# Push-out bond strength of different root canal obturation materials

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## ABSTRACT

Background: The aim of this study was to evaluate the push-out bond strength of four different obturation materials to intraradicular dentin and to determine the failure mode.
Materials and method: forty straight palatal roots of the maxillary first molars teeth were used in this study, the roots were instrumented using crown down technique and rotary EndoSequence system, the roots were randomly divided into four groups according to the materials used for obturation (n=10).Group (1): AH Plus sealer and gutta-percha. Group (2): Activ GP glass ionomer sealer and Activ GP gutta-percha (Activ GP system). Group (3): Bioceramic sealer and Bioceramic gutta-percha. Group (4): GuttaFlow2 sealer and gutta-percha. For all groups single cone obturation technique was used. After incubation period of one week, the roots were embedded in clear acrylic resin and each root sectioned into three levels apical, middle and cervical. The bond strength was measured using computerized universal testing machine, each section fixed in the machine so that the load applied from apical to coronal direction at 0.5mm/min speed and the computer drew curve to show the higher bond force before dislodgment of the filling material. After de-bonding each sample was examined under Stereomicroscopic and the type of failure mode was recorded.
Results: showed a non significant difference between AH plus group and Bioceramic group. AH Plus group showed a very highly significant difference with Activ GP group and a highly significant difference with GuttaFlow2 group. There were significant differences between coronal level and both apical and middle levels with no significant differences between apical and middle levels within each group.
Conclusion: AH plus group showed the highest mean of bond strength in comparing to other tested groups.
Keywords: Bond strength, push-out test, adhesive sealer, obturation materials. (J Bagh Coll Dentistry 2013; 25(1):14-20).

## INTRODUCTION

Successful root canal treatment depends on the thorough debridement of the root canal system, the elimination of pathogenic organisms and finally the complete sealing of the canal space to prevent ingress of bacteria from the oral environment and spread to the periapical tissue [1]. The physical properties necessary for this function include adaptation and adhesion of the filling material to the root canal wall, because gutta-percha does not directly bond to the dentin surface, the sealer should be capable of producing a bond between core material and dentin wall [2]. Different types of sealer have been introduced to endodontics, including those based on zinc oxide eugenol, calcium hydroxide, glass–ionomer cement and a range of resins. Epoxy resin-type sealers have been used for many years. They showed higher bond strength to dentin than zinc oxide eugenol types and calcium hydroxide-based sealer [3]. In recent years, different filling materials and sealers have been developed on the basis of dentin adhesion technology in an attempt to seal the root canal more effectively, and to increase fracture resistance of root filled teeth [4].

Furthermore, manufacturers have further incorporated adhesive dentistry in endodontics by introducing obturation systems with a specific focus on obtaining a “monobloc” in which the core material, sealing agent, and root canal dentin form a single cohesive unit [5]. Both Activ GP Precision system and Bioceramic sealer are based on adhesion technology [6]. Activ GP is a system which utilizes improved glass ionomer (GI) technology (both as a sealer and as a special GI coated gutta percha cone) to create a true single cone monoblock obturation [7]. Activ GP sealer is superior to previous GI-based systems in terms of handling characteristics, working time, radiopacity [8] and seal, because of the increased of its flowability [9,10].

Bioceramic sealer (BC) is a new premixed sealer, ready-to-use injectable and hydraulic cement paste. It is composed of calcium phosphate, calcium silicate, calcium hydroxide, zirconium oxide, filler, and thickening agents. Bioceramic sealer have dimensional stability and don’t shrink upon setting, consequently, remains non restorable inside the root canal [6]. GuttaFlow®2 sealer is an alternative root filling material introduced into the endodontic practice. GuttaFlow®2 is a cold flowable filling system for root canals, combining sealer and gutta-percha in one product. Adhesion properties of root canal sealers to dentin are determined by several mechanical tests. Push-out test has been described to measure the bond between sealer, canal wall and the core material [11,12]. The aim of this study was to compare the bond strength of different root canal obturation materials.

## MATERIALS AND METHODS

Forty freshly extracted maxillary first molars teeth with straight palatal root were selected from

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different health centers for this study according to specific criteria. After extraction, all teeth were stored in 0.1% thymol solution at room temperature. The roots surfaces were verified with a magnifying eye lens (10X) and light cure device for any visible cracks or fractures. Using diamond disc mounted on straight hand-piece and under water coolant the palatal root of teeth was sectioned perpendicular to the long axis of the root at the furcation area to facilitate straight line access for canal instrumentation and filling procedure. The length of the root was determined by digital caliper and marker to (10) mm from apex to cement-enamel junction.

The exact location of the apical foramen and the patency of the canals were verified by insertion of a No.15 K-file into the canal and advancing until it is visualized at the apical foramen. The root canals were prepared with Crown-Down technique to master apical file #40 using 0.06 taper EndoSequence NiTi rotary instruments (Brasseler USA, Savannah) at 500 rpm and 1.2 N/c torque. Five millimeter of 2.5% NaOCL with 27-G syringe was used for irrigation between each file size with a final rinse of 5 ml, 17% EDTA (PD Swiss quality) for 1min. Followed by copious amounts of distilled water to remove any remnant of the irrigation solutions [13,14].

**Samples grouping**

The roots were randomly divided into four groups (n=10) according to type of obturation materials, for all groups single cone obturation technique was used:

Group (1): In this group, the AH Plus sealer (Dentsply, Germany) mixed according to the manufacture's instructions. The tip of master cone #40/.06 was coated with the AH plus sealer and placed into canal to full working length (fig.1).

Group (2): Canals were obturated with Activ GP root canal obturation system (Brasseler USA, Savannah), (fig.2). After the root canals were dried with master paper points, Activ GP sealer powder and liquid in (3:1) ratio mixed following the manufacture's instructions. Then the apical half of Activ GP master cone #40/.06 was coated with sealer and inserted slowly in the canal with circular motion until it reach full working length.

Group (3): In this group the EndoSequence BC sealer and EndoSequence BC gutta-percha were used (Brasseler USA, Savannah), (fig.3). The obturation was performed with a #40/.06 BC gutta-percha master cone in combination with BC Sealer according to the manufacturer's instructions. Then the master BC gutta percha cone was coated with a thin layer of sealer, and very slowly inserts it into the canal.

Group (4): Canals were obturated with #40/.06 gutta-percha and GuttaFlow2 sealer (Coltene,Germany) according to the manufacturer's instructions (fig.4). GuttaFlow®2 was spread on a mixing slab and inserted into the root canal with the master file #40 then the master cone #40/.06 coated with sealer and inserted to the working length.

For all groups excess gutta-percha was removed with hot plugger 1mm below the orifice. All obturated roots of all groups were wrapped in saline moistened gauze in closed plastic vial allowing the sealer to set for 7 days at 37°C in an incubator [19]. After the storage period, the roots were embedded in clear orthodontic resin [15]. The sectioning of root was made by using Diamond Cut-off Saw. Four cut was made horizontally to obtain three sections (apical, middle, and coronal) of 2 mm in thickness , three sections were obtained (2), (4.5), and (7) mm from true anatomical apex. The thickness of each section was measured with a digital caliper, thus, each study group of (10) roots provided a total of (30) test specimens, consisting of (10) specimens from each root region.

**Push-out bond strength test**

Push-out test was performed by applying a compressive load to the apical aspect of each slice via a cylindrical plunger mounted on Tinius-Olsen Universal Testing Machine managed by computer software. Samples were examined under the Nikon metallurgical microscope (magnification 50X) and pictures of both sides of each section are taken with digital camera which was connected with microscope, and measurements calculated using LUCIA G software analysis program. The obturated area of the section at each level was measured from the apical side to determine the size of punch pin [16].Three different sizes of punch pins were used, 0.7 mm diameter for the coronal slices, 0.55 mm diameter for the middle slices and 0.4 mm diameter for the apical slices. The punch pins should provide almost complete coverage over the main cone without touching the canal wall and sealer [13,16] . The root filling in each section subjected to loading using a universal testing machine (WDW50) at a speed of 0.5 mm / min in an apical-coronal direction until the first dislodgment of obturating material and a sudden drop along the load deflection. The maximum failure load was recorded in Newton (N) and was used to calculate the push-out bond strength in megapascals (MPa) according to the following formula [17]:

**Push-out bond strength (MPa)** =

$$\frac{\text{maximam load } (N)}{\text{Adhesion area of root canal filling mm}^\wedge 2}$$

ANOVA test and LSD test was performed as statistical analysis for push-out bond strength.

**Analysis of failure modes**

After the push-out bond strength test, each sample was inspected with a Stereomicroscope (Kruss, Germany) at 40x magnification to determine the failure mode. Each sample was evaluated and placed into one of 3 failure modes [16, 18]: Type I: adhesive failure, either at the sealer-dentin (S/D) or between the sealer-core (S/C) interfaces, Type II: cohesive failure, within the filling material (sealer or core material), Type III: mixed failure, which contains both adhesive and cohesive failures.

# RESULTS

Mean values and standard deviation for all groups presented in (table-1). AH Plus group has the highest mean values at all levels in comparison with other groups followed by BC group, then GuttaFlow2 group, while Activ GP group has the lowest mean value at all levels. The coronal level in all groups has the highest mean push-out bond strength values, followed by middle and then the apical level (fig.5).

Analysis of variance (ANOVA) test was performed and showed that there were very highly significant differences ($p \leq 0.001$) at all levels (table-2). There was no significant difference between Group1 (AH Plus) and Group3 (Bioceramic) at all levels ($P \geq 0.05$). And also there was no significant difference between Group2 (Activ GP) and Group4 (GuttaFlow2) at all levels ($P \geq 0.05$). Group1 (AH Plus) showed a very highly significant difference ($P \leq 0.001$) with group2 (Activ GP) and a highly significant difference ($P \leq 0.01$) with group4 (GuttaFlow2) at all levels (table-3). ANOVA test between different levels within each group showed that there was a highly significant difference ($P \leq 0.01$) among different levels within each group (table-4). The least significance difference test (LSD) was performed to confirm the results of ANOVA test between each two levels for each groups and showed a significant difference between coronal level with both middle and apical levels and there was a non significance difference between apical and middle level in all groups (table-5).

**Analysis of failure mode**

The analysis of failure mode for push-out test was shown that the predominant mode of failure in AH-Plus group was adhesive failure (S/G) and mixed failure. In the Activ GP group the failure mode was predominantly cohesive failure within the gutta-percha itself and adhesive failure at S/D interface. The failure mode in the BC group was a cohesive failure mainly within the gutta-percha and mixed failure. Finally the failure mode in the GuttaFlow2 group was adhesive failure mainly at S/G with some failure at S/D interface (table-6).

# DISCUSSION

Many obturation systems were proposed to the endodontics as to approach the good sealing ability and adhesion to dentin. Despite the inadequate levels of bond strength between most current endodontic sealers and root dentin and gutta-percha [19,20] the adhesion of sealers to intra-radicular dentin via frictional resistance, chemical bond, or micromechanical retention is still necessary in maintaining the integrity of the sealer-dentin interface during mechanical stresses caused by; tooth flexure, operative procedures, or subsequent preparation of a post space [21, 22]. The AH Plus group showed the highest mean of push-out bond strength. The highest bond strength of AH Plus could be explained by the formation of a covalent bond by an open epoxide ring to any exposed amino groups in collagen [23]. Other investigations have further shown high-quality properties with epoxy resin–based sealers, including very low shrinkage while setting, long-term dimensional stability**,** flow, and long setting time, AH Plus sealer penetrates deeper into the surface microirregularities [24]. This agrees with the finding of Fisher et al.[13] and Sagsen et al.[25] .

A highly significant difference was shown between AH Plus group and the Activ GP group, like other self-curing GI cements and resin composites, may have undergone shrinkage during its setting phase creating gaps between the sealer and root dentin[26] . This result may be also attributed to the non homogeneous mix of GI sealer which is questionable which might have an adverse effect on it is properties. Moreover when comparing Activ GP group with AH Plus group in mechanisms of bonding, different mechanisms of bonding of both sealers played a role. The removal of the smear layer, by EDTA improves micromechanical retention of AH Plus sealer but also depleted calcium ions which are necessary for the Activ GP bonding. This result is in agreement with Fisher et al [13], Hashem et al. [27] and Elsheikh et al [18].

When comparing the AH Plus group with BC group no significant difference was found between them at all levels. Shokouhinejad et al. [14] also found a non significant difference in the push-out bond strength between AH Plus and BC sealer. This could be related to the combined effect of the chemical and mechanical bonding of the BC sealer to dentin wall (formation of hydroxyapatite during the setting) as well as the chemical bonding between the sealer and BC core material might have resulted in a significantly increased push out bond strength of BC sealer [(28,29)]. GuttaFlow2 group showed a significant difference with AH Plus group and BC group. According to Tummala et al.[(30)] the wettability of the root canal sealers influences its adaptability to the radicular dentin. AH Plus sealer was shown to wet the root dentin surface better than the GuttaFlow sealer and this could be attributed to its ability to penetrate into the micro-irregularities better. GuttaFlow showed poor wetting on the root dentin surface because of the presence of silicone, which possibly produces high surface tension forces, making the spreading of these materials less [(30)].

The bond strength value decreased in a coronal to apical direction and showed significant difference between the coronal and apical level with no significant difference between apical and middle levels. The explanation for this may be that the apical dentine contains less patent tubules than coronal dentine and the more complex structure of tubular dentine apparently yields itself better to infiltration compared to the sclerotic apical counterpart. This agrees with the finding of Nagas et al. [(31)] and Al-Hamed et al. [(32)].

The predominant mode of failure for AH Plus group was adhesive failure at S/G. Elsheikh et al.[(18)], showed that the failure mode for AH Plus was adhesive mainly between sealer and main cone and partially between sealer and dentin. Furthermore Nagas et al.[(33)] revealed that the failure mode was adhesive mainly between the gutta-percha and the AH Plus sealer. The predominant mode of failure for Activ GP group was adhesive at S/D interface and cohesive failure within the core material itself which might be due to weakening in the gutta-percha when sialinated with coating [(18)], and the nonhomogeneous coating of GI particle on the surface of the Activ GP cone which may be contributed to less favorable bonding[(34)]. In BC group the predominant mode of failure was also cohesive within the BC cone and this may be also attributed to weak and unfavorable distribution of the BC coating on the surface of BC cone. The predominant mode of failure for GuttaFlow2 group was adhesive failure mainly at S/G and some adhesive failure at S/D interface and this could be attributed to the lack of chemical union between sealer and gutta-percha or sealer and dentin. Within the limitation of the present study the push-out bond strength of AH Plus group was higher than other groups tested and the bond strength were affected by the tooth levels.

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**Table 1: Descriptive statistics of Push-out bond strength values (MPa) at three levels for all groups.**

| Groups | Level | No. | Mean | SD. | SE. | Min. | Max. |
|---|---|---|---|---|---|---|---|
| Group1 (AH Plus) | Coronal | 10 | 1.664 | 0.304 | 0.096 | 1.04 | 2.11 |
| | Middle | 10 | 1.276 | 0.319 | 0.101 | 0.81 | 1.81 |
| | Apical | 10 | 1.260 | 0.324 | 0.102 | 0.93 | 1.87 |
| Group2 (Activ GP) | Coronal | 10 | 1.105 | 0.314 | 0.099 | 0.83 | 1.85 |
| | Middle | 10 | 0.824 | 0.115 | 0.036 | 0.67 | 1.00 |
| | Apical | 10 | 0.817 | 0.170 | 0.054 | 0.59 | 1.12 |
| Group3 (Bioceramic) | Coronal | 10 | 1.591 | 0.283 | 0.089 | 1.25 | 2.08 |
| | Middle | 10 | 1.191 | 0.136 | 0.043 | 0.95 | 1.33 |
| | Apical | 10 | 1.155 | 0.121 | 0.038 | 1.02 | 1.40 |
| Group4 (GuttaFlow2) | Coronal | 10 | 1.256 | 0.270 | 0.085 | 0.99 | 1.69 |
| | Middle | 10 | 0.950 | 0.216 | 0.068 | 0.67 | 1.33 |
| | Apical | 10 | 0.913 | 0.193 | 0.061 | 0.58 | 1.21 |

**Table 2: ANOVA test for mean push-out bond strength among groups at each level**

| level | ANOVA | SS | df | MS | F | P-value | Sig. |
|---|---|---|---|---|---|---|---|
| Coronal Level | Between group | 2.133 | 3 | 0.711 | 8.289 | 0.000 | *** |
| | Within group | 3.095 | 36 | 0.086 | | | |
| | Total | 5.228 | 39 | | | | |
| Middle level | Between group | 1.313 | 3 | 0.438 | 9.717 | 0.000 | *** |
| | Within group | 1.627 | 36 | 0.045 | | | |
| | Total | 2.941 | 39 | | | | |
| Apical level | Between group | 1.274 | 3 | 0.425 | 9.149 | 0.000 | *** |
| | Within group | 1.671 | 36 | 0.046 | | | |
| | Total | 2.946 | 39 | | | | |

***** Very highly significant**

Table 3: LSD test for mean push-out bond strength between four groups at each level

| Level | Groups | | P-value | Sig. |
|---|---|---|---|---|
| Coronal Level | Group1 | Group 2 | 0.000 | *** |
| | | Group 3 | 0.581 | N.S |
| | | Group 4 | 0.004 | ** |
| | Group2 | Group 3 | 0.001 | ** |
| | | Group 4 | 0.257 | N.S |
| | Group3 | Group 4 | 0.015 | * |
| Middle Level | Group1 | Group 2 | 0.000 | *** |
| | | Group 3 | 0.377 | N.S |
| | | Group 4 | 0.002 | ** |
| | Group2 | Group 3 | 0.000 | *** |
| | | Group 4 | 0.193 | N.S |
| | Group3 | Group4 | 0.016 | * |
| Apical Level | Group1 | Group 2 | 0.000 | *** |
| | | Group 3 | 0.283 | N.S |
| | | Group 4 | 0.001 | ** |
| | Group2 | Group 3 | 0.001 | ** |
| | | Group 4 | 0.326 | N.S |
| | Group3 | Group 4 | 0.017 | * |

*Significant; ** highly significant difference; *** Very highly significant; N.S Non-significant difference.

Table 4: ANOVA test for mean push-out bond strength among the different levels within each group

| Groups | ANOVA | SS | df | MS | F-test | P-value | Sig. |
|---|---|---|---|---|---|---|---|
| Group1 | Between group | 1.047 | 2 | 0.523 | 5.245 | 0.012 | * |
| | Within group | 2.694 | 27 | 0.1 | | | |
| | Total | 3.741 | 29 | | | | |
| Group2 | Between group | 0.54 | 2 | 0.27 | 5.738 | 0.008 | ** |
| | Within group | 1.27 | 27 | 0.047 | | | |
| | Total | 1.81 | 29 | | | | |
| Group3 | Between group | 1.171 | 2 | 0.586 | 15.563 | 0.000 | *** |
| | Within group | 1.016 | 27 | 0.038 | | | |
| | Total | 2.187 | 29 | | | | |
| Group4 | Between group | 0.709 | 2 | 0.354 | 6.774 | 0.004 | ** |
| | Within group | 1.413 | 27 | 0.052 | | | |
| | Total | 2.121 | 29 | | | | |

*Significant; ** highly significant difference; *** Very highly significant

Table 5: LSD test for mean push-out bond strength between the different levels within each group

| Groups | Level | P-value | Sig. |
|---|---|---|---|
| Group1 | Coronal & Middle | 0.011 | * |
| | Coronal & apical | 0.008 | *(* |
| | Middle & apical | 0.911 | N.S |
| Group2 | Coronal & Middle | 0.007 | ** |
| | Coronal & apical | 0.006 | ** |
| | Middle & apical | 0.943 | N.S |
| Group3 | Coronal & Middle | 0.000 | *** |
| | Coronal & apical | 0.000 | *** |
| | Middle & apical | 0.631 | N.S |
| Group4 | Coronal & Middle | 0.006 | ** |
| | Coronal & apical | 0.002 | ** |
| | Middle & apical | 0.72 | N.S |

*Significant; ** highly significant difference; *** Very highly significant; N.S Non-significant difference.

**Table 6: Failure modes for different groups**

| Groups | Mode of failure (No.) | | | | |
|---|---|---|---|---|---|
| | Adhesive | | Cohesive | | Mixed |
| | S/D | S/G | Within sealer | Within gutta-percha | Cohesive & adhesive |
| Group1 | 6 | 13 | ---------- | ----------- | 11 |
| Group2 | 10 | --------- | -------- | 14 | 6 |
| Group3 | 7 | ----------- | ------- | 13 | 10 |
| Group4 | 10 | 14 | ------- | -------- | 6 |


Fig. 1: AH Plus Sealers


Fig. 2: Activ GP Sealers


Fig. 3: premixed Bioceramic sealer Sealers


Fig. 4: GuttaFlow2 Sealers

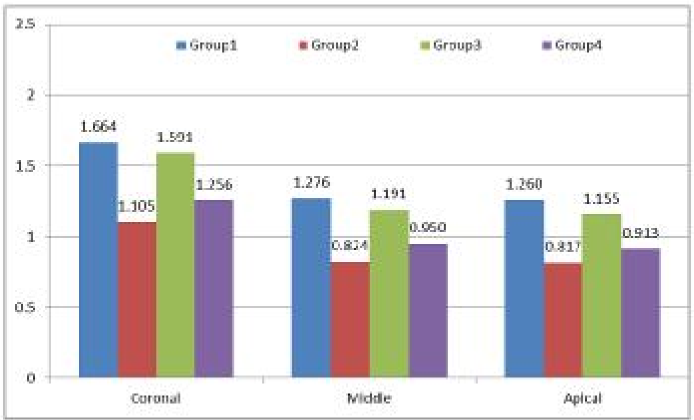


**Fig. 5: Bar chart graph for mean Push-out bond strength at each level of different groups**