Comparison of Push-out Bond Strength of Three Different Obturating Systems to Intraradicular Dentin: An *In vitro* Study

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Abstract

Background: To increase the push-out bond strength of endodontic materials, newer obturation materials and obturation techniques are being introduced. **Aim:** The present study aimed to evaluate the push-out bond strength of three different obturating materials using a universal testing machine (UTM). **Materials and Methods:** A total of thirty freshly extracted maxillary anterior teeth were collected and randomly divided into three groups of ten each. Biomechanical preparation was done in all the teeth, and they were then divided into three experimental groups according to the obturation material and technique used, as follows: Group I: gutta-percha (GP) with AH Plus root canal sealer (lateral condensation); Group II: thermoplasticized GP technique – noncarrier based (CALAMUS®) with AH Plus sealer (backfill); and Group III: C-points (self-sealing root canal obturating system) with bioceramic sealer (single cone). Each specimen was subjected to push-out test using the UTM, where the punch moved in an apical to coronal direction at a crosshead speed of 0.5 mm/min, which resulted in the displacement of the filling material. The depth of dye penetration was examined under a stereomicroscope at ×30 magnification. **Results:** All the analyses were performed using SPSS software version 16. $P < 0.05$ was considered statistically significant. Comparisons of mean values were done using ANOVA with *post hoc* Games–Howell test and ANOVA with *post hoc* Tukey's test. Group III demonstrated the highest mean push-out bond strength and Group I exhibited the least bond strength. A statistically significant difference was found between Group III and Group I with regard to the push-out bond strength assessment. **Conclusion:** Push-out bond strength differs among different obturation materials and obturation techniques.

Keywords: *Apical sealing ability, bond strength, push-out test, root canal sealer*

Introduction

Recent innovations in the field of endodontics due to improved technology and increase in knowledge about the microorganisms implicated with endodontic pathology have increased the success of endodontic therapy. Newer obturation materials and techniques have been developed with the aim of obtaining good strength as well as better seal, especially in filling irregular-shaped canals.[1]

Bowman (1867) introduced gutta-percha (GP) as a root canal sealer. Since then, it has been used widely by diverse methods, as it is least toxic and has less allergic potential. To reduce the occurrence of voids during obturation, which might act as nidus for bacterial growth, thermoplasticized obturation method was introduced. This method improved the homogeneity and surface adaptation of GP.[2,3]

Bond strength of sealer to dentin is considered the most important factor to maintain the integrity of root canal seal. In fact, the adhesion of root canal obturation material to dentinal walls is significant in both static and dynamic situations. In a static condition, it must reduce any space which permits the percolation of fluids between dentinal wall and obturation material. Whereas in dynamic condition, it is required to resist disruption of the filling caused by the mechanical stresses of tooth flexure or restorative procedures.[3]

Many studies have shown that the main cause of endodontic failure is microleakage. This has prompted research on newer obturation materials. For this purpose, Grossman studied in detail about the physical properties of various filling materials and stated that adhesion is a very important property of obturation materials.[4,5]

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Figure 1: Endodontic armamentarium

Figure 2: Endodontic obturating systems

Figure 3: Root canal sealers

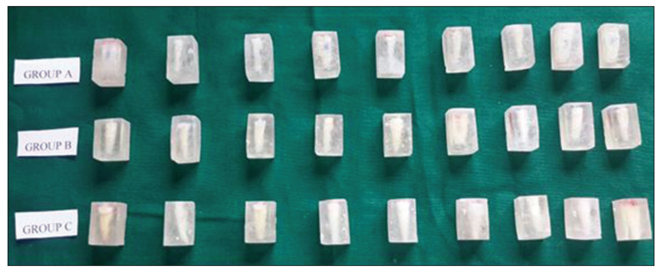

Figure 4: Preparation of specimens for push-out bond strength assessment grouping of teeth embedded in acrylic blocks

The present *in-vitro* study was intended to assess and compare the push-out bond strength of three different obturating systems to intraradicular dentin.

Materials and Methods

This *in-vitro* study was conducted on thirty intact human maxillary anterior teeth extracted for periodontal reasons. The teeth were stored in 5.25% sodium hypochlorite solution for 1 h to remove the periodontal ligament attachment, were washed under running tap water, were autoclaved, and were then stored in normal saline.

Inclusion criteria

1. Single-rooted teeth with mature root apex
2. Root canals with <20° curvature.

Exclusion criteria

1. Incompletely formed apices
2. Fractured teeth
3. Internal/external resorption
4. Previous endodontically treated teeth.

Specimen preparation

Clinical crowns were decoronated at the cemento-enamel junction by means of a diamond disc mounted in a slow-speed straight handpiece. Access cavity preparation was done using No. 2 endodontic access bur. Root canals were negotiated using a number 10 K-file and checked for patency. Working length measurement was done using number 10 K-files.

10 K-file was inserted in the canals until it reached the apical foramen later 1 mm of the measurement was subtracted to record the working length. Instrumentation was performed with a crown-down technique using K3XF™ rotary system (sybronendo corporation, 1717 west-collins, orange CA 92867) up to size 40 and 6% taper [Figure 1].

The canals were irrigated with 5.25% sodium hypochlorite and RC Help (Premier Dental Products, Tulsa, OK, USA) during instrumentation. After the cleaning and shaping process, 17% ethylenediaminetetraacetic acid was used for smear layer removal followed by normal saline rinse, and final flush was performed using 2% chlorhexidine solution. After the completion of instrumentation, the root canals were dried with paper points, and the teeth were randomly divided into three groups of ten each. The groups were divided based on the obturation material used and technique employed. Based on the obturation material and technique used, the teeth were grouped as Group I, Group II, and Group III.

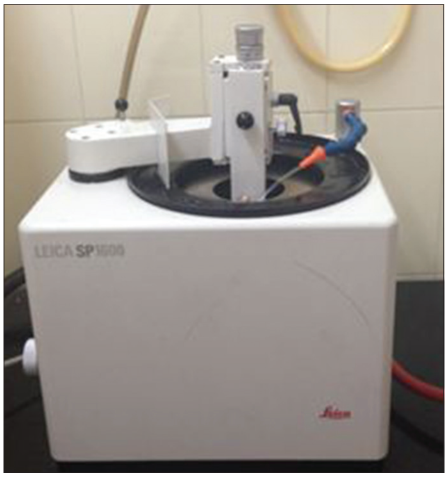

Figure 5: Hard-tissue microtome

Figure 6: Labeling and grouping of sample for push-out bond strength assessment

Figure 7: Push-out bond strength assessment using universal testing machine

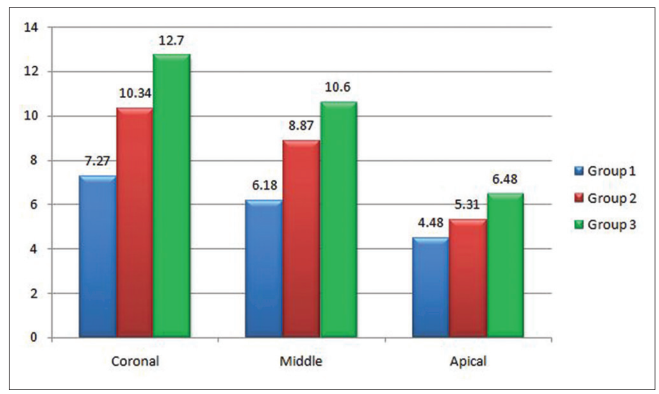

Figure 8: Bar graph representation of intergroup comparison of mean push-out bond strength at three different levels

Obturation of root canals [Figure 2 and 3]

- Group I: GP with AH Plus sealer using lateral condensation technique; a size 40/4% taper GP was trimmed till it gives tug-back resistance at working length. AH Plus sealer was placed into the root canal using a lentulo spiral. Lateral compaction was achieved with a hand spreader size A, and 2% accessory GP was placed to fill up the remaining space by lateral condensation technique. A 23 G needle with a silicon stopper attached to the cartridge was inserted into the canal 2 mm short of the working length and checked for the depth of the canal
- Group II: Thermoplasticized GP technique: a noncarrier based (CALAMUS®) with AH Plus sealer using backfill technique. Thermoplasticized GP pellets were used in beta form with a gun to hold them at the apical 3rd which was then connected to a heating unit with digital display of temperature. AH Plus sealer was placed into the canal using the lentulo spiral, and thermoplasticized GP, heated to 170°C–175°C in the delivery system, was then injected 2 mm short of the working length. The needle was then removed after injecting a small portion of GP 2 mm short of the working length, and the softened GP in the apical portion was vertically condensed to the apex with a hand plugger. The remaining root canal space was back filled in increments until excess GP was observed at the cervical aspect of the root
- Group III: C-points (self-sealing root canal obturating point) (EndoTechnologies, LLC, Shrewsbury, MA, USA) with bioceramic sealer using single-cone technique: the teeth were obturated with size 40 and 6% taper master polyamide polymer cone using single-cone technique with no accessory cones being used. The polymer core was severed at the cemento-enamel junction and condensed. The sealer used in this group was bioceramic sealer.

Push-out bond strength assessment

Ten root specimens in each of the three groups were completely embedded in clear acrylic [Figure 4]. Each root was horizontally sectioned into approximately 2-mm thick slices. The apical most 3-mm portion of each root

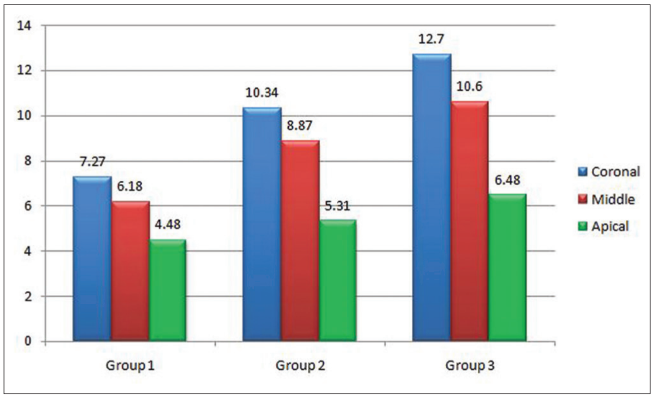

Figure 9: Bar graph representation of intragroup push-out bond strength at three different levels

was discarded to avoid possible apical ramifications. Any sample with a void or deficiency of filling material was discarded and replaced with another sample. Overall, three slices per specimen, one each from coronal, middle, and apical thirds, were obtained [Figures 5-7]. The slices were tagged for the identification of the location of the slice and orientation of the surface. The thickness of each slice was measured with a digital caliper and recorded to ensure uniformity in specimen dimension. Then, each slice was placed under a reflected light microscope where the perimeter and diameter of each obturation site were measured and recorded. The perimeter and thickness measurements were used to calculate the bonded area of the filling material. Three support jigs of different sizes (1 mm, 0.7 mm, and 0.5 mm) were selected for the coronal, middle, and apical sections, respectively. On the coronal side of the slices, the larger diameter was measured so that a support jig was selected with a hole large enough to provide clearance for the obturating material when it will be dislodged from the tooth slices. On the apical side of the slices, the smallest diameter was measured to select an appropriate sized punch to be used to supply the load with that side, making sure that the punch connected to the universal testing machine (UTM) [Figure 7] would not contact the dentin around the obturating material, causing a crack and erroneous result.

Each specimen was subjected to push-out test using the UTM where the punch moved in an apical to coronal direction at a crosshead speed of 0.5 mm/min, which resulted in the displacement of the filling material. The UTM gave the debonding force for an individual specimen.

The push-out bond strength was calculated using the following formula:

Debond stress (MPa) = Debonding force (N)/area (mm^2) where debonding force is the maximum force before debonding and area is the average value of the perimeter times the thickness (mean perimeter value × thickness).

Results

The area of bonded internal surface of specimens was measured with the help of the equation mentioned in the methodology section. The mean values of area in mm^2 and push-out bond stress in N/mm^2 or kg/cm^2 were calculated and sent for statistical analysis [Tables 1 and 2].

Statistical analysis

All the analyses were performed using SPSS software version 16 (IBM). $P < 0.05$ was considered statistically significant. Comparison of mean values was done using ANOVA with *post hoc* Games–Howell test [Table 1 and Figure 8] and ANOVA with *post hoc* Tukey's test [Table 2 and Figure 9].

The results of the present study showed higher bond strength for Group III (C-points/bioceramic [BC] sealer), which was greater than that of both Group II (thermoplasticized GP/AH Plus sealer) and Group I (GP and AH Plus sealer).

Thermoplasticized GP/AH Plus sealer with backfill technique showed a reasonably good bond strength when compared to that of GP/AH Plus sealer with lateral condensation technique.

Group I that is a combination of GP/AH Plus sealer with lateral condensation technique exhibited the least bond strength of all the groups.

Discussion

Three-dimensional (3D) sealing of the root canal is one of the main goals of endodontic treatment and is essential for preventing reinfection of the canal and for preserving the health of periapical tissues, thereby ensuring the success of root canal treatment. Complete obturation of root canal system to the cemento-enamel junction is an important goal in endodontic treatment. Root canal fillings are performed to seal the root canal system in order to prevent microorganisms and/or their toxic products from reaching the periodontal tissues. They must seal the pulp canal space both laterally and apically to prevent further apical irritation from incomplete elimination of bacterial products or continuous communication between apical tissues and oral cavity.[5,6]

The bond strength of root canal sealers to dentin is important for maintaining the integrity of the seal in root canal filling. Although sealers can form close adhesion to the root canal wall, none can bond to GP, leaving a gap through which bacteria may pass. An ideal filling technique would produce a filled root canal space without voids or gaps, with the sealer and core material forming a uniform mass securely bonded to the dentin to prevent leakage. The push-out testing method allows bond strength measurements of adhesive materials to root canal dentin.[7] It is based on the shear stress at the interface between dentin and cement, which is comparable with stresses under clinical conditions. This method allows accurate standardization of specimens and evaluation even when bond strengths are

Table 1: Intergroup mean push-out bond strength at three different levels

Level	Group 1		Group 2		Group 3		*P*	*Post hoc* test
	Mean	SD	Mean	SD	Mean	SD		
Coronal†	7.27	1.20	10.34	4.00	12.70	4.12	0.005 (S)	Group 3 > Group 1
Middle‡	6.18	1.87	8.87	3.36	10.60	2.84	0.008 (S)	Group 3 > Group 1
Apical‡	4.48	1.76	5.31	2.79	6.48	2.38	0.213 (NS)	-

†ANOVA with *post hoc* Games-Howell test, ‡ANOVA with *post hoc* Tukey's test. SD: Standard deviation; NS: Not significant; S: Significant

Table 2: Intragroup mean push-out bond strength at three different levels

Group	Coronal		Middle		Apical		*P*	*Post hoc* test
	Mean	SD	Mean	SD	Mean	SD		
Group I	7.27	1.20	6.18	1.87	4.48	1.76	0.005 (S)	Coronal > apical
Group II	10.34	4.00	8.87	3.36	5.31	2.79	0.014 (S)	Coronal > apical
Group III	12.70	4.12	10.60	2.84	6.48	2.38	0.001 (S)	Coronal and middle > apical

‡ANOVA with *post hoc* Tukey's test. SD: Standard deviation; S: Significant

low.[8] The advantages of this method over tensile and shear strength tests are that it is less sensitive to small variations among specimens and to variations in stress distribution during load application and that it is easy to align samples for testing. It has been found reliable in bond strength evaluation of 1-mm thick samples.[9] It has an additional advantage of allowing the assessment of bond strength at several root levels.

Various methods are available for filling canals ranging from cold lateral compaction to thermoplasticized techniques. The physicochemical and biological properties of the core material, sealers, as well as the obturating technique are critical to successful outcome.[10] The purpose of this study was to assess the push-out bond strength and apical leakage using three different obturation techniques in three groups namely Group I: GP/AH Plus sealer with lateral condensation technique, Group II: thermoplasticized GP/AH Plus sealer, and Group III: C-points/BC sealer.

In the present study, Group III (C-points/BC sealer) showed higher bond strength, which was greater than that of both Group II (thermoplasticized GP/AH Plus sealer) and Group I (GP/AH Plus sealer with lateral condensation). Statistically significant differences were found between the mean bond strength of root canals filled with C-points/BC sealer (Group III) and the root canals filled with GP/AH Plus sealer and thermoplasticized GP/AH Plus sealer (Groups I and II) at either levels of sectioning.[11]

Lateral condensation of GP has remained the most widely used method of obturating canals. This technique is widely accepted for its excellent long-term results, predictability, controlled placement, and relative ease of use. In the present study, lateral condensation was used as one of the techniques because it is the most commonly used and studied technique and therefore, it served as a standard with which other techniques could be compared.[12] The results of this study revealed that GP/AH Plus sealer with lateral condensation technique (Group I) exhibited the least bond strength of all the materials used. The disadvantages seen with the lateral condensation technique were lack of homogeneity of GP mass and inadequate dispersion of sealer, leaving an increased number of voids in and around the GP points. However, the findings of this study are not in accordance with the study results of Carneiro *et al*., where AH Plus sealer showed significantly higher bond strength to intraradicular dentin when used with the lateral condensation technique as compared to thermoplasticized technique.[13]

The introduction of thermoplastic GP to dentistry in the mid-19th century was a turning point in endodontic treatment. Plasticity combined with physical durability made it possible for the material to move into the recesses of the root canal system and to adapt to the canal walls.[14] The backfilling technique that was used in the second group demonstrated reasonably good bond strength. On application of heat, it flows and adapts well onto the walls of the root canal. Application of heat by plugging further compensates for any voids within the mass and results in a whole compact mass with good marginal adaptation.

In this study, it was seen that the adhesion of C-points with BC sealer to dentin was superior to that of the sealer combined with GP used either in the lateral condensation or in the backfill technique. The results of a recent study by Arora and Hegde strongly support such a notion.[5] The novel filling method using a single C-point and BC sealer increased the bond strength when compared with the traditional method using GP and AH Plus sealer. This can be attributed to the hydrophilic nature of the sealer which may have potentially resulted in more intimate contact with the canal walls than the hydrophobic AH Plus sealer. Furthermore, it could be assumed that the slow-setting nature of the BC sealer combined with the slow expansion nature of the C-point when exposed to moisture may have potentially pushed the sealer into places that lateral compaction with AH Plus sealer could not reach.[15]

The present study also focused on the ability of materials to seal the apex because relative to the coronal root, apical root sealing remains relatively vulnerable to microbial leakage. Furthermore, apical leakage jeopardizes the biological response to endodontic sealers because it facilitates the release of unreacted components from materials directly into the periapical tissues. This fact underscores the importance of a fluid-tight seal in the apical portion of the root canal filling. Thus, several types of endodontic sealers have been recommended to achieve this goal and consequently, evaluation of the apical sealing ability of sealers is important.[16]

Therefore, within the limitations of this study, it can be concluded that root canals filled with C-point and a BC sealer demonstrated considerably superior bond strength compared to the traditional methods and that microleakage was a common finding in all the samples tested. Leakage cannot be totally eliminated from the fate of a root canal-treated tooth. However, Group 2 (the thermoplasticized GP with AH Plus sealer) showed a superior result compared to the other two tested techniques. As it is a new material (C-point), further studies have to be conducted with different parameters to prove that it is an ideal root canal filling material for 3D sealing of root canal space. The use of smart seal system in conjunction with the latest equipment and techniques available in endodontics will further enhance the root canal treatment outcomes.

Conclusion

The present *in-vitro* study was intended to assess the push-out bond strength using three different obturation materials and techniques using UTM. According to the results of the present study, C-points with BC sealer demonstrated the highest mean push-out bond strength among all the three groups. GP and AH Plus sealer with lateral condensation technique exhibited the least bond strength.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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