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

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 4, Issue – 1, February - 2021, Page No. : 59 - 76

Comparative evaluation of push out bond strength of endodontic sealers to dentin and assessing the fracture modes- an in-vitro study

[1]Dr Aravindh Kumar A, Postgraduate Student, M.R Ambedkar Dental College Hospital, Cline Road Cooke Town, Banglore

[2]Dr Anantha Krishna , Professor And Head , M.R Ambedkar Dental College Hospital, Cline Road Cooke Town, Banglore

[3]Dr Pradeep P.R, Professor, M.R Ambedkar Dental College Hospital, Cline Road Cooke Town, Banglore

[4]Dr Veena Kumari R, Professor, M.R Ambedkar Dental College Hospital, Cline Road Cooke Town Banglore

[5]Dr Shreya Maiti, Postgraduate Student, M.R Ambedkar Dental College Hospital, Cline Road Cooke Town Banglore

Corresponding Author: Dr Aravindh Kumar A, Postgraduate Student, M.R Ambedkar Dental College Hospital, Cline Road Cooke Town, Banglore

Citation of this Article: Dr Aravindhkumar A, Dr Anantha Krishna , Dr Pradeep P.R, Dr Veenakumari R, Dr Shreya Maiti, "Comparative evaluation of push out bond strength of endodontic sealers to dentin and assessing the fracture modes- an in-vitro study", IJDSIR- February - 2021, Vol. – 4, Issue - 1, P. No. 59 – 76.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Background and Objectives: To evaluate the push out bond strength of four different endodontic sealers and the failure pattern in adhesion of sealer in dentinal tubules of apical and middle portion of root canal using stereo microscopy

Materials and Methods: Single-rooted mandibular premolars (n = 60) were prepared and divided into four groups (n = 15) based on sealer used Group I:AH Plus sealer ;Group II:MTA based sealer ; GroupIII:Sealapex sealer; and Group IV: Bio ceramic sealer. All the groups were irrigated with common irrigating solution (2.5% sodium hypochlorite (NaOCl)-17% ethylenediaminetetraacetic acid (EDTA). After obturation with guttapercha using the respective sealer, roots were sectioned at 2 levels – apical and middle third of root canals and push-out bond test assessed using universal testing machine. One-way ANOVA with Tukey post-hoc significant difference tests were applied to assess the significance among various groups. Few samples of groups were examined under Stereo microscope to determine the nature of the bond failures

Results: AH Plus showed significantly highest mean Pushout Bond strength as compared to other groups respectively. This was followed next by Bioroot RCS group showing significantly higher mean pushout bond strength as compared to Sealapex and MTA Sealer at $P<0.001$. However, no significant differences were noted between Sealapex& MTA sealer in mean Pushout Bond strength [P=0.99].

Adhesive failure was significantly higher in Group Sealapex and MTA sealer [66.7%] as compared to Cohesive Failure seen in AH Plus [80.0%], and Bioroot RCS Group [66.7%]. Mixed failure was more seen in MTA sealer [20.0%], followed by Bioroot RCS group [13.3%] as compared to AH Plus [6.7%] and Sealapex group [6.7%]. This difference in the modes of Failure between different study groups was statistically significant at P=0.002

Interpretation &Conclusion

1. AH plus sealer group showed the higher push out bond strength than BioRoot RCS, Sealapex, and MTA based root canal sealer(FILLAPEX).

2.Middle segment of each test group demonstrated the highest mean bond strengths than the Apical segments

Introduction

Successful endodontic therapy depends on the three-dimensional filling with an impervious, biocompatible, and dimensionally stable filling material. Since gutta-percha alone is incapable of adhering to the root canal dentin, a sealer is required to bond the gutta-percha to dentin and also to obtain a fluid tight seal[1]

It is generally accepted that micro leakage between the root canal filling and the root canal walls might adversely affect root canal treatment results. Therefore, complete sealing of the root canal system after cleaning and shaping is critical to prevent oral pathogens from colonization and re-infecting the root and per apical tissues.[2]

In endodontic therapy, a sealer is basically used to fill the irregularities of the root canal system, bond the core material to the root canal walls, and serve as a lubricant

The various root canal sealers used are Sealapex, Diaket, AH Plus, Apexit, Vitapex, MTA Fillapex, RoekoSeal, GuttaFlow, Sealer MTA Obtura ProRoot Endo Sealer, BioRoot RCs, EndoREZ, Realseal, Metaseal SE, Smartseal.[4]

Irrigation has a central role in endodontic treatment. During and after instrumentation, the irrigants facilitate removal of microorganisms, tissue remnants, and dentin chips from the root canal through a flushing mechanism. Irrigants can also help prevent packing of the hard and soft tissue in the apical root canal and extrusion of infected material into the periapical area.

Sodium hypochlorite (NaOCl) is commonly used in concentrations between 0.5% and 6%. It is a potent antimicrobial agent, killing most bacteria instantly on direct contact. It also effectively dissolves pulpal remnants and collagen, the main organic components of dentin.Sodium Hypochlorite is the only root-canal irrigant of those in general use that dissolves necrotic and vital organic tissue. It is difficult to imagine successful irrigation of the root canal without Sodium hypochlorite.[6]

Chelating agents remove the smear layer from the root canal and potentially allow better dentinal tubule penetration of root canal sealers as well as demineralizing and softening dentine. In order to obtain the maximum effect during and after instrumentation, it is necessary to use chelating agents in conjunction with a tissue solvent. An effective method to remove the organic and inorganic remnants is to irrigate the root canal with EDTA followed by NaOCl.[7]

Chlorhexidine digluconate (CHX) is widely used in disinfection in dentistry because of its good antimicrobial activity. It has gained considerable popularity in endodontics as an irrigating solution and as an intracanal medicament[6]

Other irrigating solutions used in endodontic have included sterile water, physiologic saline, hydrogen peroxide, urea peroxide, and iodine compounds. All of these except iodine compounds lack antibacterial activity when used alone, and they do not dissolve tissue either. Therefore there is no good reason for their use in canal irrigation in routine cases[6]

The tooth is retained longer only when there is excellent synergy between restorative and endodontic treatment. The use of EDTA and sodium hypochlorite (NaOCl) alternately has been proved efficient in removing endodontic smear layer for many years[8] Sealer penetration into the dentinal tubules improves the seal ability because of an increase of contact surface between filling material and dentin[9]. The bond strength of sealers to dentin is important for the maintenance of integrity of seal

Numerous studies have proved that irrigation with 5% NaOCl solution during 3 min PUI could remove more smear layer EDTA is normally used in a concentration of 17% and can remove the smear layers when in direct contact with the root canal wall for less than 1 minute.

Traditionally used root canal sealers are zinc oxide eugenol, calcium hydroxide, and resin-based sealers. Newer root canal sealers are constantly being developed to provide improved properties.

AH Plus sealer (Dentsply Maillefer, Switzerland) which is an epoxy based endodontic sealer and presents with no photo-polymerization system on its composition. Moreover it is biocompatible, radiopaque, has a short-setting time, low solubility, and good flow characteristics

AH plus sealer was used for the current study in spite of availability of various newer sealers in the market, it is because AH plus sealer has been shown to have the highest bond strength to root dentin.

MTA known for its biocompatibility, yields an impressive, hermetic seal in which the MTA particles expand, preventing microfiltration. MTA properties are good adhesion to dentin walls, adequate seal and resistance to dislodgement. Calcium hydroxide has been used in endodontic for a number of years to repair root perforations, halt root resorption, control exudate in problem teeth, and stimulate development of root formation.

BioRoot RCS is a recently launched hydraulic Tri-calcium silicate-based sealer containing Tri-calcium silicate, zirconium oxide, etc. Due to prolonged release of Ca^{+} ions after setting and alkalinity of the sealer, it possesses high antimicrobial and low cytotoxic property promoting endodontic and periodontal regeneration. It has gained popularity because of its ability to seal in presences of hydrophilic atmosphere by mineralization and apatite deposition at canal wall interface.

The present study was designed to compare and to evaluate the push-out bond strength of four different endodontic sealers are namely AH plus sealer, MTA sealer, Sealapex, BioRoot RCS with sodium hypochlorite and EDTA as irrigating solutions.

Materials and Method

Sixty single rooted mandibular 1st premolar teeth [Fig 4] that are caries free, indicated for extraction due to orthodontic reasons and periodontal problems were collected from Department of Oral and Maxillofacial surgery, M.R. Ambedkar dental college and Hospital Bangalore-Karnataka, India with patients consent. OSHA guidelines were followed in collecting and storage of sample.

The samples were divided into 4 groups (n=15) according to the sealer used and common irrigating solution:

IRRIGANT: 2.5% NaOCl + 17% EDTA

GROUP I: AH PLUS sealer

GROUP II: MTA BASED sealer

GROUP III: SEALAPEX sealer

GROUP IV: BIOCERAMIC sealer

PREPARATION OF THE SAMPLES

The extracted teeth were cleaned by removing all attached hard & soft tissues. Then the teeth were stored in the container with lid containing sterile saline at room temperature until further processing.The procedure for preparation and obturation was standardized for all groups and performed by a single operator to minimize experimental variables.

The study samples were decoronated apical to the cement enamel junction to standardize the canal length to 14 mm measured from the tip of the root to the cement-enamel junction with a diamond disc under water coolant mounted on a straight micro motor handpiece. The prepared teeth were stored in normal saline solution until use.

The samples were then mounted in a putty impression material in order to stabilize the samples for ease of working and to ensure standardization in procedure.

The canal patency was determined by passively placing a no. 8 size k-file in narrow canals and10 k-file in medium sized root canals until the tip of the file was visible at the apical foramen using a magnifying loupe and adjusted to the apical foramen. Those teeth with wider apical patency were discarded and replaced with appropriate teeth. Working lengths were established by subtracting 1mm from the measurement obtained when a size 10 file was placed into the canal until its tip was visible at the apex namely working length of 14mm.

Initial negotiation of root canal space was performed using a size 15 manual K-file used in a watch-winding motion to assure the presence of a glide path .In all the experimental groups, the coronal orifice was then sealed with sticky wax. This was done to achieve a close mode of irrigation. During instrumentation of all canals, 2ml of NaOCl (2.5%) and 17% EDTA was used as an irrigant using 30 gauge side vented needle for 1 minute. For each group , 5 ml of irrigating solution(2.5%NaOCl+17%EDTA)will be used for 2 minutes using conventional irrigation method followed by 5 ml 0.9 % saline for 2 minutes using an endodontic irrigating needle.

Root canals will be dried with paper points and then sealer will be mixed according to manufacturer's directions and will be introduced into canal using lentilospiral instrument. All the groups will be obturated with gutta percha with single cone technique using the respective sealers AH Plus sealer, MTA sealer, sealapex, BioRoot RCS .The obturated teeth will be allowed to set for 1 week before push out assessment in 37°C with 100% humidity in an incubator

Assessment of Pushout Bond Strength

Each root was then sectioned horizontally, perpendicular to the long axis, at the coronal section of the root into 2mm-thick slices, using hard tissue microtome; with the 1st slice being discarded and the one with more circular shape of the canal filling material being selected. The thickness of each slice was measured using digital caliper (Insize Co. Ltd., Germany). Two slice from each root canal which was taken from the middle and apical third of the root canal were evaluated. The slices were stored in bottles filled with 1.5 ml distilled water for 2 days. Afterwards, each section was marked on its apical side and positioned on a base with a central hole in a universal testing machine. The materials' dislocation resistance was measured using the push-out strength test with a universal testing machine (Instron, Model 5944 MicroTester Precision Instruments, Norwood, MA,USA) (IISC,BANGALORE) . The push-out test was performed by applying a compressive load to the apical side of each slice using a cylindrical plunger attached to the upper portion of the testing machine with a crosshead speed of 1 mm/min. The load upon failure was recorded in Newtons (N) and divided by the bond area (mm2) to express the bond strength in megapascals (MPa). The total bonding area for each slice was calculated using the formula:

π(R+r) [(h2+(R1r)2]0.5

R represents the coronal radius, r is the apical radius, and h is the thickness of the slice.

Failure Mode Analysis (stereomicroscope)

After the pushout bond strength test was performed, each of the root slices was examined under a stereo microscope at 40 X magnification to determine the failure mode. Modes of bond failure were considered as follows:

(1) Adhesive Failure (Sealer / Dentine interface or Mastercone / Sealer interface)

(2) Cohesive Failure (Within the sealer)

(3) Mixed failure (Both adhesive and cohesive failure)

Discussion

Root canal morphology is complex by nature and dealing with such complexities is challenging as it hampers the ability to achieve thorough disinfection of the pulp cavity. Chemo-mechanical debridement of the pulp space with the aid of instruments and irrigating solutions decides the outcome of endodontic therapy. In fact the root canal treatment is affected by clinical factors such as effective biomechanical instrumentation of the root canal to produce a debris free surface, disinfection and dissolution of organic matter to eliminate bacterial pathogens and a three dimensionally sealed and obturated canal Most root canal filling techniques use core materials associated with endodontic sealers. Core obturating materials, such as gutta-percha, usually occupy space, whereas the endodontic sealers enhance the possible attainment of an impervious seal by serving as filler for canal irregularities and minor discrepancies between the root canal wall and the core material. Sealing ability, biocompatibility, and antimicrobial activity probably influence the success of the root canal treatment. To create and maintain a three-dimensional seal of the entire root canal system, sealers should have adhesiveness, be dimensionally stable, be insoluble to oral and tissue fluids, and have an adequate flow rate.

Several new resin cement sealants have been developed to be used instead of ZOE, thereby improving the root canal seal and imparting it more strength as compared to the conventional materials. These include silicon based sealers which are well tolerated by tissues, have low water sorption ,epoxy resin–based sealers with the possibility of adhesion to dentin and with lower rates of water solubility, and a mineral trioxide aggregate (MTA)-based sealers which have the predilection toward mineralization along with all the viable properties of orthodox sealers[50]. Bioceramic have been recently launched hydraulic tricalcium silicate-based sealer containing tricalcium silicate, zirconium oxide, etc

In the present study Root canal instrumentation was performed using Protaper Universal system. The canals in this investigation were prepared with a combination of the passive step-back technique and rotary nickel-titanium instruments.

A study conducted by Hengameh Ashraf et al, evaluated Smear Layer Removal in the Apical Third of Root Canals by Two Chelating Agents and Laser prepared the apical region till size of 30/0.06 to allow adequate apical penetration of irrigations and access for the laser fiberoptic tip (300 μm) to the apical third of the canals.[11]

All irrigation protocols in this study were done using 30 -gauge needles(close-ended single side vented) as it allows the clinician to place these as apical as clinically possible without canal binding amongst all the endodontic needles according to Gopikrishna et al.[12]

Van der Sluis et al also showed that there was a significant difference in presence of Smear layer between apical and middle thirds of the canals and also showed that irrigation with 5% NaOCl solution during 3 min Passive ultrasonic irrigation could remove more smear layer than 0.5%

NaOCl from the apical and middle part of the root canal[13]. So the removal of smear layer in the apical region remains unpredictable[14, 15] Therefore smear removal will in turn affect the pushout bond strength in apical third and middle third of canals. A study conducted by Krishna Vallabhaneni et al showed that cleaning have been more effective on coronal and middle thirds than on the apical third as the size of the canals in these thirds, allowed better circulation and action of irrigating solution[16] .

In this present study, the canals were irrigated between each instrumentation with 2 ml of 3% of NaOCl using a 30 gauge needle[17.] Studies done by Baumgartner et al on efficacy of several concentrations of sodium hypochlorite for root canal irrigation have shown that irrigation with 3 ml of NaOC1 after each instrument in the study did an excellent job of removing superficial debris whether delivered with an endodontic irrigation needle or the ultrasonic device[18]. The same procedure was followed by rinsing of the canals with 5 ml of 0.9% saline to minimize potential interaction of NaOCl with any acidic irrigants that were employed as a final rinse. To prevent the escape of irrigants from the apex by simulating a clinical situation, the apex was sealed with aluminum foil coated with molten wax, simulating the clinical conditions. This method was followed by by Hasnain ET al[19.]

EDTA is normally used in a concentration of 17% and can remove the smear layers when in direct contact with the root canal wall for less than 1 minute according to Doumani et al.. The application of sealers was done by mixing according to manufacturer's directions canal wall was covered with sealer after GP cones .Then canals were obturated using single cone technique using F3 gutta percha as a master cone. Single cone obturation was done in the present study to simulate most common method employed in clinical scenario and to maintain homogeneity among groups[20].

Push-out test method was used to test the bond strength of AH Plus sealer, Bio-ceramic sealer , MTA based sealer and Sealapex sealer . Single-cone obturation technique was done in the current study to simulate most common method employed in clinical scenario and to maintain homogeneity among groups.

In the present study Group I (AH PLUS SEALER) has high pushout bond strength.(middle 8.125 ± 0.740,apical 6.653 ± 0.721) This could be explained by the formation of a covalent bond by an open epoxide ring of AH plus sealer to any exposed amino groups in root dentin collagen. Several investigations supported the high-quality properties with epoxy resin-based sealers, including very low shrinkage while setting, long-term dimensional stability, excellent flow property, deeper penetration into the dentinal tubules and surface micro irregularities. This is in agreement with the findings of several authors[21].

In the specimens obturated using AH Plus sealer (DentsplyMaillefer, Switzerland) which is an Epoxy based endodontic sealer,it is believed that homogeneous polymerization occurs, leading to higher mean values of bond strength along the canal root. Along with that chemical polymerization occurs at a low rate, delaying the gel point state and allowing for shrinkage stress relaxation, and avoiding a decrease in bond strength. This is in accordance with the study conducted by Wunderlich Rocha et al[22]

The superior results of AH Plus may be due to better adhesion to root dentine and deeper penetration into dentinal tubules (Lee et al. 2002, Mamootil & Messer 2007).

Several studies reported significantly higher bond strengths with epoxy resin-based sealers (Lee et al. 2002, Saleh et al. 2002, Gogos et al. 2004)[23]

In the present study, AH Plus has the highest push-out bond strength under all conditions. This result is similar to the studies conducted by (Ersahan & Aydin 2010, Amin et al. 2012, Nagas et al. 2012)

In the present study done it was reported that Group I showed cohesive failure [80.0%] followed by the adhesive failure [13.3%] and least showed mixed failure[6.7%] (Table 6,Graph3). When the apical and middle third was assessed, It also showed maximum number of cohesive failures respective of the area. This is in accordance with results from previous studies done by Prado et al[24], Topcuoglu et al[25],Who reported a cohesive failure pattern in the AH Plus sealer group . This may be due of the high adhesion capacity of AH Plus sealer to the canal dentin[26.]

In the present study, Group 2 in which MTA Fillapexwas used. had the lowest bond strength values(middle 4.209 ± 0.796 apical3.041 ± 0.467) (Table 1, Table 3) compared to other sealers in this study . MTA Fillapex is another new salicylate resin- and calcium silicate-based sealer It contains calcium silicate, salicylate resin, diluting resins, natural resin, nanoparticulated resin and bismuth trioxide the release of calcium and hydroxyl ions from the set sealer will result in the formation of apatite's as the material comes into contact with phosphate-containing fluids (Sarkar et al. 2005)[27].

Reyes-Carmona et al. (2009) reported that the apatite formed by MTA and phosphate-buffered saline was deposited within collagen fibrils, promoting controlled mineral nucleation on dentine, seen as the formation of an interfacial layer with tag-like structures. The reason for the low bond strength of MTA Fillapex in the present study could be the low adhesion capacity of these tag-like structures[28]

Sagsen et al. (2011) claimed that MTA Fillapex exhibited low bond strength because of its low adhesion capability. Based on these results, it can be concluded that there is an interaction between low adhesion capacity and low push-out bond strength of MTA Fillapex[29].

In this present study the push-out bond strengths of AH Plus,bio ceramic, sealapex are significantly superior to that of MTA Fillapex. But no significant differences were noted between Sealapex & MTA sealer in mean Pushout Bond strength [P=0.44]. (Refer in Graph 2)

The amount of adhesive failures (66.7 %) in the MTA Fillapex group, could explain the lowest adhesion to dentine among the other tested materials, The percentage of mixed failure was (20%) and cohesive failure was (13.3%).(REF TABLE 6 ,GRAPH 3)

In the present study ,Group III in which Sealapex was used,the Pushout bond strength

Table 1,Table 3 (middle 4.209 ± 0.796 , apical 3.041 ± 0.467) is superior to MTA sealer (GroupII) The calcium hydroxide-based sealer, gave low bond strength to dentin (0.24 MPa), confirming the low values found by Wennberg and Orstavik[30] .

High values cannot be reached because of the low tensile cohesive strength of self-cured calcium hydroxide bases. The low adhesion of the calcium hydroxide sealer to gutta-percha (0.22 MPa) has never been reported. The setting reaction occurs via a reaction between calcium hydroxide and glycol salicylate to form an amorphous calcium disalycilate, which does not bond to dentin. The pH at the surface of dentin remains neutral when Sealapex is used during obturation. Therefore, Sealapex does not produce the demineralizing effects observed with dental cements.

Sealapex displayed equivalent failure modes and bond strength on both dentin and gutta-percha, leading us to conclude that chemical bonding does not occur on any of the surfaces. Tagger et al[31],in a study of short duration, reported that the release of calcium and hydroxyl ions from the calcium hydroxide-containing sealers may be variable. The release of calcium ions from Sealapex was prolonged and gradual, whereas practically no calcium ions were released from CRCS during a 2-h test period immediately after setting.

In the present study Group IV in which BioRoot RCS was used had the 2nd highest push out bond strength (middle7.227 ± 0.864 apical6.006 ± 0.521) It is a recently launched hydraulic tricalcium silicate-based sealer containing tricalcium silicate, zirconium oxide, etc. Due to prolonged release of Ca+ ions after setting and alkalinity of the sealer, it possesses high antimicrobial and low cytotoxic property promoting endodontic and periodontal regeneration. It has gained popularity because of its ability to seal in presences of hydrophilic atmosphere by mineralization and apatite deposition at canal wall interface

Endodontic sealers based on tricalcium silicate or containing calcium silicate formulations were recently introduced with a view to transferring the well-documented biocompatibility and bioactivity of di- and tricalciumsilicate cements to root canal sealers. The release of calcium hydroxide from di- and tricalcium silicate cements due to hydration and the contact with phosphate from tissue fluids leads to a precipitation of calcium phosphate or calcium carbonate on the material's surface[32] . Also, the formation of hydroxyapatite on a calcium silicate sealer's surface after contact with phosphate hasbeen reported[33]. This is the reason for the bioactive potential of tricalcium and dicalcium silicate materials and sealers[34]. Furthermore, calcium silicates form an interfacial layer at the dentin wall denoted as "mineral-infiltration zone". The alkaline caustic effects of the calcium silicate cement's hydration products degrade the collagenous component of the interfacial dentin[35,].This degradation leads to the formation of a porous structure that facilitates the permeation of high concentrations of Ca2+, OH−, and CO32− ions, leading to increased mineralization in this region[35,36] . This chemical interaction at the interfacial dentin along with a micromechanical interaction by tag-like structures is mainly the reason for measurable adhesion between calcium silicate-based materials and dentin[35,37]. Bio Root RCS (Septodont, St. Maur-des-Fossés, France) is the newest development of a bioceramic sealer.

In the present study, the mode of bond failure was mainly cohesive (66.7%) in bioceramic sealer. This finding is in accordance with Huffman et al.[38] who showed that the failure mode for a calcium silicate-based sealer was cohesive after a 7 day storage period. Mixed failure (13.3%),adhesive failure(20%) Furthermore, Eldeniz et al[39]. revealed that the failure mode appeared to be predominantly cohesive within the sealer for AH Plus in the presence or absence of smear layer.

The present study result is similar to study done by D donnermeyer et al in 2018[40].

In the present study, both middle and apical third regions were used for to study the bond strength variations. The test results demonstrate that the mean Pushout Bond strength in Middle third region was significantly higher [4.711 ± 1.184, 7.227 ± 0.864, 4.209 ± 0.796 and 8.125 ± 0.740] as compared to Apical third region [3.110 ± 0.936, 6.006 ± 0.521, 3.041 ± 0.467 and 6.653 ± 0.721] in each study group. This difference in the mean push out bond strength between the middle and apical third region in all the groups was statistically significant at $P \leq 0.001$. which supported by Patel et al who reported that mean maximum penetration in the Cervical , middle third was greater than at the apical third.

Studies conducted by Gharib et al, Moon Y-M et al and Kara TA et al reported that areas of sclerotic dentin are more common in the apical third . In addition,the diameters of tubules in the apical third are smaller than those in the middle and coronal third, and the apical third has a lower number of tubules than the middle and coronal third .Also ,it is more diffcult to remove the smear layer from the apical third than middle and coronal third because of reduced irrigant delivery. These factors might have influenced the findings of the present study

Group I in which AH Plus sealer was used,shows high push out bond strength compare to other sealers used in the study .The result obtained is similar to other studies mention above. Group IV in which Bioceramic(Bio Root RCS) sealer was used,shows high push out bond strength compared to Sealapex and MTA sealer. . However, no significant differences were noted between Sealapex&MTA sealer in mean Pushout Bond strength [P=0.44].

On the assessment of failure mode pattern under stereomicroscope ,Group I shows 80% of Cohesive failure ,Group II shows 66.7% of adhesive failure, Group III shows 66.7% adhesive failure and Group IV shows 66.7% cohesive failure. The results are similar to other studies mention above.

Conclusion

1. AH plus sealer group showed the higher push out bond strength than BioRoot RCS, Sealapex, and MTA based root canal sealer(FILLAPEX).
2. Middle segment of each test group demonstrated the highest mean bond strengths than the Apical segments
3. BioRoot RCS sealer group showed superior result compared to Sealapex and MTA group
4. No significant different between Sealapex and MTA sealer
5. The test results demonstrate that the Adhesive failure was significantly higher in Group Sealapex and MTA sealer [66.7%] as compared to Cohesive Failure seen in AH Plus [80.0%], and BioRoot RCS Group [66.7%]. Mixed failure was more seen in MTA sealer [20.0%], followed by BioRoot RCS group [13.3%] as compared to AH Plus [6.7%] and Sealapex group [6.7%]

References

1. Vasundhara Shivanna Department of Conservative Dentistry and Endodontics, College of Dental Sciences, Davangere, Karnataka, India,Journal of the International Clinical Dental Research Organization | July-December 2014 | Vol 6 | Issue 2(The effect of different irrigating solutions on the push out bond strength of endodontic sealer to dentin and assessing the fracture modes: An In-vitro study)
2. Zhang W, Li Z, Peng B. Assessment of a new root canal sealer's apical sealing ability. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2009 Jun 1;107(6):e79-82.
3. Lee KW, Williams MC, Camps JJ, Pashley DH. Adhesion of endodontic sealers to dentin and gutta-percha. Journal of endodontic. 2002 Oct 1;28(10):684-8.
4. Singh H, Markan S, Kaur M, Gupta G, Singh H, Kaur MS. Endodontic sealers: Current concepts and comparative analysis. Dent Open J. 2015;2(1):32-7.
5. Markus Haapasalo, DDS, PhD[a,*], Ya Shen, DDS, PhD[a], Wei Qian, DDS, PhD[b], Yuan Gao, DDS, PhD(Irrigation to endodontic)
6. Mehdi Rahimi, BSc, BDS, AngsanaJainaen, DDS, PhD, Peter Parashos, MDSc, PhD, andHarold H. Messer, MDSc, PhD. JOE — Volume 35, Number 1, January 2009(Bonding of Resin-based Sealers to Root Denti.
7. J Ravikumar 1 , V Bhavana 2 , Chandrashekar Thatimatla 3 , Satyanarayana Gajjarapu 4 , S Ganesh Kumar Reddy 5 , B Rahul Reddy 6.Journal of International Oral Health 2014; 6(1): 85 – 88(The effect of four different irrigating solutions on the shear

bond strength of endodontic sealer to dentin–An In-vitro study)

8. K. Mamootil & H. H. Messer. Penetration of dentinal tubules by endodontic sealer cements in extracted teeth and in vivo. International Endodontic Journal 2007; 40: 873–881.
9. Ungor M, Onay EO, Orucoglu H. Push-out bond strengths: The Epiphany / Resilon endodontic obturation system compared with different pairings of Epiphany, Resilon, AH Plus and gutta-percha. Int Endod J 2006;39:643-7.
10. Sharma G, Kakkar P, Vats A. A comparative SEM investigation of smear layer remaining on dentinal walls by three rotary NiTi files with different cross sectional designs in moderately curved canals. Journal of clinical and diagnostic research: JCDR. 2015 Mar;9(3):ZC43
11. Ashraf H, Asnaashari M, Darmiani S, Birang R. Smear layer removal in the apical third of root canals by two chelating agents and laser: a comparative in vitro study. Iranian endodontic journal. 2014;9(3):210
12. Gopikrishna V, Swamy Sibi DA, Kumar AR, Narayanan L. An in vivo assessment of the influence of needle gauges on endodontic irrigation flow rate. Journal of conservative dentistry: JCD. 2016 Mar;19(2):189
13. Van der Sluis LW, Versluis M, Wu MK, Wesselink PR. Passive ultrasonic irrigation of the root canal: a review of the literature. International endodontic journal. 2007 Jun;40(6):415-26
14. Plotino G, Pameijer CH, Grande NM, Somma F. Ultrasonics in endodontic: a review of the literature. Journal of endodontic. 2007 Feb 1;33(2):81-95.
15. Tay FR, Pashley DH, Loushine RJ, Doyle MD, Gillespie WT, Weller RN, King NM. Ultrastructure of smear layer-covered intraradicular dentin after irrigation with BioPure MTAD. Journal of endodontic. 2006 Mar 1;32(3):218-21.
16. Vallabhaneni K, Kakarla P, Avula SS, Reddy NV, Gowd MP, Vardhan KR. Comparative analyses of smear layer removal using four different irrigant solutions in the primary root canals–A scanning electron microscopic study. Journal of Clinical and Diagnostic Research: JCDR. 2017 Apr;11(4):ZC64.
17. Tuncer AK, Tuncer S. Effect of different final irrigation solutions on dentinal tubule penetration depth and percentage of root canal sealer. Journal of endodontic. 2012 Jun 1;38(6):860-3.
18. Baumgartner JC, Cuenin PR. Efficacy of several concentrations of sodium hypochlorite for root canal irrigation. Journal of Endodontics. 1992 Dec 1;18(12):605-12.
19. Hasnain M, Bansal P, Nikhil V. An in vitro comparative analysis of sealing ability of bioceramic-based, methacrylate-based, and epoxy resin-based sealers. Endodontology. 2017 Jul 1;29(2):146.
20. Rocha AW, de Andrade CD, Leitune VC, Collares FM, Samuel SM, Grecca FS, de Figueiredo JA, dos Santos RB. Influence of endodontic irrigants on resin sealer bond strength to radicular dentin. The Bulletin of Tokyo Dental College. 2012;53(1):1-7.
21. Abada HM, Farag AM, Alhadainy HA, Darrag AM. Push-out bond strength of different root canal obturation systems to root canal dentin. Tanta Dental Journal. 2015 Sep 1;12(3):185-91.
22. Rocha AW, de Andrade CD, Leitune VC, Collares FM, Samuel SM, Grecca FS, de Figueiredo JA, dos Santos RB. Influence of endodontic irrigants on resin sealer bond strength to radicular dentin. The Bulletin of Tokyo Dental College. 2012;53(1):1-7.
23. Gogos C, Stavrianos C, Kolokouris I, Papadoyannis I, Economides N. Shear bond strength of AH-26 root

canal sealer to dentine using three dentine bonding agents. Journal of dentistry. 2003 Jul 1;31(5):321-6.

24. Prado M, Simão RA, Gomes BP. Effect of different irrigation protocols on resin sealer bond strength to dentin. Journal of endodontic. 2013 May 1;39(5):689-92
25. Topçuoğlu HS, Tuncay Ö, Demirbuga S, Dinçer AN, Arslan H. The Effect of Different Final Irrigant Activation Techniques on the Bond Strength of an Epoxy Resin–based Endodontic Sealer: A Preliminary Study. Journal of endodontic. 2014 Jun 1;40(6):862-6.
26. UzUnoglU E, Turker SA, KArAhAn S. The effect of increased temperatures of qmix and edta on the push-out bond strength of an epoxy-resin based sealer. Journal of clinical and diagnostic research: JCDR. 2015 Jul;9(7):ZC98
27. Sarkar NK, Caicedo R, Ritwik P, Moiseyeva R, Kawashima I. Physicochemical basis of the biologic properties of mineral trioxide aggregate. J Endod. 2005; 31: 97-100.
28. Reyes-Carmona JF, Felippe MS, Felippe WT. Biomineralization ability and interaction of mineral trioxide aggregate and white portland cement with dentin in a phosphate-containing fluid. Journal of endodontic. 2009 May 1;35(5):731-6
29. Sagsen B, Ustün Y, Demirbuga S, Pala K. Push-out bond strength of two new calcium silicate-based endodontic sealers to root canal dentine. International endodontic journal. 2011 Dec;44(12):1088-91.
30. Wennberg A, Orstavik D. Adhesion of root canal sealers to bovine dentine and gutta-percha. Int Endod J. 1990;23:13–9
31. Tagger M, Tagger E, Tjan AH, Bakland LK. Measurement of adhesion of endodontic sealers to dentin. J Endod. 2002;28:351–4
32. Sarkar NK, Caicedo R, Ritwik P, Moiseyeva R, Kawashima I. Physicochemical basis of the biologic properties of mineral trioxide aggregate. J Endod. 2005;31:97–100.
33. Prüllage RK, Urban K, Schäfer E, Dammaschke T. Material properties of a tricalcium silicate-containing, a mineral trioxide aggregate-containing, and an epoxy resin-based root canal sealer. J Endod. 2016;42:1784–8.
34. Torabinejad M. Calcium silicate-based cements. In: Torabinejad M, editor. Mineral trioxide aggregate: properties and clinical applications. Ames: Wiley Blackwell; 2014. p. 281–332.
35. Atmeh AR, Chong EZ, Richard G, Festy F, Watson TF. Dentin-cement interfacial interaction: calcium silicates and polyalkenoates. J Dent Res. 2012;91:454–9.
36. Watson TF, Atmeh AR, Sajini S, Cook RJ, Festy F. Present and future of glass-ionomers and calcium-silicate cements as bioactive materials in dentistry: biophotonics-based interfacial analyses in health and disease. Dent Mater. 2014;30:50–61.
37. Kaup M, Dammann C, Schäfer E, Dammaschke T. Shear bond strength of biodentine, ProRoot MTA, glass ionomer cement and composite resin on human dentine ex vivo. Head Face Med. 2015;19:11–4.
38. Huffman BP, Mai S, Pinna L, Weller RN, Primus CM, Gutmann JL, et al. Dislocation resistance of ProRoot Endo Sealer, a calcium silicate-based root canal sealer, from radicular dentine. Int Endod J 2009;42:34-46
39. Eldeniz AU, Erdemir A, Belli S. Shear bond strength of three resin based sealers to dentin with and without the smear layer. J Endod 2005; 31: 293–66.
40. Donnermeyer D, Vahdat-Pajouh N, Schäfer E, Dammaschke T. Influence of the final irrigation

solution on the push-out bond strength of calcium silicate-based, epoxy resin-based and silicone-based endodontic sealers. Odontology. 2019 Apr 15;107(2):231-6

Legend Figures and Tables

Table 1: Comparison of mean Pushout Bond strength (in Mpa) in Middle third region between different study groups using One-way ANOVA Test

Groups	N	Mean	SD	Min	Max	P-Value
Sealapex	15	4.711	1.184	2.58	6.81	<0.001*
Bioroot RCS	15	7.227	0.864	5.86	8.54	
MTA Sealer	15	4.209	0.796	2.89	5.55	
AH Plus	15	8.125	0.740	6.76	8.98	

* - Statistically Significant

Table no. 1 compares the mean Pushout Bond strength (in Mpa) in Middle third region between different study groups. The test results demonstrate that Sealapex showed a mean Pushout Bond Strength values of 4.711 ± 1.184, Bioroot RCS showed 7.227 ± 0.864, MTA Sealer showed 4.209 ± 0.796 and AH Plus showed a mean Pushout Bond Strength values of 8.125 ± 0.740. This difference in the mean Pushout Bond Strength values between different groups was statistically significant at P<0.001. [Refer Graph no. 1]

Graph no. 1 Mean Pushout Bond strength (in Mpa) in Middle third region between different study groups

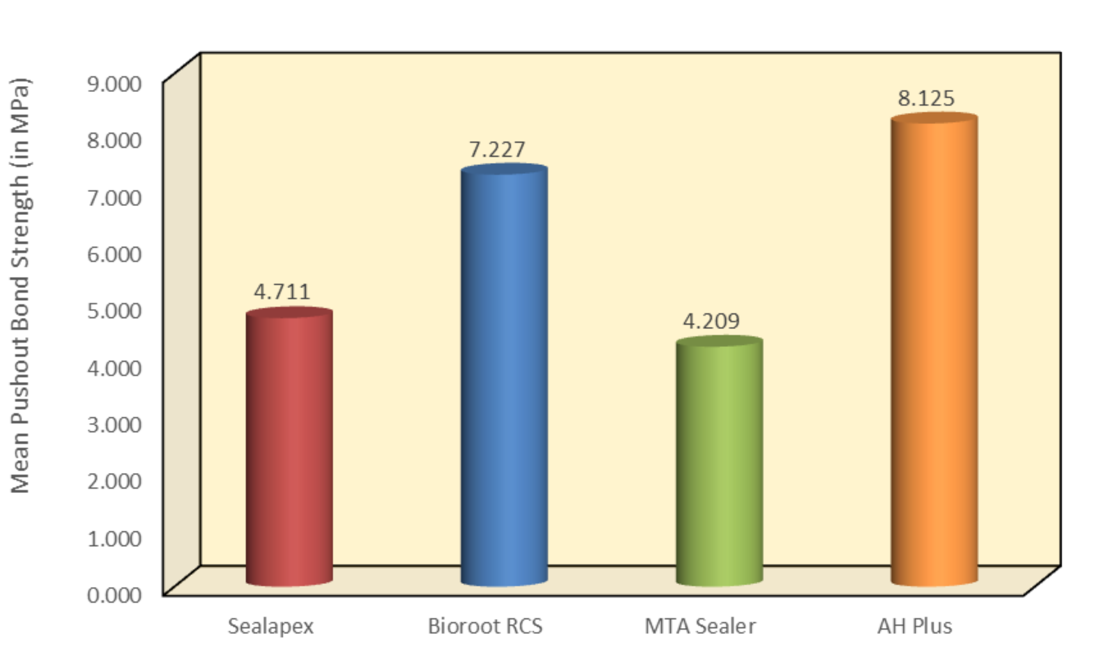

Table 2: Multiple comparison of mean diff. in Pushout bond strength in Middle third region b/w groups using Tukey's post hoc Test

(I) Groups	(J) Groups	Mean Diff. (I-J)	95% CI for the Diff.		P-Value
			Lower	Upper	
Sealapex	Bioroot RCS	-2.517	-3.399	-1.635	<0.001*
	MTA Sealer	0.501	-0.381	1.383	0.44
	AH Plus	-3.414	-4.296	-2.532	<0.001*
Bioroot RCS	MTA Sealer	3.018	2.136	3.900	<0.001*
	AH Plus	-0.897	-1.779	-0.015	0.04*
MTA Sealer	AH Plus	-3.915	-4.797	-3.033	<0.001*

* - Statistically Significant

Table no. 2 illustrates multiple Comparisons of difference in mean Pushout Bond strength (in Mpa) in Middle third region b/w groups.

The test results demonstrate that the Group AH Plus showed significantly highest mean Pushout Bond strength as compared to Sealapex and MTA sealer at P<0.001 & with Biorrot RCS group at P=0.04 respectively. This was followed next by Bioroot RCS group showing significantly higher mean pushout bond strength as compared to Sealapex and MTA Sealer at P<0.001. However, no significant differences were noted between Sealapex & MTA sealer in mean Pushout Bond strength [P=0.44]. [Refer Graph no. 2]

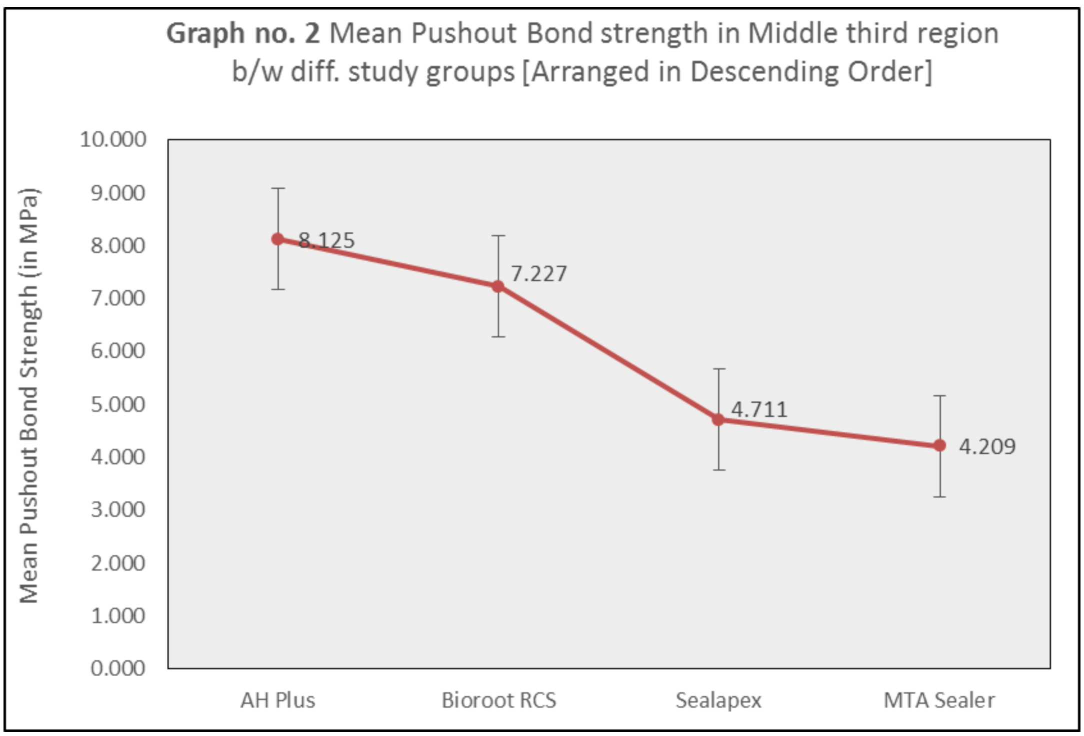

Table 3: Comparison of mean Pushout Bond strength (in Mpa) in Apical third region between different study groups using One-way ANOVA Test

Groups	N	Mean	SD	Min	Max	P-Value
Sealapex	15	3.110	0.936	1.49	4.94	<0.001*
Bioroot RCS	15	6.006	0.521	5.03	6.88	
MTA Sealer	15	3.041	0.467	2.38	3.73	
AH Plus	15	6.653	0.721	5.66	7.78	

* - Statistically Significant

Table no. 3 compares the mean Pushout Bond strength (in Mpa) in Apical third region between different study groups. The test results demonstrate that Sealapex showed a mean Pushout Bond Strength values of 3.110 ± 0.936, Bioroot RCS showed 6.006 ± 0.521, MTA Sealer showed 3.041 ± 0.467 and AH Plus showed a mean Pushout Bond Strength values of 6.653 ± 0.721. This difference in the mean Pushout Bond Strength values between different groups was statistically significant at $P<0.001$. [Refer Graph no. 3]

Graph no. 3 Mean Pushout Bond strength (in Mpa) in Apical third region between different study groups

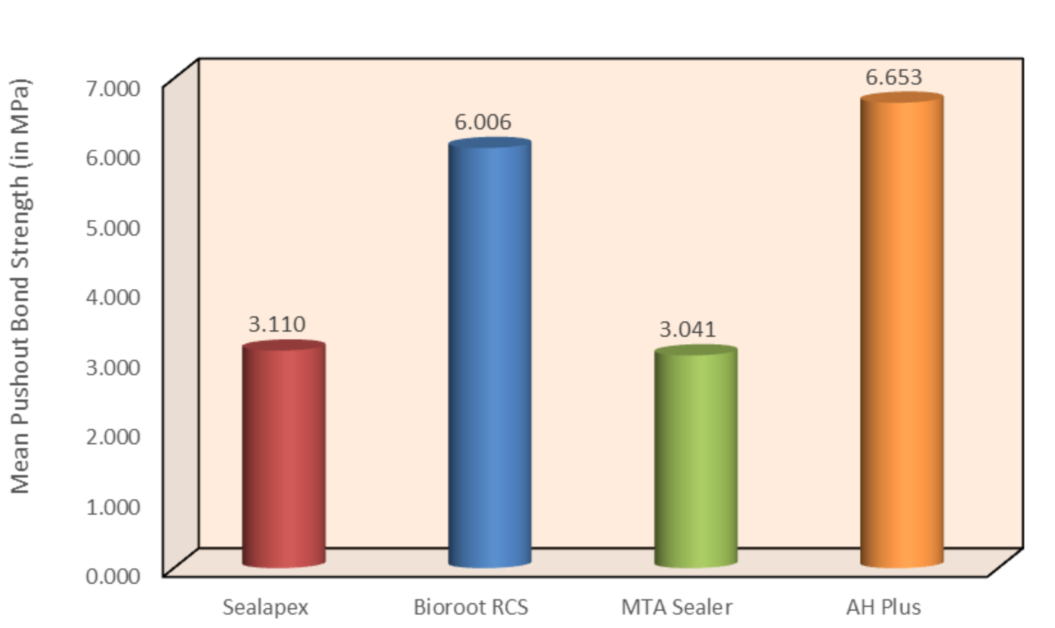

Table 4: Multiple comparison of mean diff. in Pushout bond strength in Apical third region b/w groups using Tukey's post hoc Test

(I) Groups	(J) Groups	Mean Diff. (I-J)	95% CI for the Diff.		P-Value
			Lower	Upper	
Sealapex	Bioroot RCS	-2.896	-3.560	-2.232	<0.001*
	MTA Sealer	0.069	-0.595	0.732	0.99
	AH Plus	-3.543	-4.207	-2.880	<0.001*
Bioroot RCS	MTA Sealer	2.965	2.301	3.628	<0.001*
	AH Plus	-0.647	-1.311	0.016	0.04*
MTA Sealer	AH Plus	-3.612	-4.276	-2.948	<0.001*

* - Statistically Significant

Table no. 4 illustrates multiple Comparisons of difference in mean Pushout Bond strength (in Mpa) in Apical third region b/w groups.

The test results demonstrate that the Group AH Plus showed significantly highest mean Pushout Bond strength as compared to Sealapex and MTA sealer at P<0.001 & with Biorrot RCS group at P=0.04 respectively. This was followed next by Bioroot RCS group showing significantly higher mean pushout bond strength as compared to Sealapex and MTA Sealer at P<0.001. However, no significant differences were noted between Sealapex & MTA sealer in mean Pushout Bond strength [P=0.99]. [Refer Graph no. 4]

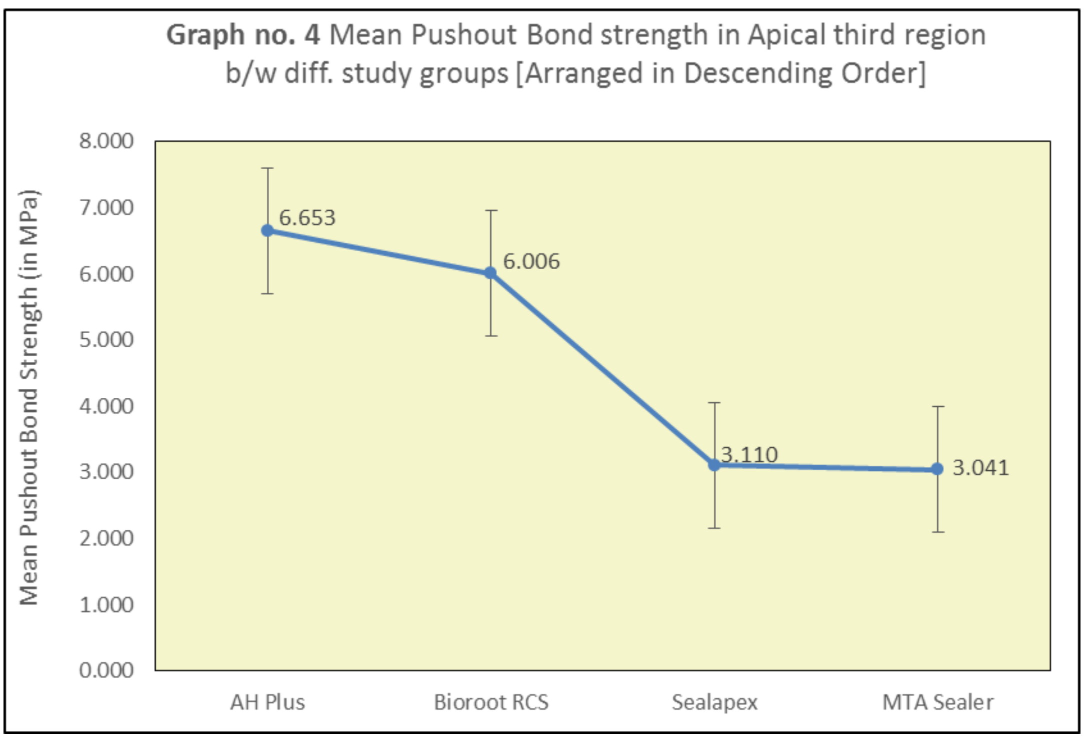

Table 5: Comparison of mean Pushout Bond strength (in Mpa) between Middle and Apical third region in each study group using Student Paired t Test

Groups	Region	N	Mean	SD	Mean Diff	P-Value
Sealapex	Middle	15	4.711	1.184	1.601	<0.001*
	Apical	15	3.110	0.936		
Bioroot RCS	Middle	15	7.227	0.864	1.221	<0.001*
	Apical	15	6.006	0.521		
MTA Sealer	Middle	15	4.209	0.796	1.168	0.001*
	Apical	15	3.041	0.467		
AH Plus	Middle	15	8.125	0.740	1.471	<0.001*
	Apical	15	6.653	0.721		

* - Statistically Significant

Table no. 5 compares the mean Pushout Bond strength (in Mpa) between Middle and Apical third region in each study group.

The test results demonstrate that the mean Pushout Bond strength in Middle third region was significantly higher [4.711 ± 1.184, 7.227 ± 0.864, 4.209 ± 0.796 and 8.125 ± 0.740] as compared to Apical third region [3.110 ± 0.936, 6.006 ± 0.521, 3.041 ± 0.467 and 6.653 ± 0.721] in each study group. This difference in the mean pushout bond strength between the middle and apical third region in all the groups was statistically significant at $P \leq 0.001$. [Refer Graph no. 5]

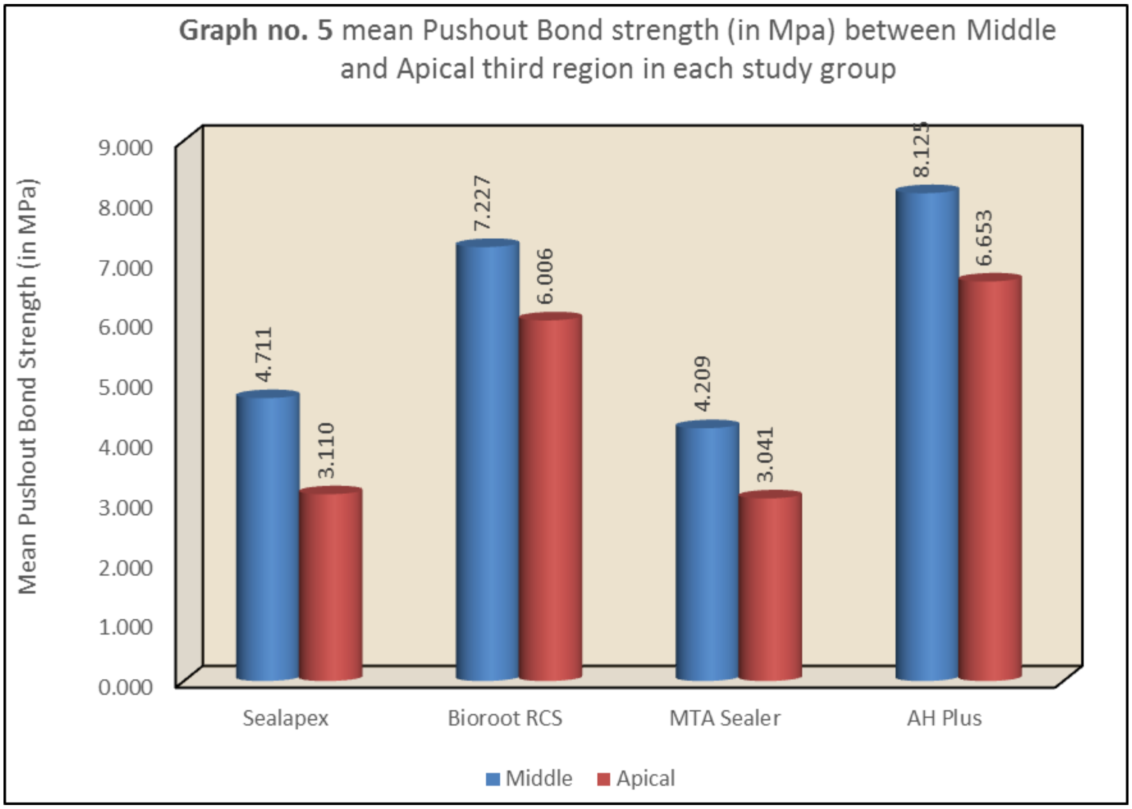
Graph no. 5 mean Pushout Bond strength (in Mpa) between Middle and Apical third region in each study group
Mean Pushout Bond Strength (in MPa)
9.000
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
4.711
3.110
7.227
6.006
4.209
3.041
8.125
6.653
Sealapex
Bioroot RCS
MTA Sealer
AH Plus
Middle
Apical

Table 6: Comparison of modes of Failure between different groups using Chi Square Test							
Groups	Adhesive		Cohesive		Mixed		P-Value
	n	%	n	%	n	%	
Sealapex	10	66.7%	4	26.7%	1	6.7%	0.002*
Bioroot RCS	3	20.0%	10	66.7%	2	13.3%	
MTA sealer	10	66.7%	2	13.3%	3	20.0%	
AH Plus	2	13.3%	12	80.0%	1	6.7%	

* - Statistically Significant

Table no. 6 compares the Modes of Failure between different groups.

The test results demonstrate that the Adhesive failure was significantly higher in Group Sealapex and MTA sealer [66.7%] as compared to Cohesive Failure seen in AH Plus [80.0%], and Bioroot RCS Group [66.7%]. Mixed failure was more seen in MTA sealer [20.0%], followed by Bioroot RCS group [13.3%] as compared to AH Plus [6.7%] and Sealapex group [6.7%]. This difference in the modes of Failure between different study groups was statistically significant at P=0.002. [**Refer Graph no. 6**].