ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 6, Issue – 5, September - 2023, Page No. : 16 - 26

Comparative evaluation of apical sealing ability of resin based sealers in comparison with other sealers using different methods: A systematic review of in -vitro studies.

[1]Dr. Sushant Patanjali, PG final year, Dept. of Conservative Dentistry and Endodontics, ITS Dental College, Greater Noida

[2]Dr. Manju Kumari, Professor, ITS Dental College, Greater Noida

[3]Dr. Rohit Kochhar, HOD, Professor, ITS Dental College, Greater Noida

[4]Dr Shagun Patanjali, Reader, Dept. of Pedodontics, SGT Dental College, Gurgaon.

Corresponding Author: Dr. Sushant Patanjali, PG final year, Dept. of Conservative Dentistry and Endodontics, ITS Dental College, Greater Noida.

Citation of this Article: Dr. Sushant Patanjali, Dr. Manju Kumari, Dr. Rohit Kochhar, Dr Shagun Patanjali, "Comparative evaluation of apical sealing ability of resin based sealers in comparison with other sealers using different methods: A systematic review of in -vitro studies", IJDSIR- September - 2023, Volume – 6, Issue - 5, P. No. 16 – 26.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Aim: The aim of this systematic review is to evaluate published data of over ten years from 2010 to 2020 of in-vitro studies evaluating the apical sealing ability of resin-based sealers in comparison with other sealers using different methods.

Materials And Methods: A systematic review methodology was followed, and database searching was done which yielded 70 records in total. 44 studies did not meet the inclusion criteria. 26 records were further reviewed, and 0 records were excluded. A total of 26 studies were further evaluated on the basis of inclusion criteria.

Results: In this review, 9 studies indicated that resin-based sealer provided better apical sealing ability than other sealers in the root canal whereas 11 studies indicated that resin-based sealers did not perform well in terms of apical sealing ability as compared to other sealers. Furthermore 6 studies concluded that there is no significant difference between resin-based sealers and other sealers in regards to apical sealing ability of the root canal system.

Conclusion: Comparing the results it can be concluded that resin based sealers are equally effective in terms of apical sealing ability as compared to other sealers as there is no significant difference.

Keywords: Root Canal, Neurons, PRISMA

Introduction

The long-term clinical success of root canal treatment depends on meticulous cleaning and shaping of the root

canal followed by three dimensional obturation of the canal resulting in a fluid-tight seal at the root canal apex.[1] The obturation of root canal is done by using a core obturating material and a root canal sealer.

The sealer fills the voids between core filling material and radicular dentin.[2] Bowman in 1867 introduced gutta-percha (GP) as a root canal filling material. Since then, it has been the most commonly used endodontic filling material worldwide.GP is a poly-isoprene based material and is considered as the "gold standard" for obturating root canals owing to its biocompatibility, inertness, compatibility, and retrievability.[3]

AH plus and AH 26, epoxy resin-based sealers are commonly used along with GP.[4] Hergt et al. stated that AH plus fulfills the requirement of a root canal filling material as defined by the specifications for root canal filling materials and guidelines of the European Society of Endodontology (ESE).[5] Microleakage followed by subsequent re-infection of the root canal accounts for approximately 60% of endodontic failures.[6] Although GP is the most acceptable and popular obturating material, it lacks the potential of forming an adhesive bond with the root canal dentin or the sealer.[7]

Many systems such as: dyes, scanning electron microscopy(SEM), fluid filtration technique, electrochemical methods, and bacteria have been used to appraise the sealing properties of root canal filling materials[11]. However, none of the assessment methods have alone totally covered the intricate nature of root canal sealing. Results still questionable even with teeth clearing method using dye penetration to detect leakage.[12]

Meanwhile, in comparing the fluid filtration with dye method, fluid filtration is more reliable precise than dye method since it permits through-and-through detection of voids along the canal.[13]Add to this, it is a non-destructive method since it permits reiterated observation of the same specimen over time. On the other hand, the SEM is a good means of assessing leakage because it gives a three-dimensional image with greater depth of field, higher resolution and multiple magnification but it requires sample destruction and may affect the accuracy of the collected data. However, there are new alternative techniques presented recently, for example: "artificial caries", "radioactive isotopes", "Micro Computed tomography", "neutron activation analysis", and "electrical conductivity".[14] The fluid filtration technique appraises the sealing ability of different restorative and endodontic sealers.[15-17] Consequently, this technique own accepted the research field of assessing the apical and coronal microleakage.[18] Compared with dye method, the fluid filtration method depends on quantitative measurements of fluid passage within the interfaces as a result of this; both techniques gave the analogous outcomes in past investigations.[19]

Materials And Methods

The current systematic review is reported following the "Preferred Reporting Items for Systematic Reviews and Meta-analysis **(PRISMA)** statement".

Research Question

Do resin based sealers (I) provide a better apical sealing ability(O) as compared to other sealers(C) in extracted human teeth(P) when assessed in vitro studies using different methods like fluid filtration, dye penetration and SEM(S)?

Eligibility Criteria

Articles were selected for inclusion in the study review if they fulfilled all of the following criteria:

(i).Original article released in the English language (ii). Articles released for a limit of 10 years from 2010–2020 (iii) Studies performed on human extracted teeth (iv)

Articles that measure apical sealing ability of different sealers using different methods of evaluation.

The exclusion criteria were as follow: (i)Any articles discussing root end filling and Retrograde / Orthograde root end filling (ii) Any articles that evaluate the coronal sealing ability(iii)Any articles measuring the sealing ability by percentage and samples taken from animals(iv)review article

Literature Search and Data Extraction

The data was collected from three search engines which are:

1. PubMed
2. Google Scholar
3. Scopus

Search was conducted for articles published in the year 2010–2020.The language was restricted to English. The combination of terms used for the database search is described in Table 1.

The combination of terms used for database search is described in the given table:-

Database	Subject	Combination of Terms Used
PubMed	Apical sealing ability	Apical seal OR sealing ability OR sealer OR resin based OR apical OR Dentin OR root canal dentin.
Google scholar	Apical sealing ability	Dye penetration OR fluid filtration OR resin sealers OR apical seal OR apical sealing PR sealing ability
Scopus	Apical sealing ability	Sealing ability OR apical seal OR resin-based sealer OR dye penetration OR root canal dentin OR fluid filtration

The reference list from included studies, published reviews and standard endodontic textbooks were screened. An additional hand search was performed from endodontic specialty journals, namely Australian Endodontic Journal, International Endodontic Journal, Iranian Endodontic Journal, Journal of Endodontics,

Titles and abstracts were evaluated, and the relevance of each study to the criteria was determined. Then, the full texts of the selected articles were obtained and reviewed.

Data Extraction

The data extraction form was created with the following contents: first author, year of publication, study type, sample size, type of sample, instrument used, kinematics, method of evaluation and results (which performed best). Data were extracted independently, and any disagreement was resolved by discussion.

Study Selection

A systematic review methodology was followed and database searching was done which yielded 56 records. Records from year 2010-2021 were taken into considerations. Additional handbook search yielded no records. Zero duplicate records were removed from total of 70. Total 70 records were screened on the basis of title.42 studies did not meet the inclusion criteria. 26 records were further reviewed and 0 records were excluded. A total of 26 studies were further evaluated on the basis of inclusion criteria, thus finally studies to be systematically reviewed came out to be 26.

Study Characteristics

1.Studies about apical sealing ability

2.Type of samples

3.Sample size

4.Type of sealer used

5.Method used for evaluation of apical sealing ability

Results

Author/Year	Sample Size	Sealer Used	Method of Evaluation	Result
De vasconcelos BC et al(2010)	n=66	1.AH Plus 2.Acroseal 3.Sealapex 4.MBP 5.MTA Obtura	Fluid filtration	AH Plus and MBP showed best results at longer observation periods(60 days)
Ersahan S and Aydin C (2012)	n=80	1.I-Root SP 2.sealapex 3.Endorez 4.AH Plus	Fluid Filtration	I root SP and AH Plus showed best sealing ability
Joseph R and Singh S (2012)	n=60	1.AH 26 2.Sealapex 3.Endoflas 4.AH Plus	Dye penetration with centrifuging method	AH plus showed best sealing ability as it showed least leakage as compared to other sealers
Roy D, Chowdhury F,Shaik M M, Alam M K et al(2014)	n=42	1.Endofil 2.Epiphany	Dye Penetration	Epiphany showed better apical sealing to root canal walls however the difference between the two were statistically insignificant
Shetty V et al (2014)	n=36	1.AH 26 2.Sealapex 3.Tubliseal	Dye Penetration	Tubliseal showed least microleakage leading to better apical sealing ability
Fernandez R, Restrepo J S, Aristizaball D C, Alvarez L G et al (2015)	n=70	1.I-Root SP 2.Topseal	Dye Penetration	Topseal showed good apical sealing ability
Patni P. M et al (2016)	n=100	1.Apexit 2.Zinc oxide eugenol 3.AH plus 4.Roekoseal automix	Dye penetration	Roekoseal which is a silicone based sealer showed significantly better apical seal followed by AH plus and apex it
Asawaworarit W, Yachor P, Kijsamanmith	n=34	1.MTA fillapex 2.AH plus	Fluid filtration	MTA fillapex promoted significantly better apical sealing ability than AH plus at 4 weeks

K,Vongsavan N et al (2016)				
Ahuja L et al(2016)	n=75	1.Adseal 2.Pro root MTA 3.MTA fillapex	Dye penetration	Adeal provided better apical sealing ability than ProRoot MTA and MTA Fillapex
Haslinda, Rovani C A, Trilaksana AC et al (2016)	n=30	1.AH plus 2.EndoREZ	Dye penetration	There was no significant difference between the apical microleakage of the two sealers
Hasnain M,Bansal P,Nikhil V et al (2017)	n=74	1.TotalFill BC 2.Hybrid root seal 3.AH plus	Dye penetration	Total fill BC provides better apical sealing ability followed by AH plus and hybrid root seal
Teoh Y Y, Athanassiadis B, Walsh J L et al(2017)	n=140	1.MTAmix 2.AH plus 3.Supercal	Bacterial Penetration	Supercell provides superior sealing ability than other sealers with considerable resistance to bacterial penetration
Bullaya S V et al (2017)	n=60	1.Sealapex 2.AH plus 3.MTA plus 4.EndoREZ 5.Endosequence BC	Dye penetration	Endosequence BC being hydrophilic showed least leakage and highest was seen in zinc oxide eugenol based sealer Sealing ability of AH Plus sealer was similar to ZOE based sealer
Meidyawati R and Suprastiwi E (2017)	n=32	1.IRoot sp 2.AH plus	Dye penetration	There was no significant difference between the two sealers
Muharsya Y, Usman M , Suprastiwi E et al (2017)	n=30	1.Bioceramic based 2.Methacrylate resin based	Dye penetration	Bioceramic sealer showed better sealing ability as it showed lower number of marginal gaps in the apical third of tooth apex
Siddiqui A A, Alam K M, Lankar A, Mian I R , Mirza J A et al (2018)	n=50	1.Endomethasone N 2.Apexit 3.AH plus 4.Sankin apatite type II	Dye penetration	Sankin apatite showed better apical sealing ability than other sealers used in the study

Nurmeisari , Djauharie N, Indrawati D et al (2018)	n=40	1.MTA fillapex 2.AH plus	Dye penetration	There was no significant difference between the two sealers, both the sealers exhibited similar sealability
Huang Y, Orhan K, Celikten B, Orhan AI, Tufenkci P, Sevimay S et al (2018)	n=24	1.AH plus 2.Endosequence BC sealer	Micro CT and Scanning Electron Microscopy	Endosequence Bioceramic sealer showed similar sealing abilitiy
Altan H**,** Goztas Z**,** Inci G **,** Tosun G et al (2018)	n=55	1.MTA fillapex 2.AH plus 3.Sealapex	Fluid filtration	AH plus and sealapex sealer showed significantly better sealing ability than MTA fillapex
Al-Kadhi M A, Zainb Al-Ani M B Z , Al-Eanizi A J et al (2019)	n=40	1.I Endo 2.Acroseal 3.Guttaflow 2 4.Totalfill BC	Dye penetration	Totalfill BC sealer is superior to other three sealers in apical sealing ability
Bhat A S and Misgar O et al (2019)	n=90	1.AH plus 2.ZOE sealer 3.Apexit	Dye penetration	AH plus showed the best sealing ability among the three sealers
Trivedi S et al (2020)	n=60	1.MTA Fillapex 2.AH plus 3.Bio ceramic sealer	Dye Penetration	AH plus showed superior apical sealing ability than other sealers as it showed highest dye penetration
Galledar S, Farhang R, Abazari M, Negahdar P et al (2020)	n=72	1.MTA fillapex 2.AH26 3.Endofill	Dye penetration	AH26 and MTA fillapex did not show significant difference in apical sealing properties
Naji N A and Al-Gharrawi A H et al (2020)	n=64	1.Guttaflow2 2.AH plus 3.Bioceramic 4.Guttaflow bioseal	Dye penetration	Guttaflow bioseal showed the best sealing ability compared to other sealers
Asawaworarit W , Pinyosopon T , Kijsamanmith K et	n=42	1.AH plus 2.Endosequence BC	Fluid Filtration	Endosequence BC sealer had significantly better sealing ability than AH plus sealer

al (2020)				
Navarro B I et al (2020)	n=100	1.AH 4Plus 2.Sealapex 3.Pulp canal sealer	Dye penetration	Sealing ability of AH plus is greater than sealapex and pulp canal sealer

Discussion

The main objective of any endodontic treatment whether performed in regular method (non-surgical) or (surgical) is three dimensional filling that maintains apical seal and follows the original root geometry.[20] On the other hand, the most common cause that lead to endodontic treatment failure is apical leakage that is affected by many factors like the obturation technique and poor sealing of root canal sealer.[21] The materials used for obturation have been rapidly changed over the past years.[22] The most common things used for filling of the root canal are the core material and sealer. For these two components, the current material that refers to core is gutta-percha and it's the most commonly used core material because of its tremendous advantages like: biocompatibility, cheap, and ease of use.[23]

Root canal sealers serve as lubricants during the obturation process, seal the space between the dentinal wall and the root filling material and fill the accessory canals, voids and irregularities in the root canals. AH Plus® is epoxy resin-based sealer and has been commonly used as gold standard endodontic sealers due to its high bond strength to dentine, adequate radiopaque, flow, dimensional stability, low solubility and high resistance.[24]

A plethora of studies has been published comparing the sealing ability of these adhesive and the conventional, nonadhesive root canal obturating systems. However, the results obtained are inconsistent, with one study conflicting the results of another, which might be attributed to the small sample size and variations in the study methods.[25-26] These varied studies are unable to provide well-defined guidance to the clinicians in making appropriate clinical choices. Therefore, this systematic review attempts to comparatively evaluate the sealing ability of different sealers in-vitro, in extracted human teeth by different evaluation testing methods.

There were few studies were apical sealing ability of Resin based sealers were superior when compared to other sealers. Amongst the resin based sealers, AH plus in most of the studies performed better.

Joseph R and Singh S (2012)[27] stated that AH Plus showed significantly less leakage than other groups and has got better sealing ability compared to AH 26, Sealapex and Endoflas FS. DeVasconcelos BC et al (2010)[28] stated that AH Plus along with MBP sealer showed less amount of microleakage at longer observations as compared to Acroseal, sealapex and MTA obtura. Roy D et al (2014)[29] corroborated that the epiphany showed better apical sealing ability than endofil sealer due to better adaptation to the root canal walls and also due to very good adhesion to the dentinal walls. The results in this study strengthens the conclusion drawn from other researchers. Altan H et al (2017)[30] concluded that the microleakage of all sealers had high values at 24 h, but at 180 days AH Plus and Sealapex had better sealing ability than MTA. AH Plus and Sealapex produce rigid and strong cross linked polymer with dentin collagens. Authors Trivedi S et al (2020)[31] concluded that superior adaptation of AH Plus is due to its ability to bond to root dentin chemically by reacting with the exposed amino groups in collagen to form covalent bonds between the epoxy resin and collagen which is corroborated by a study conducted by

Bhat A S and Misgar O(2019)[32] where it was concluded that AH plus showed best sealing ability as compared to zinc oxide sealer and apexit. Likewise Navarro B et al (2020)[33] stated that sealing ability of AH plus is superior to other sealers (sealapex and pulp canal sealer) because AH plus had lower voids formation in the apical region, and better filling scores in the lateral canals. Moreover, the B-epoxy resin sealers have shown strong adhesion to dentine and gutta-percha when compared with Sealapex and Zinc Oxide Eugenol.

On the contrary some authors indicated that resin-based sealers showed greater apical leakage when compared to other sealers.

According to some studies, Tricalcium silicate-based sealers revealed better sealing ability than resin based sealers. Y mugarsya et al (2017)[34] stated that the better sealing ability of the Bioceramic sealer than methacrylate resin based sealer was likely the result of more stable dimensions, due to its composition of inorganic minerals that do not change dimensions when hardened. The tertiary monoblock that had originally been expected to occur, due to the use of coated gutta-percha, did not form because there remained a marginal gap between the sealer and the gutta-percha.The resin sealer may contract due to polymerization process resulting in an increase in the distance between the root canal filling and canal walls thus indicating poor performance of resin based sealers. Siddiqui A A et al (2018)[35] concluded that Sankin apatite (tricalcium phosphate based) sealer showed better apical sealing ability than Endomethasone N, Apexit and AH plus. Asawaworarit W et al (2020)[36] where they concluded under SEM evaluation, EndoSequence BC Sealer® showed higher sealer penetration into the dentinal tubules than AH Plus®, especially in the apical third of root canals at all test periods. EndoSequence BC Sealer® has a smaller particle size on average of 0.2 μm, which might enhance the penetration of the particles into dentinal tubules, especially smaller tubules at the apical root area. Asawaworarit W et al (2016)[37] when compared to AH Plus, MTA Fillapex had more leakage at 7 days but at 4 weeks, MTA Fillapex had the better sealing ability. A probable explanation is that the MTA sealer could reduce the leakage to the root canal wall over time by the continuous formation of hydration products which react with dentinal calcium and phosphate ions and lead to the formation of calcium phosphate precipitate and also MTA sealer exhibited a higher flow but a lower film thickness than AH Plus. Similarly Naji NA and Al-Gharrrawi A H et al (2020)[38] stated that guttaflow bioseal showed better sealing ability than other three sealers (guttaflow 2, AH Plus and bioceramic sealer) because calcium silicate in GuttaFlow bioseal that forms a bond with the dentin surface by forming apatite interface deposits.13 These calcium and phosphate ions promote the development of a superficial layer of calcium phosphate, which can fill out the voids and progress the sealing ability. Similar results were found by Bullaya S V et al (2017)[39] stated that Endosequence BC showed better apical sealing ability than sealapex, AH Plus, MTA plus and Endorez. This was due to better sealing ability, chemical bonding with dentin, ease of placement and osseoconductive property of bioceramic sealers which enhances the sealing ability of the root canal.

However, few studies showed no significant difference in apical sealing ability between the resin-based sealers and tricalcium silicate-based sealers. Ersahan S and Aydin C (2012)[40] stated that among the four sealers tested I-Root SP, Sealapex, EndoreZ and AH Plus, AH plus showed significantly lower microleakage than sealapex and Endorez whereas no difference in

microleakage was found between AH plus and I-Root SP Meidyawati R et al (2017)[41] stated that there was no significant difference between I-Root SP and AH Plus in regards to apical sealing ability. Authors Huang Y et al (2018)[42] established that a similar volume of closed pores was observed between the EndoSequence BC sealer and the AH Plus, which indicated that tested sealers adapted or penetrated equally to the dentin in the coronal, middle, and apical sections. The possible reason for this discrepancy could be derived from the different obturation techniques and that the results from this study were based on the single-cone technique, which was proved to be an effective way obturating well-tapered root canals after adequate rotary instrumentation. Similarly, Nurmeisari et al (2018)[43] concluded that there are no significant differences in the sealing ability of MTA and epoxy sealers when used to fill the apical third of the tooth root canals. Galledar S et al (2020)[44]showed that the sealing ability of AH26 and MTA Fillapex sealers is similar in terms of apical seal, however, reported lower leakage to the Endofill sealer.

Conclusion

Regarding the outcomes gained, it can be concluded that perfect apical seal of the root canal is required, but there is no technique, obturation material or sealer type that maintain the physical or biological properties.

In this review, 9 studies indicated that resin-based sealer provided better apical sealing ability than other sealers in the root canal whereas 11 studies indicated that resin-based sealers did not perform well in terms of apical sealing ability as compared to other sealers. Furthermore 5 studies concluded that there is no significant difference between resin-based sealers and other sealers in regard to apical sealing ability of the root canal system.

Thus, it can be concluded that resin-based sealers are equally effective in terms of apical sealing ability as compared to other sealers as there is no significant difference.

References

1. Gutmann JL. Clinical, radiographic and histologic perspectives on success and failure n endodontics. Dent Clin N Am 1992 36:379 –92.
2. Kaur A, Shah N, Logani A, Mishra N. Biotoxicity of commonly used root canal sealers: a meta-analysis. J Conserv Dent 2015;18(2):83–88.
3. Combe EC, Cohen BD, Cummings K. Alpha and beta-forms of Gutta-percha in products for root canal filling. Int Endod J 2001;34:447–451.
4. Huang Y, Orhan K, Celikten B, Orhan AI, Tufenkci P, Sevimay S. Evaluation of the sealing ability of different root canal sealers: a combined SEM and micro-CT study. J Appl Oral Sci 2018;26:e20160584
5. Hergt A, Wiegand A, Hülsmann M, Rödig T. AH Plus root canal sealer – an updated literature. Endod Pract 2015;9(4):245–265.
6. Farea M, Masudi S, Bakar WZ. Apical microleakage evaluation of system B compared with cold lateral technique, Invitro study. Aust Endod J 2010;36(2):48–53.
7. Shanahan DJ, Duncan HF. Root canal filling using Resilon: a review. Br Dent J 2011;211:81–88
8. Haslinda, Rovani CA, Trilaksana AC.Apical microleakage of epoxy resin and methacrylate resin-based sealer with continuous wave obturation technique. J Dentomaxillofac Sci 2016 April 1, 17-22.
9. Shipper G, Ørstavik 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;30:342–347.

10. Tay FR, Pashley DH. Monoblocks in root canals: a hypothetical or a tangible goal. J Endod 2007;33:391–398.
11. Torabinejad M, Higa RK, McKendry DJ, Pitt Ford TR. Dye leakage of four root end filling materials: effects of blood contamination. J Endod 1994;20(4):159-163.
12. Punitha P, Shashikala K. Evaluation of the Adaptation of Resin Based Sealers Epiphany, AH plus and AH 26 to the Root Canal Dentin by Scanning Electron Microscope. Indian J Stomatol 2011;2(4).
13. Wu MK, De Gee AJ, Wesselink PR, Moorer WR. Fluid transport and bacterial penetration along root canal fillings. Int Endod J 1993;26(4):203-208.
14. Gogna R, Jagadis S, Shashikal K. A comparative in vitro study of microleakage by a radioactive isotope and compressive strength of three nanofilled composite resin restorations. J conserv dent J Conserv Dent 2011;14(2):128.
15. Bates CF, Carnes DL, del Rio CE. Longitudinal sealing ability of mineral trioxide aggregate as a root-end filling material. J Endod 1996;22(11):575-578.
16. Tang HM, Torabinejad M, Kettering JD. Leakage evaluation of root end filling materials using endotoxin. J Endod 2002;28(1):5-7.
17. Fridland M, Rosado R. Mineral trioxide aggregate (MTA) solubility and porosity with different water-to-powder ratios. J Endod 2003;29(12):814-817.
18. Yoshimura M, Marshall FJ, Tinkle JS. In vitro quantification of the apical sealing ability of retrograde amalgam fillings. J Endod 1990;16(1):5-12.
19. Camps J, Pashley D. Reliability of the dye penetration studies. J Endod 2003;29(9):592-594.
20. Schilder H. Filling root canals in three dimensions. 1967. J Endod 2006;32(4):281-290.
21. Pommel L, Jacquot B, Camps J. Lack of correlation among three methods for evaluation of apical leakage. J Endod 2001;27(5):347-350.
22. Morgan LF, Montgomery S. An evaluation of the crown-down pressureless technique. J Endod 1984;10(10):491-498.
23. Rstavik D. Materials used for root canal obturation: technical, biological and clinical testing. J Endod 2005;12(1):25-38.
24. Stratton RK, Apicella MJ, Mines P. A fluid filtration comparison of gutta-percha versus resilon, a new soft resin endodontic obturation system. J Endod 2006;32:642–645.
25. Ishimura H, Yoshioka T, Suda H. Sealing ability of new adhesive root canal filling materials measured by new dye penetration method. Dent Mater J 2007;26:290–295.
26. Baumgartner G, Zehnder M, PaquéF. Enterococcus faecalis type strain leakage through root canals filled with Gutta-Percha/AH plus or Resilon/Epiphany. J Endod 2007;33:45–47.
27. Joseph R, Singh S. Evaluation of apical sealing ability of four different sealers using centrifuging dye penetration method: an in vitro study. J Contemp Dent Pract 2012 Nov 1;13(6):830-3.
28. Vasconcelos BC, Bernardes RA, Duarte MA, Bramante CM, Moraes IG. Apical sealing of root canal fillings performed with five different endodontic sealers: analysis by fluid filtration. J Appl Oral Sci 2011 Aug;19(4):324-8.
29. Roy D, Chowdhury F, Shaik MM, Alam MK. Apical sealing ability of resilon/epiphany system. Dent Res J (Isfahan) 2014 Mar;11(2):222-7.

30. Altan H, Göztaş Z, İnci G, Tosun G. Comparative evaluation of apical sealing ability of different root canal sealers. Eur Oral Res 2018 Sep;52(3):117-121.
31. Trivedi S, Chhabra S, Bansal A, Kukreja N, Mishra N, Trivedi A, Gill P, Kulkarni D. Evaluation of Sealing Ability of Three Root Canal Sealers: An In Vitro Study. J Contemp Dent Pract 2020 Mar 1;21(3):291-295..
32. Bhat SA, Misgar O. Assessment of sealing ability of different root canal filling materials- An in vitro study. J Adv Med Dent Scie Res 2019 Feb.7(3): 148-150.
33. Barbero-Navarro I, Irigoyen-Camacho ME, Castano-Seiquer A, Zepeda-Zepeda MA, Martins F, Mauricio P. In vitro study of the periapical sealing ability of three root canal sealing cement. SRM J Res Dent Sci 2019 Jan;10:173-7
34. Muharsya Y,Usman M,Suprastiwi E. Comparison of sealability of root canal obturation using bioceramic sealer and methacrylate resin-based sealer. J Phys:Conf Ser 2017 Aug .884. 012111.
35. Lankar A, Mian R I,Mirza A J, Siddiqui AA,Alam M K. A comparative evaluation of apical sealability of various root canal sealers used in endodontics. Int Med J 2018 Feb:25(1), 39-41.
36. Asawaworarit W, Pinyosopon T, Kijsamanmith K. Comparison of apical sealing ability of bioceramic sealer and epoxy resin-based sealer using the fluid filtration technique and scanning electron microscopy. J Dent Sci 2020;15(2): 186-192.
37. Asawaworarit W, Yachor P, Kijsamanmith K, Vongsavan N. Comparison of the Apical Sealing Ability of Calcium Silicate-Based Sealer and Resin-Based Sealer Using the Fluid-Filtration Technique. Med Princ Pract 2016;25(6):561-565.
38. Naji A N,Al-Gharrawi H A. Comparison of the sealing ability of Gutta Flow Bioseal with different Obturation systems. J Int Dent Med Res 2020 Aug 13(4):1632-1636.
39. Ballullaya SV, Vinay V, Thumu J, Devalla S, Bollu IP, Balla S. Stereomicroscopic Dye Leakage Measurement of Six Different Root Canal Sealers. J Clin Diagn Res 2017 Jun;11(6):ZC65-ZC68
40. Ersahan S, Aydin C. Solubility and apical sealing characteristics of a new calcium silicate-based root canal sealer in comparison to calcium hydroxide-, methacrylate resin- and epoxy resin-based sealers. Acta Odontol Scand 2013 May-Jul;71(3-4):857-62.
41. Meidyawati R, Suprastiwi E. Comparison of sealing ability of MTA sealer and resin epoxy sealer. J Int Dent Med Res 2017 Feb*;10*,134-138.
42. Huang Y, Orhan K, Celikten B, Orhan AI, Tufenkci P, Sevimay S. Evaluation of the sealing ability of different root canal sealers: a combined SEM and micro-CT study. J Appl Oral Sci 2018;26:e20160584.
43. Nurmeisari, Djauharie N, Indrawati D. Comparison of Sealing Ability in the Apical Third of Tooth Root Canals after Post Preparation and Obturation with MTA Sealer and Epoxy Sealer. J Phys:Conf Ser 2018 Aug:1073.062018.
44. Galledar S,Farhang R,Abazari M, Negahdar P. Evaluation of the apical microleakage of MTA Fillapex, AH26, and Endofill sealers. Braz Dent Sci 2020; Jun/Sep;23(3):1-8.