2015

Evaluation and Analysis of the Apically Extruded Gutta Percha Using Thermoplasticized Technique as Sole Obturation Method (Squirting)

Pejman Parsa

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Evaluation and Analysis of the Apically Extruded Gutta Percha Using Thermoplasticized Technique as Sole Obturation Method (Squirting)

By

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Thesis Submitted to the School of Dentistry of Robert C. Byrd Health Sciences Center at West Virginia University in partial fulfillment of the requirements for the degree of

Master of Science

In

Endodontics

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2015

Keywords:

Dental, Endodontics, Obturation, Gutta Percha, Thermoplasticized, Squirting, Extrusion

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Abstract

Evaluation and Analysis of the Apically Extruded Gutta Percha Using Thermoplasticized Technique as Sole Obturation Method (Squirting)

Pejman Parsa, DDS

Introduction

Preventing apical periodontitis has been the cornerstone of endodontic therapy. For decades, clinicians have been challenged by the microorganisms present in the root canal system to help host defenses heal the apical tissues. Root canals that have been biomechanically cleaned, shaped and disinfected by instrumentation, irrigation and medication are in need of obturation. To the experienced practitioner it is prudent that a three-dimensional obturation that is fluid tight be placed in order to prevent oral and apical micro leakage. Many different techniques and materials are advocated to achieve this type of fill. The most commonly used material with the longest history of use is gutta percha. The natural chemical form is trans 1,4-poly-isoprene. This material, when heated, will flow and upon cooling it will shrink slightly. Different components are present in dental gutta percha. Namely zinc oxide, heavy metal salts, and other waxes and resins, with only about one fifth of the chemical constituent being actual gutta percha.

Traditionally gutta-percha used in obturation comes as pre-shaped cones that can be placed into canals, which creates the clinical problem of adequately filling canals that are not inherently circular in cross section with pre-shaped circular gutta percha cones. To better address this problem, warm and heated gutta-percha, with its flowable properties, has been used in combination with traditional cones to provide a fluid tight seal. Some clinicians have even used warm gutta-percha to entirely fill a canal. Using thermoplasticized gutta-percha as the sole obturation material has advantages in that a better obturation in three dimensions can be achieved. In this method, controlling the apical extent of the gutta-percha may be an unreliable and unpredictable procedure. The aims of this study were to evaluate different apical preparation sizes and examine the use of a thermoplasticized technique as the sole obturation method (squirting) while minimizing the risk of overfill and the overextension of obturation material out of the apex of the tooth.

Materials and Methods

One hundred and forty maxillary and mandibular incisors were selected. Conventional endodontic accesses were prepared in all these teeth after their crowns were sectioned off at the cemento-enamel junction. The total teeth were divided into 5 groups, with each group being comprised of 7 teeth from each particular tooth number (#8, #9, #24, #25). All teeth were prepared with 4 percent taper. Five groups of preparation sizes were used as follows: 20, 25, 30, 25, and 40. The patency of the apical foramen was tested using a #10 K file. Thereafter, the canal was negotiated with a #15 file until it was visible at the portal of exit, with the working length being determined by subtracting 1 mm from this measurement. At this measurement, the first file to bind (FFTB) was determined for each tooth. After determination of the FFTB, a glide path equal to size 20 handfile was created. The canals were shaped according to their respective groups using NiTi rotary

instrumentations in a crown down manner using copious 2.5% NaOCl irrigation. The dentinal smear layer was removed using 17% EDTA and a 2.5% NaOCL. The canals were dried with 70% alcohol and paper points and a thin layer of Roth's root canal cement was placed. Excess cemented was wicked out with paper points. Thermoplastic obturation was carried out with the Calamus DUAL[®] obturation systems by holding the extruder tip 3-5 mm away from the working length. Obturated teeth were evaluated under the microscope for extrusion. Teeth with any extrusion material were recorded in binary terms (+ and -) and logistic regression with backward selection was utilized to determine the most predictive factors using SAS 9.3 (SAS Institute, Inc., Cary, NC).

After backward selection, the final logistic regression model included FFTB, File Size Group and the interaction between these two variables, while adjustments are made to block the variability of tooth number. This means that the other variable (extruder distance from WL) does not add any additional information to our understanding of extrusion probability beyond FFTB and file size group. Since the statistical interaction between FFTB and file size group is statistically significant, all interpretations of the model were conducted jointly. So, for examples when the FFTB was a size 20, the odds of extrusion decrease 82% ($1 - 0.18 \times 100\%$) for each additional increase in file size used (from 20 to 25, 30, 35, 40).

Conclusions

The results of this study indicate that the FFTB and File Size group play a more significant role than the extruder distance from working length. While keeping the file size group constant, if the FFTB were to increase, an increase in the rate of extrusion would be seen. Therefore, the larger the difference between the original size of the canal and the final preparation of the canal, extrusion becomes less likely. This is invariably due to the larger apical stop (platform) created. This platform serves as a matrix and barrier for materials to discontinue their flow. Keeping these measurements in mind, the clinician can make mindful decisions during his procedure to prevent overextension and procedural mishaps.

Dedications

To my parents, Parviz and Shahnaz, for their nonstop and unconditional love. No matter how frustrated they were with me at times, I always benefited from their support.

To my siblings Parish, Peyman, and Parisa who always have encouraged me to do what I want regardless of how difficult it may have been. Hopefully one day I'll be reading a thesis of one of yours.

To my heart and soul, Negar. You've encouraged and inspired me to new heights. Thank you for instilling the confidence in me to pursue specialization. I hope that I've been as motivational for you as you have been for me. Love you always.

Acknowledgments

Dr. Borgia- Without you accepting me into your program, none of this would have been possible. I am extremely happy to have worked with you and been mentored by your extensive experience and expertise. I will always look forward to seeing you at the national endodontic meetings.

Dr. Komabayashi- Your consistent time and effort to help me with literature review, clinical work, and thesis preparation was invaluable. I am very happy to have worked with you and learned from you.

Dr. Hildebrand- Although our time together was short, but it was filled with great experiences and lessons. Your clinical input was always helpful, but more importantly, I'll be missing the hotdogs and chocolate milk.

Dr. Bagby- Your feedback and guidance was very helpful and it was a great experience working with you in the clinic on collaborative cases.

Dr. Leann Long- I have never encountered a non-dentist with as much enthusiasm to learn about endodontics like yourself. Your help with statistical analysis was a key part of our success.

Dr. Andrew Xu- You are the best co-resident anyone could ask for. Not only will I miss you, but I'll be missing your three little angels very much as well. Not only am I a better dentist because of you, but I also feel I've improved as a person. I enjoyed every minute of our two years together and who knows, maybe one day we'll be partners in Texas 😊

Dr. Nicholson- I'm glad to have had you as one of my second year residents, because your attention to detail and strive for perfection is unmatched. It was great seeing that kind of work. Oh and sorry I picked on you so much. You were an easy target 😊

Dr. Seifelnasr –Your vast experience was very helpful to us in clinic. I'm glad to have shared a lot of memories with you and pick your brain at will. Wish you and your lovely family the best. Hope you never lose enthusiasm for those middle mesials.

Dr. Hunter – I don't know how you make the time to do all the things you do, but it is exemplary. You've been a big help to the program and I'm sure you're going to make a fine chief and endodontist soon. Keep up the amazing work.

Dr. Sakr – Thanks for always giving me confidence in my work. You've had extremely challenging cases and you've handed them well. I have no doubt you're going to continue the amazing work. Thanks for all the support and best of luck in the near future.

Mehran Malakpour- Your ambition as a dental student was unparalleled. Without your volunteer work this project may have never finished.

WVU Endodontics Staff – Thanks for putting up with me over the past two years. Hopefully you'll have good things to say about me to future residents.

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List of Symbols, Abbreviation, or Nomenclature

Millimeters - mm

Sodium hypochlorite - NaOCl

Ethylenediameteraacetic acid – EDTA

Working Length – WL

Institutional Review Board – IRB

First File to Bind - FFTB

Root Length - RL

Dental Operating Microscope – DOM

CHAPTER 1

Introduction

In root canal therapy the main goal is to disinfect the canal space and ultimately obturate it in its totality ¹. It has been documented and accepted by many that microorganisms play a fundamental role in the development of pulpal and periapical pathology, namely apical periodontitis². However, according to Siqueira and his studies it is difficult to completely eradicate bacteria in the root canal system ³.

Once the proper cleaning and shaping procedures have been carried out and the root canal system has been thoroughly disinfected via mechanical and chemical methods, it is ideal to fill its entire extent with an appropriate filling material. Cleaning and shaping procedures are essential for clinical success in the long term, whereas it is also widely accepted that a fluid tight seal created by proper obturation has the potential to entomb any remaining bacteria that were not eliminated to prevent them from reaching the periapical tissue, causing destruction beyond the root confines. So, in this manner and according to Ng et al, filling the well-cleaned root canal system becomes an integral part of the overall success and longevity of the tooth ⁴.

The most widely used root canal filling material in the world is currently gutta percha. It has different forms, but its natural form is known as trans 1,4-poly-isoprene. Gutta percha will undergo transformation as it is heated. The temperature this happens is normally around 147⁰c. This material, when heated, will flow and upon cooling it will shrink slightly. Dental gutta-percha has different components. Namely zinc oxide, heavy metal salts, and other waxes and resins, with only about one fifth of the chemical constituent being actual gutta percha ^{5,6}.

Different approaches have been employed to achieve ideal obturation with gutta percha.

Traditional methods of obturation such as cold lateral condensation employ a solid core material, which may leave many unfilled areas in the root canal system. This technique to obturate prepared root canals has several benefits. Length control is typically better managed, since none of the gutta percha is heated. This usually ensures that no material is carried out beyond the confines of the root ¹. The major disadvantage of cold lateral compaction is its inability to produce a uniformly dense mass of gutta percha at the apical portion of each canal. Another method, warm vertical obturation, utilizes gutta percha that has been heated, which now has the ability to flow, allowing it to uniformly fill the apical portion ¹. The apical extent of the root filling is of great importance to the prudent practitioner as this apical seal will help prevent the periapical tissues from being contaminated by any remaining bacteria or their byproducts.

Statement of the Problem

Can thermoplastic obturation methods successfully and predictably fill the entire three-dimensional root canal system without extending beyond the confines of the root?

Significance of the Problem

Obturation methods have been the slowest techniques to evolve in endodontics. Materials and methods have been limited by the anatomy, configuration, and accessibility of teeth. Warm methods were first introduced as warm vertical compaction ¹. With novel approaches using warm gutta percha as illustrated by Dr. Johnson in 1978 ⁷, clinicians were able to obturate areas of the root canal system which were previously inaccessible. Several gutta-percha obturation techniques have been advocated for ease of manipulation and superior sealing ability. Yee et al introduced one of these techniques in 1977. They injected high temperature thermoplasticized gutta percha into the prepared canal space ⁸. Although these methods introduced warm gutta percha into the root

canal systems and achieved better three dimensional fills, they had the disadvantage of not having adequate length control and stability; hence, the root canal fillings are not always contained within the confines of the root. This event could cause potential problems, as it is recommended to have the root canal filling material contained within the root of the tooth and not extruded into the periapical tissues.

Null Hypothesis

When standardized rotary instrumented root canal preparations are injected with thermoplasticized gutta-percha as the sole filling material, there will be no statistically significant difference between various size groups (20/04, 25/04, 30/04, 35/04, and 40/04) with respect to presence of filling material extruding beyond the root.

Assumptions

1. Thermoplasticized gutta percha has sufficient “flowability” in the root canal system.
2. Although it is impossible to “sterilize” the root canal system completely, a well obturated root canal system is usually indicative of a well cleaned and disinfected root canal system.
3. In thermoplastic techniques, minimal sealer is needed because of flow properties of the heated gutta percha.
4. Root canal preparations with a continuous taper permit better flow of the thermoplasticized gutta percha.
5. Crown down rotary technique is currently the method of choice to produce clean canals without apical transportation. This technique produces the least amount of debris.

6. By keeping the apex of the experimental teeth open (not a closed system like the mouth, which is bounded by the periodontal ligament and alveolar bone), minimal back end pressure is present, and hence higher chances of extrusion will be present in this study.

Limitations

1. Due to time constraints, quantitative methods to measure the volume amount of extruded gutta percha were not used. The excess filler was measured in binary terms for presence or absence of extrusion (+, -). Since it is not ideal to have any material beyond the confines of the root, a binary approach was employed as a strict analysis of “yes” or “no”. Further studies should look at the amount of extruded material in volumetric terms.
2. Condensation pressure of the plugger is difficult to assess properly and can vary between different operators.
3. Obturating canals to the “feeling of backpressure” can be subjective and vary between different operators.
4. The apices of the teeth were left as an open system. Ideally, the root ends should be closed with wax and placed in acrylic stone to mimic teeth in the mouth (a closed system that has periapical tissue present outside root confines. This provides resistance to materials “flowing” out of the root canal system).
5. Human error may be involved in different steps of carrying out the experiment.
6. This in vitro study is unable to assess host tissue response.

Delimitations

1. Selected teeth were limited to maxillary and mandibular anterior incisors because they have simple, straight, and predictable root canal systems.
2. Teeth with formed apices and radiographically present canals were selected.

3. Teeth had their crowns sectioned off to give direct access to the root canal opening.
4. Evaluation of extruded material was done utilizing the dental operating microscope with direct visualization using 6.4x magnification.
5. The principal investigator performed instrumentation, irrigation and obturation steps.

Chapter 2

Review of Literature

The goal in endodontic therapy is a simple one; thorough disinfection and debridement of the root canal system through mechanical and chemical methods, followed by obturation that is fluid tight to prevent recontamination. According to Usman et al, nonsurgical endodontic treatment is composed of three steps: cleaning and disinfection, canal shaping, and root canal obturation⁹. Many authors believe cleaning and shaping are a singular event that occurs simultaneously. The most common irrigants utilized in endodontics are sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA), both of which are able to penetrate areas within the root that mechanical instruments cannot reach⁹.

Clinicians should be knowledgeable and aware of optimal instrumentation size for all root canal procedures. Ideally, the size should be large enough to mechanically remove as much bacteria as possible, while permitting the influx of irrigants to disinfect canals. Too large of instrumentation size can have unwanted effects, such as, perforating the root canal or forcing irrigants and filling materials beyond the apex. It was shown by Salzgeber and Brilliant that instrumentation of the apex beyond the size of 35 can allow irrigating solutions to pass through the apex. This passage into the periapex, in particular sodium hypochlorite, can have devastating results¹⁰.

Figure 1: NaOCL accident: Complications following an accidental sodium hypochlorite extrusion ³³

Figure 2: Overextension of gutta percha and sealer into the IANC (Inferior Alveolar Nerve Canal) ³⁴.
This patient suffers from permanent paresthesia on the bottom right side.

Once the root canal system has been adequately prepared, cleaned, and shaped, it may then be obturated with a material that will provide a stable filling in all dimensions. According to Schilder, “The objective of root canal filling procedures should be the total 3-dimensional filling of the root canals and all accessory canals” ¹. Prevention of reinfection can be attributed to a “hermetic seal” of the entire root canal system. Obturation may also act as a physical barrier separating any remaining bacteria and the periapical tissues. In this manner, bacteria and their

byproducts are entombed within the root filling, and are disabled from causing destruction to surrounding tissues ⁵.

Figure 3: Two cases obturated by Dr. Schilder using the warm vertical technique as first described by him.

With a vast selection of filling materials to choose from, gutta percha is still the most commonly used material and has the longest track record to evaluate. According to Dr. Louis Grossman, the ideal obturation material should have the following features:

- Should be easily introduced into root canal system
- Should seal canals well
- Impervious to moisture
- Should not shrink once inserted

- Be bacteriostatic
- Should be radiopaque
- Not stain tooth structure
- Not irritate the periapical tissue
- Be easily removed from root canal system, if needed.
- Should have potential to be sterilized before insertion

Figure 4: Various brands of gutta percha

According to the American Association of Endodontics (AAE): “The obturation materials are divided into two basic groups—sealers and core materials—each of which can be found in a large variety of materials and brands”³².

Since canals are never the same shape as the provided core materials, there will inherently always be a discrepancy between the core and canal walls; canals need to be filled with a flowable material that can reach the difficult areas. Endodontic sealer is that material. There are many types

of sealers available for use on the market today, and they are grouped according to their main component. It is accepted that no one specific sealer is superior to the other in terms of root canal success, and as long as the basic principles of cleaning and shaping have been followed, high success rates can be anticipated with any sealer. Some of the various sealers types include, but are not limited to zinc oxide-eugenol sealers, resin sealers, glass ionomer sealers, calcium hydroxide based sealers, and bioceramic based materials³².

Figure 5: While many different sealers are available on the market, Roth's Root Canal Cement was used for this study.

Core materials fill most of the space of prepared root canal systems. There are various core materials used in conjunction with different sealers, all of which try to achieve the same goal of a hermetic, three-dimensional, seal. Currently, gutta percha remains the most widely used core material. It has an extensive track record and has been studied thoroughly and has found to have favorable, but not ideal properties.

Before its use for root canal fillings, gutta percha was used a temporary filling material. Gutta percha by itself provides a very poor seal anywhere used, and hence the need for a sealer. It is derived from the Taban tree (*Isonandra perchas*)³². Since its first uses were identified, gutta

percha has been employed in other industries as well as dentistry. It has been used as a coat on the first trans-Atlantic cable and the inner core of golf balls³².

Like many materials, when heated, gutta-percha undergoes phase transition. Its original phase is beta, but once heated it will turn into the alpha phase. This normally takes place at 115° F. According to Goodman et al, the softening point of gutta-percha was found to be 147° F (64° C) ⁶. In thermoplastic techniques, which employ heating gutta percha, phase transitions are critical. Cheng et al have shown that heating gutta percha does not change its biocompatibility; however, if the beta form is heated above 300° F its physical properties change. Therefore the beta form is not recommended for use in the injection techniques ¹¹.

Since gutta percha shrinks upon manipulation, various attempts have been made to compensate for this phenomenon. Compaction of the material with spreaders and pluggers has been used to compensate for the shrinkage ¹². One clinical characteristic of gutta percha that is of utmost importance to the everyday clinician is its propensity to become brittle over time with exposure to air and light ¹³. To overcome this, some clinicians place the material in airtight containers in dark areas to increase its shelf life.

Many techniques and methods have been introduced and advocated over the years for obturation utilizing gutta percha as the main core. All have their advantages and disadvantages. According to Dr. John Stropko, there are several techniques that utilize gutta-percha as the obturation material of choice. These are ³²:

1. Single Cone

- In this method, only a single master cone of Gutta Percha is utilized. This cone will correspond to the final instrument size used, and sealer is introduced for cementation. (Most often a Bioceramic type sealer).

2. Lateral Condensation: Cold and Warm

- *Cold Lateral:* Based on the final instrument size used, the master cone is selected. It is delivered into the canal along with sealer. Once it reaches proper working length, the master cone is compacted laterally, followed by introduction of accessory cones. This process is repeated until a dense fill is obtained.
- *Warm Lateral:* Based on the final instrument size used, the master cone is selected. It is delivered into the canal with sealer. Once it reaches proper working length, the master cone is compacted laterally with a heated spreader and accessory cones are placed. This technique differs from cold lateral in the fact that the spreader needs to be heated and placed alongside the master cone.

3. Solvent Technique (Mainly Chloropercha)

- Gutta percha can be softened chemically. The most common solvent used for this procedure is chloroform (CHCl_3). In this method, the tip of the master cone is softened by dipping in CHCl_3 and then placing it into the canal to working length. Ideally, the softened tip will replicate the shape of the apex. The remainder of the filling procedure can be accomplished with various methods such as the cold lateral or warm lateral to introduce additional accessory cones. Chemically altering the

properties of gutta percha results in some shrinkage (1-2%) after the softened gutta percha solidifies.

4. Vertical compaction of warm GP (Schilder, continuous wave, System “B”)

- Schilder was the first to introduce this concept. It promoted a sense of “flow” for the gutta percha. Canals generally had to have large tapered preparations with small apical diameters for proper “flow” to be achieved. In this manner, the traditional master cone was fitted and delivered with sealer. Instead of placing accessory cones, the master cone was heated and packed with pluggers until a plug of gutta percha was left at the apex (about 3-5 mm in length). As the gutta percha was pushed and packed apically, it promoted flow of gutta percha and sealer. The remaining portion of the root canal was then filled from the end back to the coronal portion using warm pieces of gutta percha that were heated and packed in small increments.

5. Carrier-based (Thermafil)

- Introduced and pioneered by Dr. Ben Johnson in the late 1970’s, this idea coated a plastic carrier with gutta percha.⁷ The carrier with its gutta percha coating is heated in an oven and delivered directly into the canal using the plastic carrier’s handle. Minimal sealer is needed in this process.

6. Injection of Thermo-plasticized GP (often referred to as “squirting” using a Calamus or Obtura unit)

- Thermoplasticized gutta percha is directly injected into the canal as the core material with minimal sealer used for lubrication to promote its “flow” and ability to “wet” the canal.

Root canal fillings are placed in canals to prevent recontamination from any microbial insult to the tooth, and thus prevent any microbes or their byproducts from reaching the tissues beyond the root canal system. This concept, although simple in its idea, is challenging on many fronts. One major challenge is the vast anatomic differences found among teeth and their complex anatomy that hinder clinician’s ability to effectively clean and shape the canals. According to Al-Dewani et al.: “Unfortunately root canal systems are complex with accessory canals, fins, anastomoses, and apical deltas; not only is it difficult to prepare such systems, but it is also difficult to predictably fill the space in three dimensions.” ^{14,15}.

Out of all the above mentioned methods for utilization of gutta percha, cold lateral compaction is still the most widely used and taught in institutions (Leduc & Fishelberg 2003). Due to its long and extensive history of use in endodontics, it is the standard to which most studies will be compared (Whitworth 2005, De-Deus et al. 2008b). According to multiple studies, because of the use of the spreader, this method does not produce a homogenous mass of filling material and many irregularities can be seen within the obturation ¹⁶. In this method, due to the cold nature of the core, material movements are usually limited to the compaction of the material that occur during the use of the spreader and the sealer resulting in minimal, if any, movement of the core. Hence, cold lateral does not have the ability to produce a homogenous seal. Where the lateral compaction

technique fails to produce these homogenous masses, warm vertical methods succeed in promoting flow, and result in a uniformly dense and homogenous mass of gutta percha ¹.

The nature of the warm technique results in minimal shrinkage since the material solidifies to its cold and stable state, and whereas only minute shrinkage occurs in the lateral condensation technique, the filling there is not homogenous. It is merely composed of a mass of gutta percha cones that have been placed together in close proximity with multiple openings and channels for bacteria to pass through. The only area where homogeneity is seen is towards the coronal aspect, where the gutta percha has been heated and condensed. According to Brothman, warm vertical compaction of gutta percha increases the number of filled lateral canals compared with lateral compaction by two fold. As originally described by Schilder in 1967, during warm vertical compaction, GP is heated and packed in 3–5 interrupted waves of compaction. In an extension of the warm vertical method, *continuous wave technique*, Buchanan recommends that the System B heated plugger should be inserted to final depth 5–7 mm short of the terminus.

Methods employing warm movements of gutta percha have many benefits when compared to lateral condensation. In a study by Perry et al, man-made apical defects were best filled with warm gutta percha procedures that utilized the down pack and backfill methods ¹⁷. Perry et al reported that after warm vertical compaction, the quality of adaptation of GP to the wall of the apical root canal varies depending on the depth of heat application and the width of the apical root canal¹⁷. The plasticity of gutta percha is proportional to temperature increase. As it is heated, its plasticity increases. The more plastic deformation that gutta percha undergoes, the more it will better adapt to canal irregularities. ¹⁸. According to Keles et al regardless of the technique

employed, no root fillings were completely free of voids; however, more volume of gutta percha was attained in warm techniques versus lateral compaction.¹⁹.

A good root canal filling material should not only have minimal voids, but should also have the ability to seal the canal. The sealing ability of thermoplastic techniques versus cold lateral obturations has been evaluated by the amount of dye penetration into root fillings. Al- Dewani et al have shown that canals filled with thermoplasticized gutta-percha had significantly less apical dye penetration than those obturated by lateral condensation¹⁴. By having fewer voids in the filling material and less dye penetration at the apex, thermoplastic techniques seem to be the logical choice when obturating the root canal system.

Thermoplasticized-injectable obturation techniques (squirting) do not utilize the traditional master cone, as they have the heated gutta percha injected directly into the canal. The protocol was first described in 1977⁸. According to Yee: “The thermoplastic injection-molding involves heating a polymer to the molten state and forcing it under mechanically generated pressure into a relatively cool mold. On dissipation of the applied heat, the injected material solidifies and retains the shape determined by the internal outline of the mold cavity”⁸. The benefit of this method is that the gutta percha can flow into various areas of the canal^{18,20}. The benefit of being able to fill all the irregularities in the canals is that any bacteria or their byproduct that the operator could not effectively remove may be entombed in the filling material and hence prevent its spread into the tissue beyond the confines of the root canal.

Although the thermoplasticized gutta percha adapts well to irregularities within the canal, it still requires a medium of delivery for its flow and ensure the ability to seal the canal. This medium is the sealer.^{14,21}. Since heated gutta percha expands, it is anticipated that it shrinks as it cools. This

can leave potential voids along the gutta percha mass. These extremely small spaces can be filled with sealer, but the sealer has to be driven into them by the hydraulic forces of the warm gutta percha ^{22,23}.

These thermoplasticized techniques using gutta-percha have been employed to overcome the problem of incomplete obturation, and yet, they have not come without their potential disadvantages. The main disadvantage of this technique is the inability to control the dimensional stability at the apex. If length control is not predictable, it can lead to overfills of the canal space and cause foreign body reactions at the periapical tissue level.^{20,24} According to Mann and McWalter, gutta-percha was either underextended or overextended half the time in the thermoplastic technique ²⁵. ElDeeb has also reported that most obturations in this method will be overextended 75% of the time ²⁶.

If the apex is patent, depending on the size it's been shaped to, passage of the heated gutta percha may occur causing extrusion into the periapical tissues. This could lead to initial acute problems, such as post op pain, followed by long-term chronic foreign body reactions. If extruded gutta percha reaches crucial anatomical landmarks such as the inferior alveolar nerve, unwanted catastrophic results such as permanent lip and tongue paresthesia could occur ²⁷. Also, it is very important to remember that with increased file size, the likelihood of forcing irrigating solutions beyond the apex increases. Salzgeber and Brilliant have shown that sizes larger than a 35 could allow passage of irrigants beyond the apex. If this irrigant is NaOCl, the results are devastating in that a reaction occurs which causes severe pain and bruising for the patient, which may take months to resolve. Reeh and Messer have showed the results of such incidences. ¹⁰

In thermoplastic techniques, various factors challenge the clinician in obtaining an adequate obturation: the size of the apical preparation, the insertion depth of the injection needle, the injection rate, and the condensation force. All these factors may result in voids or obturations that are short or long of the determined working length ¹⁵.

Much of the overall success of root canal therapy is dependent on the vitality level of the pulp and the status of the periapical tissues. Studies by Sjogren and Ng have shown that if no periapical lesion is present at the time of root canal therapy, these teeth go on to be successful about 96% of the time ^{4,28}. Teeth having radiographic lesions treated for the first time or being retreated have lower success rates. Initial treatment of teeth with radiographic lesions is successful around 86% of the time, whereas retreatment of teeth with radiographic lesions is only 62% successful ²⁸.

Chapter 3

Materials and Methods

Teeth Selection

Maxillary and mandibular central incisors were selected. Teeth with open apices, resorbed roots, broken or fractured roots, or any previously treated canals were discarded.

Figure 6: Storage of extracted teeth

Figure 7: Views of teeth stored in NaOCL:H2O

After visual inspection, radiographic analysis was carried out. All approved teeth had radiographs taken in both the buccal-lingual dimension as well the as the mesial-distal dimension. Canals with severe calcifications that would require extensive drilling were excluded due to difficulty and time restraints of the study.

After passing the abovementioned selection criteria, a total of 140 teeth were selected for the study. These selected teeth were limited to maxillary and mandibular central incisors. According to a study by Dummer et al, maxillary central incisors were chosen because extrusion of gutta percha with the Thermafil technique was more frequently encountered in straight canals versus curved ones ²⁹.

Figure 8: Radiographs of maxillary central (top) and mandibular central incisors (bottom) from the frontal and proximal views.

Preparation of selected Teeth

The selected teeth had their clinical crowns sectioned off at the CEJ with brand new diamond burs. The remaining root structure was kept hydrated in a solution of 4:1 water/NaOCL in between research sessions. After sectioning the crowns, conventional endodontic access was made and canals located with a sharp endodontic explorer and the use of the dental operating microscope (Global® – Global Surgical Corporation).

Figure 9: Maxillary and mandibular central incisors with their crowns sectioned off at the CEJ.

Figure 10: Occlusal view of sectioned teeth showing their root canal at the CEJ level.

Figure 11: Dental operating microscope and attached camera for high quality images (Global® – Global Surgical Corporation).

Grouping of Teeth

Each individual tooth group (#8, #9, #24, #25) was composed of 35 teeth (Totaling 140 teeth for all groups). These groups were then divided into 5 subgroups for different preparation sizes. Each subgroup consisted of seven teeth. This is demonstrated in table 1.

Tooth #	Total Teeth	Size 20/04(SG1)	Size 25/04(SG1)	Size 30/04(SG1)	Size 35/04(SG1)	Size 40/04(SG1)
8	35	7	7	7	7	7
9	35	7	7	7	7	7
24	35	7	7	7	7	7
25	35	7	7	7	7	7

Table 1: Experimental teeth grouping.

*SG: Subgroup (Preparation group based on size of apical preparation)

During the procedures, the following measurements were recorded for statistical analysis.

- *First File to Bind (FFTB):* is the initial file that gives a tight sensation at the working length of a root canal system. It may provide canal size information.

- *Working Length:* This is defined as the apical constriction of the tooth; the point where the canal constricts before it exits the root end and where the root canal filling should ideally terminate.
- *Root length:* is the actual root measured externally from the anatomical apex to the cementoenamel junction (CEJ).
- *Extruder Distance:* This is the distance of the tip of the extruder tip (Calamus DUAL® obturation system unit) from the working length of the tooth.
- *File Size Group:* These are the predesignated instrument sizes used to clean and shape the canals to working length.

Canal Preparation

The preparation sizes used were based on a 4 percent taper of rotary files that ranged from a size 20mm through 40mm (20/04, 25/04, 30/04, 35/04, 40/04 Vortex®, Dentsply - Tulsa Dental Specialties). With a shift toward minimally invasive endodontics, the aim of this study was to keep preparation sizes as small as possible. The goal of minimally invasive endodontics is not only effective endodontics that reduce the microbial load of the offending tooth, but also the conservation of natural tooth structure to promote long term retention. Preparations and obturations were performed by a second year endodontic resident to ensure consistency.

Figure 12: 4% tapered NiTi rotary files by Vortex®, Dentsply - Tulsa Dental Specialties
From left to right: size 20, 25, 30, 35, & 40.

Figure 13: Vortex® rotary files, Dentsply - Tulsa Dental Specialties. Packaging of sizes used (20-40)

After acceptable straight line access, canals were prepared according to their respective subgroup. The patency of the apical foramen was tested using a #10 K-file. Working length was determined by placing a #15 K file until it was visible slightly out of the apex and subtracting 1mm

from this length. Patency was maintained by using the #10K-file at working length in between instruments.

Figure 14: Obtaining working length (WL) with a #15 K-File that is barely visible out of the apex.

After obtaining working length, progressively larger files were inserted at working length in order to evaluate the “tightness” of the canal. The first file to bind with the canal walls was determined for each group (FFTB) at this point. After determination of the FFTB, a glide path equal to a size #20 K-file or larger was made by hand filing. (Glide Path is a smooth and reproducible path from the canal orifice to its apex that makes passage of larger rotary files possible). The canals were shaped according to their respective groups using NiTi rotary instrumentations in a crown down manner using copious 2.5% NaOCl irrigation (using manufactures recommended settings and starting with a 40/04 and ending with the respected size group) with a #30 gauge side vented needle (Prorinse®, Dentsply - Tulsa Dental Specialties).

Figure 15: Rotary file size 20/04 placed to working length after appropriate glide path was obtained.

During rotary instrumentation a small #10 K-file was used at working length to ensure patency of the canal. The dentinal smear layer was removed with 17% EDTA (Ethylenediaminetetraacetic Acid) and a 2.5% NaOCL (Sodium Hypochlorite) irrigation with a 30 gauge needle. A final rinse was done with 70% alcohol.

Figure 16: 30 gauge side vented needle used for irrigation (Prorinse®, Dentsply - Tulsa Dental Specialties).

Figure 17: Various irrigants used during cleaning/shaping of the canals.

Canals were dried with paper points to the working length until no moisture was seen with a microscope on the paper point tip. At this point the canals were considered dry and ready for obturation.

Figure 18: Color coded paper points according to preparation size.

Figure 19: Paper point drying a canal on the left, size 20/04. Right image shows the dried canal under magnification.

Figure 20: Various handfiles used

Figure 21: Electric motor for rotary instrumentation

Canal Obturation

According to a Yelton et al: "Theoretically, when injecting GP from a needle, a wider canal preparation might facilitate needle placement further into the canal, yielding better lateral canal wall replication at the apical aspect of the preparation. However, the shape and width of the prepared canal may also affect apical GP extrusion"³⁰. This is a key concept in fluid mechanics and may apply to gutta percha that flows with in the canal. To initiate obturation, a thin layer of Roth's root canal cement was placed with in the canal using the last rotary file used in a counterclockwise hand filing motion with light apical pressure. This ensures adequate delivery of sealer. The stopper was set 1mm shy of working length to ensure no sealer was placed beyond root confines. Excess sealer was wicked out with paper points allowing for minimal amounts to facilitate the flow of gutta percha. This was verified using the dental operating microscope. Not only does the sealer facilitate the flow, but its also provides better seal of the gutta percha to the root canal wall.

Figure 22: Canal system with minimal sealer applied.

Thermoplastic obturation was carried out with an obturation unit that had a down packing heat source and gutta percha extruder (Calamus DUAL[®] obturation system, Dentsply - Tulsa Dental

Specialties) by holding the injection tip of the extruder 3-5 mm away from the working length. The tips of the extruder come in different diameters, but for this study the smallest one was chosen (#25 gauge; which has an outer diameter of roughly 0.5mm). It was ensured that the needle tip does not bind with in the canal. Once in position, the gutta percha was expressed from the tip until the operator felt backpressure on the extruder tip. After feeling the backpressure, the apical gutta percha was condensed using the appropriate size plugger with light condensation force. Compaction was terminated once a degree of resistance was encountered.

Figure 23: Left: Calamus DUAL® obturation system, Dentsply - Tulsa Dental Specialties. Right: extruder tip in place and ready for obturation.

Figure 24: Left: Electric heat pluggers sizes small (black), medium (yellow), large (blue). Right: Pluggers; Dovgan (green/white) and standard 5/7

Once the apical portion was obturated and condensed, the remainder of the canal was obturated using the same extruder tip in one step. The remainder of the canal was not filled in multiple increments since the presence of extrusion is related to the obturation of the apical portion.

Figure 25: Current armamentarium for endodontic procedures currently used at WVU SOD, department of endodontics.

Evaluation of Obturation

After obturation, the root ends were evaluated using the dental operating microscope for the presence or absence of gutta percha. Using the 6.4x-magnification setting of the dental operating microscope (Global® – Global Surgical Corporation), any sign of gutta percha extending beyond the apex was considered as extrusion. The presence of sealer out of the root confines was not considered as extrusion, since sealer will be resorbed by the body's immune system. If doubt

existed about gutta percha extrusion, the root end was washed with saline and examined by two operators on what material has been extruded. These binary results were recorded in a spreadsheet in order to perform statistical analysis. A logistic regression with backward selection was utilized to determine the most predictive factors using SAS 9.3 (SAS Institute, Inc., Cary, NC).

Figure 26: Teeth showing obturated canals with overextension of gutta percha from various angles.

Figure 27: Radiograph of an obturated incisors demonstrating overextension of the gutta percha by 2mm.

Figure 28: Picture and radiograph of properly obturated tooth without extrusion.

Chapter 4

Results

Percentage of Extrusion

Table 2 shows all gathered data. These data were recorded in a spreadsheet.

	File Size Group					Overall
	20	25	30	35	40	
N (%)						
Extrusion	9 (32%)	6 (22%)	3 (11%)	4 (14%)	6 (21%)	28 (20%)
Mean (Std)						
FFTB	22.1 (4.99)	25.5 (8.85)	23.8 (7.15)	26.8 (6.27)	27.9 (9.85)	25.2 (7.79)
Extruder Distance from WL	4.3 (0.69)	4.2 (0.51)	3.9 (0.42)	3.6 (0.77)	3.8 (0.66)	4.0 (0.67)
Root Length	13.8 (1.45)	13.7 (2.00)	13.0 (1.60)	13.1 (1.77)	13.0 (1.69)	13.3 (1.73)
WL	12.7 (1.54)	12.6 (3.04)	11.8 (1.54)	11.9 (1.82)	11.8 (1.67)	12.2 (1.75)

Table 2: Results of extrusion, mean, averages and standard deviations for variables in study.

Calculation Methods (Statistical Analysis)

To determine which clinical factors are related to extrusion rate (or probability of extrusion), a logistic regression with backward selection was utilized to determine the most predictive factors, after adjusting for tooth number. Two-way interaction terms of all factors were included in the analysis, with a model inclusion cut-point of 0.1. All statistical analyses were performed in SAS 9.3 (SAS Institute, Inc., Cary, NC).

Results

After backward selection, the final logistic regression model included FFTB, file size group and the interaction between these two variables, while adjustments are made to block the variability of tooth number. This means that the other variable (extruder distance from WL) did not add any additional information to our understanding of extrusion probability beyond FFTB and file

size group. Since the statistical interaction between FFTB and file size group is statistically significant, all interpretations of the model were conducted jointly. These interpretations are as follows:

- First, we hold final size group constant and change the FFTB

Final Size Group	OR (CI) for each increase in FFTB
20	2.7 (1.3, 5.7)
25	3.9 (2.1, 7.5)
30	5.7 (2.8, 11.7)
35	8.3 (3.3, 21.1)
40	12.2 (3.6, 40.8)

Table 3: Odds Ratio for holding size group constant and changing the first file to bind

Interpretation of above table:

- When preparing a canal to a size of 20/04, the odds of extrusion increase by 2.7 fold (170%) for each additional increase in FFTB.
- When preparing a canal to a size of 25/04, the odds of extrusion increase by 3.9 fold (290%) for each additional increase in FFTB, and so forth.
- These odds ratios are presented in the following figure:

Figure 29: Odds ratio vs file size group

Figure 30: Schematics show two root canals with same size of apical constriction, but the right side one has a larger major foramen. The larger foramen leads to higher chance of extrusion.

- Now, we hold FFTB constant and vary file size used; however, since increase file size decreases odds of extrusion the results are presented in two different manners.

FFTB	OR (CI) for each increase in Final File Size Used	OR (CI) for each decrease in File Size Used
20	0.18 (0.07, 0.47)	5.6 (2.1, 14.6)
25	0.26 (0.13, 0.53)	3.8 (1.9, 7.8)
30	0.38 (0.21, 0.68)	2.6 (1.5, 4.7)
35	0.56 (0.29, 1.06)	1.8 (0.9, 3.4)
40	0.81 (0.34, 1.93)	1.2 (0.5, 2.9)

Table 4: Odds Ratio for holding first file to bind constant and changing file size group.

Interpretation of above table:

- When the FFTB is 20, the odds of extrusion decrease 82% ($1 - 0.18 \times 100\%$) for each additional increase in final file size used (say from 25 to 30, 30 to 35, etc.)
 - Or put differently, we can say when the FFTB is 20, the odds of extrusion increase 460% for each decrease in file size used (from 35 to 30, 30 to 25, etc.)
- When the FFTB is 25, the odds of extrusion decrease by 74% for each additional increase in the file size used.
 - Or put differently, we can say the FFTB is 25, the odds of extrusion increase 280% for each decrease in file size used (from 35 to 30, 30 to 25, etc.)
- This can be interpreted for all other sizes.
- These odds ratios are presented in the following figure:

Figure 31: Odds ratio vs increase file size group

Figure 32: Odds ratio vs decrease file size group

Figure 33: Schematics show two root canals with same size of foramen, but different preparation sizes. The left one is smaller and more parallel. The right one is larger and has an apical stop that prevents extrusion.

- Another way to interpret this model is with regards to the predicted probabilities of extrusion, presented in the below plot

Figure 34: Extrusion vs FFTB at working length

Discussion

This study was designed to see if there would be a difference in extrusion rates when standardized root canal preparations with different apical preparation sizes were obturated using the thermoplasticized technique. It was discovered that larger preparation sizes showed less extrusion rate, given the first file to bind of the canal was kept constant. Initially, this is counter intuitive, but other factors that aid the material flow through the canal system must be considered. These include the taper, depth of the extruder tip, apical preparation size, and original foramen size

(as estimated by the FFTB). Other factors, such as, resistance of the periodontal ligament beyond the apex would play a crucial role in resistance of extrusion as well, but it was not included in this in vitro study. This study may have higher extrusion rates, since no external source of resistance is present. This in vitro setting may clinically better mimic teeth that have large radiolucencies around their apex and are devoid of periodontal ligament. The average size for the FFTB for most the teeth were about a size # 25 K-file. The teeth prepared to this size or smaller with a 4% taper rotary had more extrusion rates. As the preparation size increased, a platform (apical stop) was created and gave the apex slight resistance to the flow of the warm gutta percha.

In a previous study by Ritchie et al, it was shown that a 0.40mm foramen had more extrusion of gutta percha than a 0.20mm foramen ³¹ . Although this sounds like the opposite of the findings of this study, the methodology should be taken into high consideration. In their study, where they used plastic blocks, the apical openings of the teeth were prepared to a size 20 and 40. In this study the apical opening was assessed as the first file to bind and care was taken not to enlarge the major foramen. Ritchie et al went on to prepare the minor constriction to a size of 35 and 60 respectively for each group. They also did not take into account the first file to bind, as it may be of great benefit to know the size of the apical foramen before enlarging an apical stop 1.0mm shy of it. Ritchie and his group did not employ the use of rotary instrumentation and relied on hand instruments and gates glidden instruments.

In a similar study that incorporated human maxillary central incisors, Walker et al. found that at 0.5 mm from the major foramen with a size 30mm and 6% taper had no extrusion, but with a size 50mm and 6% taper showed extrusion. Their study similarly, employed rotary

instrumentation, but used a 6% taper instead of a 4%. Larger taper can lead to improved gutta percha flow based on simple fluid mechanics, which is illustrated below.

Figure 35: Fluid movement through a nonuniform pipe.

In a study by George et al, it was found that only one case had apical extrusion when prepared with a similar method to this study. Their study was significant in the fact that they tested for an adequate apical barrier, making sure the apex was not shaped out of proportion or had its original shape altered. They discarded the teeth without an adequate apical barrier. Their preparation technique, although not measuring the FFTB, was significant in that the final apical size was 3 sizes larger than their FFTB giving some justification to the size of the canal. They used dental stone and wax as resistance at the end of the tooth (periodontal ligament simulation), but they

employed hand files and gates glidden burs for preparation as rotary instrumentations with better tapered preparations were not as readily available during their study time.

According to Al-Dewani et al, low temperature thermoplasticized gutta percha has significantly more apical extrusion compared to cold lateral compaction. Cold lateral compaction has excellent length control and many studies have been compared to it. This study did not compare its obturation quality to that of cold lateral, because that has been well established over time. Rather, the focus of this study was to see if there was a trend of extrusion rates with different preparation sizes based on diameter and other variables. In Al-Dewani's group, their methodology when preparing the canals was to use a lightspeed instrument. Lightspeed instruments have parallel preparations compared to commonly used rotaries. In having parallel preparations, the operator must keep in mind that when extruding gutta percha, if the instrument tip is bound in the parallel canal it will push out the apex easier as the canal essentially becomes an extension of the extruder tip.

The results of this study showed that when the first file to bind is kept constant and the extruder distance from the apex is kept constant as well, there is less chance for apical extrusion as preparation sizes increase. During the shaping of the canal, the operator is essentially creating a platform inside the canal at the working length. This platform creates a stop-like matrix that prevents solid core materials from going out the apex and also an area to compact them against. In a closed cylindrical type system, this platform acts a step from where the molten gutta percha passes through, but does not penetrate the major foramen that was measured in terms of the first file to bind. Clinically, by knowing the size of the first file to bind, the operator can chose a

preparation size that would have lower chance of extruding gutta percha during a thermoplastic obturation technique. This can eliminate potential negative outcomes during treatment.

Given project time and resources, 80% power with 30 teeth per file size group to detect extrusion was achieved. This overall size group was significant in that the sample size was large enough to have meaningful results in order to make strong conclusions. Operator calibration and quality of the treated work was evenly controlled since all the work was performed by an endodontic resident. All the work was performed meticulously and systematically for each tooth group. The use of the dental operating microscope was utilized in all steps and high magnification pictures were taken along with appropriate radiographs.

Due to time constraints, the study design was slightly simplified to allow proper time for completion of the project. In future studies, it would be helpful to measure the amount of extruded material as a function of volume. Also encompassing the apex of the root in wax like material and embed them in stone would mimic the periodontal ligament and periapical tissues better. Teeth with straight root canals were chosen as they would facilitate more flow of material versus a canal that has curvature. In future studies curved canals may also be assessed to evaluate effects of curvature on the flow of gutta percha. All these results together may provide useful tips to properly and safely thermoplastically obturate canals with gutta percha.

Chapter 5

Conclusions

The results indicated that the first file to bind and file size group play a more significant role than extruder distance. While keeping the file size group constant, if the first file to bind were to increase, an increase in the rate of extrusion would be seen. Clinically, with an increasing

differences between the original canal size and final preparation, the chance for extrusion decreases. This is logical clinically, because as a larger difference between the two values is established, a larger apical stop is created (platform). This apical stop is a potential barrier that impedes obturation materials from extruding beyond the confines of the root. In fluid mechanics, the no slip condition refers to the fact that viscous fluids will have zero velocity at the solid boundary they contact. Fluids traveling in the center of the stream will have the highest velocity compared to the others based on a parabolic function as shown below.

Figure 36: Non slip condition. Velocity of the fluid is zero at the walls and the maximum velocity is at the center of the stream (middle of conduit/canal)

It can be concluded that as the apical stop size increases and a better platform is created, the extrusion rates decrease. Studies that examine the experimental conditions that mimic the presence of PDL around the root apex are needed. Also, volumetric studies that measure the amount of apical extruded material can have meaningful results.

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Acknowledgement Letter Not Human Subject Research NHSR

To Pejman Parsa
From WVU Office of Research Integrity and Compliance
Approval Period 06/02/2014 **Expiration Date** 06/01/2019
Subject **Not Human Subject Research Acknowledgment**
Protocol Number 1406315785
Title Squirt Technique Analysis using Thermoplasticized Gutta Percha

Thank you for your submission to the West Virginia University Institutional Review Board IRB.

It has been determined that your project does not meet the definition of human subject research for the following reasons

- In order to be considered human subject research individually identifiable private information must be obtained or used in the research. If there is no individually identifiable private information involved the project is not human subject research and does not require being submitted to the Office of Research Integrity Compliance. Private information must be individually identifiable i.e. the identity of the subject is or may be readily ascertained by the investigator or someone else associated with the information in order to constitute research involving human subjects.
- Research means a systematic investigation designed to develop or contribute to generalizable knowledge. Most case reports and most oral histories are not generalizable and therefore not research. Many classroom projects if not intended to be published are also not considered research. Many quality improvement or program evaluation studies are not research.

If you have any questions, please contact the IRB at 304 293 7073.

Thank you.

A handwritten signature in black ink, appearing to read 'Lilo Ast'.

Board Designee Lilo Ast

Letter Sent By Lilo Ast on 06/02/2014 at 18:29:11-04:00