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UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES
POSTGRADUATE DENTAL COLLEGE
NAVAL POSTGRADUATE DENTAL SCHOOL
8955 WOOD ROAD
BETHESDA, MARYLAND 20889

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Name of Candidate: Andrew D. Henning
Master of Science Degree
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Nicholas J. Hamlin
ASSOCIATE DEAN, NAVAL POSTGRADUATE DENTAL SCHOOL
Committee Chairperson

HINMAN.SUSAN.ELIZABETH.1261278240 Digitally signed by HINMAN.SUSAN.ELIZABETH.1261278240 Date: 2022.06.06 09:12:52 -04'00' 6/6/22

Susan E. Hinman
PROGRAM DIRECTOR, ENDODONTICS DEPARTMENT, NAVAL POSTGRADUATE DENTAL SCHOOL
Committee Member

OSBORNE.NANCY.1167256305 Digitally signed by OSBORNE.NANCY.1167256305 Date: 2022.06.02 12:14:52 -04'00' 6/2/22

Nancy Osborne
CHAIRMAN, ENDODONTICS DEPARTMENT, NAVAL POSTGRADUATE DENTAL SCHOOL
Committee Member

IMPACT OF REPEATED ACTIVATION ON HEAT OUTPUT OF ELECTRIC PLUGGERS

by

Andrew D. Henning
Lieutenant Commander, Dental Corps
United States Navy

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ABSTRACT

Impact of Repeated Activation on Heat Output of Electric Pluggers

Andrew D. Henning, D.M.D., 2022

Thesis directed by CAPT Nancy Osborne
Chairman, Endodontics Department
Naval Postgraduate Dental School

Introduction: Electric pluggers that output repeatable and reliable heat are required to thermoplasticize gutta percha for endodontic obturation. The purpose of this study was to evaluate the accuracy and reliability of heat output by Buchanan electronic pluggers after repeated activation cycles. **Methods**: The Elements Obturation Unit (Kerr Endodontics) was operated in "downpack" mode according to the manufacturer's recommendations with a temperature of 200°C and automatic cutoff after four seconds of continuous activation. Fifteen Buchanan Heat Pluggers (Kerr Endodontics) were tested, five of each of the following sizes: Extra Fine (XF:30/.04), Fine (F:55/.06), and Fine Medium (FM:55/.08). Pluggers were allowed to cool for 5-10 seconds between activations, and were activated 25 times per day for 80 days. There were a total of 2,000 activations per plugger. A thermocouple secured in a custom-made jig, and an electronic data logger (Omega Engineering Inc.) were used to record a single peak temperature for each plugger at the final activation of each day. **Results**: There was no significant change in heat generation across 2,000 activations for any of the plugger sizes. Size XF (0.04) pluggers output heat at a significantly lower temperature compared to the F (0.06) and FM (0.08)

pluggers. Three of the five XF pluggers lost functionality before reaching 2,000 activations. **Conclusions:** Buchanan Heat Pluggers in sizes F (0.06) and FM (0.08) can reliably output heat at a level appropriate to thermoplasticize gutta percha for up to 2,000 activations. Size XF (0.04) pluggers may be prone to lower temperature output than larger plugger sizes.

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LIST OF ABBREVIATONS

ANOVA	Analysis of Variance
°C	Degrees Celsius
XF	Extra Fine (plugger size (30/0.04)
F	Fine (plugger size (55/0.06)
MF	Medium Fine (plugger size 55/0.08)
mm	millimeters

CHAPTER 1: Introduction

Gutta percha is the most commonly used material for obturating the root canal system in non-surgical treatment. [1] It is a naturally occurring polymer that exists in two crystalline forms known as “alpha” and “beta”. The α form is soft, pliable, and compactable whereas the β form is solid. Commercially available gutta percha is usually in the β form which, when heated above 56-62º C, melts into a compactible, amorphous solid. [2, 3]

The warm vertical compaction technique as described by Schilder takes advantage of the phase changes of gutta percha by using a heated plugger to thermoplasticize the material which can then be compacted into the intricacies of the root canal system. [4] In modern endodontics, gutta percha is most commonly heated within the root canal with an electric heat plugger. These instruments come in various sizes to match common canal preparation sizes and can be set to a specific temperature by the operator.

The repeatable and reliable delivery of heat via electric plugger is of critical importance to both patient safety and clinical efficiency. It has been shown that a temperature increase above 47º C for greater than 1 minute can cause bone necrosis and that this temperature can be exceeded by electric heat pluggers. [5, 6, 7] Condensation of warm gutta percha requires a minimum temperature of 53-59º C which can be difficult to achieve in the most apical extent of a canal. [2, 8, 9] Other studies have demonstrated that electric heat pluggers may not reach their stated temperatures. [10-13] In addition to these factors, gutta percha can vary in its thermal conductivity potentially resulting in insufficient plasticization and an inadequate seal of the root canal system. [11, 14, 15] A lack

of reliability by electric heat pluggers reduces clinical efficiency and could negatively impact the safe and effective obturation of the root canal system.

With repeated use, over time accuracy and consistency of heat delivery of electric pluggers may be reduced. A recent study by Correa et al. demonstrated a reduction in the lifespan of pluggers and an increase in malfunctions with repeated autoclave cycles and/or use at high temperature settings. [16] However, a PubMed search revealed no studies evaluating the lifespan of electric pluggers after repeated activations independent of autoclave sterilization. The purpose of this study is to evaluate the accuracy and reliability of electric heat pluggers after repeated activation cycles independent of autoclave cycling.

CHAPTER 2: Materials and Methods

Materials and methods adapted from previous study completed by Dr. Anthony Fioretti [17]

Fifteen Buchanan Heat pluggers (Kerr Endodontics, Orange, CA) were used in this study. Five of each of the commonly used sizes Extra Fine (XF: 30/0.04), Fine (F: 55/0.06), and Fine Medium (FM 55/0.08) were used in combination with the corded Elements Obturation Unit (Kerr Endodontics, Orange, CA) to eliminate the variable of battery charging and the impact that could have on heat output.

A 3D printed custom jig with indented channels was fabricated with high temperature resin to allow for secure and repeatable placement of pluggers ensuring intimate contact between the plugger tip and a K-Type Thermocouple (Omega Engineering Inc, Stamford, CT). [18] Collected data was exported to a spreadsheet and maximum data points were recorded.

The preset "downpack" mode of the Elements unit with 200° C setting and 4 second automatic cutoff was used. Each plugger was tested individually and the maximum temperature output over was recorded. Five to ten seconds was given between activations to allow for cooling of the tip and to more closely replicate clinical use.

On day 1, activation 1, a baseline temperature was recorded. 24 additional activations were completed and a second temperature was recorded. Each subsequent day, 25 activations were completed with a temperature recorded on the 25th activation. This was repeated over 80 days until 2,000 total activations were completed. All measurements were taken at room temperature (20º C ± 2º C).

One-way analysis of variance (ANOVA) and Kruskal Wallis tests were performed to assess statistical significance and the Tukey Post Hoc multiple comparison test was performed to compare the heat output between the three different plugger sizes. [17]

CHAPTER 3: Results

The data showed mean heat output over time did not significantly decrease for all pluggers that functioned to 2,000 activations. The functioning XF (0.04) pluggers produced an initial mean temperature of 115.5° C, a maximum mean temperature of 176.2° C on day 10 after 250 activations, and a final mean temperature of 144.5° C after 2,000 activations. The F (0.06) pluggers produced an initial mean temperature of 171.6° C, a maximum mean temperature of 236.6° C on day 51 after 1275 activations, and a final mean temperature of 181.2° C. The FM (0.08) pluggers output an initial mean temperature of 160.7° C, a maximum mean temperature of 244.4° C on day 11 after 275 activations, and a final mean temperature of 177.3° C.

The overall mean temperature output for F (0.06) and FM (0.08) pluggers was 193.85 ± 19.33˚ C and 196.87 ± 20.51˚ C, respectively. The XF (0.04) pluggers produced a mean temperature of 134.00 ± 18.41˚ C.

One-way analysis of variance (ANOVA) and the Kruskal Wallis statistical test procedures both confirmed statistically significant differences in mean heat output of the three different plugger sizes ($p < 0.005$). The Tukey post hoc multiple comparison test indicated that there were no statistically significant differences between the F (0.06) and the FM (0.08) pluggers ($p = 0.583$). However, the XF (0.04) pluggers produced significantly lower heat output than both the F (0.06) and FM (0.08) pluggers. ($p < 0.005$).

In addition to lower mean heat output, three of the five XF (0.04) pluggers lost functionality before reaching 2,000 activations (Figure 3). The Elements Obturation unit

produced the “Check Tip Indicator” error indicator for XF (0.04) pluggers 5, 4 and 1 after 238, 313 and 421 activations, respectively; these pluggers remained non-functional through the remaining duration of the study.

CHAPTER 4: Discussion

The results of this study demonstrate that electric pluggers generally output heat at a level sufficient to thermoplasticize gutta percha over 2,000 activations in a benchtop setting. Statistical analysis revealed a significant difference between XF (0.04) taper pluggers and the larger sizes as well as a general variability across all tapers, however all functioning pluggers produced adequate heat to thermoplasticize gutta percha at the plugger tip. A prior study by Smith et al. demonstrated that heat transfer through gutta percha within a canal will only be effective 2-3mm beyond the tip of the instrument using size Medium (0.10) taper pluggers set at 200˚ C. [9] Given the results of this study, future research evaluating smaller XF (0.04) taper pluggers and their ability to adequately thermoplasticize gutta percha in a clinical setting 2-3mm beyond the plugger tip is needed.

Previous studies have shown that repeated sterilization of pluggers and operation of pluggers above manufacturer recommended temperatures may result in a reduction in heat output. [16, 19] Our findings with these variables controlled demonstrated the heat output of pluggers that maintained functionality was not significantly decreased after 2,000 activations. However, size XF (0.04) taper pluggers may be more susceptible to failure over time. Repeated activation at the manufacturer recommended settings without autoclaving, bending, or manipulation of the pluggers rendered three out of five XF (0.04) pluggers non-functional after only a few weeks of simulated clinical operation. When a non-functional plugger was inserted into the handpiece, the Elements unit emitted an error sound and displayed the “Check Indicator Tip” warning. According to

the troubleshooting section within the Owner's Manual, the Elements unit uses an electrical sensor to determine if a plugger is connected and will display these faults if an "incorrect" or "worn out" plugger is inserted. [20] Within the parameters of this study, repeated activation did not seem to negatively affect the service life of the F (0.06) and FM (0.08) pluggers. Given the limited number of each plugger size used, further studies are needed to gain a greater understanding of the failure rate of these pluggers. Additionally, combining controlled activations with autoclave cycles and manipulation or bending of pluggers may also contribute to a reduction in service life of these plugger tips.

The variability in heat output that was observed throughout this study was not of significant magnitude where the safety of the obturation unit and/or pluggers would be impacted. The risk of tissue necrosis is mitigated by the 4 second activation limit of the "downpack" mode and the variability in plugger temperatures identified in this study were within a range that does not pose a risk for irreversible tissue damage. [5, 21]

CHAPTER 5: Conclusions

Buchanan Heat Pluggers in size F (55/0.06) and FM (55/0.08) produce heat at a sufficient level to thermoplasticize gutta percha safely and reliably for up to 2,000 activations. The XF (30/0.04) pluggers may be susceptible to reduced heat generation that is still sufficient to thermoplasticize gutta percha at the level of the instrument, however further studies are needed to determine if this temperature is sufficient to thermoplasticize gutta percha 2-3 mm beyond the tip of the instrument in clinical operation.

Table 1. Descriptive Statistics after 2,000 activations. n= 41 each.

Plugger Size	Mean °C	Std Dev
0.04	134.00	18.41
0.06	193.85	19.33
0.08	196.87	20.51

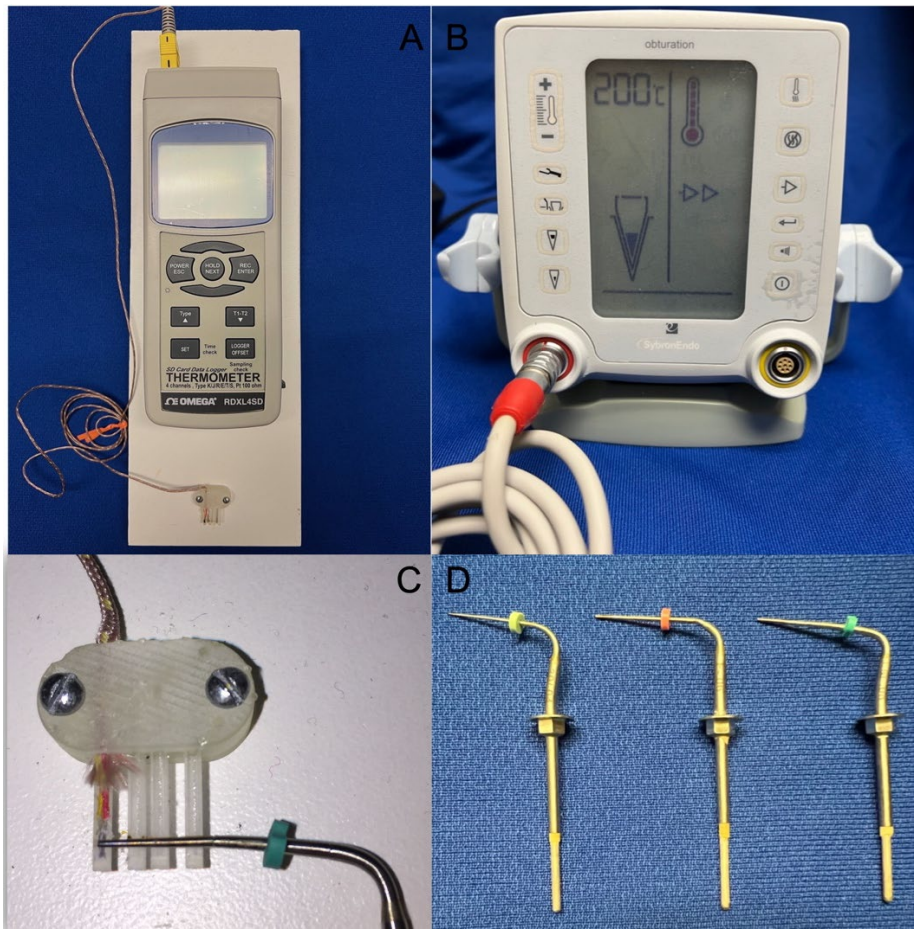

Figure 1. Experimental Setup

(A) 4-Channel RDXL-SD Series portable thermometer/data logger and K-Type thermocouple. (B) Elements Obturation Unit. (C) 3D printed custom jig with indented channels. (D) Buchanan Heat Pluggers (from left to right: XF, F, FM)

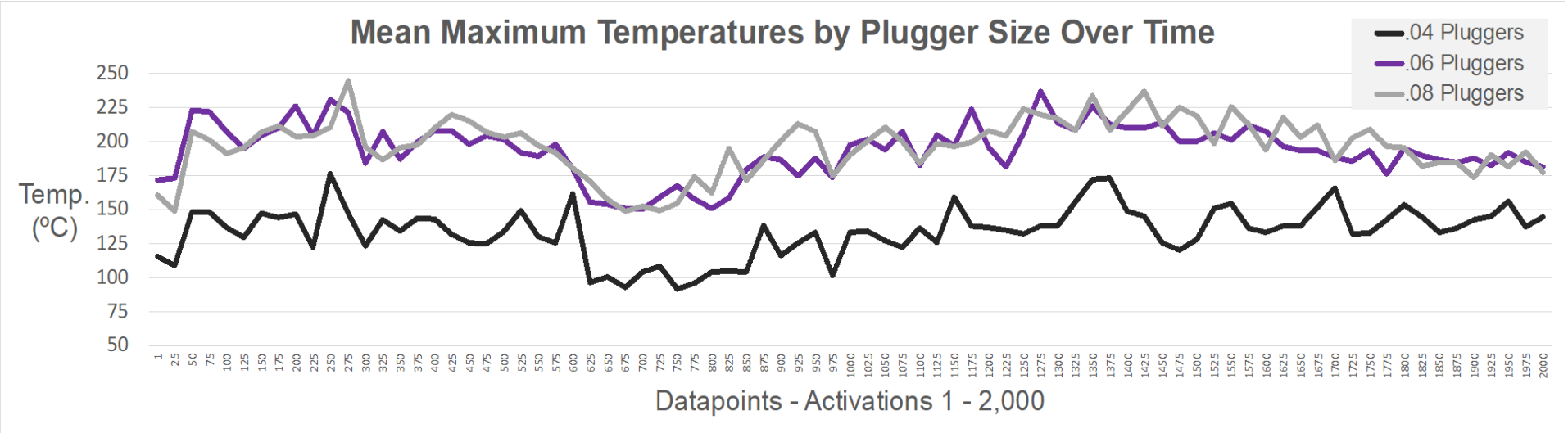

Figure 2. Mean maximum temperature output by plugger size over 2,000 activations. The purple and grey lines represent the larger Fine and Fine-Medium pluggers with mean heat output of 193.85°C (F) and 196.87°C (FM). The black line represents the Extra-Fine pluggers at a consistently lower temperature with a mean output of 134.00°C (XF).

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