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Research Article

Analysis of Wireless Obturation Units for Endodontic Purposes

M. Austin White DDS[1], Charles E. Taylor PhD[1], George H. Arch, Jr., DDS[1], David Rainwater B.S[1], Albert F. McMullen III DDS[1]*

[1]Department of Endodontics, Louisiana State University Health Sciences Center (LSUHSC), USA.

[2]Professor, Cell Biology and Anatomy Coordinator for Student Research, Louisiana State University Health Sciences Center (LSUHSC), USA.

***Corresponding Author**: M. Austin White, DDS, Department of Endodontics, Louisiana State University School of Dentistry, New Orleans, LA, USA.

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Abstract

Introduction: The objectives of endodontic therapy are to eliminate bacteria in the root canal system and obturate the prepared canal system in three dimensions. The objective of this study was to compare obturation units for (a) the rate of heating and (b) peak temperature reached.

Methods: Seven configurations were examined: B&L-Alpha II Down-pack; B&L-Beta Mini Backfill; Elements-IC Down-pack and Backfill; and Woodpecker Fi-P Down-pack, Fi-G Backfill, and Fi-E Backfill. The experimental system was comprised of a thermocouple (Omega, 5TC-TT-K-40-36), MCP9600 thermocouple EMF converter (SparkFun, SEN-16295), and an ESP32 microcontroller to capture the data (SparkFun, DEV-22924). A python notebook was used to process the saved data and perform statistical analysis using the SciPy statistical method libraries. One-way ANOVA and Tukey HSD(Honestly Significant Difference) were used to test for statistical differences.

Results: One-way ANOVA on the down-pack and backfill units' data showed significant differences. According to the Tukey HSD findings, there were no significant differences in the Woodpecker Backfill products for both max temperature and rate of heating. The max temperature showed strong similarity ($p=0.969$), while the rate of heating showed a weaker significance ($p=0.073$) but was still above threshold. All other backfill units performed statistically differently. The down-pack units all performed statistically different in both max temperature and rate of heating, except for the Elements IC and Woodpecker Fi-P units with respect to the rate of heating ($p>0.05$).

Conclusions: Statistically different performance among the seven obturation groups was observed when investigating rise to temperature time and setpoint temperature.

All materials were LSUHSC-owned equipment, donated, or purchased with internal funds.

Keywords: *Kerr, Woodpecker, B&L Biotech, Obturation Systems*

Introduction

During endodontic treatment, one of the main objectives is to eliminate and prevent the bacteria that cause pulpitis and apical periodontitis. Proper instrumentation, disinfection, and obturation of the root-canal system in three dimensions allows the best prognosis of treatment[1]. Two popular obturation techniques are: cold lateral compaction and warm vertical compaction of gutta-percha, both with sealer [1-4].

In the past, to properly perform the warm vertical technique, clinicians used metal condensers and a flame or corded obturation units to properly heat and condense the gutta-percha. As technology has advanced, companies such as Kerr, B&L Biotech, and Woodpecker have created wireless obturation units. These units make endodontic obturation more efficient and ergonomic to the operator.

A previous study, based on an outdated Kerr wireless obturation unit (Elements Free), evaluated the heat distribution and changes in temperatures to the surfaces of the teeth[5], but currently there is no literature describing how effective and accurate each system is to the specifications listed by each company.

One downfall of the warm vertical compaction technique, using any heated obturation down-pack and back-fill unit, would be overheating of the tooth and how this overheating affects the surrounding periodontal ligament and alveolar bone[6,7]. If the units used for obturation are improperly heating, compared to the outputs they are reporting, each unit can cause irreversible damage[8]. Gluskin reports that a 10°C increase in the temperature of the periodontal ligament and alveolar bone, surrounding a tooth can produce bone and attachment damage as well as dehydrate the dentin. This often leads to resorption and necrosis[9]. If the units cannot hold a set temperature for a proper length of time, the gutta-percha would harden prematurely and not allow adequate compaction in three dimensions[1]. The capability of these various obturation units may directly correlate with the prognosis of endodontic treatment.

Materials and Methods

Seven configurations were examined: B&L-Alpha II Down-pack; B&L-Beta Mini Backfill; Elements-IC Backfill and Down-pack; and Woodpecker Fi-P Down-pack; and Woodpecker Fi-G and Fi-E Backfill units.

Table 1. Units tested with model numbers and sizes.

Unit	Manufacturer	Model	Tip Size
Elements Ic Down-pack	Kerr	973-0602-TYPEB	Buchanan Fine (0.06 taper)
Elements Ic Back-fill	Kerr	973-0604-TYPEB	25g
Alpha II Down-pack	B&L	M-ASKW	45.04
Beta Mini Back-fill	B&L	ESKW	25g
Fi-P Down-pack	Woodpecker	Fi-P	45.05
Fi-G Back-fill	Woodpecker	Fi-G	25g
Fi-E Back-fill	Woodpecker	Fi-E	25g

The experimental system was comprised of a thermocouple (Omega, 5TC-TT-K-40-36), MCP9600 thermocouple EMF converter (SparkFun, SEN-16295), and an ESP32 microcontroller to capture the data (SparkFun, DEV-22924). The Omega K-type thermocouple was chosen for its small gauge wire (40 AWG, 0.08 mm diameter) to provide the smallest thermal mass and high thermal resistance to the probe. The MCP9600 was set to 0.0625°C temperature resolution and has an onboard cold-junction compensation; the ambient temperature reported is the onboard temperature used in that compensation. The ESP32 chip was programmed using Arduino libraries to interface with the MCP9600 chip to stream the data via Message Queuing Telemetry Transport (MQTT) using an open source borker (test.mosquitto.org) that was collected, plotted, and saved to a CSV file using a Google Collaboratory Notebook. Each product was taken through 10 heating: cooling cycles; the compensated junction temperature and cold-junction (room) temperature was recorded at a rate of 20Hz.

A Python notebook was used to process the saved data and perform statistical analysis using the SciPy statistical method libraries10. Differences were tested for each group (down-pack, backfill) using One-way ANOVA followed by a Tukey HSD to identify product-wise differences amongst these groups. Each group was tested for the heating rate and peak temperature reached. Ambient temperature was analyzed with a one-way ANOVA across all tests and a two-way ANOVA within the product type groups across all experiments. An alpha of 0.05 was used across all the statistical analyses to test for significance.

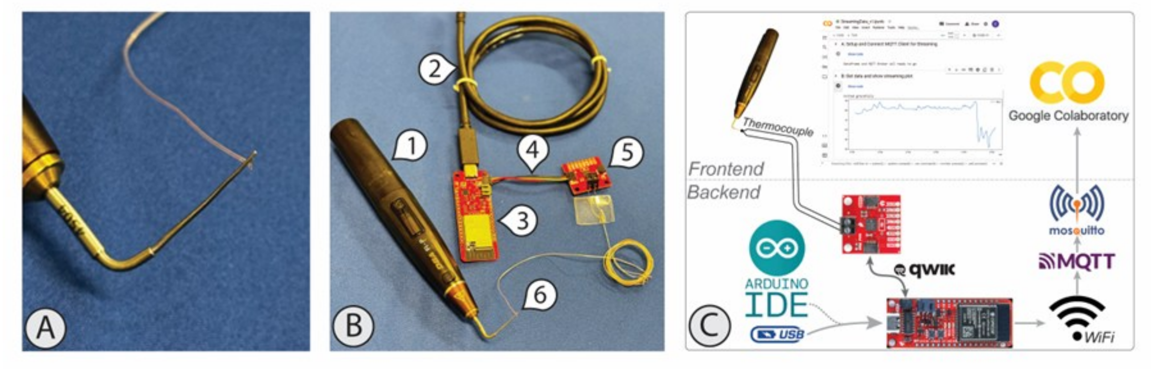

Figure 1. *Overview of experiment: showing (A) thermocouple placement on the tip; (B) layout of the hardware (1) unit being tested, (2) USB power cable, (3) ESP32 microcontroller, (4) qwiic data cable, (5) MCP9600 capture board, (6) thermocouple; (C) overview of toolchain to capture and push data to the dashboard with a delineation between the frontend (user facing) and backend.*

Results

One-way ANOVA on the backfill unit's data showed significant differences in the products, which is supported by the visualization of the waveforms. According to the Tukey HSD findings, there were no significant differences in the Woodpecker products for both maximum temperature and rate of heating. The maximum temperature showed strong similarity (p=0.969), while the rate of heating showed a weaker significance (p=0.073) but was still above threshold. All other backfill units performed statistically differently for both of those metrics.

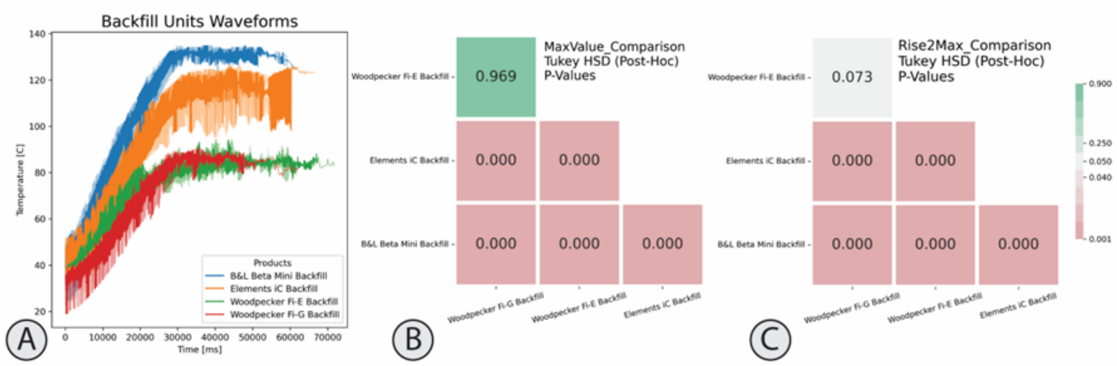

Figure 2. *Results from the Backfill unit testing: (A) median plot for each product group in bold with 95% confidence interval in background shading, (B) Tukey HSD test results for the max value test on temperature, (C) Tukey HSD test results rate of temperature change when heating.*

One-way ANOVA on the down-pack unit's data showed significant differences in the products, which is supported by the visualization of the waveforms. The down-pack units all performed statistically different in both max temperature and rate of heating, except for the Elements IC and Woodpecker Fi-P units with respect to rate of heating (p>0.05).

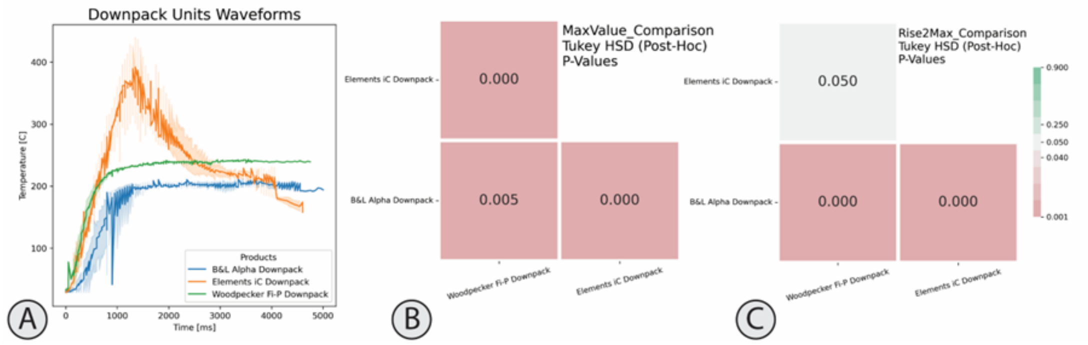

Figure 3. *Results from the Downpack unit testing: (A) median plot for each product group in bold with 95% confidence interval in background shading, (B) Tukey HSD test results for the max value test on temperature, (C) Tukey HSD test results rate of temperature change when heating.*

Analysis of the ambient temperature across all experiments found a significant difference in the room temperatures among some of the studies (p<1E-6). Further analysis showed that the Woodpecker Fi-E and Fi-G Backfill units were tested in a much colder environment; ~14.5C versus ~22.5C for the other units. A two-way ANOVA was performed to see if the room temperature affected the outcomes of max temperature and rate of heating. It was shown there was no statistically significant impact of room temperature on these study outcomes.

Discussion and Conclusion

Seven different obturation units were tested for the rate of heating and the peak temperature. It can be concluded that not all down-pack systems performed as listed by the company's specifications. Each down-pack unit was tested at 200° C but only one unit (B&L Alpha) was relatively close to this set point at approximately 200°C. The Woodpecker Fi-P was relatively close to this set point with a registered maximum temperature of approximately 230°C. The Kerr unit was, however, greater in the maximum temperature recorded, with close to 400°C registered upon heating. Based on the results of the Tukey HSDs in figure 3B and 3C, all three units tested were statistically significant with respect to each other based on both maximum temperatures generated and the rate of heating. As described prior by Hand and Lipski, improper heating can cause irreversible damage to the supporting tissues[8,11]. With the Kerr unit measuring a maximum temperature of nearly double the set temperature, it is possible that overheating could cause damage to supporting tooth structures in a clinical setting. It is important to be mindful of the heating of these down-pack tips during obturation.

Each backfill unit was set to a temperature of 180°C for testing the maximum temperature. It can be concluded based on our results that all backfill units tested did not perform to the specifications listed by the respective companies. None of the units were able to reach this 180°C set temperature at the tip of the cannula, with the B&L Beta-Mini Backfill unit having the highest temperature reached at approximately 130°C. The Elements IC Backfill unit was the second highest temperature, reached at approximately 115°C. Both Woodpecker backfill units had the lowest max temperature recorded at approximately 83°C. Tukey HSDs for both maximum temperature and rate of heating of the backfill units indicated that B&L and Kerr Backfill units were statistically different. The Tukey HSDs in figure 2B and 2C for the max temperature and rate of heating, respectively, concluded that both Woodpecker backfill units (Fi-E and Fi-G) were each significantly different in comparison to the B&L and Kerr units. However, the two Woodpecker Backfill units (Fi-E and Fi -G) showed insignificant differences in both the maximum temperatures reached and the rate of heating achieved. This lack of significant difference between the Fi-E and Fi-G units shows that both units were able to reach their respective maximum temperatures (approx. 83°C) and reach this temperature at a similar rate of heating. As discussed previously by Schilder, if obturation units cannot hold a set temperature for a proper length of time, premature hardening of the gutta-percha[12] could occur and lead to inadequate compaction in three dimensions. The set 180°C inner chamber temperature of the backfill instruments does not appear to match the backfill tip temperature based on our results which show lower unit tip temperatures for all tested tips. This observation prompts concern for the possibility of premature gutta-percha hardening occurring in canals during obturation. Further laboratory testing and numerical studies would need to be completed to accurately distinguish the heating discrepancies of these backfill units and to determine the true tip temperature reached of the units based on the set internal chamber temperature.

Further laboratory testing and analysis are needed to accurately distinguish the heating discrepancies of these backfill units and to determine the true tip temperature based on the set chamber temperature. Further testing could include using more tips from the same vendors to evaluate the variability in the tips based on the manufacturer. Other studies, replicating a clinical environment with simulated surrounding odontogenic tissues may show a response in the temperature profile of the unit tips that varies based on contact with a different external thermal mass. In this type of study, we would also want to collect the controller response of the units to maintain the unit tip temperatures in this surrounding simulated structure. A study of the long-term performance of these down-pack and backfill unit tips with repeated heating/cooling cycles could induce more variable temperature profiles over time, leading to changes in the accuracy and precision of the tips. These further possible investigations could provide a greater insight into the exact temperatures reached by the different unit tips in a clinical environment.

Acknowledgments

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Conflicts of Interest

The authors deny any conflicts of interest.

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