Push out bond strength of different obturation systems
(An in vitro study)

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ABSTRACT

Background: The bond strength of the root canal sealers to dentin seems to be a very important property for maintaining the integrity and the seal of root canal filling. The aim of this study was to evaluate the shear bond strength of four different obturation systems using push-out test.

Materials and methods: Forty straight palatal roots of the maxillary first molars teeth were used in this study, these roots were instrumented using crown down technique and ProTaper system, instrumentation were done with copious irrigation of 2.5% sodium hypochlorite and 17% buffered solution of EDTA was used as final irrigant followed by distilled water, roots were randomly divided into four groups according to the obturation system (ten teeth for each group): Group I: AH26 sealer and lateral condensation technique, Group II: AH26 sealer and single cone obturation technique, Group III: AH26 sealer and thermafil obturation technique and Group IV: RealSeal SE sealer and lateral condensation technique, the roots then stored in moist environment at 37°C for one week. The roots were embedded in clear acrylic resin and each root sectioned into three levels apical, middle and cervical. The measurement of each section was taken to prepare the supporting jig for the sections and the punch used in push-out test, the bond strength was measured using computerized universal testing machine each section fixed in the machine so that the load applied from apical to cervical direction at 0.5mm/min. speed and the computer drew curve to show the higher bond force before dislodgment of the filling material. These forces were divided by the surface area to obtain the bond strength in MPa.

Results: Statistical analysis was performed and the result showed very highly significant differences between the four obturation systems at each level and there were non significant differences between all level apical, middle and cervical within each obturation system except a significant difference found between cervical and apical level in single cone obturation system.

Conclusion: This study showed that the shear bond strength of AH26 sealer was higher than RealSeal SE sealer when the same obturation technique was used. The shear bond strength was affected by the obturation technique and lateral condensation technique showed higher bond strength than thermafil and single cone obturation technique when the same type of sealer was used and the bond strength was not or little affected by the tooth level.

Key words: bond strength, push-out test, endodontic sealers, obturation systems.

INTRODUCTION

The American Association of Endodontics defines root canal obturation as "the three-dimensional filling of the entire root canal system as close to the cementodontinal junction as possible". Over the past century, numerous obturation materials and delivery techniques have been introduced in an attempt to obtain a microbiologic barrier within the confines of the root canal system, the continued research on obturation materials is based on the concept that the primary cause for failure of root canal treatment is the apical migration of microorganisms and their byproducts in a poorly filled and leaking root canal system (1). Obturation materials and delivery techniques have been introduced in an attempt to obtain a tight seal with the dentinal tubules within the root canal system. In essence, it produces a “monoblock” effect, where the core material, sealer and root canal dentin form a single cohesive unit. Examples of systems that advertise this technology include a dual-curable methacrylate resin sealer composed of filler of calcium hydroxide, barium sulphate, barium glass and silica (Epiphany system) has been developed for use with self-etching primer and in association with new thermoplastic synthetic polyester polymer-based root canal filling material (Resilon) that replaces gutta-percha (3). Recently, 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. Examples of systems that advertise this technology include a dual-curable methacrylate resin sealer composed of filler of calcium hydroxide, barium sulphate, barium glass and silica (Epiphany system) has been developed for use with self-etching primer and in association with new thermoplastic synthetic polyester polymer-based root canal filling material (Resilon) that replaces gutta-percha. Obturation using the Epiphany/Resilon system is claimed to create a tight seal with the dentinal tubules within the root canal system. In essence, it produces a “monobloc” effect, where the core material (Resilon), sealer (Epiphany, Realseal) and dential tubules become a single solid structure. Shipper et al. (5) suggested that this monoblock would be highly desirable to provide a thorough seal of the root canal system as it would be able to minimize coronal leakage in case of loss of...
fracture of the temporary coronal restoration, an in vitro studies have demonstrated a good resistance of the Epiphany / Resilon monoblock system to bacterial leakage.

Epoxy resin - based cements have also presented a good performance as root canal sealer and had been shown to have low solubility , disintegration and a good adhesion \(^{(4)}\).

Gutta-percha is commonly used with various techniques to enable the dentist to accurately and thoroughly obturate root canal system \(^{(6)}\). Various techniques have been suggested for root canal obturation.

The evaluation and comparison of current obturation techniques is therefore important in determining there relative efficacy in achieving an optimal seal.

**MATERIALS AND METHODS**

Forty freshly extracted maxillary first molar teeth with straight palatal root canals and mature apices were selected for this study from the clinics of the University of Baghdad, college of Dentistry. The age (18-45 years) while the gender, pulpal status and reason for extraction were not considered and criteria for teeth selection included the following : straight root canal and round cross section, mature, centrally located apical foramen, Patent apical foramen, roots devoid of any resorptions, cracks or fractures and the roots would be 10 mm in length.

**Samples preparation**

After extraction, all teeth stored in distilled water at room temperature. Any soft tissue remnants on the root surface were removed with sharp periodontal curette and the root surfaces were verified with a magnifying eye lens (X 10) and light cure device for any visible cracks or fractures. Using a diamond disc with straight handpiece and water coolant the palatal roots of teeth 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 pulpal tissue was removed by using barbed broach and the exact location of the apical foramen and the patency of the canals were verified by insertion of a No.10 K-file into the canal and advancing until it was visualized at the apical foramen. The correct working length was established by subtracting 1 mm. from this measurement. The roots held with a Silicon rubber base (heavy-body) was mixed (base and catalyst) according to manufacturer instruction and inserted in plastic containers then the sectioned root was inserted inside the rubber base. Heavy body was left to set forming a small block to facilitate handling of the roots during instrumentation and obturation technique. The canals were prepared with crown down technique using ProTaper system (SX to F4). A total of 10 ml of 2.5% of sodium hypochlorite (NaOCl) was used for irrigation during instrumentation then followed by irrigation with 5 ml EDTA 17% for 1 minute to remove smear layer followed by 5 ml of distilled water to avoid development of NaOCl crystals. The roots dried with paper point after instrumentation, canal preparation considered complete when canal walls were glassy smooth.

**Samples grouping**

The roots were randomly divided into four groups of ten roots each.

**Group I:**

In this group, the AH26 silver free sealer was mixed according to the manufactures instructions, on a dry clean glass slab with a spatula. The mixture had a homogenous creamy consistency with string out at least 1 inch when spatula was raised slowly from the glass slab. The canal of each tooth was dried using paper point and sealer was introduced into the canal using ProTaper paper point F4 by rotating the paper point two times counter clock wise to coat the canal walls by thin film of sealer. The tip of master gutta percha cone corresponding to the last file size #40 was dipped into the sealer and placed into its correct position within canal, the previously checked finger spreader size #40 inserted between the master cone and the canal wall to within 1 to 2 mm from working length. Spreader taper is the mechanical force that laterally compresses and spreads gutta-percha creating a space for an additional accessory cone. The tip of accessory cone size #20 was dipped in the sealer and inserted by the space left by the spreader, this point was followed by more spreading and more accessory cone until the spreader could not enter more than 2-3mm into the canal orifice. When obturation of teeth accomplished, the excess gutta- percha removed with heated instrument to a level (1 mm) higher than the coronal end of roots and vertically condensed with root canal plugger, so the gutta-percha obturate the entire canal.

**Group II:**

In this group, the root canals were coated with sealer in the same manner described in group I. The tip of master gutta-percha cone F4 corresponding to the last file size at working length was dipped in sealer and inserted slowly in the canal to the full working length. The excess gutta- percha was removed with heated instrument to a level (1 mm) higher than the coronal end of roots and vertically condensed with root canal plugger. The evaluation and comparison of current obturation techniques is therefore important in determining there relative efficacy in achieving an optimal seal.
plunger, so the gutta-percha was obturated the entire canal.

**Group III:**
In this group, the root canals were coated with sealer in the same manner as Group I then the canal was obturated by Thermafil obturation according to manufacture instruction. The Thermafil obturator size #40 was heated in ThermaPrep plus oven and the time required and the temperature to which the cones were heated was predetermined in the oven by manufacture then the warmed obturator were inserted firmly and slowly to the working length without any twisting or rotation. The handle of the carrier was cut at orifice with high speed inverted cone diamond bur. The gutta percha, which was still in the thermoplasticized phase, was vertically compacted around the carrier with a hand plunger.

**Group IV:**
In this group, the dual syringe (with mixing tip) was used to express the sealer onto the mixing pad then the RealSeal sealer was carried to the canal in small amounts on paper point according to manufacture instruction. After the placement of the RealSeal sealer in to canal, the Resilon master cone size #40 was coated with the sealer and placed into its correct working length within canal. An endodontic stainless steel finger spreader size #40 was inserted between the master cone and the canal wall using firm apical pressure only to within 1 to 2 mm from the working length. Spread taper is mechanical force that laterally compresses and spreads Resilon point and creating space for an additional accessory cone. The tip of accessory cone size #20 was dipped in the sealer and inserted into the space left by the spreader, this point was followed by more spreading and more accessory cone until the spreader could not enter more than 2-3mm into the canal orifice. The excess Resilon was seared off with a hot instrument and vertically condensed with endodontic plugger then the coronal third cured using light curing device for 40 second according to manufacturer instruction.

After obturation, the obturated roots of all groups removed from the rubber base materials and radiographed to verify the proper condensation of the obturants, then 1 mm. of the filling materials removed from the obturated roots of all groups to create space for the temporary filling materials and the all the roots sealed with glass ionomer cement as temporary restoration. All Obturated root were wrapped in saline moistened guaze in closed plastic vial allowing the sealer to set for 7 days with 100% humidity at 37°C in an incubator.

**Root sectioning**
After the storage period the samples were embedded in clear orthodontic resin. Two ml disposable plastic syringes was used as molds into which the freshly prepared acrylic paste loaded, the flat coronal end of the obturated roots would be fixed on the face of the plastic piston of the syringes with a resin adhesive as recommended by the manufacturers so that the roots would be almost centrally located within the acrylic blocks and to ensure that the sectioning would be almost perpendicular to the long axis of the roots. The acrylic was prepared by mixing powder and liquid as recommended by the manufacturers in a porcelain jar. The material was left undisturbed for few minutes until it reached the workable stage. The syringe loaded with the freshly prepared workable acrylic paste, the piston of the syringe with the root fixed on it's face was pushed into the acrylic paste with gentle pressure to allow the complete embedding of the root into the acrylic and to allow the escape of the access material through the opened syringe tip. The material was allowed to cure under cooled water 20°C at 10kg of pressure, which was necessary to compensate for the anticipated rise in the temperature of the samples subsequent to the exothermic curing reaction of the cold cure resin. The acrylic molds were allowed to cure completely for at least 30min as recommended by the manufacturers. After complete curing of the acrylic molds the plastic syringes were cut off using diamond disc. Using diamond disc mounted on straight hand piece and engine with a rotation speed regulator, the hand piece was assembled in a cutting device. The root was cut horizontally into four sections of 2mm in thickness and the last apical 2mm section was discarded, the cuts were made at 7.0,4.5,2.0 mm from true anatomical apex, the cuts were made with flow of cold water (19-25°C) to minimize smearing. Although the diamond disc was 0.4mm in thickness it actually made a cut 0.5mm thick.

**Push-out test**
Each section was positioned in a reflected light microscope and pictures of both sides of each slice was taken with a digital camera and the measurements calculated using AutoCAD program, on the coronal side of the slices, the larger diameter was measured to select a support jig with a large enough hole (3mm) to provide clearance for the obturating material when it dislodged from the tooth slice. On the apical side of the slices, the smallest diameter measured to select a punch to be used to supply load with that side, making sure that the punch would not contact the dentin around the obturating material, causing a crack and erroneous results, the punch were 0.2mm away from the dentin wall, three punches were used (1mm, 0.6mm, 0.4mm) for coronal, middle and apical section respectively.
The thickness of each slice measured by means of digital caliper (2 mm.) These measurements and the perimeter measurements used by the computer in the push-out test to calculate the bonded area. Each specimen was attached to a support metallic jig with clearance for the dislodged material with the coronal end facing the support jig and the apical end facing the load cell, the punch fixed to the microcomputer electrical control Universal Testing Machine (WDW50). The punch will move downward apico-coronal (Fig 1 & 2) at a crosshead speed of 0.5 mm per minute until the first dislodgment of the obturating material. The punch would be positioned so that it only contacts the specimen’s obturation site, generating shear stresses on the areas to be debonded (7). The machine connected to computer that drew a load/time curve which gave the maximum failure load in kilo Newton and used to calculate the pushout bond strength in Megapascale (MPa) from the following formula (8):

\[
\text{bond strength (MPa)} = \frac{\text{load (N)}}{\text{adhesion area of filling (mm}^2)}
\]

The bonded (adhesion) area of each section was calculated as the follow:

\[
\pi (r_1^2 + \pi r_2^2) L
\]

Where \(r_2\) the coronal radius, \(r_1\) the apical radius, \(\pi = 3.14\) and \(h\) the thickness of the section.

**RESULTS**

From the present study the following results obtained (Table 1): the highest and the lowest mean values for sealer push-out bond strength were seen at cervical level of lateral condensation technique and AH26 sealer (7.2461) and apical level of lateral condensation technique and RealSeal sealer (2.8921) respectively. The rest mean values for study groups were fluctuating between these values.

To compare between the four obturation systems at each level ANOVA test was performed to identify the presence of statistically significant differences for sealer push-out bond strength between different obturation systems within each level, very highly significant differences (\(p \leq 0.001\)) were found at all levels. The least significance difference test (LSD) was performed to evaluate the significant differences between each two obturation system at each level and the results showed the follow: 1. There were very highly significant difference between group I (obturated by AH26 sealer and lateral condensation technique) and other three groups at all levels (apical, middle, cervical). 2. There were very highly significant difference between group II (obturated by AH26 sealer and single cone obturation technique) and group III (obturated by AH26 sealer and Thermafil obturation technique) at apical level, highly significant (\(p \leq 0.01\)) difference at middle and cervical level. 3. There were non significant difference (\(p \geq 0.05\)) between group II (obturated by AH26 sealer and single cone obturation technique) and group IV (obturated by RealSeal Resilon obturation system) at all levels (apical, middle, cervical). 4. There were very highly significant difference between group III and group IV at all levels (apical, middle and cervical).

Analysis of variance (ANOVA test) was performed to identify the presence of statistically significant differences for sealer push-out bond strength between different levels within each obturation system, non significant difference (\(p \geq 0.05\)) were found within all obturation systems except significant difference (\(p \leq 0.05\)) showed by group II (obturated by AH26 sealer and single cone obturation).

The least significance difference test (LSD) was performed to confirm the results of ANOVA test between each two levels. The (LSD) test showed non significant difference between the levels within all obturation systems except group II (obturated by AH26 sealer and single cone obturation) showed significant difference between the apical and cervical levels.
DISCUSSION

The bond strength of root canal sealers to dentin was important for maintaining the integrity of the seal in root canal filling in both static and dynamic situations. In a static situation, it should eliminate any space that allowed the percolation of fluids between the filling and the wall, in a dynamic situation, it was needed to resist dislodgement of the filling during subsequent manipulation. Increased adhesive properties to dentin might lead to greater strength of the restored tooth, which may provide greater resistance to root fracture and clinical longevity of an endodontically treated tooth. Bond-strength testing had become a popular method for determining the effectiveness of adhesion between endodontic materials and tooth structure. There were many methods for measuring the adhesion of endodontic root canal sealers, but none had yet been widely accepted. The tensile strength test is sensitive, with the result that small alterations in the specimen or in stress distribution during load application have a substantial influence on the results. On the other hand, a major problem with shear testing is that it is difficult to closely align the shear-loading device with the bond interface. The load was offset at some distance from the bonded interface, resulting in unpredictable torque loading on the specimen. In this study, the push-out test method was used to test the dentin bond strengths of different root canal sealers, the model had been shown to be effective and reproducible. Another advantage of this method is that it allowed root canal sealers to be evaluated even when bond strengths are low.

Epoxy resin-based sealers such as AH26 sealer (Dentsply, Detrey, GmbH, Germany) have been widely used. AH26 sealer was selected due to its robust physical properties as the sectioning process required the sealer to lock the gutta percha cone in place. The result of the present study showed the highest mean value of push-out bond strength in obturation systems that used AH26 sealer and when the same obturation technique was used (lateral condensation technique) there was a very highly significant difference between group I (obturated by AH26 sealer and gutta percha) and group IV (obturated by RealSeal SE sealer and Resilon obturation system). An explanation for these results was the formation of a covalent bond by an open epoxide ring to any exposed amino groups in collagen. Other investigations had further shown high-quality properties with epoxy resin–based sealers, including very low shrinkage while setting and long-term dimensional stability. This result also might be related to the long setting time of AH26 sealer (9-15 hours) Which allowed sufficient time for sealer penetration in dentinal tubules and development of good adhesion to dentin. These results were in agreement with the results of Al Ani and Marilia et al. Cold lateral condensation of gutta percha in combination with an insoluble endodontic sealer remains the most widely accepted and used obturation technique. In many studies, this method had served as standard against which new technique was often compared. The result of this study showed the higher push-out bond strength and there were very highly significant difference between group I (obturated by AH26 and lateral condensation technique) and other groups obturated using the same sealer AH26 but different obturation technique. These results might be attributed that sealer thickness of lateral condensation technique is less than sealer thickness in single cone obturation technique and there was no heat used in lateral condensation technique that might be affected on the bond strength of sealer.

The single cone obturation technique is simple and consists of placement of obturation point that matched the instrument used in preparation. As recommended by the manufacturer the of the ProTaper obturation system the protaper gutta percha points had been specifically designed to match the size and the taper of ProTaper files, manufacturers of matched taper points claim that they could fill tapered canals effectively as they correspond to

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<th>Table 1: Mean value of push-out bond strength in (MPa) &amp; standard deviation at three levels for different obturation systems</th>
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canal shape created by instruments of similar taper. The result of this study showed lower push-out bond strength value for group II (obturated by AH26 and single cone obturation technique) when compared with group I and group III. Both of the two groups used the same sealer AH26 but different obturation techniques. There was a very highly significant difference between these groups. These results might be related to the higher sealer thickness of single cone obturation technique when compared with other obturation techniques. As the thickness of the sealer increase the polymerization shrinkage increase and the bond strength reduced.

Thermafil, core carrier technique, demonstrated superior predictability in achieving a homogenous, well adapted root filling with a minimum sealer film. The results of the present study showed that the push-out bond strength of Thermafil obturation technique used in group III with AH26 sealer were lower than group I obturated by AH26 and lateral condensation technique. These results might be related to the effect of heat on sealer properties.

Lawson et al. concluded that the evaporation of the liquid resin component of the sealer by heat generated during obturation technique could result in a highly viscous sealer that had a limited flow capacity into the patent dentinal tubules and lower bond strength, also the rate of polymerization may be accelerated by heat generated during thermafil obturation technique and increase shrinkage and decrease bond strength. The result of this study disagreed with Panagiotis Beltes et al. who found that there was no significant difference in AH26 bond strength with and without heat application, this might be related to difference in the method of measurement bond strength, the author used single plane shear test assembly.

One of the recent trends in endodontics has been the development of bonded obturation material, in an effort to provide a more effective seal. A new material, Resilon which is the central component of the Epiphany soft resin obturation system (Pentron Clinical Technology) and RealSeal (Sybron Endo), has been developed to replace gutta percha and traditional sealer. The result of this study showed RealSeal SE sealer had lower bond strength than AH26 when the same obturation technique used. There was a very highly significant difference between group I (obturated by AH26 and lateral condensation technique) and group IV (obturated by RealSeal sealer and lateral condensation technique). This result is attributed to polymerization shrinkage of the sealer, the amount of shrinkage depends on the type, size, and content of filler particles as well as the type of matrix used. The stress associated with this shrinkage may result in separation of the resin-based sealer from the dentinal walls and consequently, the bond strength value of this interface would decrease. Another explanation for the lower bond strengths detected in the groups containing a methacrylate resin-based sealer is the effect of cavity configuration factors. C-Factor: the ratio bonded to unbonded surface. C-Factor is found to be extremely high in long, narrow root canals. Virtually every dentin wall had an opposing wall which produces a very limited unbonded surface area to provide relief from the stresses created by polymerization shrinkage. It is likely the bond between sealer core and sealer dentin is not adequate enough to resist this debilitating stress that develops during polymerization resulting in gap formation. Another cause of lower bond strength is resin sealer is light-cured to create an immediate coronal seal, because this prevents stress relief by resin flow and the resin sealer may detach from dentin walls, thus creating interfacial gaps and decreasing the interfacial strength. These result was in agreement with Marilia et al. (27), Matthew et al. (28), Ungor et al. (29) and Andrea et al. (30).

The result of this study showed non significant difference between all levels (apical, middle and cervical) within each obturation system and this result agreed with Marilia et al. (7), Matthew et al. (28) and Gustavo De-Deus et al. (31) except the group II (single cone obturation technique) which showed significant difference between the cervical and apical level, the bond strength in cervical area appeared to be higher in cervical level than apical level, this result might be attributed to differences in sealer thickness between the cervical and apical level when ProTaper obturation technique is used, the cervical level showed higher sealer film thickness than apical level.

Within the limitation of the present study the shear bond strength of AH26 sealer was higher than RealSeal SE sealer. The shear bond strength was affected by the obturation technique and the bond strength were not or little affected by the tooth levels.

REFERENCES


