

COMPARATIVE EVALUATION OF DENTIN MOISTURE EFFECT ON BOND STRENGTH AND ADHESIVE INTERFACE OF TWO EPOXY RESIN AND TWO CALCIUM SILICATE BASED ROOTCANAL SEALERS – AN IN-VITRO STUDY

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ABSTRACT

To compare and evaluate effect of three root canal drying protocols on push-out bond strength (PBS), failure modes and interfacial adaptation of epoxy resin (AH Plus, AD Seal) and calcium silicate-based (Bio-C, AH Plus Bioceramic) sealers. **Materials and Methods:** Ninety-six extracted single-rooted mandibular premolars were decoronated, prepared with ProTaper Next up to X3, irrigated and divided into four groups (n=24): Group A-AH Plus, B-AD Seal, C-Bio-C, D-AH Plus Bioceramic. Each group was further subdivided (n=8) by drying protocol: Dry (White Mac tip + flexible capillary tip + paper points), Slightly moist (White Mac tip + capillary tip only), Wet (White Mac tip + single paper point). Obturation was performed with single-cone technique using corresponding sealer, access sealed with GIC. Samples were stored at 37°C and 95% humidity for 3 months, then sectioned into 1-mm slices from cervical, middle and apical thirds. PBS was measured with universal testing machine, failure modes with stereomicroscope (adhesive/cohesive/mixed), and bond adaptation with scanning electron microscope.

Statistics: One-way ANOVA with Tukey's post hoc for PBS; chi-square for failure modes and adaptation; significance $p < 0.05$.

Results: Epoxy resin sealers showed highest PBS in dry canals across all thirds ($p < 0.001$), but decreased significantly in slightly moist and wet conditions. Calcium silicate sealers showed higher PBS in slightly moist canals ($p < 0.001$) and lowest in dry and wet conditions. Adhesive failures predominated overall, especially epoxy resin sealers in dry canals. Wet canals showed more cohesive/mixed failures and Poor to No adaptation ($p = 0.005$), while dry canals with epoxy resin sealers showed Good to Reasonable adaptation ($p = 0.04$).

Conclusion: Drying protocol significantly influences sealer-dentin bond. Dry canals favor epoxy resin sealers; controlled slightly moist canals favor calcium silicate sealers. Excessive moisture impairs bonding and adaptation for all sealers, emphasizing need for sealer-specific tailored drying protocol.

KEYWORDS: Dentin moisture, root canal sealers, push-out bond strength, Epoxy resin-based sealer, Calcium Silicate-based sealer

1. INTRODUCTION

Successful endodontic treatment relies on eradication of microorganisms and establishing a bacterial-tight seal to prevent coronal or apical leakage.¹ Root canal sealers used with gutta-percha achieve a hermetic seal. Their ability to penetrate dentinal tubules is clinically significant as it enhances adaptation, creates micromechanical interlocking,² and helps eliminate residual bacteria, reducing reinfection risk.³ An ideal sealer should exhibit excellent sealing ability, biocompatibility, dimensional stability, insolubility, and slow setting time.^{3,1}

Sealers available include resin-based, silicone-based, calcium silicate-based, bioceramic-based, MTA-based, calcium hydroxide-based, and zinc oxide-eugenol-based sealers. Among these, epoxy resin-based sealers remain most widely used due to superior physicochemical properties and biocompatibility.⁴

AH Plus is an epoxy resin-based sealer considered the gold standard for its high bond strength to dentin, adequate radiopacity, good flow, dimensional stability and low solubility.⁵

ADseal is a resin-based sealer with optimal biocompatibility, radiopacity and low solubility, maintaining long-term sealing stability. Unlike other cements, calcium silicate-based cements are hydrophilic and moisture-tolerant, which enhances sealing ability. 6

They are biocompatible, bioactive (inducing hard tissue deposition via hydroxyapatite formation), radiopaque, show expansion after setting, and have antibacterial properties.7,8

Bio-C Sealer is calcium silicate-based composed of calcium silicate, calcium aluminate, calcium oxide, zirconium oxide, iron oxide, and silicon dioxide, and its setting depends on moisture in dentinal tubules.9

AH Plus Bioceramic is a new premixed sealer containing only tricalcium silicate as reactive component13

Sealer adhesion is affected by moisture condition of canals, and drying before obturation increases adherence.10,11 However, achieving uniform residual moisture is challenging due to regional variations in tubule density and limited penetration of irrigants apically.12 Paper points are most commonly used for drying, but residual moisture may persist in isthmuses and lateral canals.13

To enhance drying, techniques like isopropyl alcohol 11,12,14 and negative aspiration systems like EndoVac12,15 have been evaluated. In present study capillary and white mac tips with vacuum adapters are introduced to improve fluid aspiration.13 Push-out bond strength (PBS) using Universal Testing Machine (UTM) evaluates resistance of filling materials to dislodgement from dentinal walls. 16

Optimal PBS enhances tensile strength, prevents microleakage, stabilizes filling, and improves clinical service. Failure modes (Adhesive, Cohesive, Mixed) are analyzed with stereomicroscope 11,13 and Scanning Electron Microscopy (SEM) evaluates adhesion interface quality. 17

This study aims to evaluate effect of dentin moisture on bond strength and adhesive interface of two epoxy resin (AH Plus, ADseal) and two calcium silicate-based sealers (Bio-C, AH Plus Bioceramic) using three drying protocols (Dry, slightly moist, Wet), as these sealers have not been tested previously for these parameters.

The null hypotheses were:

- a) Dentin moisture conditions do not influence the push-out bond strength of the tested sealers.
- b) Dentin moisture conditions do not affect the quality of sealer-dentin adaptation.

MATERIALS AND METHOD:

The present study was conducted in the Dept. of Conservative Dentistry and Endodontics, VIDS&RC. The study protocol was approved by institutional ethical review board – Ref No: VIDS/IEC/PG/APP2024/134.

Inclusion Criteria:

Intact human single rooted mandibular premolar teeth with single canal, Caries free, Un restored with minimal wear facets, Closed Root apex

Exclusion Criteria

Morphological defects, Restored teeth, previous endodontic treatment, Teeth with dilacerated roots, Calcified canals.

Sample preparation:

96 extracted single-rooted premolars (orthodontic/periodontal extraction) were collected from Dept. of Oral & Maxillofacial Surgery. Calculus was removed with ultrasonic scaler, immersed in 5.25% NaOCl for 10 min, and stored in 0.9% saline. Buccolingual and mesiodistal radiographs confirmed single canal.

Teeth were decoronated to 15 mm standardized length using diamond disc with water coolant. Working length (WL) was established 0.5 mm short of apex where #10 K-file was visible. Access prepared with round bur (size 4). Instrumentation was done with X-Smart motor using ProTaper Next up to X3 (30/.07). Irrigation protocol: 6 ml 3% NaOCl + 6 ml 17% EDTA + 6 ml NaOCl activated with ultrasonic tip (piezo unit) for 3 cycles x 20 sec. Final rinse with 5 ml distilled water.

Experimental Groups:

Roots randomly divided into 4 groups (n=24) based on sealer: Group A: AH Plus, Group B: AD Seal, Group C: Bio-C , Group D: AH Plus Bioceramic. Each group further divided into 3 subgroups (n=8) based on drying protocol: Subgroup 1 - Dry: Blot dried with 2-mm suction tip (White Mac tip, Ultradent) for 5 sec at orifice + aspiration with 0.36-mm capillary tip (Ultradent) in low vacuum with up-down motion for 5 sec + ProTaper Next X3 paper points at WL until last point visually dry. Subgroup 2 - Slightly Moist: White Mac tip + capillary tip aspiration as above, without paper points. Subgroup 3 - Wet: White Mac tip for 5 sec + insertion of ProTaper Next X3 paper point at WL.13

Obturation: Sealers delivered as per manufacturer instructions. Single-cone obturation with ProTaper Next gutta-percha X3 using up-down motion 3 times for sealer penetration. Access sealed with GIC. Samples stored at 37°C, 95% humidity for 3 months. Roots fixed in acrylic resin and sectioned with low-speed diamond disc under coolant to obtain 2 slices (1.5 mm thick) from each third (cervical, middle, apical). First slice used for push-out and stereomicroscope analysis; second slice for SEM. Evaluation:1. Push-out Bond Strength (UTM) 14,16 Performed using Universal Testing Machine. Load applied on apical side in apical-coronal direction to dislodge filling. Cylindrical plunger 0.4 mm diameter at cross-head speed 1 mm/min. Force at debonding recorded. PBS calculated as: Surface Area (A) = $2\pi r \times h$ (r=radius, h=thickness)

Bond Strength (P) = F/A (F=force, A=area)2. Failure Mode Analysis (Stereomicroscope):14

Evaluated at 50x magnification and classified (% basis):

Adhesive: Debonding at sealer-dentin interface, **Cohesive:** Fracture within dentin or filling material, **Mixed:** Combination of adhesive and cohesive 3.

Bond Interface Analysis (SEM):13

Two roots (6 slices) per subgroup randomly selected. Interface evaluated at 3 equidistant points for sealer adaptation, voids and gaps. Blinded evaluation by 2 calibrated endodontists scored as: Good: No gaps, Reasonable: Small gaps <1 µm, Poor: Gaps 1-10 µm, Without adaptation: Gaps >10 µm

Statistical Analysis:

One-way ANOVA followed by Tukey's post hoc test was used to compare the mean push-out bond strength among four sealer Groups (Group A: AH Plus, Group B: AD Seal, Group C: Bio-C Sealer and Group D: AH Plus Bioceramic Sealer) across different root canal regions (cervical, middle, apical) and three different drying protocols (Dry, slightly moist, Wet). Additionally, Chi-square tests were used to compare the distribution of failure modes and bond interface adaptation across the four Groups and drying protocols. The level of significance was set at $p < 0.05$.

RESULTS

Push-out Bond Strength Analysis: Table 1, 2, 3, Fig 1&2

Dry Root Canal Condition

At Cervical, Middle & Apical region, Group A demonstrated the highest bond strength followed by Group B, Group C and Group D. The differences among the groups were statistically significant ($p < 0.001$). Intergroup comparisons showed that the PBS Value among the groups were statistically significant at the entire region ($p < 0.05$) except for Group B & D at Middle and Apical third. (Table 1)

Slightly Moist Root Canal Condition

At the Cervical and Middle region, Group D demonstrated the highest bond strength value followed by Group C, Group A & Group B. In the apical region, Group D demonstrated the highest bond strength followed Group A, Group C & Group B. The differences among the groups were statistically significant ($p < 0.001$). The PBS Value differences among the groups were statistically significant at all the regions ($p < 0.05$) except for Group A, B & D at Apical third. (Table 2)

Wet Root Canal Condition

In Cervical, Middle and Apical region, Group A demonstrated the highest bond strength followed by Group D, Group C & Group B. The differences among the groups were statistically significant ($p < 0.001$). The PBS Value differences among the groups were statistically significant at all the regions ($p < 0.05$). (Table 3)

Table No. 1 Comparison of mean Push-out Bond Strength (Mpa) Between 4 Groups under Dry Root Canal Condition							
Regions	Groups	N	Mean	SD	Min	Max	p-value
Cervical	Group A	8	3.491	0.056	3.40	3.57	<0.001*
	Group B	8	2.894	0.027	2.85	2.93	
	Group C	8	1.701	0.015	1.68	1.72	
	Group D	8	1.600	0.076	1.50	1.70	
Middle	Group A	8	3.103	0.167	2.98	3.50	<0.001*
	Group B	8	1.921	0.074	1.87	2.10	
	Group C	8	1.118	0.010	1.10	1.13	
	Group D	8	1.800	0.076	1.70	1.90	
Apical	Group A	8	5.180	0.347	4.95	6.02	<0.001*
	Group B	8	2.015	0.024	1.98	2.05	
	Group C	8	1.235	0.012	1.22	1.25	
	Group D	8	1.900	0.076	1.80	2.00	

* - Statistically Significant

Table No. 2 Comparison of mean Push-out Bond Strength (Mpa) Between 4 Group under Slightly Moist Root Canal Condition							
Regions	Groups	N	Mean	SD	Min	Max	p-value
Cervical	Group A	8	2.001	0.033	1.95	2.05	<0.001*
	Group B	8	1.605	0.016	1.58	1.63	

	Group C	8	3.001	0.033	2.95	3.05	
	Group D	8	3.363	0.106	3.20	3.50	
Middle	Group A	8	1.769	0.175	1.68	2.20	<0.001*
	Group B	8	1.109	0.118	1.05	1.40	
	Group C	8	2.005	0.016	1.98	2.03	
	Group D	8	2.513	0.083	2.40	2.60	
Apical	Group A	8	2.798	0.035	2.75	2.85	<0.001*
	Group B	8	1.114	0.011	1.10	1.13	
	Group C	8	2.201	0.018	2.18	2.23	
	Group D	8	2.725	0.104	2.60	2.90	

* - Statistically Significant

Table No.3 Comparison of mean Push-out Bond Strength (Mpa) Between 4 Groups under Wet Root Canal Condition							
Regions	Groups	N	Mean	SD	Min	Max	p-value
Cervical	Group A	8	1.155	0.027	1.12	1.2	<0.001*
	Group B	8	0.970	0.013	0.95	0.99	
	Group C	8	0.999	0.018	0.97	1.02	
	Group D	8	1.125	0.016	1.1	1.15	
Middle	Group A	8	1.005	0.016	0.98	1.03	<0.001*
	Group B	8	0.600	0.013	0.58	0.62	
	Group C	8	0.698	0.010	0.68	0.71	
	Group D	8	0.835	0.012	0.82	0.85	
Apical	Group A	8	1.685	0.024	1.65	1.72	<0.001*
	Group B	8	0.700	0.013	0.68	0.72	
	Group C	8	0.725	0.012	0.71	0.74	
	Group D	8	0.900	0.013	0.88	0.92	

* - Statistically Significant

Group A: AH plus sealer; Group B: AD seal sealer; Group C: Bio-C sealer & Group D: AH plus Bio ceramic sealer

Failure Mode Analysis: Table 3 Fig 3

Failure mode Analysis of four different sealers (Group A, B, C & D) with different root Canal Drying protocols at different regions (Cervical, Middle & Apical) were evaluated under stereomicroscope under the following criteria. (Table 4)

Adhesion failure: Debonding at the bonding interface Cohesive failure: Fracture within the dentin structure or root filling material Mixed failure: A combination of adhesive and cohesive failure.

Dry Root Canal Protocol

At Cervical and Middle third regions there was a statistically significant difference ($p=0.001$) between Adhesive, Cohesive & Mixed failures except at Apical region with no significant difference.

Slightly Moist Root Canal Protocol

There was no significant difference noted at Cervical, Middle & Apical regions between Adhesive, Cohesive, and Mixed failures.

Wet Root Canal Protocol

Cervical region showed statistically significant difference between Adhesive, Cohesive, and Mixed failures ($p=0.03$)

Over all, Failure mode analysis showed that under dry conditions, epoxy resin-based sealers (Groups A and B) predominantly exhibited adhesive failures, whereas calcium silicate-based sealers (Groups C and D) showed mainly cohesive and mixed failures in the cervical and middle thirds ($p < 0.05$). Under slightly moist conditions, failures were evenly distributed with no significant differences among groups or root thirds. In wet conditions, Group A showed increased adhesive failures and Group D showed more cohesive failures, particularly in the cervical region ($p = 0.03$). No significant differences were observed in the apical region across groups or moisture conditions.

Table no. 4 Percentage Distribution (%) of the Failure patters observed after push out bond strength test of 4 Groups Based on each Root Canal Drying protocols							
Region	Drying Protocols	Failure Modes (n=8)	Group A	Group B	Group C	Group D	p-value
			%	%	%	%	
cervical	Dry	Adhesive	100.0	75.0	0.0	12.5	0.001*
		Cohesive	0.0	0.0	50.0	37.5	
		Mixed	0.0	25.0	50.0	50.0%	
	Slightly Moist	Adhesive	75.0	50.0	0.0	25.0	0.54
		Cohesive	25.0	25.0	37.5	50.0	
		Mixed	0.0	25.0	62.5	25.0	
	Wet	Adhesive	75.0	37.5	37.5	0.0	0.03*
		Cohesive	12.5	37.5	37.5	75.0	
		Mixed	12.5	25.0	25.0	25.0	
Middle	Dry	Adhesive	37.5	62.5	12.5	25.0	0.02*
		Cohesive	37.5	25.0	50.0	62.5	
		Mixed	25.0	12.5	37.5	12.5	
	Slightly Moist	Adhesive	50.0	50.0	25.0	25.0	0.45
		Cohesive	12.5	25.0	37.5	62.5	
		Mixed	37.5	25.0	37.5	12.5	
	Wet	Adhesive	37.5	62.5	37.5	25.0	0.85
		Cohesive	37.5	0.0	50.0	37.5	
		Mixed	25.0	37.5	12.5	37.5	
Apical	Dry	Adhesive	37.5	50.0	25.0	12.5	0.20
		Cohesive	0.0	12.5	50.0	75.0	
		Mixed	62.5	37.5	25.0	12.5	
	Slightly Moist	Adhesive	25.0	50.0	25.0	37.5	0.43
		Cohesive	25.0	12.5	37.5	25.0	
		Mixed	50.0	37.5	37.5	37.5	
	Wet	Adhesive	25.0	62.5	12.5	37.5	0.11
		Cohesive	25.0	25.0	50.0	62.5	
		Mixed	50.0	12.5	37.5	0.0	

Group A: AH plus sealer; Group B: AD seal sealer; Group C: Bio-C sealer & Group D: AH plus Bio ceramic sealer

Bond Interface Adaptation: Table 4 Fig 4

Inter examiner reliability was found to be 0.8(kappa).

Bond interface adaptation was analyzed for each experimental Group with three different root canal drying protocols. It was found that there was no significant difference between the Epoxy Resin based sealer (Group A & B). However, adaptation ranged from Good to Reasonable (50-16.7%). For the calcium silicate-based sealers (Group C & D) statistically significant difference was observed ($p = 0.03$, $p = 0.006$) (Table 5).

Dry Root Canal protocol: A statistically significant difference was observed among the Groups (50-16.7%) ($p = 0.04$). Epoxy resin-based sealers (Group A and B) were dominated from Good to Reasonable Adaptations. While Group C and D were dominated with Poor to Without adaptations.

Slightly Moist Root Canal protocol: No statistically significant difference was found among the Groups ($p = 0.06$).

Wet root canal protocol: Statistically significant difference was observed among the Groups A-D ($p = 0.005$). None of the groups exhibited good adaptation, though adaptations were dominated with Reasonable to Without adaptation (16.7 - 100%). This suggests that moisture negatively affected bond interface quality across all the Groups.

Table no. 5: Percentage Distribution (%) of Bond Interface Adaptation types of 4 Groups with each Root Canal Drying protocols						
Drying Protocols	Failure Modes (n=6)	Group A	Group B	Group C	Group D	p-value
		%	%	%	%	
Dry	Good	50.0	0.0	0.0	16.7	0.04*
	Reasonable	16.7	16.7	0.0	0.0	
	Poor	33.3	50.0	33.3	83.3	
	Without Adaptation	0.0	33.3	66.7	0.0	
Slightly Moist	Good	33.3	0.0	0.0	0.0	0.06
	Reasonable	16.7	0.0	0.0	0.0	
	Poor	33.3	50.0	83.3	16.7	
	Without Adaptation	16.7	50.0	16.7	83.3	
Wet	Good	0.0	0.0	0.0	0.0	0.005*
	Reasonable	16.7	0.0	0.0	0.0	
	Poor	50.0	16.7	100.0	0.0	
	Without Adaptation	33.3	83.3	0.0	100.0	

* Statistically Significant, Group A: AH plus sealer; Group B: AD seal sealer; Group C: Bio-C sealer & Group D: AH plus Bio ceramic sealer

DISCUSSION

Endodontic treatment requires three-dimensional obturation with adequate apical and lateral seal to prevent bacterial proliferation and failure. Monoblock, a gap-free single-unit obturation, requires sealer adhesion to radicular dentin and gutta-percha via mechanical and chemical interlocking.²⁵ Manufacturers recommend pre-obturation desiccation to facilitate sealer infiltration and sealing efficacy, but without standardized guidelines for different sealer types.^{11,13}

Previous studies evaluated factors prior to obturation such as final irrigation regimens,¹ smear layer removal¹⁸ and calcium hydroxide elimination¹⁹, with epoxy resin and calcium silicate sealers. Current study attempted to identify optimal drying protocols for epoxy resin (AH Plus, AD Seal) and calcium silicate-based (Bio-C, AH Plus Bioceramic) sealers due to limited evidence.

Paper points traditionally dry canals by direct contact and capillary action, but residual moisture may persist in intricate anatomy acting as non-displaceable barrier hindering sealer penetration.¹¹ In present study, non-flexible White Mac tip and flexible capillary tip were used for suction; capillary tip flexibility enables safer use in curved/irregular canals, deeper apical penetration, and less fracture risk.¹³

This study assessed PBS of epoxy resin and calcium silicate sealers after different drying protocols. Push-out test is repeatable, easily interpreted, effective even for low bond strengths, and generates fractures parallel to dentin-sealer interface, hence clinically reliable.¹⁴ In our study, epoxy resin sealers (AH Plus, AD Seal) showed highest PBS under dry conditions across all thirds.

Similar results for AH Plus under dry conditions were reported previously when compared to calcium silicate sealers.^{5,13,15} Its hydrophobic nature prevents good adaptation to incompletely dried walls; in our study PBS of epoxy resin sealers decreased significantly in slightly moist and wet conditions. Superior performance is attributed to covalent bonding of epoxide rings with amino groups of dentinal collagen forming strong sealer-dentin interface,²⁰ low polarity of bisphenol A/F, highly cross-linked hydrophobic structure, water insolubility with minimal shrinkage,⁵ and excellent polymerization.²²

Under slightly moist conditions, calcium silicate-based sealers demonstrated higher PBS, consistent with previous studies comparing them to epoxy resin sealers.²³ They are hydrophilic (low contact angle) and require moisture for hydration setting.^{13,24} Hydration forms calcium silicate hydrate gel and calcium hydroxide with release of calcium/hydroxyl ions,²⁵ promoting bioactivity and mineral interlocking.²⁶ Excessive drying limits moisture, impairs hydration, reduces flowability and tubule penetration, while moisture improves rheology of bioceramics.⁸

Significantly lower PBS of calcium silicate sealers in dry and wet conditions is attributed to inadequate/excessive moisture interfering with setting and dimensional stability.^{9,28} Failure mode analysis by stereomicroscope qualitatively evaluates adhesive (sealer-dentin), cohesive (within sealer), or mixed failures to identify weakest link and adhesion quality.^{17,29} In our study, no significant difference in failure modes among drying protocols, with predominance of adhesive failures. SEM provides superior resolution, magnification and depth of field for detailed interface evaluation,^{43,44} detecting

inadequate tubule penetration, sealer-gutta-percha adhesion loss, voids and gaps.^{17,31} In our study, epoxy resin sealers showed Good/Reasonable adaptation in dry canals, aligning with higher PBS ^{32,33,34} while no significant difference was found among groups in slightly moist condition. No group showed good adaptation in wet condition with significantly lower PBS across all groups, indicating excessive moisture negatively affected interface quality due to water droplet entrapment disrupting bond.³³ Thus, excessive wetness reduced bond strength and adaptation; over-wet canals must be avoided. Findings emphasize need for standardized, reproducible drying protocol, as intracanal moisture cannot be accurately measured clinically. Tailoring drying to sealer type can improve outcomes and long-term success.

Limitations: In-vitro design does not reproduce dynamic clinical environment, functional stresses and aging; precise moisture quantification was not possible. PBS applies unidirectional force not simulating clinical loading, and SEM evaluates selected sections only. Variations in tubule anatomy and inclusion of only specific sealers/protocols limit generalizability, highlighting need for long-term clinical studies evaluating other calcium silicate sealers.

CONCLUSION

Within study limitations, it can be concluded that, drying protocol significantly influenced bond strength.

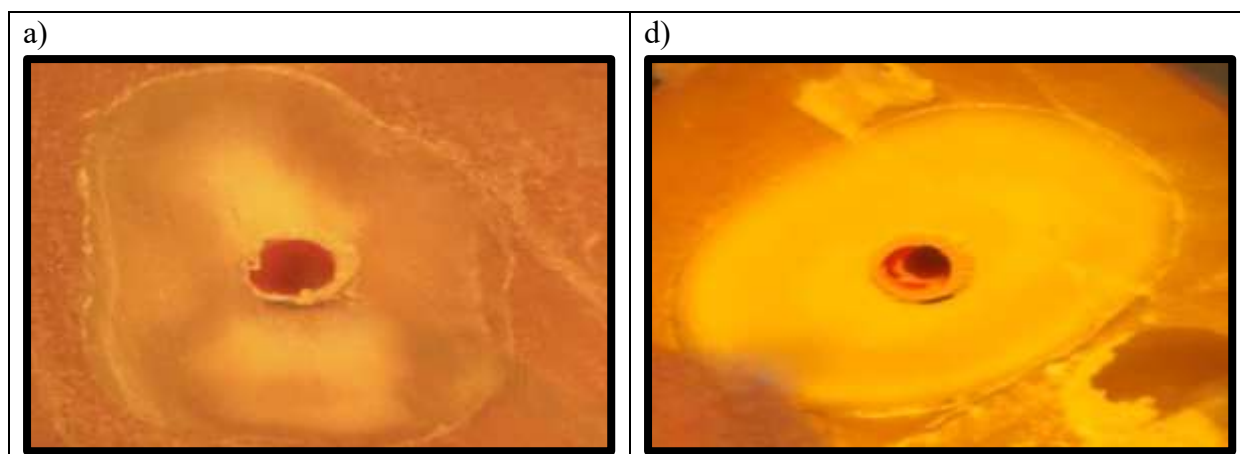
Dry protocol (White Mac tip + capillary tip + paper points) maximized PBS for epoxy resin sealers (AH Plus, AD Seal), while slightly moist protocol (White Mac + capillary tip only) maximized PBS for calcium silicate sealers (Bio-C, AH Plus Bioceramic).

Good/Reasonable sealer-dentin adaptation was observed in dry canals for resin sealers, whereas wet canals showed Poor/Without adaptation for both sealer types, confirming that residual moisture critically affects interfacial quality.

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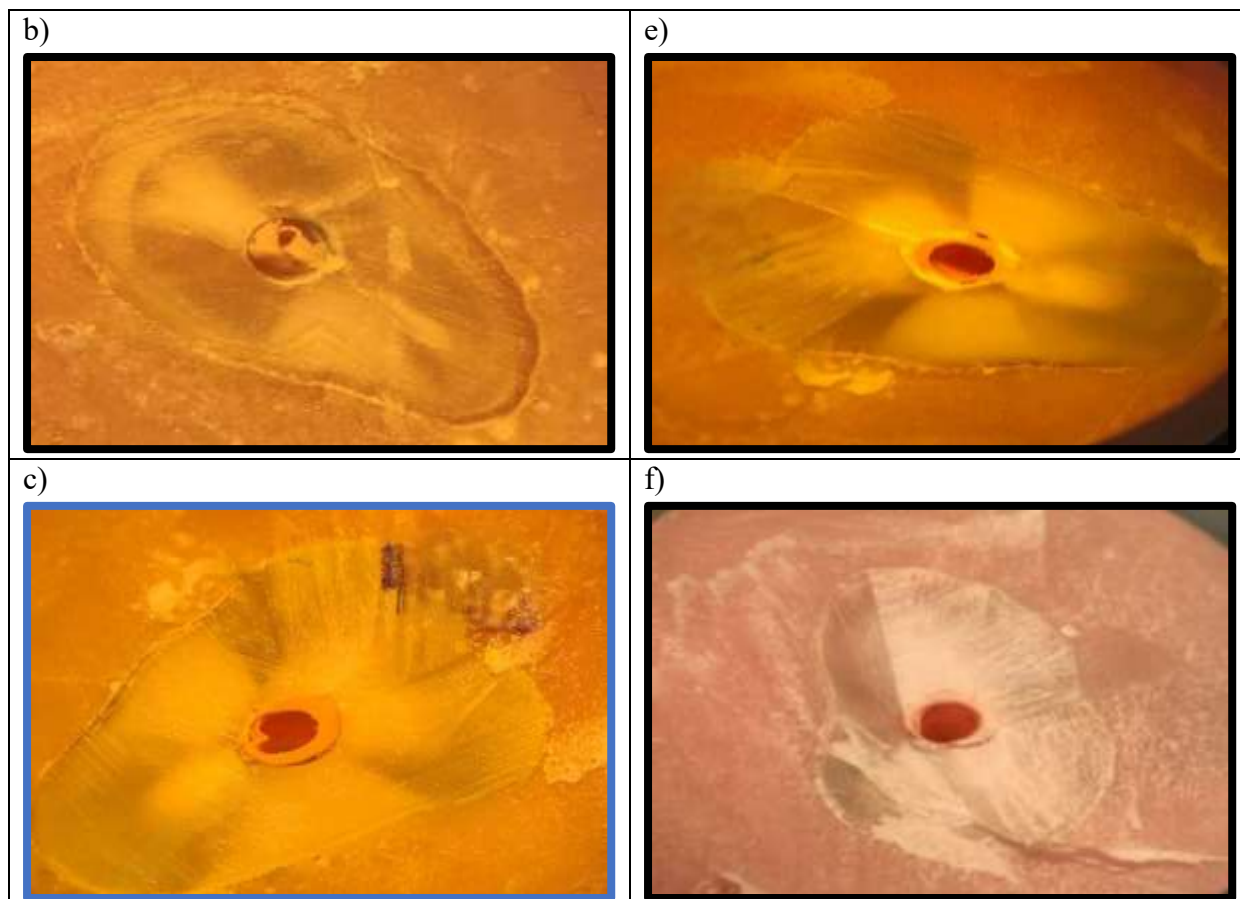
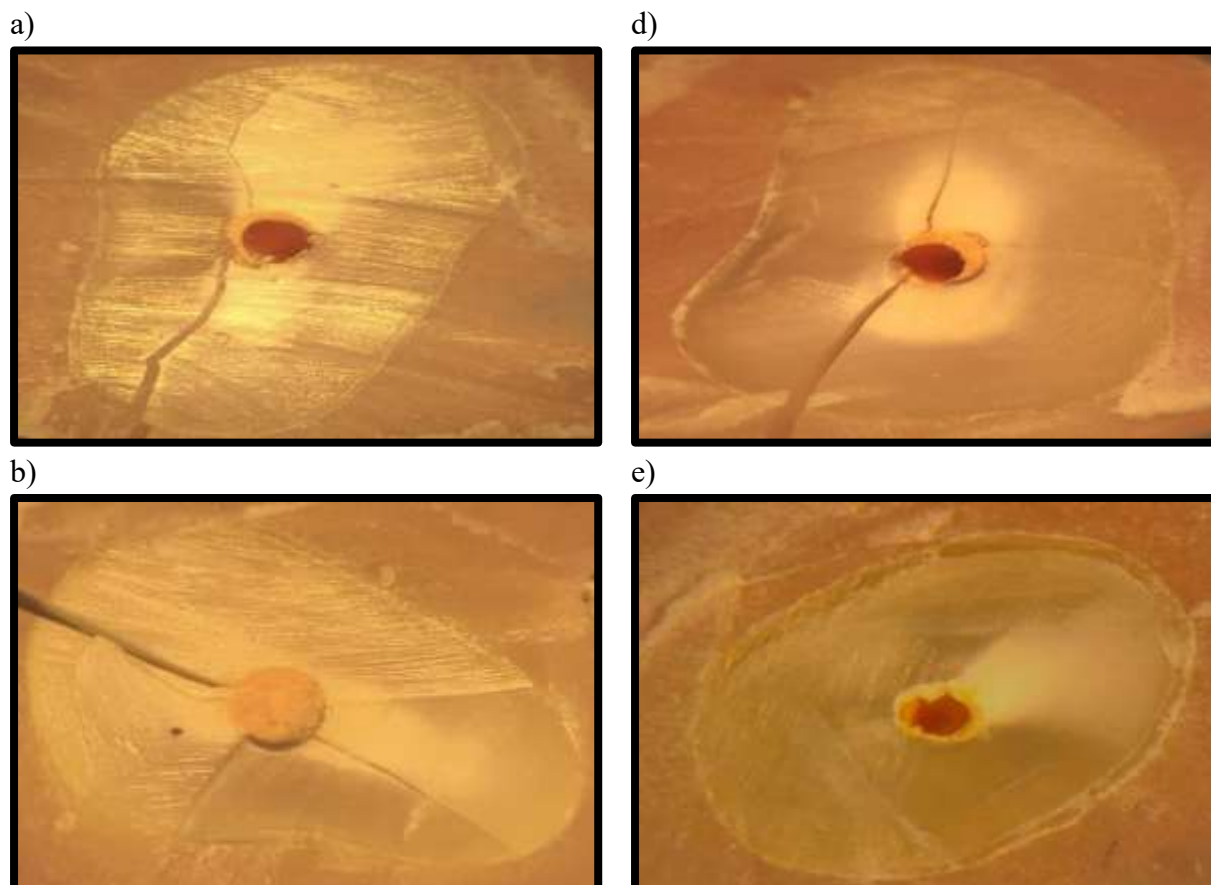


Fig-1: Representative failure modes under Stereomicroscope (x50) a) AH Plus, Dry - adhesive failure b) AH Plus, Slightly Moist - adhesive failure c) AH Plus, Wet - adhesive failure d) ADSeal, Dry - adhesive failure e) ADSeal, Slightly Moist - adhesive failure f) ADSeal, Wet – adhesive failure.



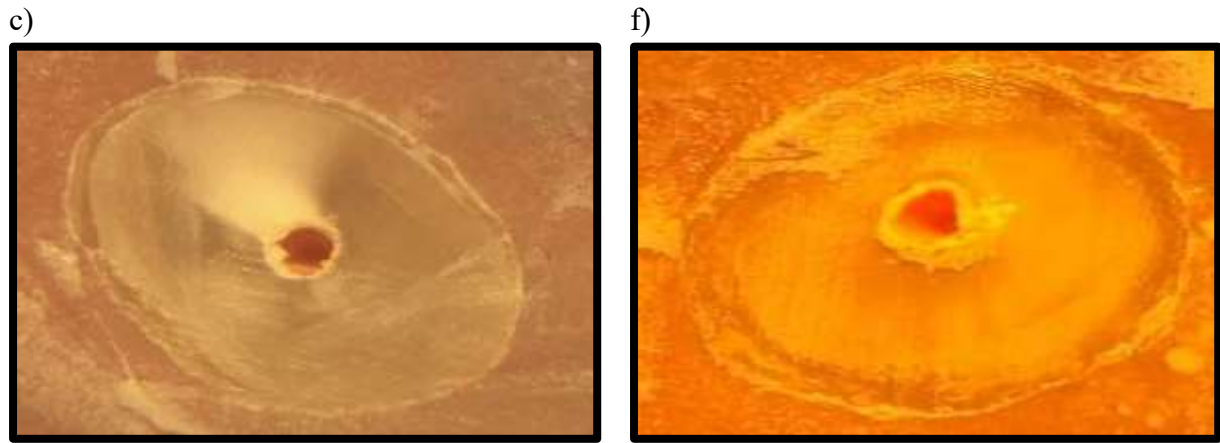


Fig-2: Representative failure modes under Stereomicroscope(x50) of a) Bio-C, Dry - mixed failure b) Bio-C, Slightly Moist - mixed failure c) Bio-C, wet - cohesive failure d) AH Plus Bioceramic, Dry - mixed failure e) AH Plus Bioceramic, Slightly Moist - cohesive failure f) AH Plus Bioceramic, Wet - cohesive failure.

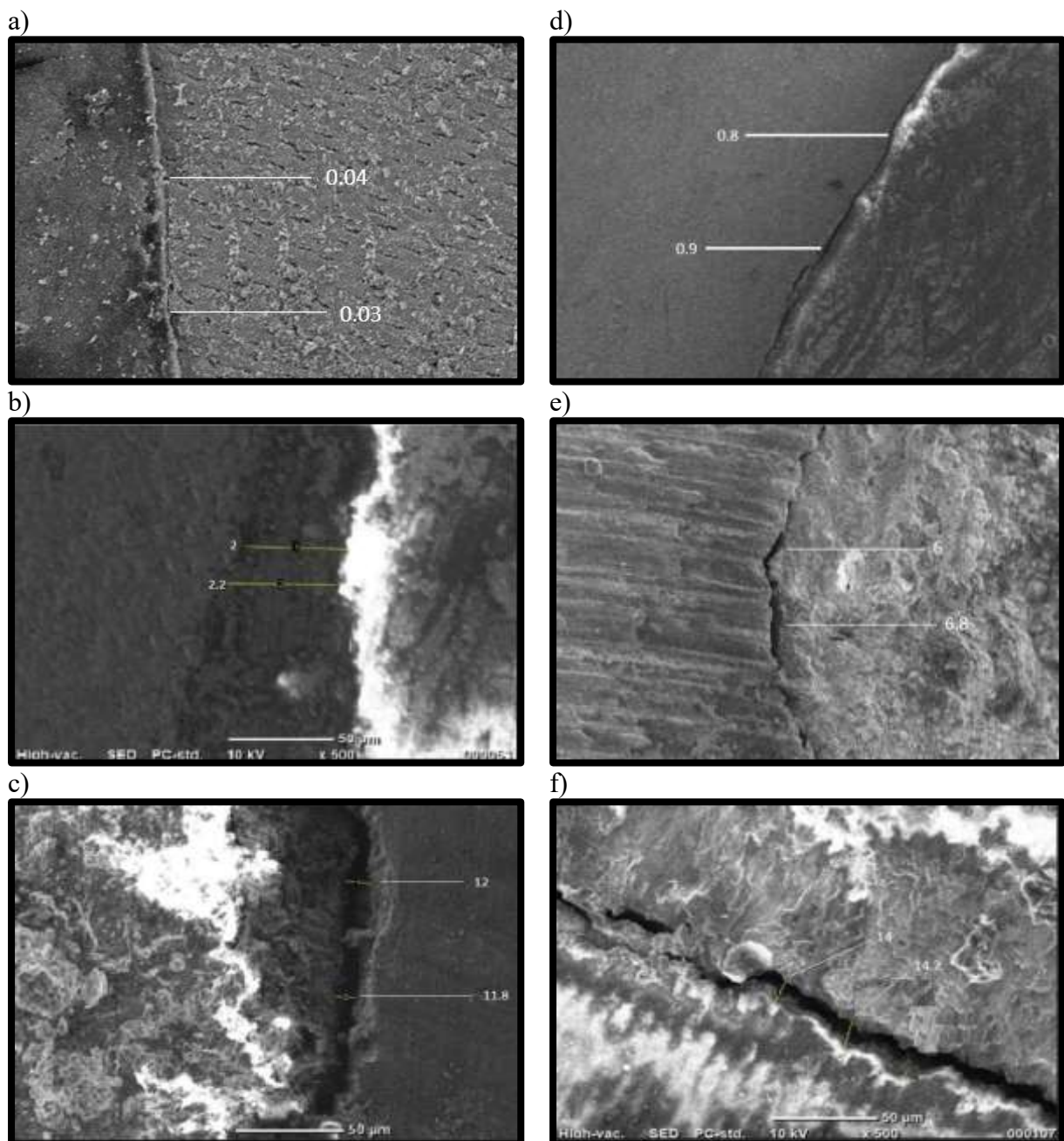


Fig-3: Scanning Electron Microscope Images: Bond interface analysis of root canal sealers a) AH Plus sealer - Dry canals b) AH Plus - Slightly moist canals c) AH Plus - Wet canals d) AD Seal - Dry canals e) AD Seal - Slightly moist canals f) AD Seal - Wet canals

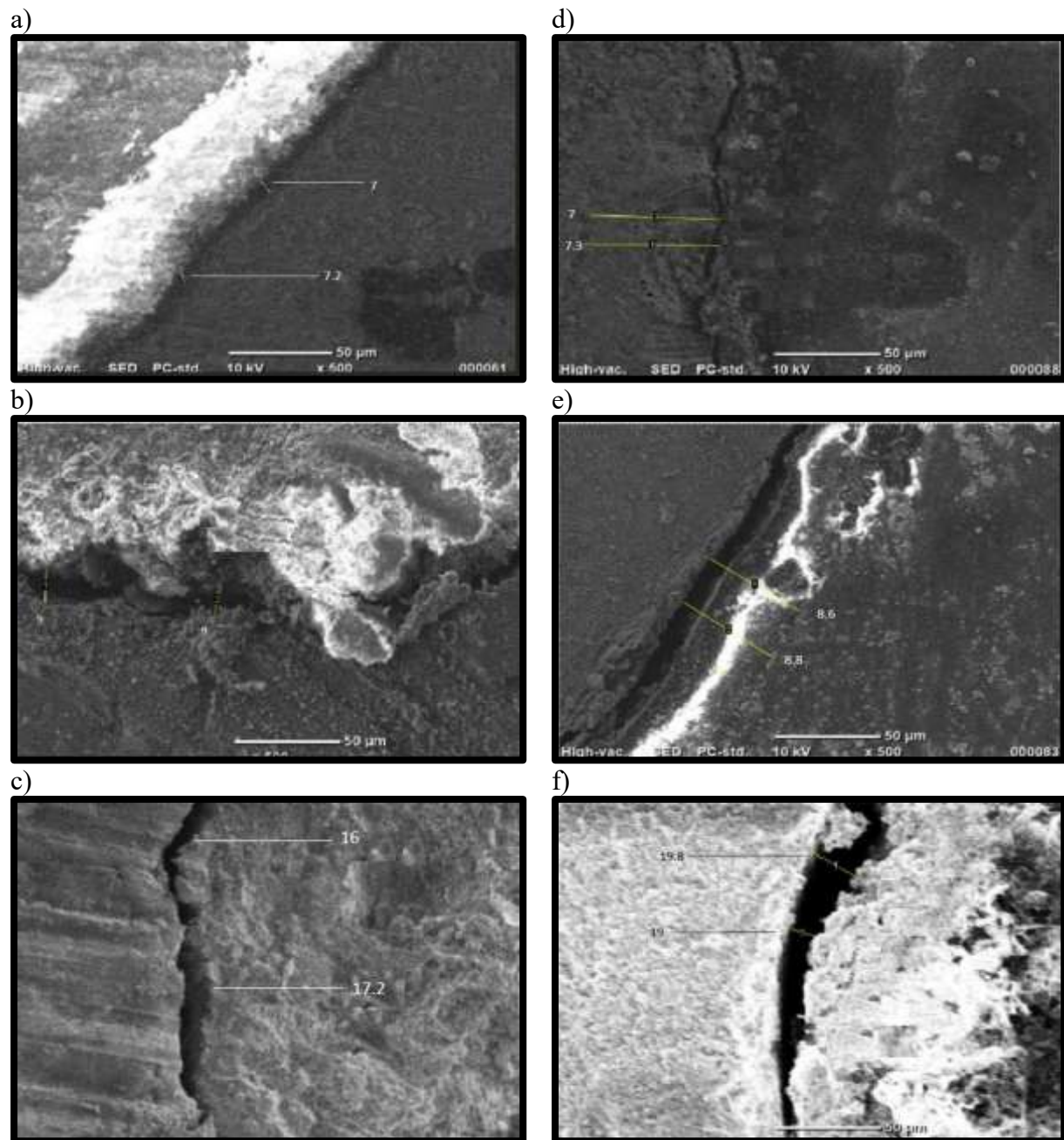


Fig-4: Scanning Electron Microscope Images: Bond interface analysis of root canal sealers a) Bio-C - Dry canals b) Bio-C - Slightly moist canals c) Bio-C - Wet canals d) AH Plus Bio ceramic - Dry canals e) AH Plus Bioceramic Slightly moist canals f) AH Plus Bioceramic sealer - Wet canals