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# Push Out Bond Strength of GuttaFlow 2, Thermafil and Guttacore (An Invitro Study)

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**Abstract**
**Background** Several root canal filling materials and techniques have been developed and studied, aiming to completely fill the root canals, their ramifications, and any anatomical variations, which are frequently observed. The objective is to investigate the push out bond strength of three different obturation materials GuttaFlow 2, Thermafil and GuttaCore at different levels. **Materials and methods** thirty extracted upper molars were collected and the palatal roots were sectioned at the CEJ of the tooth. The platal roots were instrumented with Hyflex CM rotary files to the size of 40/0.06. The instrumented samples were divided into three groups of ten samples each, the first group was obturated with GuttaFlow 2, the second group was obturated with Thermafil and the third group was obturated with GuttaCore obturating materials. After an incubation period of 7 days, each sample were sectioned into three sections of 2 mm thickness (apical, middle, coronal), each slice then introduced to the push out testing using a universal testing machine at a cross head speed of 0.5 mm/min. **Results** it showed Push-out bond strengths were significantly higher when canals were filled with GuttaCore than those filled with Thermafil and GuttaFlow 2. And Thermafil showed a higher significant difference than the GuttaFlow 2. It also showed that the bond strength values decreased from the coronal to the apical direction. **Conclusion** The thermoplasticized gutta-percha appears to achieve higher push out bond strength values than the cold flowable gutta-percha. With GuttaCore showed higher push out bond values than Thermafil.

**Keywords: Guttaflow, Guttacore, Gutta Percha, Thermafil, Root canal**

## Introduction

The goal of endodontic treatment is the three-dimensional filling of the root canal system after its cleaning and shaping. Several root canal filling materials and techniques have been developed and studied, aiming to completely fill the root canals, their ramifications, and any anatomical variations, which are frequently observed (Junior et al, 2015). Carrier-based obturation was first described in 1978 and involved the coating of endodontic files with thermoplasticized GP. The most commonly used carrier-based obturation technique is likely Thermafil. The manufacturer of Thermafil (DENTSPLY Tulsa Dental Specialties) introduced a new carrier-based thermoplasticized gutta percha obturation material in 2010, which they called GuttaCore. The main difference between the Thermafil obturator and the GuttaCore obturator is the material from which the carrier is manufactured: the Thermafil carriers are made from plastics, and the GuttaCore carrier is made from a proprietary cross-linked gutta percha (Schroeder, 2014). The advantage of this technique is the use of a carrier to compact thermoplasticized GP and sealer both laterally and vertically more rapidly than other techniques (Hale et al, 2012). In 2012, Coltène/Whaledent Inc. introduced a cold, flowable, self-curing filling material for root canals that combine gutta-percha and sealer into one injectable system (GuttaFlow 2). The sealer contains gutta-percha in particle form combined with a polydimethylsiloxane- based sealer (www.coltene.com). Adhesion of root canal filling material to dentinal walls is important in both static and dynamic situations. In a static situation, it should eliminate any space that allows the percolation of fluids between the filling and the wall. In a dynamic situation, it is needed to resist dislodgement of the filling during subsequent manipulation; Bond-strength testing has become a popular method for determining the effectiveness of adhesion between endodontic materials and tooth structure (Amara et al, 2012). Currently, microtensile bond strength test methods are commonly used to measure the bond strength of numerous dental materials (Armstrong et al, 2010). Unfortunately, the tensile bond strength test method is not appropriate for use with intracanal filling materials because of the high percentage of premature bond failures and the large variation in test results (Soares et al, 2008). A push-out test modified from the shear punch test has been advocated as a more suitable test for evaluating the bond strengths of intracanal filling materials (Goracci et al, 2004).

## Materials and Methods

Thirty freshly extracted maxillary molars teeth with straight palatal root selected from different health centers for this study according to specific criteria. 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 in cross section, mature, centrally located and patent apical foramen, roots devoid of any resorptions, initial size of #15 hand k-file, and most important the roots should be a 10 mm in length (Naser and Al-Zaka, 2013). Using a diamond disc with straight hand-piece and water coolant, the palatal root of each tooth was sectioned perpendicular to the long axis of the root at the CEJ area to facilitate straight line access for canal instrumentation and filling procedure (Garcia et al, 2014). The pulpal tissue was removed by using barbed broach, then a size 10 k-file was used to ensure apical patency, Also the size 10 k-file was used to determine the exact location of the apical foramen by advancing the file into the canal until it was visualized at the apical foramen by surgical loups 2.5 x magnifications. The correct working length is established by subtracting 1 mm. from this measurement (Naser and Al-Zaka, 2013). The roots held with a Silicon rubber base (heavy-body), to facilitate handling of the roots during instrumentation and obturation technique (Al- Ani and Al-Huwaizi, 2011). Before starting the instrumentation a size 15 k-file was used to obtain a glide path, the file was introduced to the full working length then a small stroke was used, to confirm that a reproducible glide path is present; the size 15 file was taken to full working length. The file was then withdrawn 1 mm and should be able to slide back to working length by using light finger pressure. Thereafter, the file is withdrawn 2 mm and should be able to slide back to working length, using the same protocol. When the file can be withdrawn 4 mm to 5 mm and slide back to working length, a reproducible glide path was confirmed (Van der Vyver and Scianamblo, 2014). The canals was prepared with crown down technique using Hyflex system (Coltene/Whaledent, Switzerland) to 40/.06, TC II (NSK, Japan) Endo-Motor was used to operate the files and the program was set at 300 rpm speed of rotation and 3Ncm torque. The roots were randomly divided into three groups, each group of 10 roots. The first group was obturated with GuttaFlow 2 (Coltene/Whaledent, Switzerland) the second group was obturated with Thermafil (Tulsa Dental Dentsply, Tulsa, OK, USA) and the last group was obturated with GuttaCore (Tulsa Dental Dentsply, Tulsa, OK, USA). In the first group, GuttaFlow 2 was dispensed through its automix syringe tip into a paper pad, then a size 40 k-file was used to carry the material into the canal by using a counter clockwise motion, afterwards a size 40/.06 gutta percha is coated with GuttaFlow 2 and inserted to the full working length of the canal. (www.coltenewhaledent.com). In the second group, the canals of the roots was checked with a size verifier corresponding to the last file size of instrumentation which is 40/.06, Check passivity by taking the size verifier to working length and rotating in the canal 360 Degrees which was done prior to drying the canal (Stropko, 2013). Endofill sealer (Produits Dentaires SA, Switzerland) was mixed according to the manufacturer instructions, on a dry clean glass slab with a spatula. The mixture had a homogenous creamy consistency, then a paper point size 40/.06 is coated with the sealer and used to brush the canal's coronal third then a second paper point was used to remove excess of the sealer material. (Edds A., 2013) Thermafil obturator size 40/.06 (Tulsa Dental Dentsply, Tulsa, OK, USA ) was selected and placed in the obturator holder of Thermaprep plus oven then the holder was pushed down and the size of the obturator was selected in the oven and the start button was pressed in order to start thermoplasticizing the obturator, after several seconds the obturator was signaling beeping sound which indicates that the obturator was ready to be used, the obturator was removed from the oven and placed within the canals with a pressing downward motion to the full working length of the canal. Excess was removed with round bur operating at high speed at the orifice level and a round bur at low speed was used to provide a 1mm room for HV resin modified glass ionomer (Vemisetty et al, 2014). In the third group, the size verifier was used in the same manner as in the second group while the same protocol of sealer mixing and placement in the Thermafil group was carried out in the third group. GuttaCore obturator size 40/.06 (Tulsa Dental Dentsply, Tulsa, OK, USA ) was selected and placed in the obturator holder of Thermaprep 2 oven (Tulsa Dental Dentsply, Tulsa, OK, USA) then the size of the obturator was selected in the oven and the holder was pushed down in order to start thermoplasticzing the obturator, after several seconds the obturator was beeping which indicated that the obturator was ready to be used, the obturator was removed from the oven and placed within the canal with a pressing downward motion to the full working length of the canal. The handle of the obturator and excess material extruded from the orifice was removed by bending the obturator handle right and left (Edds, 2013), a round bur operated at low speed was used to provide a 1mm room for HV resin modified glass ionomer. The roots then radiographed to ensure adequate obturation then each group was wrapped in moistened gauze, which afterwards stored in an incubator for 7 days at 100% humidity and 37

co (Ertas et al, 2014). After the storage period the samples were embedded in clear orthodontic resin (Al-Kahtani et al, 2013). Afterwards the acrylic molds were marked with a waterproof pen, the markings were used as a guide in roots sectioning process, four cuts were made at (1.5), (4), (6.5) and (9) mm to obtain three sections apical 2, middle 4.5 and coronal 7 mm from the anatomic apex. Using diamond cut off saw the cut were made under water coolant to minimize smearing (Ehsani et al, 2013) although the thickness of the diamond disk was 0.35 mm it actually made a 0.5mm cut. Each section was marked at its apical side and numbered on the coronal side. At this moment each group consist of 30 specimens with a total of 90 specimens included in the study. Push out test was performed by applying a compressive load to the apical aspect of each slice via a cylindrical plunger mounted on a Laryee universal testing machine managed by computer software (UTM software), Push-out force was applied on the obturation material in an apical-coronal direction by a Laryee universal testing machine. Each slice was oriented to ensure the apical surface faced the plunger. The plunger was centralized so as to avoid contact with dentine. Micro push-out testing was performed at a crosshead speed of 0.5 mm/min until bond failure occurred. (Aktemur et al, 2013). Push-out strength data were determined in MPa by dividing the load in Newton by the bonded surface area (SL) in mm2. SL was calculated using formula: $SL = (R1+R2)\sqrt{(R1 + R2)^2+h^2}$ where, (R1) is the apical carrier radius (base), (R2) is the coronal carrier radius (top), and h is the height of the slice. (Giachetti et al, 2012).
Collected data were analyzed using SPSS (statistical package of social science) software. In this study the following statistics were used:

A- Descriptive statistics: including mean, standard deviation, standard error, minimum and maximum and graphical presentation by bar charts.
B-Inferential statistics which include:
1- One way analysis of variance test (ANOVA): to test any statistically significant difference among the push out bond strength of all groups at all levels, and the difference among the levels in each group.
2- Least significant difference test (LSD): to test any statistically significant difference between groups at different levels.

**Results**
The findings of push out strength (MPa) test are summarized in Table 1, GuttaCore group has the highest mean values at all levels in comparison with other groups followed by Thermafil group, while GuttaFlow 2 group has the lowest mean value at all levels. 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).The least significant difference test (LSD) was performed for multiple comparisons between groups (Table 3), it shows a highly significant difference between group 3 and group 1 and 2 at all levels, and significant difference between group 2 and 3 at the apical level and non-significant at the middle and coronal level.

**Table 1: The push out bond strength values.**

| Groups | Regions | N | Mean | S.D. | S.E. | Min. | Max. |
|---|---|---|---|---|---|---|---|
| Group 1 (GuttaFlow 2) | Apical | 10 | 0.88 | 0.19 | 0.06 | 0.6 | 1.19 |
| | Middle | 10 | 1.17 | 0.31 | 0.10 | 0.58 | 1.75 |
| | Coronal | 10 | 1.29 | 0.29 | 0.09 | 0.89 | 1.94 |
| Group 2 (Thermafil) | Apical | 10 | 1.10 | 0.17 | 0.05 | 0.87 | 1.43 |
| | Middle | 10 | 1.38 | 0.28 | 0.09 | 0.99 | 1.75 |
| | Coronal | 10 | 1.46 | 0.30 | 0.09 | 1.07 | 1.94 |
| Group 3 (GuttaCore) | Apical | 10 | 1.78 | 0.20 | 0.06 | 1.53 | 2.16 |
| | Middle | 10 | 1.87 | 0.23 | 0.07 | 1.58 | 2.33 |
| | Coronal | 10 | 2.00 | 0.22 | 0.07 | 1.75 | 2.46 |

**Table 2: Comparison the push out bond strength among the groups at each level.**

| Regions | ANOVA | Sum of Squares | d.f. | Mean Square | F-test | *p*-value |
|---|---|---|---|---|---|---|
| Apical | Between Groups | 4.434 | 2 | 2.217 | 64.689 | 0.000 (HS) |
| | Within Groups | 0.925 | 27 | 0.034 | | |
| | Total | 5.360 | 29 | | | |
| Middle | Between Groups | 2.547 | 2 | 1.273 | 16.899 | 0.000 (HS) |
| | Within Groups | 2.034 | 27 | 0.075 | | |
| | Total | 4.581 | 29 | | | |
| Coronal | Between Groups | 2.717 | 2 | 1.359 | 18.483 | 0.000 (HS) |
| | Within Groups | 1.985 | 27 | 0.074 | | |
| | Total | 4.702 | 29 | | | |

**Analysis of failure mode:**

The analysis for failure modes for push out bond strength shows that the predominant mode of failure in GuttaCore was adhesive S/D, and the predominant mode of failure with Thermafil was mixed (cohesive and adhesive), finally the GuttaFlow 2 showed a predominant adhesive failure S/G.

**Table 3: LSD test for mean push out bond strength between the three groups at each level.**

| Regions | Groups | | Mean Difference | S.E. | *p*-value |
|---|---|---|---|---|---|
| Apical | Group 3 (GC) | Group 1 (GF 2) | 0.90 | 0.083 | 0.000 (HS) |
| | | Group 2 (TH) | 0.68 | 0.083 | 0.000 (HS) |
| | Group 1 (GF 2) | Group 2 (TH) | -0.22 | 0.083 | 0.013 (S) |
| Middle | Group 3 (GC) | Group 1 (GF 2) | 0.70 | 0.123 | 0.000 (HS) |
| | | Group 2 (TH) | 0.49 | 0.123 | 0.000 (HS) |
| | Group 1 (GF 2) | Group 2 (TH) | -0.21 | 0.123 | 0.103 (NS) |
| Coronal | Group 3 (GC) | Group 1 (GF 2) | 0.71 | 0.121 | 0.000 (HS) |
| | | Group 2 (TH) | 0.54 | 0.121 | 0.000 (HS) |
| | Group 1 (GF 2) | Group 2 (TH) | -0.17 | 0.121 | 0.182 (NS) |

## Discussion

An effective method for determining the strength of adhesion between endodontic materials and root structure is push-out bond strength testing (Ehsani et al, 2013). It allows assessment of regional differences in bond strength along the root canal and is less prone to premature specimen failure (Aktemur et al, 2013). In this study each Sample were sectioned into three of 2-mm-thick slices, the three sections represent the apical, middle, and the coronal sections to calculate the push out bond strength on different levels within each root. A 2 mm sections were used in order to prevent premature debonding (Barbizam et al, 2011). Since punch diameter may affect the bond strength (Sirisha et al, 2014), three different punch sizes were used to provide complete coverage of the core material in the three sections of each sample. Push-out force was applied on the obturation material in an apical-coronal direction, the stainless steel cylindrical plunger mounted on a Laryee universal testing machine. Each slice was oriented to ensure the apical surface faced the plunger. The plunger was centralized so as to avoid contact with dentine. The crosshead speed was 0.5 mm/min, crosshead speeds of 0.50 mm/min and 0.75 mm/min should be preferred due to their better cohesive versus adhesive results (Sirisha et al, 2014). In this study carrier based obturation materials (Thermfil and GuttaCore) shows a highly significant difference with the cold flowable obturation material (GuttaFlow). This could be explained that carrier based obturation technique allowed thermoplastic gutta-percha to flow better into lateral canals, had fewer voids, and replicated the root surface better. More recent studies reported that canals obturated with core- carrier techniques had the highest gutta-percha content within the filled canal space (Li et al, 2014). In addition studies have shown that canal irregularities were filled with both the sealer and gutta-percha with the carrier based obturation techniques demonstrating greater GP adaptation to the intricacies of the root canal system (Bhandi, 2013). Also the carrier based obturation technique possesses a very good quality of compression and fluency that allows the penetration of gutta-percha with the formation of numerous of gutta-percha tags inside the dentinal tubules and good seal of the endodontic space (Migliau et al, 2014). Moreover, SEM findings at the 4-mm sectioned canal level, that speci-mens obturated with GuttaCore carriers were completely gap-free and void-free (Li et al, 2014), this results is in agreement with (Hwang et al, 2015). A high significant difference was found between the GuttaCore and the Thermafil group, possibly due to the fact that GuttaCore made completely from gutta-percha in two different forms thereby GuttaCore carrier appeared to offer better micromechanical retention to the surrounding gutta-percha than the Thermafil carrier (Al-Hashimi et al, 2014) which could reduce the possibility of failure within the core material. A noticeable drawback in the Thermafil obturation technique represented with the stripping of gutta-percha when the carrier placed in the canal Stripping may be due to both the characteristics of the alpha-phase gutta-percha and the constraints on the inflexible carrier (Juhlin et al, 1993).These challenges were eliminated in the GuttaCore through its cross-linked, thermoset elastomer of gutta percha (Gutmann, 2012). This result was in agreement with (Al-Hashimi et al, 2014). When comparing the GuttaFlow 2 with the GuttaCore and the Thermafil it shows a significant difference, this might be attributed to the minute voids, within the core of the GuttaFlow, may be a result of the manufactur-ing process (Anantula & Ganta, 2011). Also it could be related to the smaller contact angles that the GuttaFlow 2 and other silicone – based sealers have. Such a finding implies decreased wettability of GuttaFlow compared with conventional sealers (Na-kashima and Terata, 2005; Saraf-Dadpe and Kamra, 2012; Tummala et al, 2012; Aba-da et al, 2015). It was reported that the matrix of this thixotropic sealer might flow under the pressure applied by the inserted gutta-percha cones, leaving only the gut-ta-percha particles between the cones and the dentin wall (Kandaswamy et al, 2009; Jain et al, 2014). Moreover the use of a single cone technique may result that the vol-ume of sealer is high relative to the volume of the cone, and this ratio promotes void formation and reduces the quality of the seal (Bouillaguet et al, 2008). This result agrees with (Punia et al, 2011) and (Bhandi, 2013). The results of the current study indicate that in all the three groups, the bond strength is decreasing from the coro-nal to the apical regions which may be due to decreased density and the diameter of dentin tubules towards the apical (Ebrahimi et al, 2014). Also the lack of access of the apical region to the irrigation solutions and the consequent incomplete removal of the smear layer may decrease the penetration of the sealer into dentinal tubules and may thereby affect adhesion in the apical region (Hegde and Arora, 2015).

**Conclusion**

Under the circumstances of this study, GuttaCore showed the highest push out bond strength mean values followed by Thermafil. Gutta flow 2 showed a minimum bond strength mean value. The bond strength mean values decreased from the coronal part to the apical part in all the samples. Analysis for failure modes showed a predominant S/G failure mode with GuttaFlow 2, while the predominant mode of failures with Ther-mafil was mixed and S/D with GuttaCore.

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