Evaluation of Obturation Extrusion of Guttacore with Varying Insertion Rates

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Evaluation of Obturation Extrusion of Guttacore with Varying Insertion Rates

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Master of Dental Science Thesis

Evaluation of Obturation Extrusion of Guttacore with Varying Insertion Rates

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John T. Barrett, D.M.D.
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Abstract:

Introduction: The aim of this study is to determine whether the insertion rate of the Dentsply/Sirona Guttacore obturation product with Dentsply AH Plus sealer has an effect on 1. the extrusion amount of the obturating materials and 2. the extrusion probability of the obturating materials out of root canal apex.

Methods: Thirty root canal simulating plastic blocks were prepared with Waveone Gold nickel titanium rotary files to a size “primary” file. The prepared blocks were divided into three groups: group 1 was obturated using GuttaCore size primary obturator (analogous to the reciprocating file size) at a rate of 1 seconds; group 2 was obturated at a rate of 7 seconds; and group 3 was obturated at a rate of 16 seconds. The results were statistically analyzed by evaluating the amount and the probability of the obturating material extrusion.

Results: The average amount of the extruded obturation material was .44 mg (Group 1), .22 mg (Group 2) and .17 mg (Group 3). The probability of the obturation material extrusion was 60% (group 1), 30% (Group 2) and 22% (Group 3). There are no statistical differences for the amount of extruded obturation materials among the three groups (P>0.05). There are also no statistical differences for the probability of the obturation material extrusion among the three groups (P>0.05).

Conclusion: This study suggests that the insertion rates of the Guttacore obturator have no effect on the extrusion of the obturation materials.
I. Introduction:

Need for root canal

Multiple factors can result in a patient needing a root canal treatment. Some examples include: trauma, repeated dental procedures on a tooth, pulpal inflammation due to exposure to chemicals (tooth bleaching), the need for post placement for prosthetic considerations as well as pulpal inflammation and/or infection from bacteria in caries. When looking at the last-mentioned example of bacteria, Kakehashi et al 1965 showed us in an animal model with rats that exposed pulps in the absence of bacteria could heal, specifically showing dentin bridging as early as 2 weeks and reaching completion 1-2 weeks later. These teeth showed no presence of abscess, granuloma or necrotic pulp. The opposite was true in an exposed pulp with bacteria present. Necrosis, granuloma’s and abscesses were found in all of these samples after 8 days. This showed that whether or not bacteria were present was the “major determinant” in the progression of pulpal disease or healing. In a study performed by Hahn et al 2007 the author discusses when looking at bacteria in a carious lesion, the gram-positive bacteria contained in tooth decay can irritate or inflame the pulp with a variety of virulence factors, one such factor being lipoteichoic acid (LTA). LTA as well as LPS can both diffuse pulpally through the dentin, binding to CD14, activating Toll-like receptors resulting in the production of proinflammatory cytokines (IL-1, TN-alpha, etc.). It has also been shown that some bacterial strains such as Streptococcus mutans have the capacity to induce apoptosis in pulpal cells due to secretion of LTA (Wang et al 2001). The goal of the root canal is to (as thoroughly as possible) eliminate the presence of
bacteria through chemo-mechanical cleaning and preparation of the canal followed by obturation or filling and sealing off the pulpal space to avoid future bacterial contamination/colonization.

**Root filling materials**

In Ingle’s sixth edition *Endodontics* book the requirements for the “ideal root canal filling material” are as follows:

1. Easy to introduce into canal
2. Provides both an apical and lateral seal
3. Zero shrinkage after placement
4. “Impervious to moisture”
5. Discourage bacterial colonization
6. Radiopaque
7. Doesn’t result in staining of tooth
8. No irritation of periradicular tissue
9. Easily sterilized or already sterile
10. Easy to remove from canal

Many materials have been used to fill the prepared canal space after preparation has taken place however many fall short of satisfying each of the aforementioned requirements. The focus moving forward will be specific to gutta percha based obturation materials.

**Gutta Percha**
Sap off a specific family of tropical trees is where we obtain our precious root canal filling material gutta percha (GP). The actual name “gutta-percha” is derived from the Malay dialect with its roots being in the words ‘Getah’ and ‘Pertia’, translated to ‘gum’ and the latter being the Malay title for the tree GP comes from (Gandagnini-Jahhegnin et al 1979). Two methods have been employed for obtaining the GP. The first method is the collection of leaves from the trees which are then crushed and processed. The second method is stripping away bark from the trees and collecting dried sap off the tree in cups. This collected latex is then coagulated by boiling the sap with some water to prevent drying. The GP is folded and worked under running water which is then laid into sheets being sure to remove all air for even drying. The final step is to place the GP into a “masticator”, a large industrial machine that takes the GP and manipulates the material through rotation, heating, shearing and softening until it is ready for use. GP is easily the most used obturation material for endodontics with some reporting it’s prevalence in as high as 90% of all root canals (Borthakur 2002). In this same study by Borthakur it is explained that to simply make a stick out of GP is not a difficult process but endodontics requires precision for GP cones. To achieve said precision it requires specialized equipment mixing the GP with other materials which are then shaped through powerful vacuum suction into molds or rolled by hand.

GP is what’s referred to as a high molecular weight polymer. GP and rubber both fall into this category and consist of the same basic molecular unit, isoprene. (see figure 1 below).
The difference between rubber and GP lies in the “cis” and “trans” forms of the polymer “polyisoprene”. Rubber consists of this cis form meaning the CH2 groups are found on the same side of the double bonds throughout the polymer causing kinks and issues with alignment thus giving rubber its elastic qualities. Juxtapose the trans configuration of GP which has the CH2 groups alternating sides ultimately resulting in more of a linear molecular relationship of the polymers (see figure 2). This results in GP’s differing physical properties of increased hardness and lower modulus of elasticity as opposed to the more elastic and softer rubber compound (Goodman et al 1974).
Figure 2 (cis and trans configurations of polyisoprene)

C.W. Bunn et al 1942 points out that GP exists in two distinct crystalline phases known as alpha and beta phases (figure 3). GP in its natural state (that is, as it is collected from the tree) is considered to be in the alpha phase. When heated to a temperature above 65 degrees Celsius its state becomes amorphous and pending on the speed at which it is cooled can remain in the alpha phase or transform into the beta phase. If cooled slowly (i.e. .5 degrees celsius/hr) recrystallization to alpha occurs but if cooled more rapidly the GP will assume the beta form. The melting temperature of the beta
Figure 3: Molecular image of two phases of gutta percha, alpha(top) and beta(bottom).

form is lower than the alpha form at 56 degrees Celsius. The beta form is ultimately the less thermally stable of the two forms at all temperatures due to its lower crystallization point and it being the first of the two phases to crystallize on cooling at normal or rapid rates. There is some disagreement between studies on the transformation and melting
points of the two phases of GP. Purity and if the GP has been heated and cooled prior to testing has shown to affect the melting points this is discussed by Mandelkern, Quinn and Roberts in 1955, who reported 64 and 74 to be the transformation temperatures for B and alpha phases of GP. Flanagan and Rijke in 1972 showed the values of 79.5 and 82.4 degrees Celsius for beta and alpha phased GP respectively. It is important to recognize however that the base material used in their study had a much higher molecular weight than naturally occurring GP and likely influenced the reported results. GP has been used in both cold and warm obturation techniques but we should note that irreversible changes in density and volume can occur by exposing GP to varying temperatures (Dean 1932).

**Composition and History of Gutta Percha**

When looking at the composition of GP cones we see that 60-70% of each cone is composed of zinc oxide, with 10% being unidentified and only the remaining 20% actually being constituted by GP itself (Spangberg 1999). Historically GP made its introduction in the 17th century to Europe as “mazer wood”. In 1845 the GP Company of the United Kingdom was founded and began manufacturing anything from musical equipment to garments and even boats out of GP. In 1847 it was introduced as a temporary filling material and in the late 1950’s standardized GP was made available for endodontic purposes. In 1967 Dr Schilder revolutionized the use of GP in endodontic tx from simply being condensed in a cold state with sealer in the canal (cold lateral condensation) to a thermoplastized state by applying heat through metal carriers to sear and compact the GP. This was known as warm vertical compaction (WVC). Since then various other changes/advancements have been made such as injectable
thermoplastized GP, carrier-based GP, etc. (Vishwanath 2019). GP has good
dimensional stability, it is radiopaque and biocompatible. GP has stood the test of time
and although many other materials have tried to replace it, as of now it still remains the
gold standard for root canal obturation. Nevertheless, as was previously touched on
briefly, there are a myriad of ways one can obturate with GP.

Obturation

When obturating a root canal space the goal is to prevent bacterial contamination
and future apical or coronal leakage through sealing the apex from remaining irritants in
the canal as well as the canal from tissue fluids from the apex (Pathways of the Pulp
2005). As mentioned by Ingle 1994, one of the primary reasons root canals fail is due to
inadequate removal of etiological factors, however incomplete obturation is shown to be
responsible for 59% of failures due to “apical percolation” (Guigand et al 2005). Some
have gone so far as to say that until a material exists that is proven to have molecular
bonding to the surface of the canal it will be impossible to prevent micro leakage.

Currently there isn’t a single material that can perfectly and completely seal the
entirety of the pulp space and as such techniques with multiple materials are used.
Generally, GP is either cold or heat condensed in the canal space with a sealer used to
fill the remaining spaces between the GP and canal walls (Al Rafei 1975). So how do
we know when the canal is ready for obturation? Ingle 6e states that obturation should
commence once the canal is of “ideal size”. While there is no clear consensus on what
that size is Ingle does however mention that it is agreed that the canal should not have
fluid left in it but be dried prior to obturation. Let’s begin our discussion regarding obturation techniques with what many regard as the “gold standard” (Ansari et al 2012).

**Cold Lateral Condensation**

Of the various obturation methods that can be used, cold lateral condensation (CLC) is the most commonly taught and employed technique globally (Wong et al 2017) and some even look at it as the benchmark against which other obturation techniques should be compared (Weine 2004). After cleaning and shaping is finished a master GP cone is placed and fitted apically. A spreader is placed in a canal to a depth of 1-2mm short of working length however some have shown placement to depths as close to working length as .2mm in canals prepared with an .06 taper (Bal et al 2001). When the filling is complete there are many GP cones fit tightly in the canal that have been compacted laterally with spreaders which are now joined with a sealer/cement substance and frictional force. Advantages of this strategy include length control of the filling material as well as low cost. However, if one is to inspect the root filling it is not a homogenous volume of GP as there are spaces between the round cones and walls of the canal and one is often depending on the sealer/cement to occupy these spaces (Peng et al 2007). Clinton et al 2001 found that when CLC technique was compared with thermoplasticized GP (i.e. Thermafil Plus-Tulsa Dental Products, Tulsa, OK) a statistically significant difference was found regarding the areas of voids, ability to flow into lateral spaces and capacity to replicate the internal root surface, with the thermoplasticized product having less voids, better adaptation to lateral spaces and ability to replicate internal anatomy. Also observed was better length control and less
apical extrusion of filling material with CLC vs the carrier based heated GP. In 2006 Collins conducted a study in a split tooth model, comparing CLC with warm lateral and warm vertical obturation techniques on ability to replicate root canal irregularities. The results showed both warm techniques were superior to CLC. Farzaneh 2004 showed a difference in 4-6 year outcome in warm vertical versus lateral compaction with results showing 90% healing in the former and 80% in the latter. CLC is a viable option for endodontic treatment and can provide a patient with a good outcome, however as warm vertical was introduced it has increasingly become more popular due to it’s ability to better adapt to the pulpal anatomy (Ingle 6e).

**Warm Vertical Condensation**

Properly sealing the prepared canal space in 3 dimensions is one of the goals of obturation. As previously mentioned, although correctly performed CLC can result in endodontic success, it does not contain a homogeneous mass of GP and if sealer is not present in every space not occupied by GP then voids will be present. Some have also noted with regards to CLC that the coronal and middle thirds are the most densely filled with the apical portion not finding great benefit in seal from the accessory GP cones (Schilder 1967). Berg 1959 gave a different approach to custom fit the GP cones to the previously shaped/reamed canals. Slight warming of a plugger/condensor that was then used to condense previously inserted GP into the canals of molar teeth allowed for adaptation of GP to the shape of the canal. In 1967 a dentist from Boston University by the name of Herbert Schilder took the idea of heating the GP to a whole new level and thus the Vertical Condensation of Warm Gutta-Percha Technique (WVC) for endodontic
obturation was born. This “wavelike” condensation employed minimal sealer and the use of heat carriers to soften GP in a coronal to apical direction followed by pluggers (not heated) to condense the softened GP allowing it and sealer (through hydrostatic forces) to flow into lateral canals/pulpal spaces. A little GP was removed with each step or wave of this process until the apical third was reached. The empty canal space was then backfilled by inserting small GP pellets into the canal followed by heat application and condensation create a continuous to fit/filled canal space. This step was repeated with more pellets until one reached the desired depth (depending on if post space was needed or simply filling to canal orifice). Dr Schilder illustrates his reasoning behind the creation of a new obturation technique with this line: “What is required is a deeper appreciation of the importance of filling canals laterally and in depth as well as vertically”. When looking at the literature there are various comparisons that have been made with the CLC and WVC techniques. In 1981 a study by Wong et al looked at a comparison between obturation methods of WVC, CLC and chlorapercha all without the use of sealer and their ability to conform/adapt to the canal space anatomy. The results showed the best results for the WVC technique. Torabinejad et al 1978 showed in a comparison of CLC, WVC and a thermoplasticized injectable GP technique that with regards to CLC the root filling material was well adapted apically and coronally but voids were often observed especially in the mid root section of the samples. WVC showed close adaptation in both apical and middle thirds.

As technology advances and adapts to the demands and challenges of clinical procedures, the clinical techniques can also progress and become more efficient. In the early 1980’s Dr Carl J. Masreleiz invented an electronic heat carrier, instantly increasing
clinical efficiency on the obturation step of root canals if one had previously employed WVC. Rather than heating your carriers red hot over a flame you now had a device that heated them instantly. Previously in 1977, Yee et al introduced a device that allowed thermoplasticized GP to be introduced into the canal. These two innovations used together decreased obturation time and were instrumental in the creation of a new obturation technique, the continuous wave technique (CW). In 1989 an endodontist by the name of Stephen Buchanan developed a more efficient technique to obturate the canal with warmed GP using the latest instruments and technology. After a master GP cone was placed in the dried, cleaned and shaped canal with sealer, an electric heated plugger was introduced into the canal to a depth just short of binding or engaging against the canal walls. The theory was that instead of Schilder’s method of multiple waves of heating and condensing the GP until one reached the desired apical depth, this could be accomplished in one “continuous wave”. The claim was that it was superior at filling lateral complexities as the lateral pressure was higher in the CW approach. After burn down of GP with the heated plugger, CW hand pluggers made out of dead soft steel that can be curved are used for further condensation. A handheld GP gun dispensing thermoplasticized GP is then employed for GP backfill of desired depth at which point the obturation portion of the RCT is complete. CW has become one of if not the most common obturation method used among endodontic specialists.

**Carrier based obturation**

**Thermafil**
Looking at the previously discussed obturation methods of CLC, WVC and CW we see that in all cases the operator is relying on force of condensation to move filling material into the lateral canals, fins and irregularities of the root canal. This requires substantial skill to make sure the master cone is fit well with an apical stop so the apex is sealed but no material is pushing outside of the tooth. In 1978, Johnson introduced a new method known as Thermafil (TF) for placing GP in an effort to reduce difficulty and technique sensitivity when placing the master cone (used in all condensation techniques) by melting alpha phase GP around a hand file and using the file as a delivering system to get the GP to WL (see figure 4).

Image 1

Image 2

Figure 4: Image 1 shows a #30 hand file with a coronal notch (this will break the file when twisted after insertion into canal) and coronal flutes ground smooth. Image 2 shows warmed alpha phase GP placed onto hand file carrier prior to insertion into canal. Johnson 1978.

Since then various TF products have been released with carriers evolving from stainless steel, to titanium alloy, followed by plastic and now cross linked gutta percha. We have
since come to know that carrier based obturation is not without it’s complications. Barkins et al showed that in curved canals the thermoplasticized gutta percha would strip off the Thermafil carriers, likely explaining one of the reasons these samples showed higher leakage when compared with samples obturated with CLC. A study by Juhlin in 1993 evaluated Thermafil carriers in curved plastic blocks. The study showed zero samples had carriers completely encased in gutta percha at the apex and observing only the carrier itself was not uncommon. There are however some pro’s when examining the TF approach.

A benefit when considering core carrier options for obturation is strain on the radicular tissue. The final product of a root canal is evaluated with a post operative periapical radiograph is taken to verify a clinically acceptable result. What can’t be seen on the radiograph however is the force that has been exerted on the tooth structure from condensing the filling and the possible cracks or fractures that said force has propagated. Saw et al 1995 compared different obturation techniques and ultimately found that the TF technique exerted less strain on the tooth when compared with placement of thermoplasticized GP or lateral compaction. Reducing technique sensitivity and strain on the tooth may explain why in a survey performed by Savani et al 2014 core carrier based obturators were second in popularity with general dentists in the USA for root canals.

As with any differing techniques that have the same goal in mind it is important to compare the outcomes. Chu et al 2005 looked at CLC in contrast to TF with regards to time to obturate as well as outcome after a 3 year follow up. Findings showed that there was no statistically significant difference in outcome between the two techniques but
that on average the operator spent an average of 20 minutes less on obturating with the TF technique versus CLC. Kandemir et al 2016 found that when comparing CLC with TF the two-year success was 98% and 96% respectively while Wong et al 2015 showed a lower 2 year success rate regarding TF at 88%.

Something that clinicians are always trying to prevent when obturating is pushing material out the apex of the canal and while TF has many studies supporting better adaptation to canal anatomy than CLC it also has been known to have a higher extrusion rate. In a study where 28 teeth were obturated using TF the extrusion rate was evaluated and results showed 73% of teeth had overfilling (Silvani et al 2013). Tennert et al 2013 contrasted WVC to TF in 162 teeth to find the rate of overfill in TF almost double of WVC at 80% versus 42%. However, in another study with a sample size of 260 teeth it was found that there was no significant difference in overfilling and the adaptation was superior in TF (Bhatti et al 2000). It is reasonable to attribute some discord amongst studies to the operators themselves and how comfortable they are with the obturation techniques resulting in better or worse results pending their own experience. Regardless of this fact, the literature seems to show a trend of more extruded material apically in TF cases. Foreign material entering the periapical tissue has been shown to cause postoperative discomfort.

Pain is very often what motivates patients to come in for dental care. Treating the pulp can offer relief to patients who are suffering from a necrotic/infected or inflamed pulp, however one in twenty patients report pain six months after root canal treatment (Nixdorf 2010). If a treatment modality increases this post-operative discomfort then that should be taken into account when one is selecting treatment options. Twenty-four
hours after root canal treatment, 97% of TF treated teeth showed postoperative pain in comparison to 61% of CLC treated teeth (Alonso-Ezpeleta et al 2012). He et al 2004 looked at 50 TF treated teeth seven days after treatment to find 24% reporting pain. And of the 220 teeth treated with the TF technique in Wong’s study it was found that 17% reported pain after one week. Efficiency, prognosis, discomfort after treatment are all significant factors when delivering care to a patient. But what about when a treatment fails? Does the material or technique employed for the failed treatment affect our ability to re-treat the root canal?

**Guttacore**

We know that the pulpal anatomy makes it impossible to completely eliminate all tissue and contaminants even with the most thorough of chemo-mechanical preparation (Baker 1975). We also know from Ingle 1965 that 59% of endodontic failures are due to inadequate obturation. While clinicians hope for the best outcomes and should always be delivering care that gives their patients the best chance for success it is also understood that failures do occur and endodontic re-treatment is going to be necessary in some cases. In light of this fact it is only logical to evaluate what obturation methods facilitate endodontic re-treatment with more ease, efficiency and ultimately better outcome/prognosis. Wilcox et al 1994 looked at retreatment speed and mean GP left in all thirds of canal with CLC and TF with metal carriers and found that there was only a slight difference in time to retreat and significantly more GP in coronal third of TF cases. In another study conducted by Imura et al 1992 it was noted that the plastic carriers had ease of removal on retreatment, leaving behind similar amounts of material as CLC. In
contrast Zuolo et al 1994 discovered that the TF carrier material was significant in the increasing or decreasing the amount of time one needed to re-treat a tooth with metal carriers taking significantly more time than plastic carriers. Just as plastic was easier than metal, GuttaCore is reported to be faster to retreat than the plastic carrier TF system or even CW (Beasley et al 2013). The Dentsply/Sirona GuttaCore system uses a cross-linked GP core as the carrier which with the claim that it does not melt under heat or dissolve with solvent. This carrier is rigid enough to place the surrounding coating of heated alpha phase GP to WL under hydraulic forces. When comparing ease of orthograde endodontic re-treatment between CW, TF and GuttaCore Nevares et al 2015 found that removal of filling material was significantly longer for TF at 7.1 minutes/canal versus 2.91 minutes/canal for GuttaCore, with CW being the quickest at 1.93 minutes/canal. The same study observed that there was no significant difference between the groups regarding amount of residual filling material remaining in canal after instrumentation.

WVC and CW utilize heat to warm GP and condense it into places CLC is not capable of going. It has been shown however that the depth to which one heats the GP has an effect on the quality of obturation. Smith et al 2000 illustrated that as heat was moved coronally from the apical 3mm (which happens in many teeth due to anatomical restrictions, etc.) the quality of the obturation decreased. Because GuttaCore has heated GP already on the carrier prior to insertion into the canal one does not need to introduce heat to such a depth. Also, GuttaCore has shown to deliver higher density of GP without voids both coronally and apically than CLC and warm vertical (Li et al 2014).
GuttaCore may be superior in adaptability to the canal and easier to retreat than TF but how does it perform in length control? Levitan et al 2003 studied the effects of insertion rates on a similar method by looking at TF with respect to distance from or past the prepared apex and found that as insertion rate increased so too did extruded material beyond the apex while slowing the insertion rate resulted in shorter fills. It stands to reason that the results would be similar in GuttaCore however no research has been conducted on the effect insertion rates have on length control in the GuttaCore product.
II. Aim of Study

It is clear that there are multiple ways a clinician can obturate a canal space with each option having its various benefits and drawbacks but regardless of the approach one must recognize the importance of executing the technique correctly. In dentistry there are directions for use (DFU’s) with each product to inform the clinician how to operate within the limitation of the material/instrument. With the Dentsply/Sirona GuttaCore product the DFU’s do not state anything with regards to insertion rate but the company’s “Step-By-Step Guide” advises a rate of insertion of 7-10 seconds. Teeth however come in differing shapes and lengths and if a clinician proceeds inserting at rate of 7 seconds on a 30mm canal would that produce a different result than a 19mm canal? If so, how does the clinician make adjustments for canal length? The aim of this study is to determine whether the insertion rate of the Dentsply/Sirona GuttaCore obturation product with Dentsply AH Plus sealer has an effect on 1. the extrusion amount of the obturating materials and 2. the extrusion probability of the obturating materials out of root canal apex.

Hypothesis

The null hypothesis is that the rate will have no effect on the possibility or amount of extruded material out of the canal in any of the three groups.
III. Materials and Methods

Groups/Control

To determine the effects that varying rates have on extrusion/short filling and overall apical extent with GuttaCore, Dentsply/Sirona Endo Training Bloc’s (J-Shape 015, .02 taper) were used to simulate the root canal. The blocks were divided into 3 groups of 10.

The three groups were as follows:

Group 1: 1 second insertion rate/AH Plus Sealer (n=10)
Group 2: 7 second insertion rate/AH Plus Sealer (n=10)
Group 3: 16 second insertion rate/AH Plus Sealer (n=10)

Preparation of plastic blocks

Preparation of all plastic blocks were instrumented according to manufacturer’s instructions using the reciprocating WaveOne Gold Endodontic File system (WOG) and operating microscope was used for preparation of each block. For this experiment, working length (WL) was defined as the length of a stainless steel #10 K file as the tip of the file was flush with apical exit of the plastic block. Prior to instrumentation #10 K file was taken .5mm patent (beyond apex) to verify patency of each block as well as verify WL after file was drawn back into canal flush with the apex. One patency had been verified and WL established and recorded the protocol was followed for remaining steps to shape canal. The canal glide path expanded to a #15 K file by hand until file could reach WL without resistance. Total of 2 mL .5% sodium hypochlorite (NaOCl) was used
to irrigate between hand filing to ensure prevention of blocking canal. Patency was again checked to ensure apex was not blocked with plastic debris. The Dentsply/Sirona X Smart IQ motor (figure 5) was then used with a WaveOne Gold Primary File.

Figure 5: Dentsply/Sirona X Smart IQ motor. Can be programmed with multiple settings for various shaping systems (rotary, reciprocating-i.e. WaveOne Gold).

Measurements for the WOG primary file are .025mm for tip diameter and .07 taper (however Dentsply/Sirona reports this as variable taper) and the material is made from nickel titanium (NiTi). The file system claims a single file use for shaping a canal. In this experiment the primary size WOG file was used as the final size at which the canal was obturated. Canal was flooded with .5% NaOCl and WOG primary file was inserted into canal orifice running at settings pre-programmed in X Smart IQ motor under gentle pressure 2-3 passes were made into canal. Afterward the file was withdrawn, cleaned with an alcohol soaked 2x2 gauze and inspected for unwinding. Canal was flushed with .5% NaOCl, #10 K file recapitulated to .5mm beyond WL to ensure patency. Rinsed
again with NaOCl. When flutes of WOG primary file were cleaned and verified to be in good condition it was reinserted into the canal to shape another 2-3 passes and have the process repeated until WL was reached. As per the DFU’s for the WOG file system once WL was reached the file was withdrawn immediately to avoid over enlargement of foramen. Plastic debris was observed in apical flutes of WOG primary file, assuring that shaping was complete as per DFU’s (if no debris is noted at this point it is advised to increase to a larger size file to adequately shape the apical portion of the canal). Patency was verified with #10 K file and a final rinse with 2ml .5% NaOCl followed by drying the canal with paper points (PP’s).

**Obturation of Blocks**

After canals were shaped and dried DFU’s for GuttaCore were followed. Canal size was gauged using a GuttaCore “size verifier” (SV) that matched the WOG primary sized GuttaCore obturator. The SV is made from NiTi and has a silicone stopper that can be used to mark the WL. The SV was taken to WL to verify it reached WL passively. If the SV reached WL it was rotated 180 degrees to ensure adequate room for obturator. If SV had any binding DFU’s suggest using it for “minor” apical shaping rotating it in a clockwise direction with only slight pressure apically. In these cases SV was used for minor shaping as per the directions until it was at WL passively, this was followed by a final NaOCL rinse and dried with PP’s.

GuttaCore Obturator size WaveOne Gold Primary was removed from package and silicone stopper was set to WL. Prior to initiating any obturation steps (including mixing and placing sealer) the operator was calibrated for the insertion rate of the group...
to be obturated. By using 15 attempts with a #10 K file on a plastic block and referencing a stop watch in conjunction with calibration markings on the plastic block (figure 6).

Figure 6: Note calibration marks. One calibration block per group used to divide total insertion time into 4 measurements to make sure rate stayed consistent.

The operator would attempt to achieve a consistent rate from orifice to WL in the group's time (either 1, 7 or 16 seconds). AH Plus sealer was then hand mixed on glass slab to ensure quality mix of sealer. PP was dipped in sealer and applied to dried canal walls in a circumferential manner. Another PP was then used to remove any excess sealer that had pooled at apex or on the walls.

The GuttaCore Obturator was then heated in a Dentsply/Sirona Thermaprep 2 oven (figure 7).
Figure 7: GuttaCore Obturator Oven. Two holders to run multiple obturators at the same time. Can be set based on size of obturator

The oven was taken out of stand-by mode and made ready for use. Both obturator holders were put in the upper position. The GuttaCore obturator was placed in the holder with the rubber stopper below the holder and only the handle holding it in place. Care was taken when depressing holder into seated position to make sure obturator was straight and did not touch the sides of the heater. The position for the corresponding primary sized obturator was selected for a time of 20 seconds. After the oven beeped once the obturator holder was pushed and the obturator removed vertically from the oven. The handle of the obturator was grasped, taking care not to
touch the warmed GP. Obturator was immediately placed in orifice of canal and inserted at the group’s respective rate to WL. Obturator was inserted to WL as indicated by silicone stopper or until obturator stopped moving with moderate apical pressure. A #15 Bard-Parker blade was used to remove the handle/excess filling material coronal to the orifice of the plastic blocks. As these canals were not large, oval or irregularly shaped and did not have any internal resorptive defects the following step of placing a piece of GP lateral to the core and condensing was not performed.

**Weighing Extruded Material**

To quantify the amount of material that was extruded from the canals a Bard-Parker #15 blade was used to sever and remove any material external to the apex of the prepared canal (see appendix for obturated canals/extruded material). Prior to this step, all obturated blocks were set aside for a period of 48 hours to ensure material had adequately set. Each block that had extruded material was weighed individually on an Analytical Balance. Placement of a plastic weigh boat on the scale was followed by taring the reading. The extruded material from a plastic block was then placed on the scale and the reading was recorded. This process was repeated for each block with extruded material.

**Statistical Analysis**

T-test was performed to determine if there was a statistically significant difference between extrusion amount of the different experimental groups. Chi Squared
test was also performed with a p value set at less than or equal to .05, to explore the possibility of extrusion amongst groups.
IV. Results

Data from obturation extrusion at various insertion rates as well as respective values of weights are illustrated in Appendix I. The average amount of the extruded obturation material was .44 mg (1s Group), .22 mg (4s Group) and .17 mg (16s Group) (Table 1). Mean weights for samples indicates an upward trend from 16s<7s<1s in both extrusion and mean weight of extruded material. However, there are no statistical differences for the amount of extruded obturation materials among the three groups (P>0.05) (Table 2). The probability of the obturation material extrusion was 60% (1s group), 30% (4s Group) and 22% (16s Group) (Table 3). There are also no statistical differences for the probability of the obturation material extrusion among the three groups (P>0.05) (Table 4).
V. Discussion

Many studies have supported the philosophy of restricting the root filling material to the root canal and avoiding extrusion beyond the apex. Ng et al showed that keeping the root filling within 0-2 mm of the apex was a significant factor in treatment outcome. When studies have been conducted evaluating the length of root filling material in reference to the tooth’s apex there are three classic categories often used; first, greater than 2mm short of apex (aka “short”), second, 0-2mm to apex (“flush”) and lastly, past the apex (“long”). Seltzer 1963 concluded that short fills were superior to long fills for success rates. Nelson et al also supported short over long fills for better outcomes of root canals. The body of literature that supports flush fillings over long fillings with an improved outcome is lengthy. Some examples include Strindberg 1956, Sjogren 1990, and Orstavik 1993. In a meta-analysis performed by Ng 2008 it was shown that flush root fills had a 2.34 times higher chance of success when compared with extruded or long fills. In contrast, both Bystrom in 1987 and Sjogren in 1997 showed no association in root canal length and outcome.

Presence or absence of periapical inflammation and infection have been shown to have influence on treatment outcomes as well. Does the trend of success rates of short, long or flush fillings change when one takes into consideration the periapical status? According to Smith 1993 and Bender 1964 the answer would be yes, they both showed that teeth with a periapical lesion prior to fill were more likely to heal if flush versus long. But as most root canals are not simply filled with gutta percha and require sealer as an adjunct to aid in more effective and successful obturation it is prudent to
investigate how outcomes may or may not change if only sealer finds it’s way out of the apex.

Since 1967, the concept of filling the canal space in three dimensions as introduced by Dr Schilder also sparked debate regarding the “sealer puff” and what effect it may or may not have. In phase II of the Toronto study it was determined that such a puff would not have an adverse outcome on root canals. And when looking at the commonly used AH Plus sealer, Sari et al had similar findings. As it so often seems in research however there is frequently another side of the proverbial coin that begs to differ and to this point, in a systematic review performed by Aminoshariae et al extrusion of sealer resulted in a 32% higher risk of root canal failure when compared with root canal treated teeth without extrusion. It is worth noting that many of these studies categorized root canals in teeth as being flush or short-without extruded sealer used a two dimensional radiograph, thus the possibility of minute extruded sealer is entirely possible and cannot be ruled out. This lack of information certainly muddies the water in terms of outcomes and conclusions. While the apical extrusion of small amounts of sealer are likely to be better tolerated than root filling material such as gutta percha the data show clinicians should err on the side of caution to prevent pushing foreign material out the apex of the tooth (Ricucci 2016).

Research has also shown that the type of sealer used may affect the body’s ability to both tolerate and resorb the extruded material. This was observed in the study by Ghanaati et al 2010 evaluating tissue reaction of AH Plus and GuttaFlow sealers in subcutaneous implantation in Wistar rats. The results showed that the cytotoxic effect of AH Plus may have aided in inducing self-degradation. Other factors having some
influence on the fate of extruded sealer could include how susceptible the material is to phagocytosis and solubility of the sealer in the tissue fluids.

While debates can rage over prognosis and resorption of minor amounts of extruded material, what cannot be debated is the anxiety both patient and clinicians can experience if structures neighboring the apicies of teeth are compromised or damaged from extruded material. The literature is full of case reports that relay a smattering of postoperative complications induced by extruded material. To illustrate this point a few examples include paresthesia from nerve compression/damage due to extruded sealer/root filling material into structures such as the inferior alveolar nerve (Koseoglu 2006). Headaches, periorbital pain and sinus infection due to overfilled material entering the maxillary sinus (Yaltirik 2003). Aspergillus infections of the sinus due to extruded sealer containing ZOE (Managetta 1983). These are only to name a few. While these cases often require surgical intervention, there are some less serious cases where simply watchful waiting can result in resolution of symptoms (Froes 2009).

Ultimately the adverse effect that extrusion has on successful root canal treatment is due to two factors, infection and the ensuing inflammation (Siqueira et al 2014). A clinical consideration can include the concept that extrusion may be an indication of the presence of iatrogenic error and a violation of the apical stop has occurred, resulting in an over instrumented or transported apex. Such a clinical situation could make the goal of adequately sealing off the apex more difficult. This followed by a lack of biocompatibility or cytotoxicity of extruded materials will contribute to decreased success rates (Murazabel 1966). And lastly a foreign body reaction to extruded material
that is novel to the apical tissue is another proposed factor in compromised treatment outcome (Nair 1990).

As was mentioned previously, there is a trend of many dentists using carrier based obturation techniques due to efficiency and ease of placement when compared with other techniques. Many considerations need to be made regarding obturation of a root canal prior to treatment. Ease of re-treatment, biocompatibility, adequacy of seal, volumetric stability, solubility and ease of control/technique sensitivity are just a few factors when looking at selection of filling material and technique. We could easily list more but it is obvious that this decision is complex. It is important to rely on evidence-based decision in the selections and when evaluating the literature, we find a trend towards improved prognosis when filling material is not “long”. In this particular study when GuttaCore carrier’s insertion rate was increased, so too was the mean amount of material extruded. This could be due to increased hydraulic force and/or less time for the thermoplasticized material to cool and harden, as we know that thermoplasticized gutta percha is thixotropic, meaning as its insertion rate increases it flows with less viscosity (Levitan 2003). Something to keep in mind as the temperature for the thermoplasticized gutta percha is approximately 200 degrees Celsius when inserted into the orifice (Heeren 2012). While statistical analysis showed no statistical significance the mean amount of extrusion decreased as the rate decreased. Perhaps an increase in sample size would result in statistically significant results if future studies are performed. Another limitation of the study is unlike the in vivo model, plastic teeth lack a periodontal ligament adjacent to the apex and are simply open to the air. Perhaps the addition of a simulated periodontal ligament around the plastic block would give a closer
representation of the anatomic reality of real-world root canals with a resultant reduction or modification in extrusion of root filling material (Juhlin et al). Another unanswered question that has clinical relevance is if these results would change as the size of the prepared canal and corresponding GuttaCore carrier increased. In this particular study the selection of the smallest carrier, the primary sized WaveOne Gold GuttaCore carrier was selected. Whitten et al showed that the taper of the canal was significant in amount of extruded material. Results showed that with an insertion rate of 3 seconds on a WL of 18mm in extracted, mature human pre-molars that constant taper prepared canals (40 .04) had an incidence of overextension in 47.2% of cases. This was juxtaposed to the 10.5% overextension in a variable taper prepared canal where the apical 2mm were prepared to 40 .02. Future studies could also investigate if increased size in a similar taper exhibited any difference in overfill.
VI. Conclusion

This study suggests that the insertion rates of the Guttacore obturator have no effect on the extrusion of the obturation materials.
VII. Appendix:

<table>
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<th>16s</th>
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Table 1. Weight of Extruded Material in 1s, 7s and 16s Insertion Groups
* No statistical difference between groups

Table 2. Comparison of extruded Weight Amount Among Groups
Table 3. Number of Extruded Samples in 1s, 7s and 16s Insertion Groups

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<tr>
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<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>
* No statistical difference between groups

Table 4. Comparison of Extrusion Possibility Among Groups
Unprepared plastic blocks (lateral and frontal view):
#10 K file (left), WaveOne Gold Primary file (right), both to WL:
Lateral and Frontal Views of Prepared Plastic Blocks:

Note calibration marks. One calibration block per group used to divide total insertion time into 4 measurements to make sure rate stayed consistent.
1 second (insertion time)-Individual Blocks

Starting top (left to right) blocks #’s 1-10. Note extruded material-blocks 1-6.
7 seconds (insertion time)-Individual Blocks

Starting top (left to right) blocks #’s 1-10. Note extruded material-blocks 1-3.
16 seconds (insertion time)-Individual Blocks

Starting top (left to right) blocks #’s 1-9. Note extruded material-blocks 1 and 2.


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Image references:

WaveOne Gold Reciprocating Files DFU EN

WaveOne Gold Reciprocating Files Tip Card EN

GuttaCore DFU Rev. 07 EN

GuttaCore Step-By-Step Guide EN

DIRECTIONS FOR USE (OVEN THERMAPREP® 2)

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