

Evaluation of the push-out bond strength of root canal obturation materials filled by four different obturation techniques

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ABSTRACT

Background: The aim of this study was to comparatively evaluate the push out bond strength (PBS) of root canal fillings using four different obturation techniques (single cone (SC), cold lateral compaction (CLC), continuous wave (CW), and carrier based gutta percha (CBG)).

Materials and Methods: Forty mandibular premolar decoronated and instrumented with rotary ProTaper to F3 then teeth were divided randomly into 4 groups of 10 teeth for each as follow: group (I) single- cone obturation with matched-taper gutta-percha, group (II) cold lateral compaction technique, group (III) continuous wave of obturation technique, and group(IV) carrier based gutta-percha technique. Zinc oxide eugenol (ZOE) sealer was used as a root canal sealer for the four groups. After obturation of the root canals, all the roots were sectioned horizontally at three levels in the apical, middle, and cervical thirds of each group. PBS test was performed using digital universal testing machine. Mode of failures was evaluated using digital stereomicroscope (40 X). Collected data were analyzed statistically using one way ANOVA and Tukey test.

Results: PBS of CW and CBG significantly higher than SC and CLC, but significantly there were no differences between CW and CBG, and between SC and CLC.

Conclusion: Under the condition of this study it can be concluded that thermoplasticized techniques obtain superior PBS of the filling materials in comparisons with cold gutta percha obturation techniques.

Key words: obturation techniques push-out, ProTaper, root canal. (J Bagh Coll Dentistry 2014; 26(2): 37-43).

INTRODUCTION

Root canal treatment is achieved by chemo-mechanical debridement of the root canal system followed by obturation. Nearly 60% of all endodontic failures have been attributed to incomplete obturation of the root canal system. The obturating material acts as a barrier which prevents the ingress of oral fluids and microorganisms resulting in reinfection of the root canal system through micro leakage ⁽¹⁾.

Successful obturation requires the use of materials and techniques that are capable of densely filling the root canal space three-dimensionally to provide a fluid tight seal to prevent microorganisms from re-entering the root canal system and to entomb any microorganisms that may remain within the tooth from nutrients in the tissue fluids ⁽²⁾.

Different obturation techniques have been introduced ranging from solid core filling of gutta-perch to softening techniques with either solvents or heat aiming to achieve a three dimensional obliteration of the root canal system ⁽³⁾. Gutta-percha has been the material of choice since the middle 1800s, and it remains the most popular material for obturation due to its biologic, chemical, and physical properties ⁽⁴⁾.

It is the material of choice to be used with many obturation techniques, including single cone, lateral condensation, warm lateral condensation, warm vertical condensation, and continuous wave techniques ⁽⁵⁾. Recently a technique, which uses a central carrier, pre-coated with thermoplasticised gutta-percha, seems to achieve an obturation that is as well adapted to the root canal system ⁽⁶⁾.

To evaluate the adherence force (adhesion) of the filling to the root canal walls, the strength of the material-dentine interfacial bond should be measured. The push-out bond strength seems to provide the most similar conditions as those observed in clinical conditions, as it measures the material-dentine interfacial bond strength along the entire length of the root canal. It also provides repetitive results, allows for testing of materials with low bond strength with dentine and the samples for testing are easy to align. It is also less sensitive to differences in sample sizes and differentiated stress distribution during load application ⁽⁷⁻⁹⁾.

The aim of this current study was to comparatively evaluate PBS of root canal fillings using four different obturation techniques (single cone (SC), cold lateral compaction (CLC), continuous wave (CW), and carrier based gutta perch (CBG)) at materials-dentin interface.

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MATERIALS AND METHODS

Sample Preparation

Forty human mandibular premolars extracted for orthodontic purpose were collected and stored in distilled water at 37°C. The crowns of the teeth were cut at the level of the cemento-enamel junction to standardize root segments of 15 mm length, by using a diamond sectioning disc that was mounted to a straight handpiece with copious water irrigation. Then K-file size 10 was introduced into the root canal to the full working length until it could be seen at the apical foramen under digital stereomicroscope at (X 20) magnification (Motic, Taiwan). Then 1 mm was subtracted from this length to determine the working length. Then the teeth were planted in a blocks of silicone impression material of 2 cm length, 2 cm width and 2.5 cm height in order to provide more control and standardization of instrumentation and obturation technique. All root canals were instrumented with ProTaper (NiTi) rotary instrument to size F3 using contra-angle rotary handpiece (Endo-Mate DT, NSK NAKANISHI, INC., JAPAN). The speed of rotation was maintained at 250 rpm and torques 3 Nm. Sodium hypochlorite (2% NaOCl, 2 ml) was used for irrigation between each file size. After completion of canal preparation, the canals were rinsed with 5 ml 15% ethylenediamine tetra-acetic acid (EDTA). A final rinse of 5 ml distilled water was used to remove any remnant of the irrigating solution. Canals were dried using ProTaper paper points size F3^(9,10).

The samples were divided randomly into 4 groups of ten teeth each, as follows:

Group I: The samples were obturated with single cone obturation technique using matched taper gutta percha for ProTaper (size F3) (SC).

Group II: The samples were obturated with cold lateral compaction technique (CLC).

Group III: The samples were obturated with the continuous wave of obturation technique by using the Diapen Diagon cordless obturation system (CW).

Group IV: The samples were obturated with carrier based gutta-percha technique using the Soft-core ® system (CBG).

Obturaion of the Root Canals:

Group I: A size F3 ProTaper gutta-percha was pre-fitted into the root canal to the full working length and tug-back was tested. Zinc oxide eugenol (ZOE) sealer was applied with size 30 K-file. The cone

was also coated with sealer and introduced into the canal and the excess filling material was removed with a heated spoon excavator⁽⁹⁾.

Group II: A size 30 ISO-standardized gutta-percha cone was pre-fitted into the canal to the full working length and tug-back was tested. ZOE sealer was applied to the root canal walls with size 30 K- file. The master cone was also coated with sealer and inserted to the full working length. Then accessory cones (size 25) were used with a light sealer coating and a finger spreader was applied under vertical loading for 10-60 seconds to deform the material apically and laterally. Compaction and accessory cones insertion continued until the spreader would reach no further than 2-3 mm into the canal⁽¹¹⁾ and finally excess gutta percha was removed with a heated spoon excavator.

Group III: A size F3 ProTaper gutta-percha was pre-fitted into the root canal to the full working length and tug-back action was tested. The gutta-percha cone was then removed and according to the manual instructions of Diapen and Diagon cordless obturation system, Diapen tip was inserted into the root canal to the point (4-7)mm short of the working length, then a rubber stopper was moved and set accordingly. ZOE sealer was also used in this group and was applied into the root canal in the same manner as for the first two groups. After that Dia-pen devise was powered on and set to the medium temperature mode(200°C).The pen tip was placed in the orifice of the canal, and the middle of the gutta-percha cone was cut and condensed to the point (6-9) mm short of the working length for about (1.5-2) seconds only. Then the gutta-percha was again compacted to the point (4-7) mm short of the working length, and then a conventional hand plugger was used for condensation of the remaining gutta-percha and completion of down pack. Then the coronal back filling was started at (200° C).The Dia-Gun's tip was quickly introduced to the canal and thermoplasticised gutta-percha was extruded into the canal and pulled out gently backward until the canal was filled. Then a conventional hand

plugger was used to compact the gutta-percha at the orifice of the canal⁽¹²⁾.

Group IV: A size (30) Soft-core[®] size verifier was pre-fitted into the root canal to the full working length. The soft core[®] DT oven was powered on to start heating of the size 30 Soft-core[®] regular endodontic obturator. ZOE was introduced into the canal with size 30 K- file and the heated obturator was placed slowly to the full working length in a single motion. When the gutta-percha was cooled, the plastic handle with a metal insertion pin of the obturator was removed by twisting the handle leaving the plastic core and the gutta-percha inside the canal⁽¹⁰⁾.

All the samples were sealed coronally with tetric N-ceram composite resin, and then the roots were removed from the blocks and were incubated for 7 days at 37°C in 100% humidity to allow complete setting of the sealer.

Push-out Bond Strength (PBS)

Specimens in all groups were then sectioned perpendicular to their long axis into 3 thirds (coronal, middle, and apical) with 5 mm thickness using a mintom (Struers, Denmark) with constant water cooling. A 1 mm thick section from the cervical part of each third was prepared. Both apical and coronal aspects of each sample were photographed by digital stereomicroscope (X 20) and examined before testing to confirm a circular canal shape and that the sealer filled the entire canal space without voids (Figure (1)). If the canal was not circular in shape or there was any void in

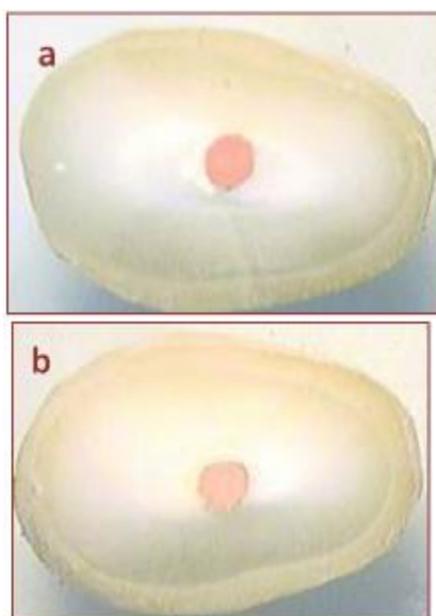


Figure 1: Prepared sample for PBS. (a): Coronal aspect. (b): Apical aspect.

the sealer, it was excluded from the experiment and a replacement tooth prepared in the same way. After that, the samples were aligned over a 2 mm diameter circular hole along the center of an acrylic block (10 mm-thick and 16 mm diameter). The samples were mounted in an apical to coronal direction to avoid any constriction interference due to root canal taper during push out testing. The filling material was loaded with a 1 mm (coronal sections), 0.8 mm (middle section), and 0.5mm (apical section) diameters cylindrical stainless steel plunger which was mounted in the upper part of a digital universal testing machine (TERCO, MT, 3037, Sweden) (Figure 2) and should provide almost complete coverage over the main cone without touching the canal wall. The test was conducted at a cross head speed of 0.5 mm/min. The highest value recorded when failure occur was taken as the PBS. The area under load was calculated by $\frac{1}{2} \times (\text{circumference of coronal aspect} + \text{circumference of apical aspect}) \times \text{thickness}$, in which the circumferences and surface area of apical and coronal canal were measured by Motic Image software connected to digital stereomicroscope. The PBS in Mpa was calculated from force (N) divided by area in mm^2 ⁽¹³⁾.

Mode of Failures

Each sample was viewed at 40X magnification digital stereomicroscope to determine the failure mode and put into one of the following categories: (1) adhesive (at the filling material/dentin interface) (2) Cohesive at filling material; and (3) mixed in both adhesive and cohesive modes.



Figure 2: Digital universal testing machine with the tested sample.

RESULTS

One way analysis of variance and Tukey post Hoc multiple range tests ($P \leq 0.05$) were performed to evaluate the differences on PBS among tested groups. One way analysis of variance demonstrated significant differences on the PBS among tested groups as shown in Table (1).

Tukey test revealed that PBS for groups obturated by CW and CBG at different root segments significantly higher than other tested

groups, but significantly there were no difference between CW and CBG at different root segments except for apical root segment. Result also revealed that PBS of group obturated with SC significantly not different from that obturated by CLC at different segments of the root as shown in Table (2).

The types and the percentage of mode of failures among different tested groups were listed in Table (3) and Figure (3).

Table 1: One way analysis of variance for the differences on push-out bond strength at different root segments using different root canal filling techniques.

Root Segments		Sum of Squares	df	Mean Squares	F	P-value*
Coronal	Between Groups	11.101	3	3.700 0.029	127.334	0.000
	Within Groups	1.046	36			
	Total	12.148	39			
Middle	Between Groups	11.147	3	3.716 0.049	75.444	0.000
	Within Groups	1.773	36			
	Total	12.920	39			
Apical	Between Groups	8.037	3	2.679 0.086	31.035	0.000
	Within Groups	3.108	36			
	Total	11.145	39			

*df=degree of freedom, * $P \leq 0.05$ mean significant different exist.

Table 2: Tukey test for the differences on push-out bond strength among different root canal segments using different root canal filling techniques

Techniques	Root Segments		
	Mean(Mpa) \pm SD		
	Coronal	Middle	Apical
SC	1.78 \pm 0.17 B*	1.63 \pm 0.21 B	1.57 \pm 0.32 C
CLC	1.93 \pm 0.19 B	1.820 \pm 0.23 B	1.74 \pm 0.22 C
CW	2.83 \pm 0.18 A	2.70 \pm 0.22 A	2.33 \pm 0.25 A
CBG	2.97 \pm 0.19 A	2.84 \pm 0.21 A	2.69 \pm 0.27 B

*The different letters vertically mean significant difference exist.

Table 3: Failure mode among tested root segments using different filling techniques

Techniques	Root Segments	Failure Mode %		
		Adhesive	Cohesive	Mixed
SC	Coronal	40	20	40
	Middle	40	20	40
	Apical	50	20	30
CLC	Coronal	40	20	40
	Middle	40	20	40
	Apical	50	20	30
CW	Coronal	80	10	10
	Middle	70	10	20
	Apical	80	10	10
CBG	Coronal	80	10	10
	Middle	80	0	20
	Apical	90	0	10



Figure 3: Different failure modes. (a) Adhesive failure; note clean canal wall. (b) Cohesive failure; within tested material. (c) Mixed failure; note the material residual inside the canal.

DISCUSSION

Ideal adherence of the filling to the root canal dentine is one of the critical factors, for it eliminates leakages in static conditions, which could endanger the tooth by the fluid penetration into the cavity. In dynamic conditions, however, it prevents the material from being translocated by the occlusal load⁽¹⁴⁾. Therefore, adherence of the root canal obturation materials filled by different techniques was evaluated in this present study using push out bond strength at materials-dentine interface.

No single currently available material is capable of providing perfect root canal filling, which is why most techniques use several materials, the most common being a combination of gutta-percha and cement sealer. For best results, the gutta-percha is generally cold or heat condensed to force the cement sealer into the dentinal tubules⁽¹⁵⁾. Thus, this current study was performed to confirm the most suitable technique that had a capacity to forcibly compact the filling materials within root canal space.

In this experimental study, PBS of groups obturated with CW and CBG were significantly higher than those obturated by SC and CLC in all different root segments. The single-cone technique is considered to be less reliable than other methods due to the unfavorable sealer to gutta-percha ratio, which facilitates the microleakage and quality decrease of interfacial integrity of root canal fillings⁽¹⁶⁾. The single-cone technique comprises the use of a single gutta-percha point at environment temperature, with a variable cement thickness depending on the adaptation of the point to the root canal walls⁽¹⁷⁾. This technique has been considered less effective in sealing root canal because of the greater volume of cement that can be expected in the absence of condensation and of the possible anatomic variations of the root canal, which cannot always be filled with larger master cones corresponding to the geometry of the NiTi rotary instruments⁽¹⁸⁾. In the single point technique the

major part of the endodontic space is filled with a cold gutta-percha point, while its irregularities are permeated by the sealer. The amount of sealer in this technique was referred to be greater than in other compaction techniques; so that, porosities in large volumes, contraction, cement dissolution and a lower adaptation of the single cone in the middle and coronal thirds of the canal with irregular shape are the main disadvantages of this technique⁽¹⁹⁾. Therefore, the poor adhesion observed with single-cone ProTaper gutta-percha technique may be related to the fact that the gutta-percha is not compressed, but only inserted into the working length with a large amount of cement⁽²⁰⁾.

Cold lateral condensation is a proven, classic technique. While one of the most widely used techniques, its effectiveness has often been called into question, with a number of studies reporting that lateral condensation results in non-homogenous obturation, poor adaptation of gutta-percha to canal walls, and gaps between the main and accessory cones, voids, spreader tracks, spaces between the gutta-percha points and sealer pools have been reported by various investigators after obturation by lateral condensation⁽²¹⁾. For that reasons it will result in low PBS in the present study.

Thermoplasticised gutta-percha techniques have been developed in an effort to improve the obturation of root canal irregularities, to improve density of the fill, and to reduce voids. CWT which was a single master cone corresponding to the master apical file was used in conjunction with a heat source and pressure from the heated plugger. This technique provides an effective apical seal in addition to obturating lateral canals. The continuous wave of condensation uses a plugger attached to a heat source. The heated plugger is used to vertically compact the gutta-percha in one motion^(22,23). One of the most recent techniques, which use central carriers pre-coated with thermoplasticized gutta-percha, seems to achieve an obturation that is well adapted to the

root canal system. The advantage of carrier-based systems is the potential for plasticized gutta-percha to flow into the canal irregularities⁽²⁴⁾. Because of these before describe reasons thermoplasticized gutta-percha techniques obtained a good PBS than other techniques in the present study. But, the cause of that CW produce higher PBS than CBG in apical third of the root might be related to the fact that friction against the canal walls can lead to loss of gutta-percha from the carrier especially in the apical third of the canals therefore exposing the carrier and creating a gap⁽²⁵⁾.

Marciano *et al.*⁽²⁶⁾ performed a study aiming to compare the gutta-percha/cement percentage and empty spaces through four different techniques. Result showed that more gutta-percha, less cement and empty spaces can be observed in thermoplasticized techniques than in SC and CLC. Another study revealed that a key of clinical success is complete closure of the dentinal wall obturation interface especially in the apical part to achieve the best apical seal. Most endodontic sealers are soluble and shrink slightly; so, it is best to rely as little as possible on sealers and more on gutta percha material⁽¹⁵⁾. Therefore, as thermoplasticized techniques result into thin film thickness of the sealer in comparison to that of cold gutta percha obturation techniques so they obtained a highly significance PBS than cold compaction techniques in the current study.

Several studies also demonstrated that in thermoplasticized techniques, the softening gutta percha had the ability to flow into deep depression, lateral canal, accessory canal, and irregularities that are not filled by sealer cement^(15,23,26,27). Therefore, thermoplasticized techniques facilitate compaction of the filling material into root canal space more preferably than cold gutta percha obturation techniques; and this reason can be consider as most important factor that result into superior PBS of thermoplasticized technique over cold gutta percha obturation techniques in our present study.

The most common mode of failures obtained in this study was adhesive and mixed. Although thermoplasticized techniques can produce better compaction of the filling material in the canal space but it remains their adhesion is effected by the type of sealer used in conjunction with the gutta percha, as ZOE sealer was used in this study and it's well known that ZOE had weak adhesion to the canal wall and gutta perch. So, it will effect in the adhesions properties of the filling materials.

Within the limitation of this study it can be concluded that the filling techniques and material

used will influence the push-out bonding strength of the material-dentin interface.

According to the findings of the present study it can be concluded that the force needed for the displacement of root canal filling obturated by thermoplasticized techniques was significantly higher than that required for the displacement of the filling materials obturated by cold gutta percha obturation techniques.

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