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RESEARCH ARTICLE

COMPARATIVE EVALUATION OF THE PENETRABILITY OF NOVEL ROOT CANAL SEALERS – AN INVITRO SCANNING ELECTRON MICROSCOPE STUDY

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ABSTRACT

Aim: To compare and evaluate the penetrability of three different root canal sealers – An Invitro study.

Materials and Methods: Eighty freshly extracted mandibular premolars were used in the present study. The teeth were decoronated and canal lengths were established 1 mm short of the apex and divided into 4 groups. Group 1 used epoxy resin based sealer, Group 2 used polydimethylsiloxane based sealer, Group 3 used calcium based sealer and Group 4 used zinc oxide based sealer (control). The canal system was prepared using the protaper universal rotary system. Smear layer was removed by irrigating the canals with 3 ml of freshly prepared 17% EDTA solution, followed by irrigation with 3 ml of 5.25% NaOCl, for 3 minutes. EDTA was employed as the final rinse followed by a rinse with distilled water. Roots were sectioned using diamond disc, these sections were gold sputtered and examined under scanning electron microscope. Dentin sections were fixed in acrylic resin block, polyethylene tubes were cut to form 3-mm-high cylinders. The sealers were mixed according to the manufactures instructions and dispersed into the cylindrical space. The samples were then engaged perpendicularly at their base of universal testing machine at a cross head speed of 1 mm min-1.

Results: It was found that Group 1 had higher depth of sealer penetration than the other group of sealers evaluated in the study.

Conclusion: Calcium silicate sealer had comparable penetrability to that of epoxy resin sealer. Within the limitations of the present study it can be concluded that epoxy resin based sealer had better penetration when compared to that of other sealers evaluated in this study.

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INTRODUCTION

Success of endodontic treatment depends upon diagnosis, biochemical preparation and obturation (Mosby) The success of obturation relies mostly on obtaining a three dimensional fluid tight hermetic sealand 60% endodontic failure results from leakage associated with improper filling of the root canal space (Polineni S) Sealers play a major role in achieving the above goal by sealing the interface formed between root dentin and core material (Muliyar S) Gutta-percha is the most commonly used core filling material. The advantage of gutta-percha is its inertness and good biocompatibility. The major disadvantage is lack of bonding to the root dentin making the role of sealers vital in achieving an impervious seal along root canal wall (Cohen). According to Grossman ideal root canal sealer should possess adequate penetration into dentinal tubules and adaptation to the root dentin and gutta-percha, which depends on the rheological behaviour of sealers such as film thickness, viscosity and basic composition of the sealer.

According to Erickson penetration of root canal sealers into dentinal tubules is essential to achieve a good bond strength (Rached-Junior FJ) The stability of the bond formed between the root dentin and gutta-percha interface should be adequate to reduce the failure associated with leakage of material (Neelakantan P). Traditionally endodontic sealers based on ZOE were used, but the major disadvantage with the above sealers was the poor sealing efficacy and bonding ability to the core material and canal wall. Various modifications have been made in the sealer chemistry and formulation to improve the penetration and bond strength of sealers (Şen BH). The sealers investigated in the present study were AH plus sealer, Guttaflow sealer, Bio ceramic sealer and Zinc oxide eugenol

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sealer. AH Plus an epoxy resin based sealer composed of diepoxide calcium tungstate and -adamantane amine N, N'-dibenzyl-5-oxa-non- an diamine- as key ingredients. It penetrates deep into irregularities present in root canal and bond chemically to the collagen fibres present in root dentin. Additionally it possess good physical properties and manipulative abilities (Kossev AD). Gutta-Flow a polydimethylsiloxane based sealer composed of gutta-percha powder, nanosilver particles flows readily at room temperature. The above sealer because of its homogenicity adapts better to the core material and undergoes post setting expansion (Marín-Bauza GA). Recently bio ceramic sealer based on calcium silicate have been introduced into the market composed of zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, and other filling agents as major ingredients. The hydrophilic formulationUtilizes moisture present in the root canal to complete the setting reaction and undergoes setting expansionTunga U)

Zinc oxide–eugenol (ZOE) sealers based on Grossman's formula is composed of Zinc oxide, bismuth sub-carbonate, staybelite resin, barium sulfate, sodium borate as major ingredients. The settingreaction occurs between the zinc ions present in the zinc oxide powder and eugenol content of the liquid and forms a chelate with the calcium ions of root dentin. The major disadvantage is inadequate strength and bonding to the root canal wall (S, Mishra P). The aim of the present in-vitro study was to evaluate and compare the penetrability using scanning electron microscope.

Aim: The aim of the present invitro study was to evaluate and compare the penetrability using scanning electron microscope .

Objective: The objective of the present study in -vitro study was to evaluate and compare penetrability of three root canal sealers, namely epoxy resin based sealer, Polydimethylsiloxane based sealer, calcium silicate based sealer and zinc oxide eugenol based sealer was used as a (Control group).

1. By assessing the penetration of sealers in to dentinal tubules using Scanning Electron microscope in micron meters.

METHODOLOGY

Eighty freshly extracted human mandibular first premolar with single straight root canals were used in the present study. They were randomly divided into four equal groups of 20 samples each. Group 1 used epoxy resin based sealer, Group 2 used polydimethylsiloxane based sealer, Group 3 used calcium based sealer and Group 4 used zinc oxide based sealer (control). All teeth were stored in saline solution, organic debris from the outer surface of the tooth was removed by immersing the teeth in 2% Naocl solution for 4 days before starting of the experiment and subsequently placed in saline solution until they were used. The crowns of all teeth were cut at cemento-enamel junction using slow speed cutting airotor under water coolant. The working length were established by placing a size ISO 10 size K file into each sample until the tip of the file was visible at the apex, canal length was established 1 mm short of the apex. The root canals were prepared using the protaper rotary system (Dentsply) to an apical size of F3 and apical patency was rechecked using size -10 K- file throughout the preparation. During the entire preparation alternate irrigation and recapitulation was done with 5.25% sodium hypochlorite (NaOCl) and #10 K-file, respectively. Smear layer was removed by irrigating the canals with 3 ml of freshly prepared 17% ethylene diaminetetracetic acid (EDTA) solution (Pulpdent, USA), followed by irr igation with 3 ml of 5.25% Naocl, each for 3 minutes. EDTA was employed as the final rinse, followed by a rinse with distilled water. All root canals were obturated with above sealers by warm vertical condensation technique. The root canal sealers were mixed according to the manufacture r's instructions. In all groups gutta-percha was removed from the coronal 3 mm of all obturated root canals with a heated instrument and the coronal access cavities were sealed with Cavit. Samples were kept at 37oC for 1 week in 100% humidity to ensure complete setting of the sealer. Samples were then sectioned in the bucco-lingual direction with the help of diamond disc. Smear layer produced during sectioning were removed by cleansing with 17% EDTA and 3% Naocl. Samples were studied for dentinal tubule penetration at all the three levels coronal, middle and apical levels. Samples were dehydrated and gold sputtered for SEM evaluation.

Fig.1. Samples collection for assessment of sealer penetration

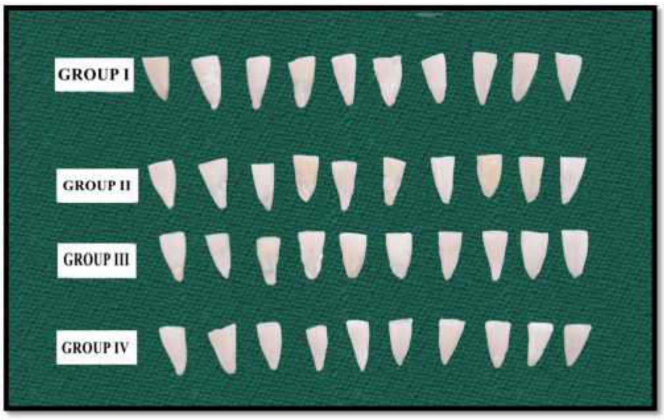


Fig.2. Decoronated sample specimens

RESULTS

The present study was conducted to compare and evaluate the penetrability of four different sealers. The sealer penetration was estimated using scanning electron microscope images [Fig.1-12] by calculating the distance from the sealer/gutta-percha interface to the root dentin in micrometers from each samples with n=10 with magnification range. (1500X – 2000X) Mean and standard deviations were estimated from the samples with (n=10) for each study group.

Fig.3. AH Plus (Group 1) Gutta flow (Group 2). Bioceramic (Group 3) Zinc oxide eugenol sealer (Group4)

Fig.4. Transverse section of obturated samples for evaluation of sealer penetration in Group I

Fig.5. Transverse section of obturated samples for evaluation of sealer penetration in Group 2

Fig.6. Transverse section of obturated samples for evaluation ofsealer penetration in Group 3

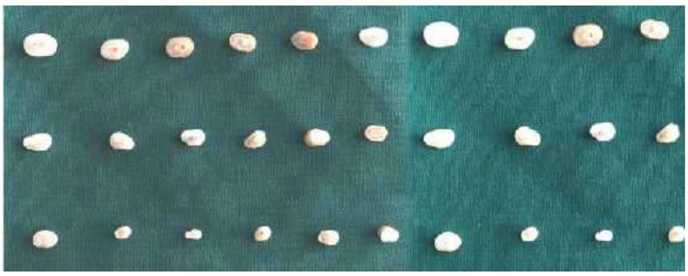


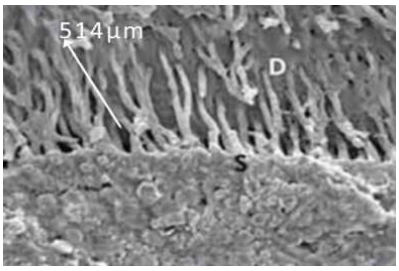
Fig. 7. Transverse section of obturated samples for evaluation of sealer penetration in Group 4

Fig. 8. Dehydrator

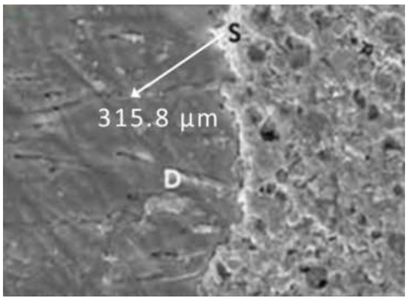
Fig. 9. Metallization chamber

Fig. 10. Scanning electron microscope

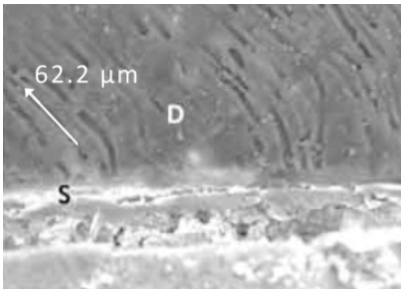
Group 1(AH PLUS)



a. Coronal level

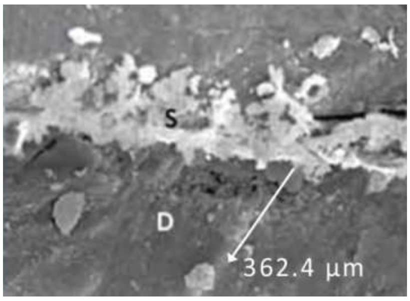


b. Middle level

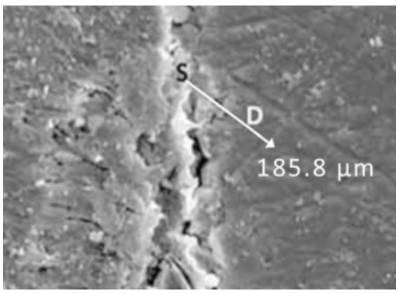


c. Apical level

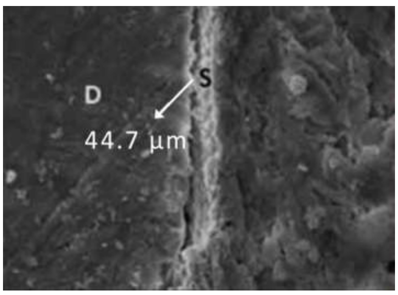
Group 2 (GUTTA FLOW)



a. Coronal level

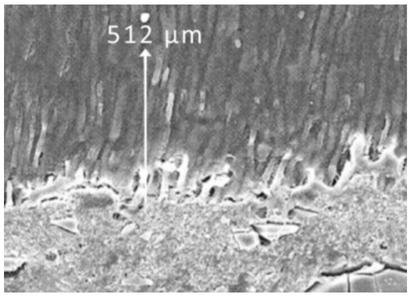


b. Middle level

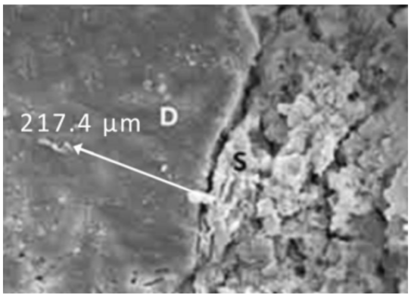


c. Apical level

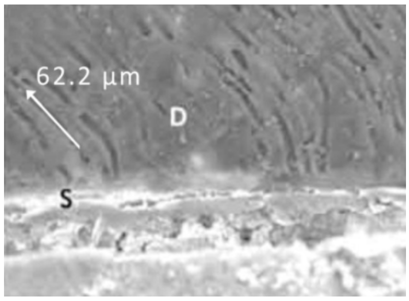
Group 3(BIO CERAMIC)



a. Coronal level

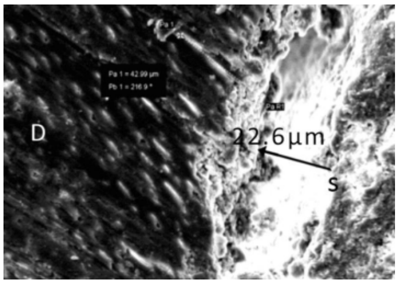


b.Middle level

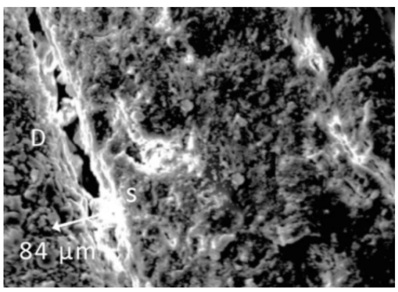


c. Apical level

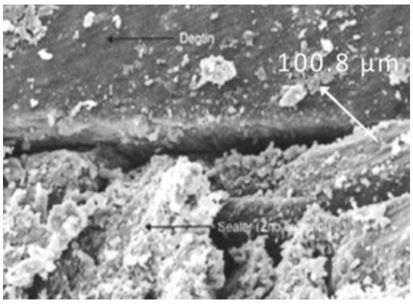
Group 4(ZINC OXIDE EUGENOL)



a. Coronal level



b. Middle level



c. Apical level

The results of the present study were subjected to statistical analysis to interpret the significant differences in assessing the penetrability. One-way ANOVA followed by Tukey's test was used for statistical analysis in the present study. Tukey's post hoc test was employed to do multiple comparisons in between the groups and within the groups. The data were tabulated in Table.1 and Table.2 respectively. All statistical analysis was done at the 0.05 significant levels. SPSS version 19.0 was used to perform all statistical analysis.

Table 1. ANOVA with mean and standard deviation for sealer penetration

Anova with mean and standard deviation for sealer penetration

Groups	Mean	S.D	F-Value	P-Value
Group 1	308.19	179.054	274.658	
Coronal	514.78	42.7268		
Middle	315.81	52.7056		0.000
Apical	93.9900	15.3731		
Group 2	238.1067	153.56681		
Coronal	426.69	42.6709	347.019	0.000
Middle	222.82	26.9697		
Apical	64.8100	17.2427		
Group 3	292.6533	185.62501		
Coronal	513.24	53.6889	217.900	0.000
Middle	285.09	57.9314		
Apical	79.6300	15.4544		
Group 4	115.17	70.5476		
Coronal	193.80	38.1915		0.000
Middle	117.41	19.1752	100.635	
Apical	34.3100	8.40138		

Table 2. Multiple comparisons for sealer penetration (Tukey's test)

A	Coronal Level	Groups	Mean	Std. Error	Sig.
	Group 1	Group 2	75.96000	35.04849	.175
		Group 3	8.64000	35.04849	.995
		Group 4	318.00000*	35.04849	.000
	Group 2	Group 1	-75.96000	35.04849	.175
		Group 3	-67.32000	35.04849	.259
		Group 4	242.04000*	35.04849	.000
	Group 3	Group 1	-8.64000	35.04849	.995
		Group 2	67.32000	35.04849	.259
		Group 4	309.36000*	35.04849	.000
	Group 4	Group 1	-318.00000*	35.04849	.000
		Group 2	-242.04000*	35.04849	.000
		Group 3	-309.36000*	35.04849	.000
B	Middle level				
	Group 1	Group 2	78.36000	28.07695	.057
		Group 3	28.02000	28.07695	.753
		Group 4	171.90000*	28.07695	.000
	Group 2	Group 1	-78.36000	28.07695	.057
		Group 3	-50.34000	28.07695	.312
		Group 4	93.54000*	28.07695	.020
	Group 3	Group 1	-28.02000	28.07695	.753
		Group 2	50.34000	28.07695	.312
		Group 4	143.88000*	28.07695	.001
	Group 4	Group 1	-171.90000*	28.07695	.000
		Group 2	-93.54000*	28.07695	.020
		Group 3	-143.88000*	28.07695	.001
C)	Apical level				
	Group 1	Group 2	27.20000*	8.77822	.032
		Group 3	15.12000	8.77822	.345
		Group 4	62.98000*	8.77822	.000
	Group 2	Group 1	-27.20000*	8.77822	.032
		Group 3	-12.08000	8.77822	.531
		Group 4	35.78000*	8.77822	.004
	Group 3	Group 1	-15.12000	8.77822	.345
		Group 2	12.08000	8.77822	.531
		Group 4	47.86000*	8.77822	.000
	Group 4	Group 1	-62.98000*	8.77822	.000
		Group 2	-35.78000*	8.77822	.004
		Group 3	-47.86000*	8.77822	.000

Inter group analysis

Mean sealer penetration was found to be high in the cervical third then the middle and apical third for all groups of sealers tested in the study. Statistically significant difference was found in the depth of sealer penetration between Group 3 and Group 1 at all levels evaluate $P<0.005$. INTER GROUP ANALYSIS: The mean sealer penetration was found to be higher in Group 1 and lower in Group 4 with significance level of $P<0.005$. Overall ranking for the sealer penetration evaluated in the study:

GROUP 1 >GROUP 3> GROUP 2>GROUP 4

DISCUSSION

Endodontic success depends on multiple factors, the major factor includes a) chemo-mechanical debridement b) Root canal filling c) Post endodontic restoration (S, Mishra). Chemo-mechanical preparation involves debulking of bacterial load and debris in root canal space, the success in achieving of thorough debridement involves complete removal of bacterial pathogens located in the apical third (Tunga U). The chemicals used during the above process aids in achieving the above goal by sterilizing the endodontic space and improves healing of peri-apical tissues (Hammad M) The key factor in achieving endodontic success depends on filling the sterile environment created by chemo-mechanical preparation with materials possessing good biological properties and long-term dimensional stability (Estrela C) Gutta-percha is the most commonly used core material and offers the advantages such as inertness, bio-compatibility, less technique sensitivity, ease of manipulation and reinforces the root canal system. The major drawback of gutta-percha is lack of inherent bonding to the root dentin and it can be balanced by using root canal sealer to enhance the adaptation to root canal wall (Prakash R,) According to Grossman, an ideal endodontic sealer should have good adaptation to the root dentin and core filling material, good rheological behavior, adequate lubricant action, least solubility, high antibacterial activity, should be easy to manipulate and should posses adequate dimensional stability (Zhou HM). The discrepancies between the core material and root dentin is the zone of action endodontic sealers, they seals of areas inaccessible to the instruments and irregularities ensuring between the root dentin and the core material (Bernardes RA,) Sealer composition plays a major role in the clinical performance and can be grouped as, zinc oxide eugenol based sealers, resin based sealers, calcium hydroxide based sealers, and glass-ionomer based sealers (D'souza LH)
The selection of sealers depends upon analysis of various factors. The flow of sealer is a major factor that aids in improving the adhesion and adaptation to the dentin which indirectly improves the stability of root filling (Lee KW). The penetration of root canal sealers depends upon diameter and density of the dentinal tubules. In addition the surface activity of the sealers, contact angle formed between sealer and the dentin, obturation technique employed for root filling and sectioning method involved in the sample preparation plays a key role in the sealer penetration (Mamootil K). The diameter and density of the dentinal tubules is more at the coronal and middle third of the root canal system whereas minimal at the apical third this factor plays a major role in sealer penetration (Lo Giudice G)

According to Boyde, smear layer is an organic matter trapped within translocated inorganic dentine and is formed during instrumentation which is composed of organic and inorganic substances that include fragments of odontoblastic processes, microorganisms and necrotic materials (pashley) (Violich DR) Smear layer plays a major role in the penetration of root canal sealers especially in the apical third. Removal of the smear layer not only improves the sealing ability of sealers but also increases bond strength to dentinal walls, and reduces bacterial penetration and is removed using various demineralizing agents (Rouhani A) Viscosity of the sealers is indirectly proportional to the penetration, higher the viscosity, lower the penetration which also depends upon the composition of the sealer (Lacey S). The chemical nature of sealers plays a major role in the sealer penetration, hydrophilic sealers penetrates deeper than hydrophobic sealers (Afaf AH) Ideally obturation with least void and gaps is the major desirable outcome of the endodontic filling, which depends on good surface adaptation and less shrinkage of sealer between the core material and root dentin (Schilder H) Obturation technique employed should displace the sealer into the dentinal tubules (Weis MV) In single cone technique due to high volume of the sealer with minimal compaction forces the sealer penetration is very low especially when combined with warm vertical technique creates more voids at the sealer dentin interface, simulates more leakage which might be filled with only water molecules (Weis MV) Cold lateral compaction technique is commonly employed for root canal filling as the compaction forces generated by the spreader laterally helps in better penetration of the sealer. In cold lateral compaction micro-leakage is comparatively less, but it is highly technique sensitive (Monticelli) Sectioning technique employed also plays a key role in the outcome of sealer penetration, mostly longitudinal sections are made to evaluate the coronal and middle third of the root canal system, variability in the thickness of the root canal and the canal curvature at the apical third makes it difficult to section longitudinally (Gilbert SD) In the apical third direction of dentinal tubules is mostly perpendicular to the canal wall, to overcome the difficulties associated with the sectioning method samples were split transversely in bucco-lingual direction (Veríssimo DM) Dryness of the canal also plays a role in sealer penetration. Ideally slight moisture is needed for the hydrophilic materials whereas hydrophobic materials require dry canal for better penetration of sealer (Balguerie E) Many studies have been evaluated to assess the sealing ability of the endodontic sealers through various methods such as dye penetration method, electrical methods, fluid filtration technique, radioisotope tracing, and scanning electron microscopy (Kalra M)

In this study scanning electron microscope was utilized to estimate the mean penetration of root canal sealers. The advantage of using SEM over various sealing methods is that in SEM the defects at the submicron level can be observed at required magnification and final evaluation can be done by preserving microphotographs (VarunKapoor) Conventional zinc oxide eugenol based sealers lack adequate penetration which lead to the modification in the sealer composition (Khader MA.) In a quest for search of newer materials in this direction sealers based on adhesive principles is gaining popularity because of good retention by micromechanical bonding but the shrinkage associated with setting reaction is a major problem for the resin based sealers (Isabelle Elia,). Silicone based sealers with poly-dimethylsiloxane as a major ingredient has been developed to reduce the disadvantages associated with conventional and resin based sealers. This group of sealers has been found to have better adaptation to the root canal wall adhering to monoblock principle52. Recently Calcium silicate based sealers have been introduced in to the market which denatures the collagen present in the dentin providing a 'mineral infiltrated zone' is found to have better penetration and dimensional stability (Aline Savariz) AH Plus is available as two paste system which contains epoxide as a base and amine as a catalyst. Epoxide paste has Diepoxide Calcium tungstate Zirconium oxide Aerosil Pigment, Amine paste has 1-adamantane amine N,N'-dibenzyl-5-oxa-non-andiamine-1,9 TCD-diamine Calcium tungstate Zirconium oxide, Aerosil Silicone oil AH plus has good biocompatibility, tissue tolerance, long-term dimensional stability, and sealing ability but silicone oil content of AH plus increases surface tension thereby shrinkage occurs at the sealer-dentin interface (Aline Savariz Sevimay S). Gutta-flow was introduced (2008) as a root filling material consists of Polydimethylsiloxane matrix highly filled with gutta-percha powder (<30 lm) and nano-silver particles which prevents the bacterial growth. It has a unique sealing property to the core because of its low solubility, excellent flow and undergoes post setting expansion. (Maryam Bidar.) Incorporation of gutta-percha particles into the sealer does not drastically improve the leakage potential of sealers especially in the absence of a solvent or heat, as there is no chemical union between the gutta-percha particles and the master cone (Pitout E). A new calcium silicate based sealer consists of tricalcium silicate, dicalcium silicate, calcium phosphates, colloidal silica, calcium hydroxide and zirconium oxide.The formation of calcium hydroxide as a by-product of the setting reaction produces a very high pH (12.8) rendering it highly anti-bacterial during its setting, Additionally it has better handling properties, osseo-conductivity, dimensional stability, low setting shrinkage, and remain non-resorbable inside the root canal (Preeti Jain) Removal of smear layer done by irrigating the samples with 10ml of 17% EDTA for 1min, neutralized with 10ml 3% Naocl and finally cleansed with 3ml of distilled water (Chadha R). All the samples were divided into four groups and the sealers manipulated as per the instructions of the manufacturer and obturated with 6% Gutta-percha cones. Samples were preserved for 1 week for complete setting of the sealers at 37°C. Sectioning were made using diamond disc in transverse direction of 2mm, 5mm, and 8mm from the working length. Smear layer produced during sectioning were removed by cleansing with 17% EDTA and 3% Naocl (Hamid Reza Yavari,) Samples were dehydrated in an evaporator for 4 hrs in a vacuum machine. Metallization was done for 3mins using sputtering system and the specimens were analyzed using SEM.In the present study samples were kept in 2% Naocl for 4 days before starting and subsequently placed in saline until they were used. 2% Naocl effectively removes organic debris and storing in saline prevents dehydration of the samples (Hamid Abbas Hamid).

After the cutting of roots, the samples were cleaned in a beaker filled with EDTA 17% and Naocl 3% to remove the smear layer produced during sectioning. This procedure could influence the sealer adaptation in the tubules facing the cutting surface and the dimension of the tubule opening (Hamid Reza Yavari,). In the cervical third of the root canal mean penetration values were : GROUP 1 (514 μm) > GROUP 3 (513 μm) >GROUP 2 (426 μm)> GROUP 4 (193.8 μm) In the middle third of the root canal mean penetration values were GROUP 1 (315.8 μm) > GROUP 3 (285 μm) >GROUP 2 (222 μm) >GROUP 4 (117 μm) In the apical third of the root canal mean penetration values were: GROUP 1 (93.9 μm) > GROUP 3 (79.6 μm) >GROUP 2(64.8 μm) >GROUP 4 (34.3 μm) In the present study Group 1 had good penetration at the cervical third than the middle and apical third because of its low particle size and film thickness of AH plus which is in the range of 20-25μm might be a key factor to have a better penetration than GROUP 2 with particle size which is in the range of 28-30μm than GROUP 4 which has an particle size of about 30-35μm reflected in the outcome of the results. The acidic nature of the AH plus etches the inorganic component of the dentin helps in better penetration of sealer at all levels, this trend was in accordance with the study conducted by (Ackay et al & Afaf Alhaddad et al Akcay M). An interesting finding observed in the study is that the particle size of GROUP 3 (2μm) though was less than that of GROUP 1 (20-25μm), had lesser penetration than GROUP 1which might be due to the dissolution of the smear layer by AH plus helped in greater penetration of the sealer. Additionally low solubility of AH plus on exposure to tissue fluids aids in better penetration. The results of the present study were in agreement with the previous study conducted by Borges et al. In this present study Group 2 had better penetration in the coronal third but less than that of GROUP 3 and GROUP 1 this might be due to the poor wetting ability and high film thickness to root dentin. The presence of silicone creates high surface tension forces, making the sealer more difficult to spread resulting in lower penetration. This was is in agreement with the previous studies conducted by (Tiyagi et al and Ozok et al.) Another result confounded in the present study was the penetration in the middle and apical third for GROUP 2 is less than GROUP 1 and GROUP 3 which might be due to regional discrepancies in the middle and apical portion of the root canal, such as presence of canal complexities such as resorption, cementum like tissue and a tubular dentin. GROUP 2 had better penetration at all levels when compared to GROUP 4 might be due to the variation in particle size. In the present study penetration of GROUP 3 at the cervical level was comparable to that of GROUP 1, but significantly higher than other groups which might be due to its extreme level of particle size (2 μm) and low viscosity. Penetration of GROUP 3 in the middle and apical third was comparatively less than GROUP 1, this might be due to higher sealer volume created more gaps between the sealer and dentin, in addition oval shape of premolar root in the middle third might be challenging in preparation and filling. This trend is in accordance with the previous study conducted by (Carvalho et al).

In the apical third, decrease in penetration might be due to alkaline nature of the GROUP 3, whereas acidic nature of GROUP 1 dissolves the smear layer better than GROUP 3. When compared with GROUP 2 and GROUP 4 penetration of GROUP 3 was significantly high at all the levels this might be due to the difference in particle size of the sealers. In our study GROUP 4 showed poor penetration at all the levels when compared to GROUP 1, GROUP 2 and GROUP 3 might be due to the higher film thickness and higher solubility. Overall results for good penetration of sealers seen at the coronal and middle third because of increased density, diameter of the dentinal tubules along with better smear layer management and flow properties. Low penetration of sealers was seen at in apical third this might be due to the variation in the film thickness, rheological behaviour of the sealers, poor smear layer removal, and canal complexities/aberrations in the apical third. This trend was in accordance with the studies conducted by (Oksan et al and Silva et al)

Overall ranking for the sealer penetration evaluated in the study: GROUP 1 >GROUP 3> GROUP 2>GROUP 4

Conclusion

From the results of the present study it can be concluded that;

1. Particle size plays a major role in penetration of the endodontic sealers. Epoxy resin based AH plus sealer with filler particle size 20-25 revealed better penetration when compared with the other dental sealers namely Bioceramic sealer, Gutta flow and Zinc oxide eugenol sealer revealed with scanning electron microscope.
2. An interesting observation made in the present study was that the Bioceramic sealer with a particle size of 2 which was less than that of AH plus sealer (20-25) had less penetration which might be due to the dissolution of the smear layer by the acidic nature helped in better penetration of the sealer.
3. Another valuable finding observed was better penetration for all the sealers were revealed at coronal third than the middle third which might be due to the difference in diameter and density of the dentinal tubules.
4. Another finding observed was lower penetration for all the groups were revealed at the apical third due to the complexity of the canal morphology and difficulty in effective management of smear layer.

Within the limitations of the present study it can be concluded that AH plus sealer Group 1 had better penetration when compared with the other sealers evaluated in the study. From this investigative study it can be summarized that the clinical performance and longevity of endodontic sealers could be enhanced by a scientific decision making in selection of materials based on the compositional factors such as particle size, sealer chemistry and bonding characteristics.

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