer in clinical practice where the human oral cavity is comprised of a wide variety of microbial flora.

Different methods have been employed to assess the apical sealing ability of endodontic filling materials such as: dye leakage [28], bacterial leakage [29], electrochemical method [30], fluid filtration [31], radioisotope labelling [32] and scanning electron microscopic analysis [33]. Among these techniques, Grossman's dye penetration method is very simple and easy to perform [34]. This passive method implies the significant phenomenon of capillarity, where the root apex is submerged in dye (e.g., eosin, methylene blue, black India ink, Procion brilliant blue, Rhodamine B etc.,) that penetrates through any available space between the canal walls and the root canal filling material [35]. Then, the specimens are sectioned transversely or longitudinally or cleared following which, the effective linear dye penetration is evaluated [36]. Hence, this dye penetration methodology was employed in the current study to evaluate the apical seal of the root canal because of its sensitivity, ease of use, convenience and cost effectiveness [37].

However, the validity of dye leakage studies has been questioned because of the possible effect of entrapped air on ingress of dye solution [38] which may falsify the depth of dye penetration and it is not any more a commonly used method [39]. To overcome these problems, dye penetration under vacuum or centrifugation techniques are preferred [40]. Hence, in the present study, dye leakage under vacuum was performed for assessing the apical seal of the specimens. Rhodamine B dye was used in the present study because it presents greater diffusion in human dentin than methylene blue [41]. The molecules of Rhodamine B dye are nanometric and are optimal to simulate bacterial enzymes and their toxins to assess microleakage. Other factors favouring the use of Rhodamine-B dye in leakage studies include: small particle size, water solubility, ease of visualization, better diffusability into dentinal tubules and hard tissue non-reactivity [42].

In the present study, apical enlargement of the canals was done unto 40 size hand K-file. This is due to the fact that increasing the size of apical file to #40 could reduce the bacterial count significantly more than smaller sizes as shown by Siqueira et al., in a study [43].

LIMITATION

The samples used in this study were single-rooted maxillary central incisors with relatively straight canals. Thus, our results may be limited to only such clinical cases. Further studies can be conducted to evaluate the post obturation apical seal of multirooted teeth in curved canals with Resilon / Epiphany SE sealer following 17% EDTA, 10% citric acid, and MTAD as final irrigants. Different leakage methods can also be employed, as this may provide further information about the sealing ability, particularly when there is lack of standardized method for estimating leakage in vitro.

CONCLUSION

Within the limitations imposed by this in vitro study, it could be concluded that there was no significant difference in the apical sealing ability of Resilon/Epiphany SE with 17% EDTA, 10% citric acid, and MTAD solutions when used as a final irrigant in combination with NaOCl.

ACKNOWLEDGEMENTS

Our sincere thanks to Dr. S. Krishnaraj Somayaji (Reader, Manipal College of Dental Sciences, Manipal University, India), Dr. D. Lingeshwar (Assistant Professor, Royapettah Government Hospital, Chennai, India), for their contribution and helpful feedback towards this research project.

REFERENCES

[1] Zogheib C, Naaman A, Medioni E, Bourbouze G, Arbab-Chirani R. The quality of thermafil obturations with different final apical tapers: A Three-dimensional microcomputed tomographic comparative study. J Contemp Dent Pract. 2012:13(3);322-26.
[2] Pathways of the pulp. In: Cohen S, Burns RC. 4th ed. St. Louis: CV Mosby Co;1987.p 183.
[3] Wu MK, De Gee AJ, Wesselink PR. Leakage of four root canal sealers at different thickness. Int Endod J 1994;27:304-08.
[4] Shipper G, Orstavik D, Teixeira FB, Trope M. An evaluation of microbial leakage in roots filled with a thermoplastic synthetic polymer-based root canal filling material (Resilon). J Endod 2004;30:342-47.
[5] Clark-Holke D, Drake D, Walton R, Rivera E, Guthmiller JM. Bacterial penetration through canals of endodontically treated teeth in presence or absence of the smear layer. J Dent 2003;31:275-81.
[6] Baumgartner JC, Mader CL. A scanning electron microscopic evaluation of four root canal irrigation regimens. J Endod. 1987;13:147-57.
[7] Wayman BE, Kopp WM, Pinero GJ, E.P. Lazzari. Citric acid and lactic acids as root canal irrigants in-vitro. J Endod. 1979;5:258-65.
[8] Torabinejad M, Johnson WB. The effect of various concentrations of sodium hypochlorite on the ability of MTAD to remove the smear layer. J Endod. 2003;29:233-39.
[9] Tunga U, Bodrumlu E. Assessment of the sealing ability of a new root canal obturation material. J Endod. 2006;32:876-78.
[10] Farhad A, Barekatainand B, Koushki A. The effect of three different root canal irrigant protocols for removing smear layer on the apical microleakage of AH26 sealer. Iran Endod J. 2008;3:62-67.
[11] Shabahang S, Torabinejad M. Effect of MTAD on enterococcus faecalis-contaminated root canals of extracted human teeth. J Endod. 2003;29:576-79.
[12] Baker P, Evans R, Coburn R. Tetracycline and its derivatives strongly bind to and are released from the tooth surface in active form. J Periodontol. 1983;54:580-85.
[13] Mancini M, Armellin E, Casaglia A, Cerroni L, Cianconi L. A comparative study of smear layer removal and erosion in apical intra-radicular dentine with three irrigating solutions: A scanning electron microscopy evaluation. J Endod. 2009;35:900-903.
[14] Takeda F, Harashima T, Kimura Y, Matsumoto K. A comparative study of the removal of smear layer by three endodontic irrigants and two types of laser. Int Endod J. 1999;32:32-39.
[15] Khedmat S, Shokouhinejad N. Comparison of the efficacy of three chelating agents in smear layer removal. J Endod. 2008;34:599-602.
[16] Reis C, De-Deus G, Leal F, Azevedo E. Strong effect on dentin after the use of high concentrations of citric acid: An assessment with co-site optical microscopy and ESEM. Dent Mater J. 2008;24:1608-15.
[17] Machado-Silveiro L, González-López S, González-Rodríguez M. Decalcification of root canal dentine by citric acid, EDTA and sodium citrate. Int Endod J. 2004;37:365-69.
[18] Yamada RS, Armas A, Goldman M, Lin PS. A Scanning electron microscopic comparison of a high volume final flush with several irrigating solutions. Part-3. J Endod. 1983;9:137-42.
[19] De-deus G, Soares J, Leal F, Luna AS, Fiedel S, Fiedel RA. Similar glucose leakage pattern on smear-covered, EDTA-treated and BioPure MTAD-treated dentin. J Endod. 2008;34(4):459-62.
[20] Shokouhinejad N, Sharifian M, Aligholi M, Nekoofar M. The sealing ability of resilon and gutta-percha following different smear layer removal methods: An ex-vivo study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010;110:e44-e49.
[21] Akhlaghi M, Behrooz E, Saghiri, Ali M. Efficacy of MTAD, glyde and EDTA in debridement of curved root canals. Iran Endod J. 2009;4:58-62.
[22] Economides N, Liolios E, Kolokuris I, Beltes P. Long term evaluation of the influence of smear layer removal on the sealing ability of different sealers. J Endod. 1999;25(2):123-25.
[23] Economides N, Kokorikos I, Kolokouris I, Panagiotis B, Gogos C. Comparative study of apical sealing ability of a new resin-based root canal sealer. J Endod. 2004;30:403-05.
[24] Farhad AR, Elahi T. The effect of smear layer on apical seal of endodontically treated teeth. J Res Med Sci. 2004;3:28–31.
[25] Tay F, Loushine R, Lambrechts, P, Pashley D. Geometric factors affecting dentin bonding in root canals: A theoretical modeling approach. J Endod. 2005;31:584-89.
[26] Garcia- Godoy F, Loushine R, Itthagavun A, Murray P. Application of biologically-oriented dentin bonding principles acquired over the last two decades to the use of endodontic irrigants. Am J Dent. 2005;18:281-90.

[27] Mochizuki M, Hirami M. Structural effects on the biodegradation of aliphatic polyesters. Polym Adv Technol. 1998;8:203-09.
[28] Antonopoulos K, Attin T, Hellwig E. Evaluation of the apical seal of root canal fillings with different methods. J Endod. 1998;24:655-58.
[29] Michailesco P, Valcarel J, Grieve A, Levallois B, Lerner D. Bacterial leakage in endodontics: An improved method for quantification. J Endod. 1996;22:535-39.
[30] Jacquot B, Panighi M, Steinmetz P. Evaluation of temporary restorations by means of electrochemical impedance measurements. J Endod. 1996;22:586-89.
[31] Pommel L, Camos J. Effects of pressure and measurement time on the fluid filtration method in endodontics. J Endod. 2001;27:256-58.
[32] Haikel Y, Wittenmeyer W, Bateman G, Bentaleb A, Allemann C. A new method for the quantitative analysis of endodontic microleakage. J Endod. 1999;25:172-78.
[33] Sugawara A, Chow Lc, Takagi S, Chohayeb H. In-vitro evaluation of the sealing ability of a calcium phosphate cement when used as a root canal sealer. J Endod. 1990;16:162-65.
[34] Fathia E, Hassan Abu-Bakr N, Yahia I. A comparative study of the microleakage of resilon/epiphany and gutta-percha/Ah-plus obturating systems. Iran Endod J. 2012;7:139-43.
[35] Zarei M, Javidi M, Ghoddusi J, Naghavi N, Roohani E. An in-vitro evaluation of sealing ability of real seal using fluid filtration. Iran Endod J. 2007;2:11-14.
[36] Forough Reyhani M, Ghasemi N, Rahimi S, Salem Milani A, Mokhtari H, Shakouie S, et al. Push-out bond strength of Dorifill, Epiphany and MTA-Fillapex sealers to root canal dentin with and without smear layer. Iran Endod J. 2014;9:246-50.
[37] Mokhtari H, Shahi S, Janani M, Reyhani MF, Mokhtari Zonouzi HR, Rahimi S et al. Evaluation of apical leakage in root canals obturated with three different sealers in presence or absence of smear layer. Iran Endod J. 2015;10:131-34.
[38] Spradling PM, Senia ES. The relative sealing ability of paste type filling materials. J Endod. 1982;8:543-49.
[39] Mittal R, Singla MG, Garg A, Gupta S, Bansal A. Comparative analysis of apical leakage for two obturating materials-Resilon and Gutta percha with two resin-sealers. Saudi Endod J. 2012;12(1):14-18.
[40] Oliver CM, Abbott PV. An in-vitro study of apical and coronal microleakage of laterally condensed gutta percha with Ketac Endo and Ah-26. Aust Dent J. 1998;43:262-68.
[41] Grempel M, Antoniazzi J, JG P. Determination of the natural root dentin permeability of anterior human teeth, according to the age range and the type of dye used. Rev Paul Odontol. 1990;12:4-14.
[42] Azoubel E, Veeck E. Analysis of the apical seal in monoradicular teeth Submitted to retrograde filling and ND: YAG laser irradiation. Rev Fac Odontol Univ Fed Bahia. 1998;17:25-36.
[43] Siqueira JF Jr, Lima KC, Magalhaes FA, Lopes HP, de Uzeda M. Mechanical reduction of the bacterial population in the root canal by three instrumentation techniques. J Endod. 1999;25:332–35.

PARTICULARS OF CONTRIBUTORS:
1. Reader, Department of Conservative Dentistry and Endodontics, SRM Dental College and Hospital, Ramapuram, Chennai, Tamil Nadu, India.
2. Professor, Department of Conservative Dentistry and Endodontics, Manipal College of Dental Sciences, Manipal University, Manipal, Karnataka, India.
3. Professor, Department of Conservative Dentistry and Endodontics, Manipal College of Dental Sciences, Manipal University, Manipal, Karnataka, India.
4. Professor, Department of Conservative Dentistry and Endodontics, Manipal College of Dental Sciences, Manipal University, Manipal, Karnataka, India.
5. Reader, Department of Conservative Dentistry and Endodontics, Vivekanandha Dental College and Hospital, Thiruchengode, Tamil Nadu, India.
6. Dental Officer, 336 Field Hospital, C/O 56 APO, Saugor, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. B. Saravana Karthikeyan,
Reader, Department of Conservative Dentistry and Endodontics, SRM Dental College and Hospital,
Ramapuram, Chennai-600089, Tamil Nadu, India.
E-mail: skmdc2006@gmail.com

FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Submission: **May 14, 2016**
Date of Peer Review: **July 27, 2016**
Date of Acceptance: **Sep 17, 2016**
Date of Publishing: **Feb 01, 2017**