ISSN Print: 2394-7489
ISSN Online: 2394-7497
IJADS 2023; 9(2): 01-10

www.oraljournal.com
Received: 10-01-2023
Accepted: 11-02-2023

Hosam Abdelhady Ahmed
Master Candidate, Department of Endodontic, Faculty of Dentistry, Cairo University, Egypt

Hany Samy Sadek
Professor, Department of Endodontic, Faculty of Dentistry, Cairo University, Egypt

Dina Ahmed Morsy
Lecturer, Department of Endodontic, Faculty of Dentistry, Cairo University, Egypt

Corresponding Author:
Hosam Abdelhady Ahmed
Master Candidate, Department of Endodontic, Faculty of Dentistry, Cairo University, Egypt

Effect of nano-silver gel and calcium hydroxide paste on the bond strength of epoxy-resin based sealer to root canal dentin in anterior teeth: An *in vitro* study

Hosam Abdelhady Ahmed, Hany Samy Sadek and Dina Ahmed Morsy

DOI: https://doi.org/10.22271/oral.2023.v9.i2a.1703

Abstract
Aim: The objective of this study was to determine and compare the Push-out bond strength of AH Plus sealer of root canal following prior application of calcium hydroxide ($Ca[OH]_2$) paste and Nano-silver gel as intracanal medication in single-rooted human extracted maxillary incisors.
Methodology: Using of ProTaper System up till master apical file # F5 have been carried out to prepare root canals of 30 human extracted maxillary incisors. According to the intracanal medication applied, division of teeth were carried out in random manner into three groups. Group I: Control group (No intracanal medication), Group II: Nano-silver gel and Group III: Calcium hydroxide $Ca(OH)_2$. Three weeks later, the elimination process of the intracanal medications were achieved by using passive ultrasonic irrigation of 5 mL 2.5% NaClO, in addition to that, a 17% EDTA was used in the step of final flush for duration of 60 seconds succeeded by 5 mL of distilled water. Using the master cone #F5 and AH plus sealer, the single cone approach was used to fill the canals. After 1 week, the universal testing machine was implemented to test the push out-bond strength of the samples, which was performed for a 2-mm-thick of coronal, middle and apical thirds of each root.
Results: A remarkable difference was evident between the control group and the comparison groups ($p<0.001$). Within the control group, the greatest value was evident (4.85±1.65), followed by calcium hydroxide (2.11±1.17), meanwhile the lowest value was discovered in nano-silver (1.41±1.08). Post hoc pairwise comparisons demonstrated a remarkably higher value in the control group than the rest of groups ($p<0.001$) with no statistically remarkable difference between calcium hydroxide and Nano-silver group.
Conclusion: Prior calcium hydroxide and nano-silver placement seemed to decrease the push-out bond strength of epoxy resin-based Ah plus sealer.

Keywords: Ah plus sealer, Calcium hydroxide, Push-out bond strength, Nano-silver

Introduction
The main contributors to pulpitis, apical periodontitis, and root canal failure are microorganisms. The elimination or cutting back on the number of these microorganisms is the endodontic therapy's major objective [1-4]. Total bacterial eradication via instrumentation is doubtful [5, 6]. Intracanal medications is necessary to eliminate or decrease the number of microorganisms and their by-products, hence it can treat infections, reduce inflammation (and hence discomfort), help in clear apical exudate, control root resorption which is triggered by inflammation, and aid in preventing contamination between the scheduled visits [6, 7].
Calcium Hydroxide is among the most well-recommended inter-appointment medications owing to its antibacterial activity which is due to the hydroxyl ions [8]. Nano-silver is a well-known Nano product. Nano-silver (NS) has a potent antibacterial effect [9, 10]. The silver ion is presumed to be accountable for the biological effects of silver. Because of their extremely wide surface area, that permits for better contact with pathogens, these nanoparticles displayed powerful antimicrobial properties when compared to other medicaments [11].
As the gutta-percha cones' adherence to the root canal dentin is insufficient, to ensure optimal obturation, a sealer should be used in conjunction with gutta-percha to enhance its adaptability to the wall of root canal dentin by establishing a fluid-tight seal coronally as well as apically [12, 13].

An epoxy resin-based sealer such as the AH plus sealer is widely recommended because of its high bond strength to wall of dentin [14].

In order to acquire the optimal contact between the root canal filling material and the dentinal walls of the canal, removing the intracanal dressings from the root canals is a mandatory step before the procedure of final obturation [15, 16]. Remnant medicament might act as a physical barrier between the sealer and the dentin of the root canal, inhibiting sealers from penetrating the dentin walls [17, 18].

Adhesion of the obturating filling material to dentin is considered fundamental to avoid dislocation in both static and dynamic situations. Push-out bond strength (POBS), also known as dislodgement resistance, is a method that is considered as a relevant prognostic factor to assess how well a root canal sealer adheres to wall of the canal as well as the core material [19]. Leakage and push-out bond strength were shown to be negatively correlated, i.e., those treatments that resulted in the least leakage revealed the highest dentin bond strength [20].

Thus, this study aimed to assess how the AH plus sealer's bond strength to wall of dentin is affected by intracanal medicaments. The null hypothesis stated that it would be predicted that the influence of calcium hydroxide intracanal medication and nano-silver gel intracanal medication have no appreciably different effects on the bond strength of the AH plus sealer.

Materials and Methods

Ethical Approval: The Faculty of Dentistry at Cairo University's research ethics committee authorized the study with an approval number of 5-10-20.

Sample size calculation

The (PS software) was used to perform the calculation of size of sample, based upon earlier study by Guiotti *et al*., (2014) [18]. In terms of the primary outcome (assessing the strength of AH sealer's bond strength to dentin of root canal), It has been found that using a total sample size of 30 teeth splitted into 3 groups, 10 teeth for each group, power is 80% and α error probability =0.05 is the suitable sample size for the study. Mean and standard deviation of the relevant variable were acquired from the literature, allowing us to estimate the impact and the magnitude we were aiming to detect.

Selection of samples

For this study, A thirty recently extracted human permanent (adult) maxillary incisors were chosen. The collection of teeth was from dental clinic of National Diabetic Centre and Endocrinology Institute in Cairo and department of Oral Surgery, Faculty of Oral and Dental Medicine Cairo University. Periodontal problems were the main causes of tooth extractions.

Eligibility criteria

Maxillary anterior incisors with completely formed single root and straight single canal having average length of 22 to 25mm. Teeth with neither external nor internal resorption of root as well as no signs of cracks. Mesio-distal and bucco-lingual preoperative radiographs were taken for all the teeth.

Preparation of the samples

The teeth were thoroughly washed under running water for two minutes. The periodontal scaler was used to mechanically eliminate the remnants of soft tissue, in addition to the calculi on the external root surface of these samples. An immersion of the teeth in 5.25% sodium hypochlorite (NaClO) solution (JK Dental vision, Mansoura; Egypt) were performed for 15 minutes to disinfect them. The teeth were then sterilized in a Class B autoclave (Jardim Irajá - Ribeirão Preto; Brazil) for fifteen minutes at a temperature of 121 °C. The teeth were stored in sterile isotonic saline until usage to preserve natural teeth hydration. A preparation of standard access cavity was performed for the entire samples, utilizing an endo access bur as well as diamond round bur under water coolant mounted on a high-speed handpiece. A #15 k-file (Dentsply Maillefer, Ballaigues Switzerland) was positioned just beyond the apex and afterwards withdrawn in order to flush with the apex, establishing working length in addition to canal patency. To adjust the working length, one common technique for making this is to subtract 1 mm from the flushed tooth length measurement. The ProTaper Universal Rotary System files (Dentsply Maillefer, Ballaigues, Switzerland) were used for instrumentation of the teeth up to size F5 (The tip of the instrument is 0.5 mm in diameter and apical taper is 5%) using an endo motor named X-Smart (Dentsply Maillefer, Ballaigues Switzerland) in accordance with the guidelines provided by the manufacturer. A 27-gauge needle was used to irrigate the canals using 5 mL 2.5% NaOCl between each subsequent file. A 5 mL 2.5% NaClO was utilized in final irrigation which was performed by passive ultrasonic irrigation using a file of #15 K-file (K15; Acteon Satelec, Merignac, France) in an ultrasonic device (P5 Newtron XS, Acteon Satelec) and a power setting adjusted to 6 for a duration of 1 minute shorter than the measured working length. Final flush was done using 17% EDTA (JK Dental vision, Mansoura; Egypt) for 60 seconds succeeded by using a 27-gauge needle to flush with 5 mL distilled water. Specimens were dried using sterile absorbent paper points (#50.04 and #50.06) to confirm complete dryness of the root canals.

Grouping of the samples

Group I (n=10): Control group in which the root canals were obturated without prior intra-canal medication application.

Group II (n=10): Intervention 1 (I1) in which a Nano-silver gel intra-canal medication (Nanotech Corp, 6th October, Egypt) was injected into root canals using a plastic syringe of 27-gauge needle to a length 2 mm shorter than the measured working length. The gel was injected slowly during withdrawal till the tested gel was revealed at the canal's orifice in order to guarantee that the canals were filled completely.

Nano-silver gel preparation

Thesynthesize of the spherical silver nanoparticles was carried out by the reduction of silver nitrate in aqueous solution to obtain silver ions. The chemical reduction was achieved by the inorganic reducing agent Sodium Borohydride (NaBH4) [21]. Polyvinylpyrrolidone (PVP) was added to the mixture to interact with the particle surfaces in order to stabilize the growth of particle in addition to prevent the occurrence of agglomeration and sedimentation to the particles [22]. Lastly, the product was prepared in gel form by using inactive ingredient polymer gel 1.5% hydroxyethyl-cellulose gel [23].

Group III (n=10): Intervention 2 Where Calcium hydroxide paste (Meta Dental Corp. Ltd., Elmburst, NY) intracanal medication were injected into the root canals using the nozzle of the readymade injectable paste. In order to guarantee the canals were filled, the nozzle or syringe was placed into the root canal to a length 2 mm shorter than the working length and it was slowly injected during withdrawal till the tested paste was demonstrated at the canal's orifice to assure that the canals were filled.

The leakage was prevented by packing the coronal access of the teeth with a tiny cotton pellet in addition to material of temporary filling (Cavit G; 3M ESPE, Seefeld, Germany). To better simulate clinical conditions, storage of the specimens was at 37 °C in 100% humidity for a duration of 3 weeks.

Obturating of the samples

After three weeks, the specimens were collected to remove the intracanal medications. A final wash with 5 mL 2.5% NaClO was activated by passive ultrasonic irrigation. This was followed by a final flush using 17% EDTA for one minute and finally 5 ml distilled water using a 27-gauge needle was used to remove any remaining debris. Sterile absorbent paper points were used to confirm complete dryness of the specimens. Mixing of AH plus sealer was done on a paper pad in according to manufacturer's guidelines. A single cone of gutta-percha (F5) (Dentsply Maillefer, Ballaigues, Switzerland), was slightly coated with the sealer and positioned inside the root canal to the measured working length. The excess gutta percha was then cut with a pre-heated condenser at the orifice of the canal and any excess sealer was removed by a moistened cotton pellet. After obturation, a temporary filling was filled into the coronal opening and storage of the specimens were at 100% humidity at 37 °C for 1 week in order to allow setting of the sealer. The quality of obturation was checked by the postoperative radiographs carried out for all teeth.

Bond strength evaluation

Decoronation of the teeth was done at the cemento-enamel junction in such a way that the diamond disc is positioned perpendicular to the long axis of the root. This diamond disc was mounted in a hand piece of low-speed type. A root of approximately 16 mm was obtained after the decoronation process. Pink acrylic resin model was used to embed each root that had a 2 cm diameter, 3 cm height and 5 mm thickness of wall. After the acrylic resin had set, a precision saw Iso Met 4000 of low-speed water-cooled type was used to cut each root into three horizontal sections, a section belongs to the coronal one third, a section belongs to the middle one third, and a section belongs to the apical one third, Figure (1). Using a digital caliper, we determined the thickness of each slice, yielding to 30 horizontal sections for each group Figure (2). A marker was used to mark every section on its coronal side. An examination of each specimens' aspect was performed under stereomicroscope prior to testing to confirm that there are no signs of any dentin cracks or presence of voids in the filling materials.

Fig 1: Buehler IsoMet 4000 micro-saw

Fig 2: A digital calliper

To prevent sample movement during testing, all root slices were set up in a loading fixture. This was performed so that stress would be distributed equally. A universal testing machine was utilized to apply a compressive load to the filling of root canal solely in each section of root (Model Instron universal testing machine model 3345 England) at a crosshead speed of 0.5 mm/min using a stainless-steel cylindrical plunger of varied sizes 0.55, 0.7 and 0.9 mm in diameter for apical thirds, middle thirds and coronal thirds respectively to provide most extended coverage without touching the canal walls Figure (3) and (4).

Fig 3: Universal Testing Machine

Fig 4: Stainless-steel cylindrical plunger of three different sizes 0.9, 0.7 and 0.55 mm

An application of load was carried out apico-coronally till failure of bond occurs, which was demonstrated by filling material extrusion as well as an instant drop in load. The maximum load prior to the failure occurrence was reported in newtons (N). The force was recorded using computer software Blue hill 3 version. The bond strength of push-out was calculated in megapascals (MPa) in accordance with the following formula:

Push-out bond strength (MPa) = Maximum load (N)/Adhesion area to dentin (A)

- The calculation of adhesion surface area (A) for every section will be as follow [24]:

$$A\ (mm^2) = (pr1 + pr2) \times L$$

- "L" is calculated as the square root of $(r2 - r1)^2 + h^2$
- "p" is the constant 3.14
- "r1" is the smallest radius
- "r2" is the largest radius
- "h" is the section's thickness expressed in millimeters

Statistical analysis

The presentation of numerical data was conducted as values of mean and standard deviation (SD). The exploration of numerical data for normality involved the use of the Shapiro-Wilk test and an examination of the data distribution. Since the data exhibited a parametric distribution, intergroup analysis ((i.e., between the three groups) was conducted using one-way ANOVA followed by Tukey's post hoc test as well as repeated measures ANOVA followed by the test of Bonferroni post hoc which was used for intragroup (i.e., within each single group) comparisons. The level of significance was determined at $p \leq 0.05$. R statistical analysis software version 4.1.2 for Windows [R Core Team (2021)] was used to perform statistical analysis.

Results

Effect of intracanal medication

Mean, Standard deviation (SD) values of push-out bond strength (MPa) for various sorts of intracanal medications were demonstrated in Table (1) and Figure (5).

The experimental groups showed a significant difference compared to the control group ($p<0.001$). The highest mean value was observed in the control group (4.85±1.65), followed by calcium hydroxide (2.11±1.17), and the nano-silver group had the lowest mean value (1.41±1.08). Post hoc pairwise comparisons revealed that the control group exhibited significantly higher values than all other groups ($p<0.001$).

Table (1): Mean, Standard deviation (SD) values of push-out bond strength (MPa) for different types of intracanal medications

Push-out bond strength (MPa), (Mean ± SD)			P-Value
Control	Calcium Hydroxide	Nano silver	
4.85 ± 1.65^{A}	2.11 ± 1.17^{B}	1.41 ± 1.08^{B}	< 0.001*

In the same horizontal row, a statistically significant difference was indicated by various superscript *; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$).

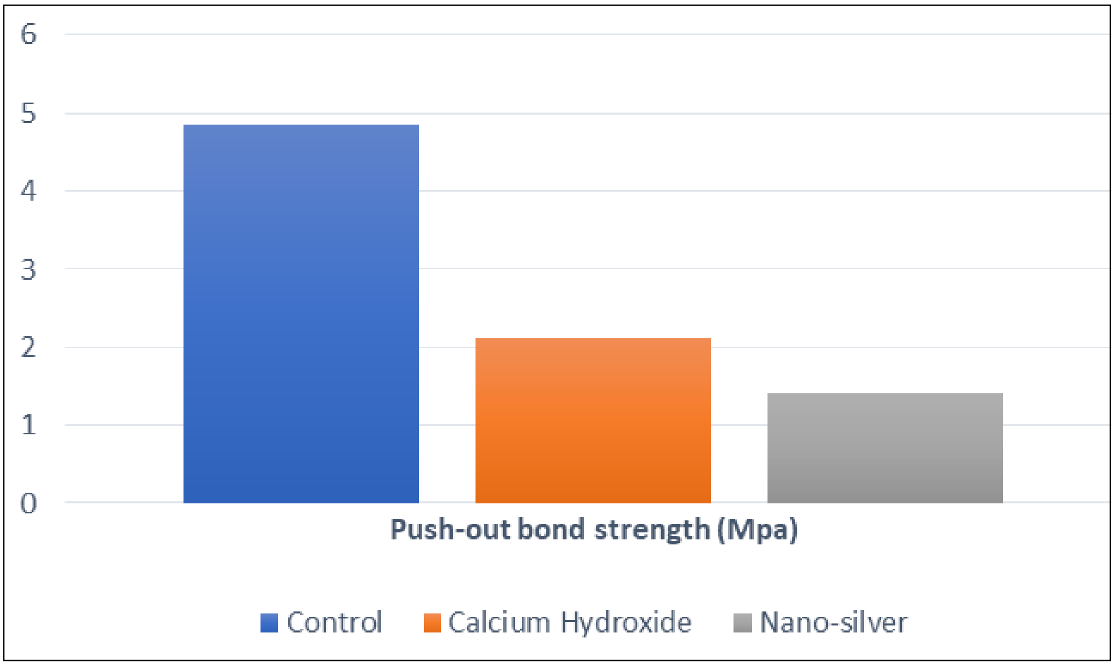

Fig 5: Bar chart displaying average push-out bond strength (MPa) for various sorts of intracanal medications

Effect of intracanal medication within each section of root

The values of mean, Standard deviation (SD) of push-out bond strength (MPa) for various sorts of intracanal medications within each root section were demonstrated in Table (2) and Figure (6).

- **Coronal:** A remarkable difference between various groups ($p<0.001$) was evident. The control group demonstrated the greatest value (6.13±1.70), followed by calcium hydroxide (3.33±0.21), while the lowest value was found in nano-silver (2.87±0.30). It has been shown by post hoc pairwise comparisons that control group to have a remarkably higher value than the other two groups ($p<0.001$), whereas the calcium hydroxide and Nano-silver groups did not vary statistically from one another.
- **Middle:** A remarkable difference between various groups ($p<0.001$) was evident. The control group demonstrated the greatest value (4.74±1.46), followed by calcium hydroxide (2.30±0.64), while the lowest value was found in nano-silver (0.89±0.08). It has been shown by post hoc pairwise comparisons that different groups to own remarkably distinctive values from one another ($p<0.001$).
- **Apical:** A remarkable difference between the experimental groups and control group ($p<0.001$) was evident. Control group (3.68±0.64) demonstrated the greatest value, succeeded by calcium hydroxide (0.69±0.17), while in nano-silver, the least value was evident (0.47±0.07). No statistically remarkable difference was evident between calcium and nano-silver groups. It has been shown by post hoc pairwise comparisons that control group possesses a remarkably greater value than rest of groups (p 0.001).

Table (2): Mean, Standard deviation (SD) values of push-out bond strength (MPa) for different types of intracanal medications within each root section

Root section	Push-out bond strength (MPa), (Mean ± SD)			P-Value
	Control	Calcium Hydroxide	Nano silver	
Coronal	6.13 ± 1.70^{A}	3.33 ± 0.21^{B}	2.87 ± 0.30^{B}	<0.001*
Middle	4.74 ± 1.46^{A}	2.30 ± 0.64^{B}	0.89 ± 0.08^{C}	<0.001*
Apical	3.68 ± 0.64^{A}	0.69 ± 0.17^{B}	0.47 ± 0.07^{B}	<0.001*

In the same horizontal row, a statistically significant difference was indicated by various superscript *; significant ($p \leq 0.05$) ns; non-significant ($p > 0.05$).

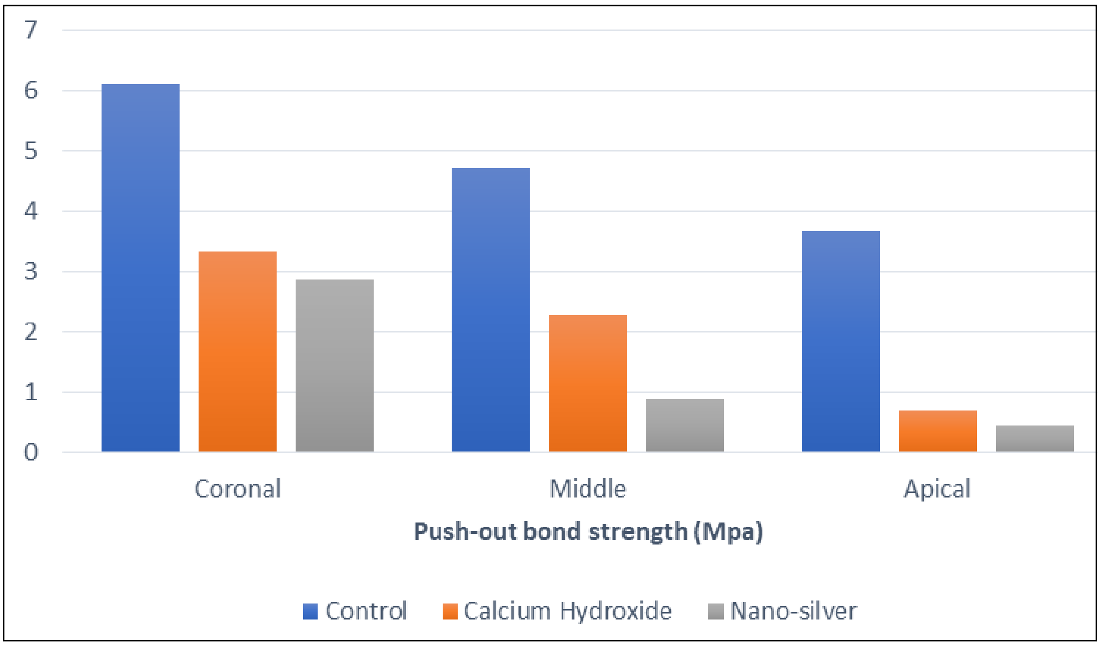

Fig 6: Bar chart displaying average push-out bond strength (MPa) for different types of intracanal medications within each root section

Discussion

Application of intracanal medication has been advised to ensure appropriate and satisfactory disinfection process of the root canal system and its dentinal tubules, ramifications, accessory canals, anastomoses, and apical delta [25]. Despite the importance of intracanal medicaments against bacterial biofilms and planktonic bacteria that are not eradicated after conventional root canal biomechanical preparation, their total removal from the root canal system is unachievable and this might affect the bond strength of the endodontic filling material [26].

The prevailing belief for a considerable period of time has been that Calcium hydroxide [$Ca(OH)_2$] is the most accepted intracanal medication. This is due to its high pH value, significant potential for reducing inflammation, considerable antibacterial properties [8]. Calcium hydroxide also has a mineralizing effect because of its high pH [27].

Several disadvantages have been reported regarding $Ca(OH)_2$, including limited efficacy against E. faecalis, facultative anaerobic bacteria, and yeasts [28]. One other obstacle is that $Ca(OH)_2$ is frequently impossible to be eliminated from the root canal walls completely [25]. Consequently, other medications were used as alternatives to calcium hydroxide. One of these materials is Nano-silver gel (AgNPs gel).

AgNPs have an oligodynamic activity, which is the mechanism by which heavy metals can be destructive to bacterial and viral cells at minute levels. It is possible that this impact is bacteriostatic (growth inhibition) or perhaps bactericidal (kills bacteria) [29]. AgNPs' antibacterial properties have been evaluated in several *in vitro* [30, 31] and in vivo research [32].

Ah Plus endodontic sealer was chosen as it remains the gold standard [33]. The relatively satisfactory adhesion of AH Plus sealer is thought to be due to the ability of an open oxide ring to form a covalent bond with the exposed amino groups present in the collagen network of dentin [34].

This in-vitro study aimed to evaluate how the bond strength of AH Plus epoxy resin-based sealer to root canal dentin is affected by root canal medication using either calcium hydroxide paste or Nano-silver gel.

In order to mimic the clinical situation, the intracanal medications were left in the prepared root canals for three weeks and the teeth were incubated at 37 °C and 100% humidity [35]. After the storage period, final irrigation was performed using passive ultrasonic stimulation of 5 mL 2.5% NaClO [36]. According *to* Harms *et al.*, *2021* [25] and Sluis *et al.*, *2007* [37], the use of passive ultrasonic stimulation of the irrigation effectively eliminated medication from the root canal.

EDTA was used due to its ability to target the inorganic or mineral component of the smear layer and facilitate its elimination [38, 39]. As a result, sealers can infiltrate deeper into the dentinal tubules, thereby increasing the contact area between the filling material and dentin which subsequently leads to enhanced adhesion [40].

The longevity of dental root filling material is measured moderately by its adhesive strength. Adhesive strength can be measured by bond strength testing. The reason behind selecting the push-out test is that it evaluates the level of shear stress occurring at the interface between dentine and cement (sealer), which is like the stresses experienced in clinical situations. Additionally, the push-out test is an effective and replicable method that is less prone to minor variations in stress distribution across samples while applying the load. [41].

However, some aspects that should be considered during testing could alter the results and validity of push-out bond strength tests. Plunger sizes, root canal diameters, and specimens' orientation are all factors to be considered.

For these reasons, Pane *et al.*, 2013 [19] concluded that when the diameter of the pin was 90% of the canal diameter, no influence on the punch diameter was seen. To minimize the impact of variables, this study employed plunger tips with varying diameters; 0.9 mm for the coronal thirds, 0.7 mm for the middle thirds, and 0.55 for the apical thirds. This further avoided excessive pressure or notching of the obturating material, as well as guaranteed that the stress delivered is restricted at the sealer dentin interface [42].

Based on the results obtained, our investigation uncovered a notable difference between the control group and the experimental groups based on the results obtained (p<0.001). The control group recorded the highest value of (4.85±1.65), followed by calcium hydroxide with a value of (2.11±1.17), whereas Nano-silver had the lowest value of (1.41±1.08).

However, no significant difference was observed between the calcium hydroxide and nano-silver groups.
Our findings are in accordance with Guiotti *et al*., 2014 [18]. Ghabraei *et al*., 2017 [26], Üstün, *et al*., 2013 [43] and *Gupta et al*., 2020 [44] who reported that application of calcium hydroxide intracanal dressing led to a decrease in the bond strength between the root canal sealer and dentin. Unlike others who found that the usage of calcium hydroxide intracanal dressing could not be able to improve the AH Plus sealer's bonding strength but did not impair it either [24, 45, 46]. Carvalho *et al*., 2013 [47] findings were contrary to ours, as they reported a positive effect of calcium hydroxide intracanal dressing on the bond strength between dentin of the root and AH Plus sealer.
In several studies, such as Rödig *et al*., 2010 [48] and Uzunoglu-Özyürek *et al*., 2018 [49], the use of calcium hydroxide was found to decrease dentinal permeability by physically plugging the tubules in the dentin. This could be a possible explanation for the observed decrease in push-out bond strength following the application of calcium hydroxide.
The effects of Nano-silver gel intracanal medication on the bond strength of epoxy resin-based sealer to root dentin are limited in the literature. As a result, this study's findings can only be compared to research that used Nano-silver particles inside root canals but not as a medication.
Our findings are in agreement with Nashaat *et al*., 2019 [34] and Gabal *et al*., 2018 [50]. Marginal adaption and bond strength were considerably reduced by increasing the proportion of Nano-silver particles in endodontic sealers, according to their findings [50]. Nashaat *et al*., 2019 [34] assessed the AH Plus sealer's push-out bond strength following root canal irrigation using Sodium hypochlorite and a solution containing Nano-silver. Their results demonstrated that AH plus sealer had a lesser value of push-out bond strength in the Nano-silver group than in Sodium hypochlorite group, with statistically significant differences observed in both the coronal and apical thirds.
Reduction in Push-out bond strength following the use of nano-silver gel may be due to their effect of blocking the dentinal tubules. This may be interpreted by the findings of Fan *et al*., 2014 [51] who used Field Emission Scanning Electron Microscope (FE-SEM) to capture images and detect the influence of nanoparticles on the dentinal tubules.
As for the comparison between coronal, middle and apical segments in each group, results in all groups showed that the greatest bond strength was found in the coronal segments succeeded by middle segments and apical segments the least. A significant difference in our study between values measured at various sections ($p<0.001$) was evident. The measurement revealed that the coronal section possesses the greatest value (4.11±1.76), succeeded by the middle section (2.64±1.84), meanwhile the apical section had the lowest value (1.61±1.53).
In the control group (no medication), our findings regarding the three segments are consistent with others Topçuoğlu *et al*., 2014 [52]; Abada *et al*., 2015 [53]*;* Ozkocak *and* Sonat, 2015 [54]; and Kurup *et al*., 2021 [55]. The explanation of these results can be demonstrated by higher density of tubules within the coronal third compared to the middle as well as apical thirds [56]. Added to that, the impact of EDTA on the removal of smear layer declines while moving from coronal to apical [57]. This could be associated with increased number of opened dentinal tubules in the coronal third therefore more resin tags and higher AH plus bond [52, 54].
Irrigants may be prevented from penetrating due to the effect of the vapor lock in the apical region [52]. As a result, the chelating impact in the apical third may be reduced, leaving blocked dentinal tubules behind.
However, some previous findings contrast with the findings of our study [58, 59]. Mannocci *et al*., 2004 [58]; found that low densities of dentinal tubules are related to the high values of dentin bond strength, and also, apical regions of root dentin own greater bond strength than coronal and middle regions. Mishra *et al*., 2017 [59]; suggested that in the apical third segment, better compaction of obturating material due to down packing might result in better sealer penetration into the dentinal tubules and this, in turn, reduces voids and achieves homogenous mass at the interface of dentin-sealer as well as the interface of sealer-cone that raises the push out bond strength.
In $Ca(OH)_2$ group, our findings regarding the three segments are in accordance with Üstün *et al*., 2013 [43]; and Gupta *et al*., 2020 [44]. These findings may be interpreted by studies that have reported that, it is very challenging to remove the $Ca(OH)_2$ medicament from the apical part of the root canal wall [60, 61]. A root canal with a conical morphology and a smaller diameter at the apical region may result in decreased irrigation effectiveness in this area, leaving behind on the canal walls residues of the medication used [62].
Nano-silver groups had the lowest values for push-out bond strength in our experiment. This might be related to the inability to remove nano-silver gel with a resinous sticky form from the root dentin walls, especially at the apical third which may be interpreted by the findings of Balvedi *et al*., 2010 [64], where the circulation volume of the solution of irrigation was lower than at the coronal and middle thirds.
However, Camargo *et al*., 2016 [65] found that no statistically significant difference was evident in the efficiency of the removal of medicaments in the three portions of the root canal (apical, middle, and coronal third).
This discrepancy between the studies might have caused by various methodological variations including duration of irrigation and the amount of irrigants used, various approaches of intracanal removal, period of storage, various thickness of the section of root, and size of plunger used during the push out bond test procedures.

Conclusions

Within the limits of this experiment, the following conclusions could be decided

1. Application of intracanal medication decreased the average push-out bond strength.
2. Push-out bond strength in case of using nano silver gel is less than that when using calcium hydroxide.
3. The push-out bond strength values recorded at the various segments varied significantly, with the coronal segment recording the greatest value followed by the middle segment, and the apical section recording the lowest value.
4. Regarding the effect of intracanal medication within each root section; results of coronal, middle, and apical sections showed significant difference. Control group demonstrated the highest push out bond strength, following that was the calcium hydroxide group, while nano-silver group revealed the lowest value.

Recommendations

- More research should be done to see how different intracanal drugs, as well as their removal techniques, affect the bond strength and sealing capacity of several endodontic sealers.

- Further research is needed to figure out what causes bond failure: adhesive (i.e., at the interface between the filling material and the dentine) or cohesive (i.e., within the filling material)
- More research using digital photographs, stereomicroscopes, scanning electron microscopes (SEM), micro-computed tomographic imaging (Micro-CT), and spiral computed tomographic imaging (Spiral-CT) to assess the remnants of various intracanal medicaments on the walls of the root canal dentin and the efficacy of different irrigating solution and its activation technique.
- To have enough proof of the therapeutic outcome of Nanosilver gel intracanal medication compared to the therapeutic outcome of Calcium hydroxide intracanal medication, randomized clinical trials are suggested.

Source of Funding
This study is self-funded

Conflict of Interest
The authors state that they do not have any no conflict of interest regarding the publication of this paper

References

1. Kakehashi S, Stanley HR, Fitzgerald RJ. The effects of surgical exposures of dental pulps in germ-free and conventional laboratory rats. Oral surgery, oral medicine, oral pathology. 1965 Sep 1;20(3):340-349.
2. Lin LM, Skribner JE, Gaengler P. Factors associated with endodontic treatment failures. Journal of endodontics. 1992 Dec 1;18(12):625-627.
3. Siqueira Jr JF, Rôças IN, Favieri A, Abad EC, Castro AJ, Gahyva SM. Bacterial leakage in coronally unsealed root canals obturated with 3 different techniques. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and End odontology. 2000 Nov 1;90(5):647-650.
4. Siqueira Jr JF. Aetiology of root canal treatment failure: why well-treated teeth can fail. International Endodontic Journal. 2001 Jan;34(1):1-10.
5. Byström A, Sundqvist G. Bacteriologic evaluation of the efficacy of mechanical root canal instrumentation in endodontic therapy. European Journal of Oral Sciences. 1981 Aug;89(4):321-328.
6. WU MK, Wesselink PR. Timeliness and effectiveness in the surgical management of persistent post-treatment periapical pathosis. Endodontic Topics. 2005 Jul;11(1):25-31.
7. Chong BS, Ford TP. The role of intracanal medication in root canal treatment. International endodontic journal. 1992 Mar;25(2):97-106.
8. Siqueira Jr JF, Lopes H. Mechanisms of antimicrobial activity of calcium hydroxide: A critical review. International Endodontic Journal. 1999 Sep;32(5):361-369.
9. Lotfi M, Vosoughhosseini S, Ranjkesh B, Khani S, Saghiri M, Zand V. Antimicrobial efficacy of Nano silver, sodium hypochlorite and chlorhexidine gluconate against Enterococcus faecalis. African Journal of Biotechnology. 2011;10(35):6799-6803.
10. Rai MK, Deshmukh SD, Ingle AP, Gade AK. Silver nanoparticles: The powerful nanoweapon against multidrug-resistant bacteria. Journal of Applied Microbiology. 2012 May 1;112(5):841-852.
11. Bo D, Kayombo CM. Effect of Nano silver gel, chlorhexidine gluconate, and camphorated phenol on Enterococcus faecalis biofilm. International Scholarly Research Notices; c2014. p. 380278.
12. Li GH, Niu LN, Zhang W, Olsen M, De-Deus G, Eid AA, *et al*. Ability of new obturation materials to improve the seal of the root canal system: a review. Acta biomaterial IA. 2014 Mar 1;10(3):1050-1063.
13. Tuncel B, Nagas E, Cehreli Z, Uyanik O, Vallittu P, Lassila L. Effect of endodontic chelating solutions on the bond strength of endodontic sealers. Brazilian oral research. 2015 May 15;29:1-6.
14. Ørstavik DA. Materials used for root canal obturation: technical, biological and clinical testing. Endodontic topics. 2005 Nov;12(1):25-38.
15. Erickson RL. Surface interactions of dentin adhesive materials. Operative dentistry; c1992. p. 81-94.
16. Lambrianidis T, Margelos J, Beltes P. Removal efficiency of calcium hydroxide dressing from the root canal. Journal of Endodontics. 1999 Feb 1;25(2):85-88.
17. Arslan H, Capar ID, Saygili G, Uysal B, Gok T, Ertas H, *et al*. Efficacy of various irrigation protocols on the removal of triple antibiotic paste. International Endodontic Journal. 2014 Jun;47(6):594-599.
18. Guiotti FA, Kuga MC, Duarte MA, Sant'Anna Júnior A, Faria G. Effect of calcium hydroxide dressing on push-out bond strength of endodontic sealers to root canal dentin. Brazilian Oral Research. 2014 Jan 24;28:1-7.
19. Pane ES, Palamara JE, Messer HH. Critical evaluation of the push-out test for root canal filling materials. Journal of Endodontics. 2013 May 1;39(5):669-673.
20. Neelakantan P, Sharma S, Shemesh H, Wesselink PR. Influence of irrigation sequence on the adhesion of root canal sealers to dentin: A Fourier transform infrared spectroscopy and push-out bond strength analysis. Journal of Endodontics. 2015 Jul 1;41(7):1108-1111.
21. Güzel R, Erdal G. Synthesis of Silver Nanoparticles. Silver Nanoparticles - Fabrication, Characterization and Applications [Internet]. 2018 Jul 18; 03–20. Available from: http://dx.doi.org/10.5772/intechopen.75363
22. Al-Thabaiti SA, Malik MA, Al-Youbi AA, Khan Z, Hussain JI. Effects of surfactant and polymer on the morphology of advanced nanomaterials in aqueous solution. Int. J. Electrochem. Sci. 2013 Jan 1;8(1):204-218.
23. Bruniera JF, Silva-Sousa YT, Lara MG, Pitondo-Silva A, Marcaccini AM, Miranda CE. Development of intracanal formulation containing silver nanoparticles. Brazilian Dental Journal. 2014;25:302-306.
24. Amin SA, Seyam RS, El-Samman MA. The effect of prior calcium hydroxide intracanal placement on the bond strength of two calcium silicate–based and an epoxy resin–based endodontic sealer. Journal of Endodontics. 2012 May 1;38(5):696-699.
25. Harms CS, Husemann V, Schäfer E, Dammaschke T. Removal of calcium hydroxide dressing from the root canal system using different irrigation solutions and methods. Dtsch Zahnärztl Z Int. 2021; 3:276-282.
26. Ghabraei S, Bolhari B, Yaghoobnejad F, Meraji N. Effect of intra-canal calcium hydroxide remnants on the push-out bond strength of two endodontic sealers. Iranian Endodontic Journal. 2017;12(2):168-172.
27. Estrela C, Sydney GB, Bammann LL, Felippe Junior O. Mechanism of the action of calcium and hydroxy ions of

calcium hydroxide on tissue and bacteria. Brazalian Dent al Journal. 1995;6(2):85-90
28. Kanumuru NR, Subbaiah R. Bacterial efficacy of ca (oh) 2 against E. faecalis compared with three dental lasers on root canal dentin-an invitro study. Journal of Clinical and Diagnostic Research: JCDR. 2014 Nov;8(11):ZC135–ZC137.
29. Gong P, Li H, He X, Wang K, Hu J, Tan W, *et al*. Preparation and antibacterial activity of Fe3O4@ Ag nanoparticles. Nanotechnology. 2007 Jun 15;18(28):285604.
30. Krishnan R, Arumugam V, Vasaviah SK. The MIC and MBC of silver nanoparticles against Enterococcus faecalis-a facultative anaerobe. J Nanomed Nanotechnol. 2015 May 1;6(3):285.
31. Alabdulmohsen ZA, Saad AY. Antibacterial effect of silver nanoparticles against Enterococcus faecalis. Saudi Endodontic Journal. 2017;7(1):29-35
32. Hassan R, Khallaf M. Effect of a silver nanoparticle intracanal-based medicament on the microhardness of human radicular dentine. Endod Pract Today. 2018 Jun 1;12(2):125-127.
33. Lee JK, Kwak SW, Ha JH, Lee W, Kim HC. Physicochemical properties of epoxy resin-based and bioceramic-based root canal sealers. Bioinorganic chemistry and applications. 2017 Jan 22;2017:2582849.
34. Nashaat YM, Sabry HA, Omar N, Negm A, Ghoneim WM. Evaluation of the bond strength of AH Plus sealer after irrigation of the root canals using nano-silver and sodium hypochlorite. Egyptian Dental Journal. 2019 Apr 1;65(2):1517-1526.
35. Mustafa M, Alaajam WH, Azeim AA, Alfayi NA, Alqobty RM, Alghannam S. Diffusion of calcium hydroxide through dentinal tubules of retreated root canals: An *in vitro* study. European journal of dentistry. 2018 Jul;12(03):386-392.
36. Marion JJC, Manhães FC, Bajo H, Duque TM. Efficiency of different concentrations of sodium hypochlorite during endodontic treatment. Literature review. *Dental Press Endod.* 2012;2(4):32-37.
37. 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 June;40(6):415-426.
38. Hülsmann M, Heckendorff M, Lennon A. Chelating agents in root canal treatment: mode of action and indications for their use. International endodontic journal. 2003 Dec;36(12):810-830.
39. Kokkas AB, Boutsioukis AC, Vassiliadis LP, Stavrianos CK. The influence of the smear layer on dentinal tubule penetration depth by three different root canal sealers: an *in vitro* study. Journal of Endodontics. 2004 Feb 1;30(2):100-102.
40. Eldeniz AU, Erdemir A, Belli S. Shear bond strength of three resin based sealers to dentin with and without the smear layer. Journal of Endodontics. 2005 Apr 1;31(4):293-296.
41. Üreyen Kaya B, Keçeci AD, Orhan H, Belli S. Micropush-out bond strengths of gutta-percha versus thermoplastic synthetic polymer-based systems–an ex vivo study. International Endodontic Journal. 2008 Mar;41(3):211-218.
42. Chen WP, Chen YY, Huang SH, Lin CP. Limitations of push-out test in bond strength measurement. Journal of Endodontics. 2013 Feb 1;39(2):283-287.
43. Üstün Y, Arslan S, Aslan T. Effects of calcium hydroxide and propolis intracanal medicaments on bond strength of resin-based endodontic sealer as assessed by push-out test. Dental Materials Journal. 2013 Nov 28;32(6):913-919.
44. Gupta A, Kumar M, Taneja S. Effect of intracanal calcium hydroxide dressing on the push out bond strength of AH Plus, MTA Fillapex®, and endosequence BC sealer. End odontology. 2020 Jan 1;32(1):33-37.
45. Akcay M, Arslan H, Topcuoglu HS, Tuncay O. Effect of calcium hydroxide and double and triple antibiotic pastes on the bond strength of epoxy resin–based sealer to root canal dentin. Journal of Endodontics. 2014 Oct 1;40(10):1663-1667.
46. Gokturk H, Bayram E, Bayram HM, Aslan T, Ustun Y. Effect of double antibiotic and calcium hydroxide pastes on dislodgement resistance of an epoxy resin-based and two calcium silicate-based root canal sealers. Clinical oral Investigations. 2017 May;21(4):1277-1282
47. Carvalho CN, Bauer J, Ferrari PH, Souza SF, Soares SP, Loguercio AD, *et al*. Influence of calcium hydroxide intracanal medication on bond strength of two endodontic resin-based sealers assessed by micro push-out test. Dental Traumatology. 2013 Feb;29(1):73-76.
48. Rödig T, Vogel S, Zapf A, Hülsmann M. Efficacy of different irrigants in the removal of calcium hydroxide from root canals. International Endodontic Journal. 2010 Jun;43(6):519-527.
49. Uzunoglu-Özyürek E, Erdoğan Ö, Türker SA. Effect of calcium hydroxide dressing on the dentinal tubule penetration of 2 different root canal sealers: a confocal laser scanning microscopic study. Journal of Endodontics. 2018 Jun 1;44(6):1018-1023.
50. D Abo Gabal A, SH Aly M, H Mohamed M, S Al-Ghazawy SE. The effect of adding nanosilver particles on push out bond strength and marginal adaptation of endodontic sealers. Al-Azhar Journal of Dental Science, 2018;21(4):395-400.
51. Fan W, Wu D, Tay FR, Ma T, Wu Y, Fan B. Effects of adsorbed and templated Nano silver in mesoporous calcium-silicate nanoparticles on inhibition of bacteria colonization of dentin. International Journal of Nan Medicine. 2014;9:5217-5230.
52. 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 Endodontics. 2014 Jun 1;40(6):862-866.
53. 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):185-191.
54. Ozkocak I, Sonat B. Evaluation of effects on the adhesion of various root canal sealers after Er: YAG laser and irrigants are used on the dentin surface. Journal of endodontics. 2015 Aug 1;41(8):1331-1336.
55. Kurup D, Nagpal AK, Shetty S, Mandal TK, Anand J, Mitra R. Data on the push–out bond strength of three different root canal treatment sealers. Bio information. 2021 Jan 31;17(1):67-72.
56. Lo Giudice G, Cutroneo G, Centofanti A, Artemisia A, Bramanti E, Militi A, *et al*. Dentin morphology of root canal surface: A quantitative evaluation based on a scanning electronic microscopy study. BioMed Research International. 2015 Aug 27;2015:164065.

57. Soliman AY, Roshdy NB, Lutfy RA. Assessment of the effect of chitosan nanoparticles on the ultra-structure of dentinal wall: A comparative *in vitro* study. Acta Sci Dent Sci. 2020;4(01):32-38.
58. Mannocci F, Pilecki P, Bertelli E, Watson TF. Density of dentinal tubules affects the tensile strength of root dentin. Dental Materials. 2004 Mar 1;20(3):293-296.
59. Mishra P, Sharma A, Mishra S, Gupta M. Push-out bond strength of different endodontic obturation material at three different sites-In-vitro study. Journal of Clinical and Experimental Dentistry. 2017 Jun;9(6): e733-e737.
60. Kim SK, Kim YO. Influence of calcium hydroxide intracanal medication on apical seal. International Endodontic Journal. 2002 Jul 1;35(7):623-628.
61. Silva LJ, Pessoa OF, Teixeira MB, Gouveia CH, Braga RR. Micro-CT evaluation of calcium hydroxide removal through passive ultrasonic irrigation associated with or without an additional instrument. International Endodontic Journal. 2015 Aug;48(8):768-773.
62. Kenee DM, Allemang JD, Johnson JD, Hellstein J, Nichol BK. A quantitative assessment of efficacy of various calcium hydroxide removal techniques. Journal of Endodontics. 2006 Jun 1;32(6):563-565.
63. Denna J, Shafie LA, Alsofi L, Al-Habib M, AlShwaimi E. Efficacy of the rotary instrument XP-Endo Finisher in the removal of calcium hydroxide intracanal medicament in combination with different irrigation techniques: A micro tomographic study. Materials. 2020 May 12;13(10):2222.
64. Balvedi RP, Versiani MA, Manna FF, Biffi JC. A comparison of two techniques for the removal of calcium hydroxide from root canals. International endodontic journal. 2010 Sep;43(9):763-768.
65. Camargo CH, Leal FM, Silva GO, De Oliveira TR, Madureira PG, Camargo SE. Efficacy of different techniques for removal of calcium hydroxide-chlorhexidine paste from root canals. General dentistry. 2016 Mar 1;64(2): 9-12.

How to Cite This Article
Ahmed HA, Sadek HS, Morsy DA. Effect of nano-silver gel and calcium hydroxide paste on the bond strength of epoxy-resin based sealer to root canal dentin in anterior teeth: An *in vitro* study. International Journal of Applied Dental Sciences. 2023;9(2):01-10.