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Original Research Article

An In Vitro Study on Relation of Gutta Percha & Apical Seal for Posts

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Abstract

Objective: The objective of this study is to compare the apical sealability of mineral trioxide aggregate (MTA) Fillapex and Endosequence BC sealer at three different lengths of remaining gutta-percha after postspace preparation. ***Materials and Methods:*** A total of 160 freshly extracted human maxillary anterior teeth were decoronated, biomechanically prepared, and randomly divided into four groups; Group A and Group B served as positive and negative control with 20 teeth each. The teeth in Group C and Group D (with 60 teeth each) were obturated with gutta-percha using MTA Fillapex sealer and Endosequence BC sealer, respectively. Teeth in Group C and Group D were further subdivided into three subgroups depending on the length of remaining apical gutta-percha, i.e., 3, 4, and 5 mm after postspace preparation. Apical leakage was assessed using dye penetration method under stereomicroscope. ***Results:*** In both the Groups C and D, there was overall no statistically significant difference in leakage; however, Group C showed slightly more leakage than Group D. There was a statistically significant difference in leakage at 3 mm and 5 mm level in both groups. ***Conclusion:*** Although less microleakage occurred, the bioceramic sealers could not totally eliminate leakage.

Keywords: Gutta Percha, Apical Seal, Endosequence.

INTRODUCTION

Obliteration of the root canal space with an inert filling material, formation of a hermetic seal, and elimination of any portal entry or exit to periapical tissues have been suggested as objectives for effective endodontic treatment. A key to successful endodontics and a major aim of modern nonsurgical root canal treatment is to seal completely both the apical and coronal routes of potential leakage and maintain the disinfected status achieved by chemical or mechanical cleaning and to prevent reinfection and passage of bacterial byproducts, allowing the periodontium to maintain its integrity and to achieve healing [1, 2]. Ingle and colleagues radiographically studied endodontic success and failure; they indicated that 58% of treatment failures were due to incomplete obturation [3, 4]. Gutta-percha is a biocompatible obturating material and can be used to fill the radicular space. However, the use of gutta-percha alone is not sufficient to create three-dimensional closure, as it cannot be attached to the canal wall; therefore, the use of sealer, which helps to create adhesion between gutta-percha and canal walls, is required. Root canal sealer material acts to fill minor irregularities and discrepancies between the gutta-percha and the canal walls. It also serves as a lubricant and can fill accessory canals, meaning that the use of a root canal sealer and gutta-percha plays an important role in creating a fluid tight seal. Sealers should be non-toxic, antibacterial, resistant to dissolution and should have a healing effect on periapical lesions [3-5]. The best result visualized for an endodontic treatment would be hard tissue closure, separating the obturated canal from the periapical tissues and maintaining a biologically conducive environment. The dynamic metabolic processes in the biologically conducive environment. The dynamic metabolic processes in the periapical tissues make the filling of the apical third of the root canal different from the rest of the canal. The property of osseoconductivity in an endodontic sealer helps in achieving three dimensional closure of root canal foramen in a wet environment in time [6, 7]. Bonding of the sealer to the

root canal dentin wall and formation of a monoblock can eliminate microleakage at sealer-dentin or sealer-core material interface. The tight seal at the apex can be enhanced if the sealer bonds chemically to the dentinal wall of root canal and slightly expands to improve its adaptation to the canal walls. One of such sealers is bioceramic (BC) sealer [3, 4]. Bioceramic sealers are exceedingly biocompatible, non–toxic, do not shrink and are chemically stable within the biological environment. Additionally, bioceramic sealer will not result in a significant inflammatory response if an over fill occurs during the obturation process [8]. EndoSequence BC Sealer (Brasseler, Savannah, GA, USA), is a calcium phosphate silicate based cement. Its major inorganic components include tricalcium silicate, dicalcium silicate, calcium phosphates, colloidal silica, and calcium hydroxide. It uses zirconium oxide as the radiopacifier and contains water-free thickening vehicles to enable the sealer to be delivered in the form of a premixed paste. Hydroxyapatite is co‑precipitated within the calcium silicate hydrate phase to produce a composite-like structure, reinforcing the set cement. The introduction of a premixed calcium phosphate silicate based sealer eliminates the potential of heterogeneous consistency during on-site mixing. Because the sealer is premixed with non-aqueous but water-miscible carriers, the water-free paste will not set during storage in the syringe and only hardens on exposure to an aqueous environment. EndoSequence BC Sealer uses the moisture within the dentinal tubules after canal irrigation to initiate and complete the setting reaction. The setting time of EndoSequence BC Sealer is 4 hours and it may be extended in overly dry canals. The pH of EndoSequence BC Sealer during the setting process is higher than 12 (Material Safety Data Sheet information), which increases its bactericidal properties [9]. In 2010, a new endodontic sealer based on MTA, MTA Fillapex, was developed by Angelus (Londrina/Parana/Brazil) and was launched commercially. This product is more stable than calcium hydroxide. It constantly releases calcium ions and maintains a pH which elicits antibacterial effects. MTA Fillapex is a sealer presented in a paste/paste system and is composed of MTA, resins, bismuth trioxide, nanoparticulated silica and pigment [10]. The presence of nanoparticles enables a homogeneous mixture and better flow of the product. The setting time of MTA Fillapex is 2 hours and 10 minutes [11]. Its manufacturer claims that it has an excellent radiopacity, easy handling and a good working time (23 minutes). However, only a few studies have investigated the sealing ability of MTA Fillapex [10, 12-14].

After endodontic treatment, the remaining dental structure may require a post to retain the restoration and replace the lost tooth [15, 16]. During preparation of the post space the residual filling material may be dislodged, twisted or vibrated which creates a pathway for bacterial invasion and re-infection of the root canal system. Several factors can affect the integrity of the apical seal while post space is prepared such as length of remaining gutta-percha, time of removal of the filling material and method of gutta-percha removal [17-19]. Several studies have shown varying results on the effect of timing of post space preparation following obturation on the apical leakage. The required post space may be prepared either immediately after completing the obturation of the pulp space or after 1 week. Metzger *et al*., demonstrated that the sealing is proportional to the length of the remaining obturated material [20]. Authors of most previous studies agree that keeping 5 mm of the obturating material in the apical region constitutes a safe margin [21, 22]. According to Ingle, post space should be prepared such that the post length is approximately three-quarters the length of the root when treating long-rooted teeth. When average root length is encountered, then post length is dictated by retaining 5mm of apical gutta-percha. But in cases of short root length, it might be necessary sometimes to retain 3 mm of apical gutta percha only, to maintain the proper crown root ratio without affecting the integrity of the apical seal. In these cases, a sealer that does not shrink and is chemically stable might play an important role in maintaining the apical seal. Since bioceramic sealers have these property, it might maintain the apical seal in cases of short root length. There is limited literature available on studies comparing the effect on apical sealability using two different bioceramic sealers; i.e Endosequence BC (calcium silicate phosphate based) and MTA Fillapex (MTA based). So, this in-vitro study was conducted to compare the effect on apical sealability using two bioceramic sealers with different levels of remaining gutta-percha in teeth prepared to receive posts using dye penetration method.

MATERIAL AND METHODS

160 non-carious, straight rooted, human maxillary anterior teeth, extracted for periodontal reasons with mature apices were selected for the study. Teeth with pre-existing carious lesions, cracks, fracture, endodontic treatment, resorption or open apices were excluded from the study. All the samples were decoronated using a diamond disc at the level of CEJ standardizing the root length to 12 mm, to facilitate straight line access, for precise length control and easy canal preparation Size #10 K file was then inserted into the canals till the tip of the file was visible at the apical foramen. The working length was then recorded 1mm short of the apical foramen. All the samples were stored in normal saline in order to prevent dehydration until use. Biomechanical preparation of the samples. After preserving canal patency with size #10 K- file, cleaning and shaping was done using standardized protocol with copious irrigation of 1 ml of 5% Sodium hypochlorite and 17% EDTA after use of every successive instrument. The final apical preparation was done with a size 50 K-file. Recapitulation was done using a smaller size file between change of each instrument. Step back preparation was done till size 60 K-file. The

canals were dried with sterile absorbent paper points. The teeth were then randomly divided into six experimental groups and two control groups, containing 10 teeth each. The method of obturation used was cold lateral compaction. Radiographs were taken to evaluate root canal filling. Orafil–G (Prevest Denpro) was placed in the coronal end of prepared teeth and all groups were kept for 7 days at room temperature to allow the sealer to set. The post spaces were prepared with Peeso reamers from size 1 to 4 at low speed to a depth that left 3 mm of gutta-percha apically in Group I and IV; 4 mm in Group II and V; and 5 mm in Group III and VI. A cotton pellet was placed in the coronal parts of the canals and sealed with Glass Ionomer Cement. In all the experimental groups and positive control groups, the entire surface of the roots except the apical 2 mm were covered with two layers of nail polish. The purpose of the positive control group was to demonstrate the capability of the method to disclose voids present in the root canal filling because of the absence of a sealer. In the negative control group, the external root surface was completely covered with two layers of nail polish including the apical portion and the apical foramen. The purpose of the negative control group was to verify the ability of the root coverage to prevent dye penetration through the lateral root surfaces and the canal. After 1 hour when the nail varnish had completely dried, all the teeth were immersed in a solution of 2% methylene blue for 24 hours at room temperature. The teeth were then removed from the dye and were washed under running tap water to remove dye on external root surface and nail paint was scraped from the tooth surface using a # 11 Scalpel blade (Bard Parker, Surgivan).

The teeth were then sectioned vertically along the long axis. The filling materials were removed from the canals of the teeth in all the experimental groups using an explorer and both halves of the samples were split. Out of the two halves, that part was selected for evaluation under stereomicroscope which showed more dye penetration compared to the other. The samples were then evaluated under a stereomicroscope (20 X) for visible coronal extent of dye penetration (in millimeters) from the apical constriction. A graph was placed under each samples and the number of grids were counted corresponding to the highest value for the dye penetration. The data was collected and put to statistical analysis. Successful long-term retention of endodontically treated teeth requires integration of both endodontic and restorative disciplines. Whenever there is considerable loss of tooth structure, it is necessary to use post and cores to facilitate fabrication of the final restoration [23]. The procedure of post and core involves the removal of gutta percha / root canal filling from the root canal to an appropriate length for insertion of a post, known as post space preparation. The length of post space preparation is dictated by the mechanical retention requirement of the post on one hand and on the other by the need to leave sufficient length of apical root canal filling to maintain apical seal. In relation to the length of remaining root canal filling, 5 mm is generally considered a safe margin [22]. Some authors considered 3 mm to be the minimum length of remaining apical root filling to preserve the seal. However, Arbamovitz *et al*., reported that a reduction of fillings to 3 mm produced an unpredictable seal. But in cases of short root length requiring post, sometimes it might be necessary to retain 3 mm of apical gutta percha only, to maintain the proper crown root ratio without affecting the integrity of the apical seal. In such a situation, sealer is crucial to preserve the apical seal [22, 23]. The application of sealer fills the irregularities at the interface of filling material and the root canal walls. A variety of sealers with different compositions and properties are available for use. AH Plus, an epoxy resin based sealer has been used as a gold standard for comparison with the newer sealers. Recently bioceramic sealers have been developed which can bind to the root dentin, thus improving the sealer dentin bonding.

RESULTS

Stereomicroscopic examination showed that all the negative controls demonstrated no detectable dye penetration. The positive controls demonstrated extreme amounts of apical leakage. The mean microleakage (mm) of the two sealers, i.e; MTA Fillapex and Endosequence BC. MTA Fillapex showed slightly higher microleakage when compared to Endosequence BC. The mean microleakage (mm) recorded in the study at three different lengths; 3 mm, 4 mm and 5 mm. More microleakage was observed at 3 mm of remaining apical gutta percha, followed by 4 mm and 5 mm, irrespective of the sealer used. The comparison between the mean microleakage (mm) recorded in the two sealers at all the three lengths. Endosequence BC showed a slightly lesser microleakage at all lengths of remaining apical gutta percha when compared to MTA Fillapex. Statistical analysis was done using Analysis of Variance (ANOVA). ‘p’ values < 0.05 was considered statistically significant. The application of ANOVA to the mean microleakage values recorded. It was observed that with respect to the sealers, there was no significant difference in the microleakage values, however when the three lengths of apical gutta percha were compared the difference was statistically significant. Bonferroni test was applied for multiple comparisons to find out among which pair or groups, there existed a significant difference. It was found that 3 mm of remaining apical gutta percha did not show statistically significant difference in microleakage when compared to 4 mm groups but showed statistically significant results when compared to 5 mm groups. Mean microleakage at all levels for both the sealers was as follows: 3 mm (maximum leakage)>4 mm > 5 mm (least leakage).

Table 1: Showing mean microleakage in millimeters.

Material	Length of apical GP	Mean	Standard Deviation	Minimum	Maximum
MTA Fillapex	3 mm (Group I)	3.55	0.68	3	5
	4 mm (Group II)	3.45	0.44	3	4
	5 mm (Group III)	3.3	0.48	2.5	4
Endosequence BC	3 mm (Group IV)	3.5	0.57	3	4.5
	4 mm (Group V)	3.4	0.39	3	4
	5 mm (Group VI)	3.2	0.35	2.5	3.5

DISCUSSION

Endosequence BC and MTA Fillapex sealer at different apical lengths are scarce. Thus, the present study was designed to compare the effect of three different lengths (3 mm, 4 mm and 5 mm) of remaining apical gutta-percha when samples were obturated using these two bioactive sealers; on their sealing ability after post space preparation. Maxillary upper anterior teeth with single canals were selected and preserved in normal saline so as to avoid any chemical alteration of the tooth tissue. The samples were decoronated to facilitate straight line access, for precise length control and easy canal preparation. Similar length of 12 mm was maintained for standardization of samples for subsequent procedures of shaping and cleaning [23]. Positive and negative controls were used in the study. The purpose of the positive control group was to demonstrate the capability of the method to disclose voids present in the root canal filling because of the absence of a sealer. The purpose of the negative control group was to verify the ability of the nail varnish to prevent dye penetration through the lateral root surfaces and the canal. The technique of obturation used in this study was cold lateral compaction. Both the sealers used (MTA Fillapex and Endosequence BC) are pseudoplastic in nature, i.e; their viscosities are reduced and flow is increased when shear stress is increased during compaction. So, during lateral compaction the sealers would flow into the lateral canals and completely fill the space between the root canal wall and the filling material.44 Zhou *et al*., had found that MTA Fillapex and Endosequence BC sealer had better flow properties when compared to two epoxy resin based sealers (AH Plus and Thermaseal), a silicone based sealer (Gutta – Flow) and a zinc oxide eugenol based sealer (Pulp Canal Sealer) [24]. The technique of post space preparation could also have an effect on the apical seal. In the case of a gutta-percha filling, post space preparation can be done by various methods such as chemical (by using solvents), thermal (by using heated instruments), or mechanical (by using rotary instruments); either by one technique alone or in combination with another [23]. Various studies have evaluated the effect of various techniques of gutta percha removal on the apical sealing ability. Kwan and Harrington showed that the influence of rotary instruments on the apical seal is minor since frictional heat causes softening of gutta-percha, slight apical pressure may act as vertical condensation, thereby improving the apical seal [25]. So in the present study, post space preparation was performed using Peeso reamers. Various studies have evaluated the time of post space preparation and found that sealing ability is affected by the timing of post space preparation. In accordance to study done by Chen G and Chang YC21, in this study, the post space was prepared after 7 days for complete setting of the sealer, since it may be possible that the filling could become twisted or vibrate during immediate mechanical post space preparation, in a way to cause disruption of the apical seal if complete setting of the sealer is not achieved [17, 17]. Leakage studies comprise a major part of contemporary endodontic research. Though a variety of new methods are available to evaluate apical seal like dyes, radioisotopes, bacteria and their by products and other methodologies like dye extraction, dye penetration, fluid filtration techniques etc [26]. Still linear dye penetration is followed most commonly because of its simplicity, ease to perform, relatively inexpensive and does not require complex equipment [23]. Thus, this method was chosen for this study. The studies using dye penetration technique employ different materials and dyes to assess the amount of microleakage. Methylene blue dye has molecular size similar or smaller than that of bacterial products, so it has been considered suitable for the detection of apical microleakage. The degree of leakage could be reduced by using a material that adapts and forms adequate seal with root canal walls [27-29]. Matloff *et al*., compared methylene blue dye with radioisotopes of carbon, calcium chloride and iodine and found that dye penetrated farther than any of the isotopes, and also commented on its solubility in water and ease of use [30]. 2% methylene blue dye was used in the present study as the leakage marker because it is readily detectable under visible light, soluble in water, is able to diffuse easily and is not absorbed by dentin matrix apatite crystals [23, 31]. The method of producing longitudinal sections was by splitting the specimens into two halves to examine the exposed filling and any dye penetration into the material and root canal wall interface. This technique would give a much true picture of the leakage pattern as compared to transverse sectioning method, by minimizing the risk of the dye washing away [23, 32]. Stereomicroscopic examination was chosen for this study as it gives a three dimensional view of the surface to be examined and

needs no pretreatment of the specimen as in Scanning Electron Microscopy [23]. The results of the stereomicroscopic evaluation showed that the negative controls registered no detectable dye penetration. This means that the two coats of nail varnish applied to the external root surfaces to avoid dye penetration was effective. The positive controls demonstrated extreme amounts of apical leakage indicating that the dye penetration method was correctly executed. In the present study, although statistically significant difference was not found, a lower percentage of leakage was found using Endosequence BC sealer versus MTA Fillapex sealer in all of the groups. The better apical sealability of Endosequence BC sealer, as observed in this study can be attributed to its property of expansion on setting as compared to MTA Fillapex which shrinks on setting by 0.022%.44 Deyan Kossev and Valeri Stefanov found that during setting, there was expansion of Endosequence BC by about 0.2% [9]. The low contact angle allows it to spread easily over the canal walls, providing better adaptation and good hermetic seal. It also has the ability to form a chemical bond with the canal dentin walls. It forms hydroxyapatite during setting which creates an ultimate bond between dentinal wall and sealer, further enhancing its sealing properties. In the presence of moisture, nano-calcium silicate (hydrophilic component) is formed which exhibits minimal or no shrinkage [9]. The reason for the slightly higher microleakage of MTA Fillapex could be because of the low adhesion of the material that could be due to incomplete polymerization of its resin components leading to formation of poor microtags on setting. This finding is in accordance with the study done by Al Haddad *et al.*, who found that due to incomplete resin polymerization there was decreased bonding and adaptation of MTA Fillapex to the dentinal walls. Among the three different lengths, higher mean microleakage was recorded at 3 mm followed by 4 mm and 5 mm respectively. When 3 mm was compared to 5 mm, there was statistically significant difference in the microleakage values. The results of the present study are in accordance with other studies that showed a correlation between the length of remaining apical root canal filling and the efficacy of its seal. Mattison *et al.*, found that shorter the remaining apical filling, the higher was the leakage measured [33]. Limitations of the study include inability to completely simulate in-vivo conditions which could have led to the variations due to effect of moisture environment, temperature difference etc. Both the sealers might show different results if different methods of obturation are used other than cold lateral compaction. Most of the recent studies done on Endosequence BC sealer and MTA Fillapex sealer are in vitro, and there is a need and necessity for more clinical studies regarding the sealability to establish its long‑term use. Further studies are required to establish the sealing ability of both the sealers using different techniques of obturation, using more number of sample size and using other methods to assess the apical leakage.

CONCLUSION

Under the limitations of the present study, it can be concluded that both the sealers used in this study i.e; MTA Fillapex and Endosequence BC sealer showed microleakage at all the lengths of remaining apical gutta-percha, with no significant difference between the two sealers. Endosequence BC sealer showed slightly lesser microleakage when compared to MTA Fillapex sealer, but the results were statistically insignificant. More microleakage was found at 3 mm of remaining apical gutta percha, followed by 4 mm and 5 mm. However, between 3 mm and 4 mm there was not a significant difference whereas between 3 mm and 5 mm of remaining apical gutta percha statistical significance was reached. Therefore, the results of the present study showed that irrespective of the type of sealers used, a 5 mm length of remaining apical Gutta-percha provided a better apical seal than 3 mm and 4 mm of remaining apical Gutta-percha.

REFERENCES

1. Anantula, K., & Ganta, A. K. (2011). Evaluation and comparison of sealing ability of three different obturation techniques—Lateral condensation, Obtura II, and GuttaFlow: An in vitro study. *Journal of conservative dentistry: JCD*, *14*(1), 57-61.
2. Patil, P., Rathore, V. P., Hotkar, C., Savgave, S. S., Raghavendra, K., & Ingale, P. (2016). A comparison of apical sealing ability between GuttaFlow and AH plus: An in vitro study. *Journal of International Society of Preventive & Community Dentistry*, *6*(4), 377-382.
3. Pawar, S. S., Pujar, M. A., & Makandar, S. D. (2014). Evaluation of the apical sealing ability of bioceramic sealer, AH plus & epiphany: An in vitro study. *Journal of conservative dentistry: JCD*, *17*(6), 579-582.
4. Ingle, J. I., Bakland, L. K., & Baumgartner, J. C. (2008). Ingle's Endodontics 6th ed. Hamilton: BC Decker Inc, 1053-87.
5. Kumar, S. A., Shivanna, V., Naian, M. T., & Shivamurthy, G. B. (2011). Comparative evaluation of the apical sealing ability and adaptation to dentine of three resin-based sealers: An in vitro study. *Journal of conservative dentistry: JCD*, *14*(1), 16-20.
6. Gandhi, B., & Halebathi-Gowdra, R. (2017). Comparative evaluation of the apical sealing ability of a ceramic based sealer and MTA as root-end filling materials–An in-vitro study. *Journal of clinical and experimental dentistry*, *9*(7), e901-905.
7. Friedman, S. (1991). Retrograde approaches in endodontic therapy. *Dental Traumatology*, *7*(3), 97-107.
8. Koch, K., Brave, D., & Nasseh, A. A. (2012). A review of bioceramic technology in endodontics. *CE article*, *4*, 6-12.

9. Tyagi, S., Mishra, P., & Tyagi, P. (2013). Evolution of root canal sealers: An insight story. *European Journal of General Dentistry*, *2*(3), 199-218.
10. Asawaworarit, W., Yachor, P., Kijsamanmith, K., & Vongsavan, N. (2016). Comparison of the apical sealing ability of calcium silicate-based sealer and resin-based sealer using the fluid-filtration technique. *Medical Principles and Practice*, *25*(6), 561-565.
11. Mta Fillapex - Endodontic Sealer Scientific Profile: 4-29.
12. Gomes-Filho, J. E., Watanabe, S., Bernabé, P. F. E., & de Moraes Costa, M. T. (2009). A mineral trioxide aggregate sealer stimulated mineralization. *Journal of Endodontics*, *35*(2), 256-260.
13. Taşdemir, T., Er, K., Çelik, D., Tahan, E., Serper, A., Ceyhanli, K. T., & Yeşilyurt, C. (2014). Bond strength of calcium silicate-based sealers to dentine dried with different techniques. *Medical Principles and Practice*, *23*(4), 373-376.
14. Morgental, R. D., Vier-Pelisser, F. V., Oliveira, S. D. D., Antunes, F. C., Cogo, D. M., & Kopper, P. M. P. (2011). Antibacterial activity of two MTA-based root canal sealers. *International endodontic journal*, *44*(12), 1128-1133.
15. Barros, J. D., Cruz, J., Carvalho, M. F., & Pina-Vaz, I. (2013). Influence of the timing of post space preparation on apical sealing. *RGO. Revista Gaúcha de Odontologia (Online)*, *61*(2), 199-204.
16. Cheung, W. (2005). A review of the management of endodontically treated teeth: Post, core and the final restoration. *The Journal of the American Dental Association*, *136*(5), 611-619.
17. Al-Sabawi, N. A., Ismail, S. A., & Al-Askary, R. A. (2012). Effect of Different Techniques of Immediate and Delayed Post Space Preparation on Apical Seal. *Al-Rafidain Dental Journal*, (16), 249-256.
18. Aydemir, H., Ceylan, G., Tasdemir, T., Kalyoncuoglu, E., & Isildak, I. (2009). Effect of immediate and delayed post space preparation on the apical seal of root canals obturated with different sealers and techniques. *Journal of Applied Oral Science*, *17*(6), 605-610.
19. Moshonov, J., Slutzky-Goldberg, I., Gottlieb, A., & Peretz, B. (2005). The effect of the distance between post and residual gutta-percha on the clinical outcome of endodontic treatment. *Journal of endodontics*, *31*(3), 177-179.
20. Padmanabhan, P., Das, J., Kumari, R. V., Pradeep, P. R., Kumar, A., & Agarwal, S. (2017). Comparative evaluation of apical microleakage in immediate and delayed postspace preparation using four different root canal sealers: An in vitro study. *Journal of conservative dentistry: JCD*, *20*(2), 86-90.
21. Chen, G., & Chang, Y. C. (2013). The effect of immediate and delayed post-space preparation using extended working time root canal sealers on apical leakage. *Journal of Dental Sciences*, *8*(1), 31-36.
22. Abramovitz, I., Lev, R., Fuss, Z., & Metzger, Z. (2001). The unpredictability of seal after post space preparation: a fluid transport study. *Journal of endodontics*, *27*(4), 292-295.
23. Rita, C., Kalyan, S., Kala, M., & Biji, B. (2014). Comparison of apical sealability of AH plus and GuttaFlow sealers at three different levels of remaining gutta-percha in teeth prepared to receive posts: An in vitro study. *Endodontology*, *26*, 270-278.
24. Zhou, H. M., Shen, Y., Zheng, W., Li, L., Zheng, Y. F., & Haapasalo, M. (2013). Physical properties of 5 root canal sealers. *Journal of endodontics*, *39*(10), 1281-1286.
25. Kwan, E. H., & Harrington, G. W. (1981). The effect of immediate post preparation on apical seal. *Journal of endodontics*, *7*(7), 325-329.
26. Veríssimo, D. M., & do Vale, M. S. (2006). Methodologies for assessment of apical and coronal leakage of endodontic filling materials: a critical review. *Journal of oral science*, *48*(3), 93-98.
27. Ahuja, L., Jasuja, P., Verma, K. G., Juneja, S., Mathur, A., Walia, R., ... & Singla, M. (2016). A comparative evaluation of sealing ability of new MTA based sealers with conventional resin based sealer: An in-vitro study. *Journal of clinical and diagnostic research: JCDR*, *10*(7), 76-79.
28. Ingle, J. I., Newton, C. W., & West, J. D. (2002). Obturation of the radicular space. In: Ingle, J. I., Bakland, L., eds. Endodontics, 5th Edition. Hamilton Ontario: BC Decker, 571.
29. Roberts, H. W., Toth, J. M., Berzins, D. W., & Charlton, D. G. (2008). Mineral trioxide aggregate material use in endodontic treatment: a review of the literature. *Dental materials*, *24*(2), 149-164.
30. Matloff, I. R., Jensen, J. R., Singer, L., & Tabibi, A. (1982). A comparison of methods used in root canal sealability studies. *Oral Surgery, Oral Medicine, Oral Pathology*, *53*(2), 203-208.
31. Limkangwalmongkol, S., Burtscher, P., Abbott, P. V., Sandler, A. B., & Bishop, B. M. (1991). A comparative study of the apical leakage of four root canal sealers and laterally condensed gutta-percha. *Journal of Endodontics*, *17*(10), 495-499.
32. Ahlberg, K. M. F., Assavanop, P., & Tay, W. M. (1995). A comparison of the apical dye penetration patterns shown by methylene blue and India ink in root-filled teeth. *International Endodontic Journal*, *28*(1), 30-34.
33. Mattison, G. D., Delivanis, P. D., Thacker Jr, R. W., & Hassell, K. J. (1984). Effect of post preparation on the apical seal. *The Journal of prosthetic dentistry*, *51*(6), 785-789.