



Push-out Bond Strength Evaluation for Different Endodontic Sealers (A Comparative Study)

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Abstract

Aims: The aim of this study was to compare the push-out bond strength values between four different types of sealers. **Materials and method:** Forty extracted straight, single-rooted, sound human mandibular first premolar teeth were selected for this study. The crown portion of each tooth was decoronated to the level of the cement-enamel junction (CEJ) to standardize the root length to 16 mm. The working length was measured and the canals were instrumented using Nickel-Titanium ProTaper Universal Rotary System up to size F3. The canals were rinsed with 2.5% sodium hypochlorite followed by 17% EDTA, then the samples were divided into four groups (n=10) according to the sealer to be used with F3 gutta-percha. These are (AH Plus, GuttaFlow 2, GuttaFlow Bioseal and MTA Fillapex) sealers. The push-out bond strength test was performed and the data were analyzed using one way ANOVA, and post hoc Duncan's multiple range tests at ($p \leq 0.05$). **Results:** There was a statistically significant difference in the push-out bond strength among the four sealers' groups at ($p \leq 0.05$). The highest mean value of bond strength (3.605) MPa was shown in the AH Plus group. Bioseal group produced (1.833) MPa followed by (0.822) MPa for GuttaFlow2 group. The lowest value (0.645) MPa was shown in MTA Fillapex group. **Conclusion:** Based on the findings of this study, AH Plus sealer revealed the highest bond-strength value followed by GuttaFlow Bioseal and GuttaFlow 2, whereas MTA Fillapex showed the least bond value.

الخلاصة

الاهداف: مقارنة قوة الدفع التخرجي لأربعة أنواع مختلفة من السمنت اللبني. **المواد والطرائق العمل:** أستعمل أربعون سنناً بشرياً مقلوعاً (قبل الضرسى الأوطأ) من فئة الجذر الواحد المستقيم وتم قطع تيجان هذه الاسنان عند مستوى الملتقى المينائي الملاطي كي يبلغ طول الجذر ١٦ ملم، وقد تم قياس طول العمل للقنوات اللبية وتحضيرها باستخدام أنظمة تيتانيوم-النيكل الدوّارة (protaper) الى حجم F3 Gutta-percha وتم غسل القنوات اللبية باستخدام ٢,٥٪ من محلول هيبوكلوريت الصوديوم و ١٧٪ من محلول (اي دي تي أي)، ثم ملئت الأقفية بأربعة أنواع مختلفة من السمنت اللبي مع ال Gutta-Percha وهذه الانواع هي: AH Plus, GuttaFlow2, GuttaFlow Bioseal , MTA Fillapex. بعد ذلك خللت البيانات إحصائياً عن طريق إختبار التحليل الأحادي الإتجاه للتباين وإختبارات دنكان. **النتائج:** أظهر التحليل الاحصائي للنتائج وجود فروق معنوية لقوة الدفع التخرجي بين مجاميع السمنت اللبي المختلفة عند ($p \leq 0.05$) وسجلت مجموعة ((AH Plus)) أعلى قيمة لقوة الدفع التخرجي ((٣,٦٠٥) ميغا باسكال، بينما سجلت مجموعة ((Bioseal)) قيمة ((١,٨٣٣) ميغا باسكال تعقبها مجموعة ((GuttaFlow 2)) وقيمتها ((٠,٨٢٢) ميغا باسكال، في حين أنتجت مجموعة ((MTA Fillapex)) أقل قيمة للربط التخرجي ((٠,٦٤٥) ميغا باسكال. **الإستنتاجات:** من النتائج أعلاه نستنتج أن السمنت اللبي ((AH Plus)) أظهر أعلى قيمة لقوة الربط التخرجي يعقبه كل من GuttaFlow Bioseal و GuttaFlow 2 على التوالي. في حين سجل ((MTA Fillapex)) أقل قيمة لقوة الربط في هذه الدراسة.

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INTRODUCTION

Endodontic sealer plays a crucial role in root canal treatment. It fills the spaces, root canal irregularities and minor discrepancies between the core filling material and the canal walls so that they form a coherent mass ⁽¹⁾. The key for successful endodontic therapy is to obtain a three-dimensional root canal obturation along with proper instrumentation and disinfection ⁽²⁾. The most commonly used obturation technique is that consisting of the use of gutta-percha along with a sealer ⁽³⁾. To be ideal, root canal sealer needs to have good wetting properties with low viscosity to ease its flow into the canal irregularities, multiple apical foramina and accessory canals ⁽⁴⁾. Many kinds of sealers have been utilized in endodontics such as zinc-oxide-based, calcium hydroxide, glass ionomer-based, various types of resins, silicone and bioceramics. Since there is no ideal sealer, the development of newer materials is continued.

AH Plus (Dentsply/ Germany) is a mixture of epoxy-amines that is regarded as the gold standard and the reference material in the laboratory and clinical researches for the other materials ⁽⁵⁾. It is a biocompatible sealer and more radiopaque, with a shorter setting time, lesser solubility, and a better flow properties compared with AH26 ⁽⁶⁾.

GuttaFlow 2 (Coltene/Whaldent, Switzerland) was available in 2012 as an advancement of the previous GuttaFlow material, having the same excellent

properties but with a stiffer consistency and changes in the form of silver particles used. GuttaFlow 2 is composed of a mixture of poly-dimethyl-siloxane, gutta-percha powder with particle size smaller than 30 μm , zirconium dioxide, platinum catalyst and a preservative of microsilver particles. This cold flowable system is one material that combines both gutta percha and sealer ⁽⁷⁻¹⁰⁾. GuttaFlow2 also does not shrink, instead, it expands slightly by about 0.2%. Also it adheres considerably to the gutta-percha points and dentinal walls. This combined action of expansion and adhesion produces an excellent seal ⁽¹¹⁾.

GuttaFlow Bioseal (Coltene/Whaldent, Switzerland) has been produced in late 2015. It has a bioactive ceramic glass in addition to gutta-percha, poly-dimethyl-siloxane, zirconium oxide and platinum ⁽¹²⁾. This bioactive glass contains silica, sodium oxide, calcium oxide, and phosphorus oxide. GuttaFlow Bioseal has a nanosilver component also instead of a microsilver. These bioactive components are able to form hydroxyapatite crystals when they contact tissue fluids so that they could result in stimulation of tissue regeneration and healing ⁽¹³⁻¹⁴⁾.

MTA Fillapex (Angelus, Brazil) is a calcium silicate containing bioceramic sealer. It combined the physico-chemical characteristics of resin-based sealers in addition to the biological features of MTA (Mineral Tri Oxide Aggregate) ⁽¹⁵⁾.

Push-out test has been commonly used to assess the dislodgement resistance

of the filling materials and the sealer-dentin bonding strength ⁽¹⁶⁾.

The study aimed to compare the push-out bond strength of four different sealers (AH Plus, Gutta Flow 2, GuttaFlow Bioseal and MTA Fillapex) to root dentin.

MATERIALS AND METHODS

Forty straight, single-rooted, sound human mandibular first premolar teeth with completely formed apexes extracted for orthodontic purposes nearly have similar root size and length were selected for this study. The teeth were radiographed to exclude any teeth with signs of internal or external resorption, restored, fractured or cracked teeth, endodontically treated teeth, and teeth with developmental defects, calcified canals or bifurcating canals from this study. The external surface of each root was cleaned from any soft tissues remnants with scaling instruments, the teeth were disinfected using 5.25% sodium hypochlorite NaOCl solution for 30 minutes. Then, they were carefully rinsed under running tap water and kept in sterile distilled water at room temperature to avoid dehydration till further use. The crown portion of each tooth was decoronated at the cement-enamel junction (CEJ) using 0.2 mm thick diamond disk with high speed handpiece under copious water cooling to standardize the root length to 16 mm. the pulpal tissue was removed using barbed broach. The apical patency was ensured using No. 10 K file. Then, No. 15 K file was inserted inside the canal and advanced

gently using a reciprocating back and forth motion until the tip of the file was seen at the apical foramen. This distance was measured by endodontic ruler. The working length was established by subtracting 1mm from the visually determined canal length. The samples were subjected to the same crown down instrumentation procedure through enlargement of the root canals using Nickel-Titanium ProTaper universal rotary system instruments used with contra-angle rotary handpiece. A total of six instruments (SX, S1, S2, F1, F2 and F3) were used. The speed of rotation was maintained at 300 rpm (revolutions per minute) and torque 3.0 Ncm (Newton centimeter). The canals were rinsed using freshly prepared 2.5% sodium hypochlorite between each instrument change. After the completion of the canal instrumentation, the canals were rinsed with 3ml of distilled water to remove any remnants of NaOCl then washed with 5ml of 17% EDTA solution for 1 minute, followed by washing with another 5ml of 2.5% NaOCl for 1 minute. The root canals were finally flushed with 5ml of distilled water to remove the remnants of the irrigating solutions from the canals, after that all canals were dried carefully with F3 paper points to be ready for obturation. The canals were divided into four groups (n=10) according to the sealer to be used for obturation with F3 gutta-percha cones. These are (AH Plus, GuttaFlow 2, Gutta Flow Bioseal and MTA Fillapex) groups. When the obturation procedure was

completed, the apical and coronal portions of the roots were sealed with soft wax. Then, the samples of all groups were kept moist by wrapping them in a saline moistened gauze in a closed container, and were incubated for 7 days at 37 C° with 100% humidity in an incubator to ensure the complete setting of the sealer.

The roots were vertically placed and centered in clear cold cured acrylic resin custom-made molds. A waterproof pen was used to mark the acrylic molds as a guide during the root sectioning process. Sectioning of each root was carried out in a horizontal plane perpendicular to the long axis of the main canal using a circular water-cooled diamond disk to obtain 2 mm thick disks (apical, middle and coronal root sections respectively). The exact thickness of each disk was measured using a digital caliper. Both coronal and apical surfaces were carefully examined to select only a circular root section with a uniform sealer layer in order to ensure a uniform distribution of the force during push-out testing and thus accurate measurements.

Push-out Bond Strength Test Evaluation

Each sample was carefully positioned on a metal base with a central

$$\text{Bond Strength (MPa)} = \frac{\text{debonding force (N)}}{\text{Surface area (mm}^2\text{)}}$$

The surface area was measured by the following formula:

$$A(\text{mm}^2) = \pi(r_1 + r_2)\sqrt{[(r_1 - r_2)^2 + h^2]}$$

hole with an apical surface having a smaller diameter was facing the plunger of a universal testing machine. The center of the tested specimen was aligned over the hole so that the filling material can fall freely through once the bond between the dentin wall and the test material was broken. A vertical load was applied by a cylindrical stainless steel plunger especially designed for this study in an apical to coronal direction. The plunger was positioned so that it only contacts the root canal filling to displace it downward and not to touch the dentinal walls to avoid misreading therefore three different sizes of plunger were used (0.7mm for coronal third, 0.5mm for middle and 0.3mm for apical third) to provide the proper coverage matching the filling material without touching the canal walls. Diameter of the canal in both apical and coronal aspects was measured using a stereomicroscope (Optica, Italy) at 40x magnification. The test was performed at a cross-head speed of 1 mm/min until the occurrence of bond failure and the highest force value at the time of debonding was recorded.

The bond strength was measured in megapascals (MPa) and calculated by dividing the maximum force (F) measured in newton (N) over surface area (A):

Where π is the constant 3.14, r_1 is the coronal radius, r_2 is the apical radius, h is the thickness of the section in mm.

The statistical analysis was performed using SPSS. A p-value of ≤ 0.05 was regarded statistically significant. The data

RESULTS

One Way ANOVA test demonstrated a statistically significant difference at ($p \leq 0.05$) between the four sealers' groups as shown in (Table.1). Based on the results of Duncan's multiple range test, the

were analyzed using one way ANOVA and post hoc Duncan's multiple range test to compare the mean bond strength value of the four sealer groups (AH Plus, GuttaFlow2, GuttaFlow Bioseal and MTA Fillapex).

ranking of bond strength in descending order was given as follows: AH Plus > GuttaFlow Bioseal > GuttaFlow2 > MTA Fillapex as summarized in (Table.2). The mean values of bond strength for each sealer are illustrated in (Figure.1).

Table (1): One Way ANOVA test of push-out bond strength for comparison of the four sealers' groups (AH Plus, GuttaFlow2, GuttaFlow Bioseal and MTA Fillapex).

	Sum of Squares	df	Mean Square	F	Sig.*
Between Groups	165.913	3	55.304		
Within Groups	70.662	116	0.609	90.78	0.000
Total	236.576	119			

df: degree of freedom, F: value of calculated F, Sig*: high Significance ($p\text{-value} \leq 0.05$).

Table (2): Duncan's Multiple Range test for comparison of four sealers' groups (AH Plus, GuttaFlow2, GuttaFlow Bioseal and MTA Fillapex).

Sealer groups	N	Mean	Standard Deviation	Duncan's groups**
Group A: AH Plus	30	3.605	1.198	A
Group C: GuttaFlow Bioseal	30	1.833	0.793	B
Group B: GuttaFlow2	30	0.822	0.490	C
Group D: MTA Fillapex	30	0.645	0.359	D

*N: Number of Samples, **: Different letters mean significant difference.

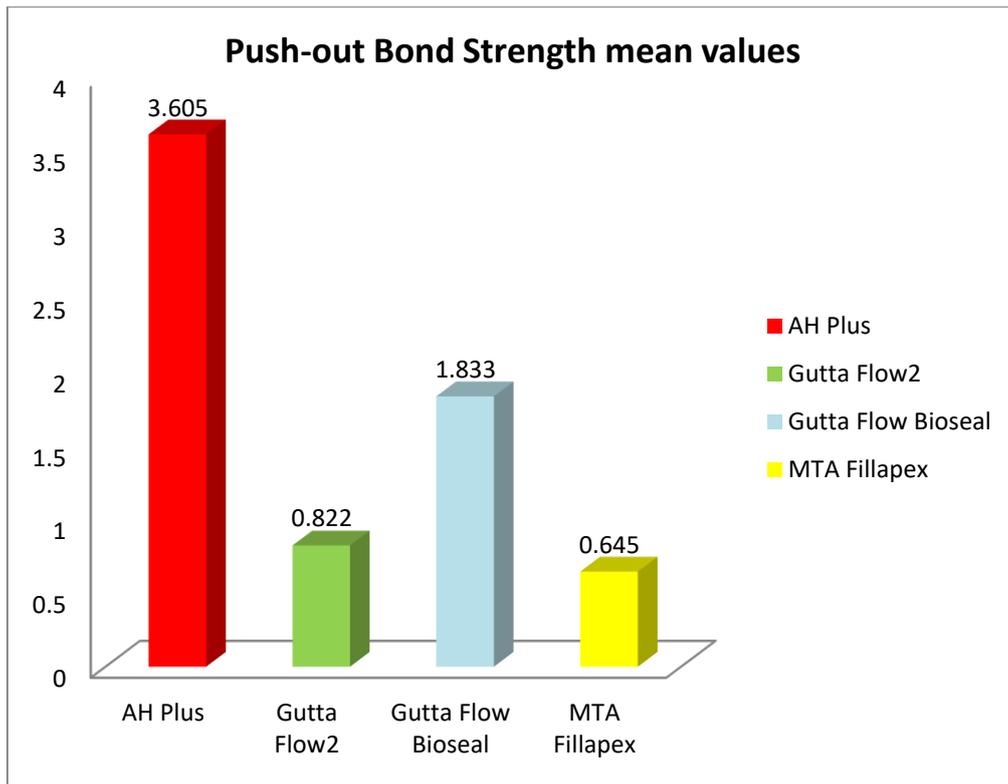


Figure (1): Histogram shows Push-out bond strength mean values for all sealers' groups used in the study (AH Plus, GuttaFlow 2, GuttaFlow Bioseal and MTA Fillapex).

DISCUSSION

Sealers play a crucial role in the obturation process and they can influence the quality of the root canal treatment ⁽¹⁷⁾. The sealer bond strength to root canal dentin wall is a very desirable property because it helps keep the integrity of this sealer-dentin interface without disruption in long term ⁽¹⁸⁾. In the present study, throughout canal preparation, irrigation is done using (3ml) of (2.5%) sodium hypochlorite (NaOCl) since it is the simplest available endodontic irrigant having an organic tissue dissolving property. Inorganic component of smear layer was removed using (5ml) of (17%) EDTA remained in the canal for 1 minute since it may cause peritubular and intertubular erosion of the dentin if it is applied for more than this time ⁽¹⁹⁾. The combined use of these two irrigants represents the most commonly used protocol in clinical practice ⁽²⁰⁾. After that, sodium hypochlorite (NaOCl) was used to ensure the complete removal of the remnants of EDTA from the canal. This irrigation protocol yields more exposure of dentinal tubules and dentinal collagen network, thus enhances the bond strength for most sealers to dentin via increasing sealers' penetration into the dentinal tubules and their mechanical interlocking to the root canal wall ⁽²¹⁻²²⁾. The canals were finally washed with distilled water in order to eliminate the negative effect of sodium hypochlorite (NaOCl) as it is a potent agent that leaves behind on the dentinal surface an oxygen rich layer leading to the reduction in the bond strength value ⁽²³⁾.

In the current study, four different types of sealers were examined, therefore the use of gutta-percha as the main core material was to be considered as a constant, also to firmly simulate the clinical conditions ⁽²⁰⁾. In addition, these different types of sealers are poorly comparable because of their different hardness if they were used without core material ⁽²⁾. The obturating material adhesion to dentinal walls is assessed using bond strength testing. Numerous methods such as: shear bond strength, push-out and microtensile tests have been employed to evaluate the bond strength. Among these tests, push-out bond strength was conducted in the present in-vitro study to compare among four different types of sealers since it is one of the most reliable and reproducible techniques. It is capable of evaluating the bond strength of the material-dentin interface in the different surfaces and portions of the root canal ⁽²⁴⁾. In the present study, three sizes of plungers were used for each root third (apical, middle and coronal) in order to completely cover the core material in each third of the sample. The plunger was centralized to avoid contact with dentin and the force was applied on the obturating material in an apical to the coronal direction in order to avoid any constriction interference caused by root canal taper ⁽²⁵⁾. The dentin thickness used for push-out test has also been considered a variable in several studies. Thin slices, about 1mm, are in risk of sealer detachment during slicing as mentioned by Gesi, *et al.*, 2005 ⁽²⁶⁾. A 2mm thickness slices were used so as to avoid premature debonding ⁽²⁵⁾.

According to the findings of this study, AH Plus has shown the greatest bond strength

value in comparison to the other sealers used in the study. This performance of AH Plus sealer is well documented in many studies ⁽²⁾⁽¹³⁾⁽²⁷⁻²⁸⁾. This can be related to the inherent volumetric expansion property of AH Plus sealer that can form a covalent bond between open epoxide ring of epoxy resin sealer and the exposed amino-groups of radicular dentin ⁽²⁹⁾. In addition, it could be discussed that AH Plus displays a significant cohesion between its molecules which could be translated to a great adhesion property. Also, AH Plus deeply penetrates the micro irregularities as a result of its creep capability, excellent flowability with a long polymerization time. This can increase its mechanical interlock with the radicular dentin and its dislodgment resistance ⁽³⁰⁾.

The lower bond strength of GuttaFlow 2 can be related to the hydrophobic nature of root canal dentin following the use of chelating agent (EDTA). The use of EDTA alone or combined with NaOCl decreases the surface free energy of radicular dentin because it removes the inorganic part of dentin and demineralizes the intertubular and peritubular dentin leading to collagen fibers exposure and patent dentinal tubules with increased surface roughness, hence making the dentinal surface hydrophobic and decreases its wettability that interferes with the wettability and thus the bonding of GuttaFlow 2 ⁽³¹⁻³²⁾. Also, the presence of silicone resin in the composition of Gutta Flow 2 can increase their surface tension, resulting in more difficult flow and spreading of these materials with poorer wetting effects ⁽²¹⁾ ⁽³³⁾. Subsequently, it can be supposed that there is no chemical but only slight mechanical

interaction between silicone-based sealers and radicular dentin ⁽²⁾.

Regarding GuttaFlow Bioseal sealer, which is a novel polydimethylsiloxane sealer similar to GuttaFlow 2 but it contains calcium silicate, it was found under the conditions of this study that it has a bond strength lower than AH Plus but higher than both GuttaFlow 2 and MTA Fillapex. Once GuttaFlow Bioseal contacts with the tissue fluids, the bioactive material yields calcium silicate that will form a physical bond with the dentinal surface through the formation of hydroxyapatite interface deposits ⁽³⁴⁻³⁵⁾. After the release of such ions, tag-like structures will extend into the dentin. This will significantly improve the sealer's adhesion and hence the push out bond strength ⁽³⁶⁾. The reason for the lower bond strength of Gutta Flow Bioseal compared to AH Plus may be related to the lower adhesion capacity of these tag-like structures in comparison to AH Plus mean bond strength value ⁽³⁷⁾. Gandolfi *et al.*, (2016) ⁽³⁵⁾ described that when slight calcium released, the low solubility and alkalizing action of calcium and phosphate ions stimulate the formation of a superficial calcium-phosphate layer that can fill out the voids at the sealer-dentin interface.

MTA Fillapex produced the lowest push-out bond strength value in the present study. This performance is well documented in many studies ^{(16) (27) (38-39)}. The chemical composition of MTA Fillapex may affect its bonding to dentin. The set sealer releases calcium and hydroxyl ions that lead to apatite formation and deposition in collagen fibrils represented by tag-like structures. The low bond strength of MTA Fillapex in the current study can be

related to the lower adhesion capability of these tag-like structures ⁽¹⁶⁾⁽⁴⁰⁾.

CONCLUSION

Based on the results of this study, it can be concluded that AH Plus has higher bond strength to radicular dentin followed by Gutta Flow Bioseal and GuttaFlow 2. MTA Fillapex has shown the lowest bond strength value.

Conflicts of interest

There are no Conflicts of interest.

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