Comparative Evaluation of Radicular Push-out Bond Strength of EndoSequence BC, MTA FillApex, Apexit Plus and AH Plus Sealers as Affected by the Modified Plunger: Base Orifice Size Relation.

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ABSTRACT

Background: Sealers are universally used along with gutta-percha to obturate the root canals in three dimensions. Push-out bond strength is considered appropriate to measure the adhesion capacity of sealers. Aim: To compare the bond strength of recently introduced bioceramic sealer with commonly used sealers and to evaluate the effect of plunger: base orifice size ratio on push-out bond strength. **Methods**: One hundred mandibular premolars with single canals were decoronated and instrumented up to master apical file F3 Protaper. Specimens were randomly divided into four groups (n=25) based on the sealer used: Group 1-EndoSequence BC Sealer, Group 2-MTA FillApex sealer, Group3-Apexit Plus sealer & Group 4-AH Plus sealer and obturated using cold lateral compaction technique. After two weeks, 1±0.1mm thick slice of each radicular third of specimens was subjected to push-out testing with modified and standardised plunger: base orifice size ratio for each slice and bond strength calculated. Subsequently the slices were observed under stereomicroscope for failure mode analysis. **Results**: Results showed that AH Plus sealer had the highest overall bond strength followed by EndoSequence BC sealer and MTA FillApex while as Apexit Plus had lowest bond strength. Bond strength of all sealers reduced from coronal to apical direction except in EndoSequence BC sealer which showed better strength in critical apical third. Higher bond strength values were obtained due to modified relation of plunger with base orifice size. **Conclusion**: Bond strength of all sealers tested except EndoSequence BC reduces in apical direction and is impacted by plunger: base orifice size ratio.

Keywords: AH Plus, Apexit Plus, EndoSequence BC, MTA FillApex, Push-Out Strength.

INTRODUCTION

The endodontic triad of debridement, thorough disinfection, and obturation for success in endodontic treatment that has been successfully used for more than five decades still forms major part of modern endodontic principles. An important tenet of endodontic obturation is effective sealing of root canal system to prevent apical and coronal leakage.[1] But the gutta-percha (GP) routinely used for obturation does not seal by itself due to poor adhesiveness of gutta-percha to dentinal wall and is therefore, used in conjunction with root canal sealers to accomplish this goal.[2,3]

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One highly desirable feature of an ideal endodontic sealer is adhesion.[4] There is no standard method to measure the adhesion of a sealer to the root dentin; therefore, the adhesion potential of the root filling material is commonly tested using microleakage and bond strength tests. Although there appears to be no direct correlation between sealer bond strength and clinical success, it is likely that obturation materials with low bond strength will show more defects between the dentin surface and the sealing material because of polymerization stress. These disruptions may lead to re-infection and failure of the endodontic treatment.[5] Also, the strong bond between the root canal sealer and the root dentin is essential for maintaining the integrity of the sealer-dentin interface during the preparation of post-spaces and during tooth flexure.[6]

The push-out test is commonly used to evaluate bond strength between the sealer and canal walls because tensile bond strength is not appropriate for use with intracanal filling materials due to high percentage of premature bond failures and the large variation in test results.[7] A number of studies have been conducted using push-out test setup to determine the dislocation resistance of different intracanal sealers, with many lacking the benefit of simulating clinical procedures in natural canals.[8-10] Perusal of literature showed that no study has been conducted where recommendations for base orifice size, as well as ratio of plunger diameter to intra canal material width have been incorporated in the study design. So, the purpose of this study was to compare push-out bond strength of recently made available Bioceramic sealer (EndoSequence BC) with MTA-based sealer (MTA Fillapex) and calcium hydroxide-based sealer (Apexit Plus) using epoxy resin-based sealer (AH Plus) as reference material for comparison and also to evaluate the impact of the base orifice size and plunger diameter on bond strength.

MATERIALS AND METHODS

Hundred freshly extracted human mandibular premolars were disinfected and decoronated below cemento-enamel junction using water cooled diamond disc so that the length of all roots was adjusted to 14mm. To standardize the working length, a size #15K file (Dentsply, Maillefer, Ballaigues, Switzerland) was inserted into the canal until it could be visualized at the apical foramen. The working length was determined by subtracting 1mm from this length. Glide path preparation was done by instrumentation of canals with K-Flexofiles (Dentsply Maillefer, Ballaigues, Switzerland) up to size #20. Instrumentation was completed by use of Protaper rotary files (Dentsply, Maillefer, Ballaigues, Switzerland) in the crown down technique as per manufacturer's recommendations upto master apical file of #F3. Irrigation with 5ml of 5% sodium hypochlorite (NaOCl) preceding the use of each instrument was performed using side vented close ended needles (Canal Clean, Biodent Co. Ltd. Korea). Finally, the canals were irrigated with 5ml of 17% ethylenediaminetetraacetic acid (Prevest Denpro, Jammu, India) for 3 minutes, followed by 5mL of 5% NaOCl for smear layer removal. All the canals were rinsed with 10mL of 0.9% sterile saline (Denis Chem Lab, India) for washout and neutralization of residual chemicals and dried with F3 absorbent paper points (Pearl Dent Co. Ltd., Korea).

The roots were randomly divided into four groups, 25 roots per group (http://www.random.org) and obturated using one of the sealers as follows:

Group 1: Bioceramic Sealer (EndoSequence BC, Brasseler, USA)

Group 2: MTA –based sealer (MTA Fillapex Angelus, Londrina, Brazil)

Group 3: Calcium hydroxide-based sealer (Apexit Plus, Ivoclar Vivadent, Liechtenstein)

Group 4: AH Plus sealer (Dentsply, Detrey, Germany).

EndoSequence BC sealer group

The sealer was used as per manufacturer's instructions. The intracanal tip was placed in coronal third of canal and small amount of sealer dispensed (1 Calibration marking per canal) by compressing the plunger of the syringe. Then, the master gutta-percha cone was lightly coated with sealer and slowly inserted into the canal till working length. Additional gutta-percha accessory cones were placed in the canal until #25 finger spreader no longer penetrated more than 2-3mm into the canal. Excess gutta-percha was seared-off at the orifice level and lightly condensed with hand pluggers.

MTA Fillapex group

Equal amount of base and catalyst paste were mixed and dispensed using automixing tip. Mixed sealer was picked up with a lentulo spiral and spinned into the canal. Master gutta-percha cone of size #30 was placed into the canal upto the working length. Accessory gutta-percha cones were placed in the canal until #25 hand spreader no longer penetrated more than 2-3mm into the canal. Excess gutta-percha was seared-off at the orifice level and lightly condensed with hand pluggers.

Apexit Plus Group

Equal amounts of base and activator were automatically mixed and dispensed during extrusion from double push syringe of Apexit Plus. Mixed material was spinned into the canal and specimens obturated using lateral compaction as in MTA Fillapex group.

AH Plus Group

Equal volume units (1:1) of paste A and paste B of AH Plus root canal sealer were mixed on mixing pad using a metal spatula till homogeneous consistency was achieved. Light coat of sealer was applied by lentulo spiral advanced up to apex and withdrawn very slowly while running to avoid the formation of air bubbles and overfilling of the canal. The canals were then obturated similar to other groups.

After the root canal filling procedure the cervical opening was sealed with temporary restorative material (Prime Dental Products, India). A radiograph was made for each root to verify the absence of voids. The specimens were stored in incubator (Macro Scientific Works, Delhi, India) for 2 weeks at 37°C in 95% humidity to allow sealers to set.

Push – out test

After 2 weeks, the roots were centrally placed in a cylindrical mold of 1cm diameter and embedded vertically in acrylic resin (Samit products, New Delhi, India). The specimens were stored at room temperature for 24 hours. Each root was horizontally sectioned into 1.0 ± 0.1mm thick slices using a diamond disc under continuous water cooling. Each slice was evaluated with a digital calliper (Mitu, Japan) to an accuracy of 0.01mm. Slices with voids in the filling material or non circular shape of filling material were excluded from the study. Three slices from each root corresponding to coronal, middle and apical third were selected. The diameter of the coronal and apical end of intracanal filling material was determined with a digital calliper and 6× magnifications of surgical loupes (Heine LED Loupes, Israel) measured to the nearest hundredth. Apical and coronal end of each specimen was marked with indelible marker. The selected samples were placed on top of metallic jig with base orifice to allow the filling material to fall through after failure of the bond. The push out test was performed using a universal testing machine (HEICO, New Delhi, India) at a crosshead speed of 1mm/min. Five different sized plungers with diameter of 0.35mm, 0.5mm, 0.65mm, 0.8mm and 1.0mm were used. Each sample was loaded in apical to coronal direction to avoid any interference because of the root canal taper during push-out test. Plunger size that provided 75 to 80% coverage of intracanal material without touching the circumferential dentin and base orifice diameter of jig close in size (0.7, 1.0, 1.3, 1.6 and 2mm), but slightly larger than diameter of intracanal material was selected for each specimen. The maximum load applied to the filling material before debonding occurred was recorded in Newton’s (N). For each section, bond strength value (MPa) was calculated by dividing the failure load (N) by the interface area between the root canal filling and dentine using the following formula.[11]

Bond strength = $\frac{F}{\pi(r+R)s}$

Where the slant height, s = $\sqrt{(R-r)^2+h^2}$

R and r being coronal and apical radius of filling material corresponding to bases of frustum and h is the slice thickness.

Failure analysis

After the push-out test, the specimens were analyzed using a stereomicroscope (Kyowa Getner, Japan) at 40× magnification to evaluate the failure modes (adhesive, cohesive and mixed) according to the displacement of the sealer from the specimen. Adhesive failures were observed when the dentin surface was completely without a sealer, cohesive failures occurred within the filling material when the dentin surface was completely covered by the sealer, and mixed failures occurred when both adhesive and cohesive modes (dentin surface partially covered by the sealer) were verified.

Statistical Analysis

Statistical software SPSS (version 20.0) and Microsoft Excel were used to carry out the statistical analysis of data. Descriptive statistics of data including mean, standard deviation and 95% Confidence Interval for mean were reported. The normality test of Kolmogorov-Smirnov (K-S) and Levene’s variance homogeneity test were applied to the data. The data were normally distributed, and there was homogeneity of variance amongst the groups. Analysis of variance (ANOVA) and the post hoc Holm-Sidak test were used for analysis of data. A P-value of less than 0.05 was considered statistically significant.

RESULTS

Table 1: Mean and Standard Deviation (SD) and the 95% Confidence Intervals of the push-out strength of sealers (MPa).

	Mean	SD	95% Confidence Interval for Mean		P-value
EndoSequence BC	7.01	3.70	6.14	7.88	<0.001*
MTA Fillapex	5.24	1.62	4.86	5.62	
Apexit Plus	4.94	2.14	4.44	5.44	
AH Plus	7.63	2.80	6.97	8.29	

The mean bond strength values of sealers showed that AH Plus Sealer had the highest bond strength followed by Endosequence BC sealer and MTA Fillapex sealer while as Apexit plus sealer had the least bond strength [Table 1]. No significant differences were observed amongst the push-out strengths obtained from different locations in Endosequence BC sealer. In case of MTA Fillapex significant differences in bond strength were found at all levels with highest bond strength at coronal and lowest at apical third (P<0.001). Apexit Plus and AH Plus showed highest bond strength at coronal third and lowest at apical third with insignificant difference in bond strength between coronal and middle third while as apical third had significantly lower bond strength than middle (P<0.001) and coronal (P<0.001) third [Table 2].

Comparison of bond strength between different sealers at each root third [Table 3] showed that at coronal level significantly lower bond strength was shown by EndoSequence BC sealer MTA Fillapex and Apexit Plus as compared to AH Plus. At mid-root level only MTA Fillapex (P<0.001) and Apexit Plus (P=0.003) showed significantly lower bond strength as compared to AH Plus. At apical third EndoSequence BC sealer showed highest bond strength followed by AH Plus, MTA Fillapex and Apexit Plus with statistically significant differences in bond strength between each other except between MTA Fillapex and AH Plus Sealer (P=0.798).

Table 2: Push-out bond strength (MPa) to root dentine at each root third.

		Mean	SD	95% Confidence Interval for Mean		P-value
EndoSequence BC	Coronal	7.52	3.04	6.24	8.81	0.328
	Middle	7.43	5.06	5.29	9.57	
	Apical	6.09	2.48	5.04	7.13	
MTA Fillapex	Coronal	6.36	2.03	5.51	7.22	<0.001*
	Middle	5.27	0.87	4.90	5.64	
	Apical	4.10	0.74	3.78	4.41	
Apexit Plus	Coronal	5.91	2.04	5.05	6.78	<0.001*
	Middle	5.89	1.95	5.06	6.71	
	Apical	3.01	0.54	2.78	3.24	
AH Plus	Coronal	9.48	2.44	8.45	10.51	<0.001*
	Middle	8.85	1.65	8.15	9.54	
	Apical	4.58	0.86	4.21	4.94	

Table 3: Bond strength at different levels among various groups.

		Mean	SD	95% Confidence Interval for Mean		P-value
Coronal	EndoSequence BC	7.52	3.04	6.24	8.81	<0.001*
	MTA Fillapex	6.36	2.03	5.51	7.22	
	Apexit Plus	5.91	2.04	5.05	6.78	
	AH Plus	9.48	2.44	8.45	10.51	
Middle	EndoSequence BC	7.43	5.06	5.29	9.57	<0.001*
	MTA Fillapex	5.27	0.87	4.90	5.64	
	Apexit Plus	5.89	1.95	5.06	6.71	
	AH Plus	8.85	1.65	8.15	9.54	
Apical	EndoSequence BC	6.09	2.48	5.04	7.13	<0.001*
	MTA Fillapex	4.10	0.74	3.78	4.41	
	Apexit Plus	3.01	0.54	2.78	3.24	
	AH Plus	4.58	0.86	4.21	4.94	

Table 4: Modes of failure.

Group	Failure mode		
	Cohesive	Adhesive	Mixed
EndoSequence BC (n=75)	45	9	21
MTA Fillapex (n=75)	45	6	24
Apexit Plus (n=75)	30	21	24
AH Plus (n=75)	57	-	18

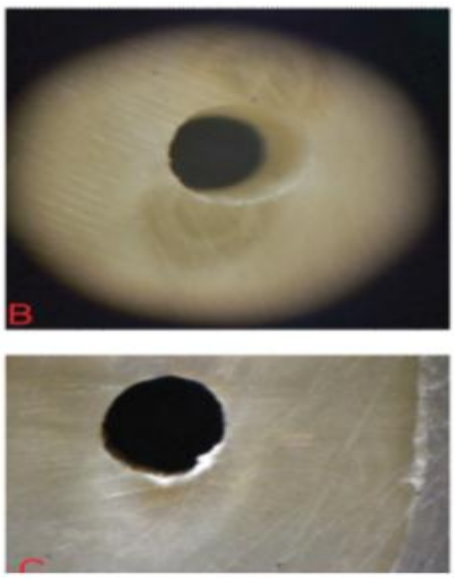

Figure 1: Stereomicroscopic images showing (A) Cohesive failure, (B) Adhesive failure and (C) Mixed failure.

Failure mode analysis [Table 4] showed that cohesive failures mostly occurred in all groups followed by mixed failures and very low percentage of adhesive failures except in Apexit plus in which more number of adhesive failures and lesser cohesive failures were observed as compared to other groups. In case of AH Plus failure mode was predominantly cohesive with none of adhesive failures observed [Figure 1].

DISCUSSION

Adhesion, which is the capacity of a root canal sealer to adhere to the root canal walls, has been studied since the development of experimental model proposed by Grossman and improved by Ostravik.[4,12] Some variables interfere with the outcome and understanding of sealer adhesion to root canal walls according to the employed methodology, treatment of dentine surface and type of material. Earlier studies on bond strength of sealers submitted different surfaces for bond strength testing and bond strength was measured through the conventional tensile test or shear test on external dentinal surface.[13-15]

Since the adhesive capacity of internal radicular dentin is ambiguous and depends on the pattern of dentinal tubules, which differs not only from one tooth to another but can also differ within the same tooth. Thus, Gesi et al,[16] introduced the thin slice push-out test for measuring interfacial strength of root canal sealers. Since then, number of studies were conducted on bond strength of sealers with large variation in methodology; canals prepared with burs and filled with sealers alone or long root cylinders were used during push-out test setup.[8,11,17] Also artificial canals were prepared in longitudinal tooth slabs of radicular dentine or cross sections of radicular dentine and obturated with sealers only.[6,9] A difficulty with the later procedure is that tubule density and orientation do not mimic the natural canal, and the method may have no advantages over conventional micro-tensile and micro-shear bond testing.

Earlier studies on push-out bond strength used the same punch and base to test the bond strength on slices from different root thirds, despite the fact that the diameter of root canal decreases towards the apical direction. To overcome this problem Stiegemeier et al,[18] utilized three different sized plungers to closely match the diameter of the root filling materials, obtained from different root levels. Chen et al,[19] suggested that plunger diameter should be smaller than 0.85 times the filler diameter while as Pane et al,[20] noted little difference in push-out strength above the punch diameter of at least 70% of the canal. A similar finding was reported by Nagas et al, who reported that plunger diameter has a significant effect on push-out bond strength.[21] Recently Zanatta et al showed that diameter of orifice base has a more significant influence on the stress distribution than did the punch diameter.[22] Base: punch ratio of around 1.7 was considered best for push-out test. For this reason, both factors should be taken into account during push-out experimental tests.

In this study five different plungers (0.35mm, 0.5mm, 0.65mm, 0.8mm and 1.0mm) and five different base orifice sizes (0.7mm, 1.0mm, 1.3mm, 1.6mm and 2mm) were used in order to determine the effect of base orifice size and plunger diameter relation on push-out bond strength of sealers along with standardization of other previously used methodological variables. The plunger that provided 75 -80% coverage of intracanal material without touching dentinal walls was used for each sample. Correspondingly base orifice size of twice the plunger diameter was used in a manner that samples were centralized on base orifice and plunger was centralized over the intracanal material with the aid of 6× magnification of surgical loupes (Heine LED Loupes, Israel). Each sample was loaded in an apical to coronal direction to avoid any interference because of root canal taper during push-out test reducing the contribution of frictional sliding to the dislocation resistance. The same gutta-percha core material was used for all groups since the elastic modulus of filling material has effect on the push-out bond strength.[19,20]

Results obtained in the present study indicated that the push-out bond strength values were significantly affected by the materials tested ($P<0.001$). The mean bond strength of AH Plus was significantly higher than other groups except EndoSequence BC sealer group. A statistical ranking for bond strength tests was obtained as follows:

AH Plus ≥ EndoSequence BC > MTA Fillapex > Apexit Plus.

Statistical comparison between AH Plus and Endosequence BC Sealer showed similar bond strength. The results are in agreement with Sagsen B et al,[23] who observed that AH Plus and iRoot SP had significantly higher bond strength values than MTA Fillapex with no significant difference between AH Plus and iRoot SP. Emre Nagas et al,[24] reported significantly higher bond strength of iRoot SP bioceramic sealer as compared to AH Plus. However, in their study a single plunger was used for push-out of all samples obtained from coronal to apical regions and may be the reason of variability of results. Oliveria et al,[25] found that bond strength of iRoot SP and MTA Fillapex was significantly lower when compared to AH Plus and MTA cement. The discrepancy among the studies can be explained on the variability between the experimental designs (e.g. filling techniques, plunger diameter, and/or anatomical conditions).

The relatively high bond strength of AH Plus may be explained by its ability to form covalent bonds between its open epoxide ring and any exposed amino group in collagen.[8] Its flowability and long setting time are beneficial to tag formation and might be superior in mechanical bonding to micro-irregularities present in the dentin.[26]

Endosequence BC is a new premixed bioceramic sealer with principle constituents of calcium phosphate, calcium silicate, zirconium oxide and calcium hydroxide.[27] The polymerization shrinkage stresses that develop along the root dentine–sealer interface might result in debonding of the sealer,[28] Zhang et al,[29] reported that iRoot SP (also known as EndoSequence BC) does not shrink during setting and hardens in the presence of water. The manufacturers suggest that this sealer has features such as osteoconductivity, hydrophilicity, adhesiveness and chemical bonding to root canal dentinal walls.

Results of our study also showed that MTA Fillapex had significantly lower bond strength than AH Plus and EndoSequence BC sealer. Similar results were obtained in a study by Sonmez et al[30] who compared the push-out bond strength of MTA Fillapex with ProRoot MTA and AH Plus. The results of this study are also in accordance with several recent studies which reported lower bond strength of MTA Fillapex in comparison to AH Plus.[9,23-25] The lower bond strength of MTA Fillapex can be explained on the basis of higher percentage of gap containing regions observed due to lower adaptation of MTA Fillapex to canal walls because sealers containing salicylate in their composition show initial volumetric shrinkage during setting reaction,[31] increasing the contraction factor.[32] On the other hand, epoxy resin sealers (AH Plus) are considered to have low contraction factor and some degree of expansion during the setting reaction as in Endosequence BC sealer.

Apexit plus showed the least bond strength among the groups. The results are in agreement with the study of Haragushiku GA et.al,[17] in which Apexit Plus showed lowest bond strength and AH Plus showed highest bond strength. Our result also corroborate with the previous laboratory studies of Gopikrishna et al,[33] and Eymirli et al,[34] who found that the bond strength of AH Plus was higher than Apexit Plus. It has also been earlier reported that Apexit presents low adhesion to dentin,[12,14] which is justified by the low cohesion of its molecules although sealer penetration into the dentinal tubules may occur in the absence of smear layer.[35]

Statistical analysis showed that both the type of sealer and root third had significant impact on push-out bond strength values. Push-out bond strength was highest in the coronal and lowest in the apical third. Bond strength was significantly lower in apical third of all groups as compared to middle and coronal specimens with the exception of Endosequence BC sealer in which reduction in bond strength from coronal to apical was insignificant. The results are in similarity with those of Neelakantan et al,[36] Martins et al,[37] Araujo et al,[38] and Topcuoglu et al.[39] The explanation for this may be the lesser number and smaller diameter of dentinal tubules in the apical region, which is responsible for the adhesion of filling material to the dentine walls.[40] Moreover, the limited accessibility of apical areas to the irrigating solutions to deplete the smear layer impairs the penetration of sealers into the dentinal tubules and reduces the contact between the filling material and root dentin walls.[41,42] The higher bond strength of Endosequence BC sealer in the apical region may be due to higher flow of Endosequence BC sealer as compared to AH Plus,[43] due to extremely low particle size of Endosequence BC that allows the sealer to fill the spaces of difficult access.[44] Also hydroxyapatite that is co-precipitated within the calcium silicate hydrate phase produces a composite-like structure, reinforcing the set cement.[44]

In the present study, the mode of bond failure was mainly cohesive followed by mixed failures for all groups. This finding is in accordance with Huffman et al,[6] who showed that the failure mode for a calcium silicate-based sealer was cohesive after a 7 day storage period. Furthermore, Eldeniz et al,[45] revealed that the failure mode appeared to be predominantly cohesive within the sealer for AH Plus in the presence or absence of smear layer. Moreover, Shokouhinejad et al,[46] showed that the mode of failure was mainly cohesive for both EndoSequence BC sealer and AH Plus.

Higher bond strength value of AH Plus in present study was confirmed by the presence of only cohesive and mixed failure of the sealer after push-out test. Similar results were observed in the study of Vilanowa et al.[47] In the Apexit Plus group considerably higher numbers of adhesive failures were observed than other groups that relates well to the lower bond strength obtained in the push-out test.

Overall, considerably higher bond strength values were obtained in the present study for all groups as compared to the previous studies that may be attributed to the improved relation of punch: base orifice ratio in this study.

CONCLUSION

Within the limitations of this study it can be concluded that: -

1. Bond strength of AH Plus and Endosequence BC is significantly better than MTA Fillapex and Apexit Plus.
2. Bond strength of all sealers except EndoSequence BC sealer is less, in the critical apical third of root canal.

3. The base orifice size has an impact on the bond strength measurements in the push-out test design.

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