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Research Article

Efficiency of Removing a Novel Radiopaque Smear Layer Using Different Activation Instruments

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Abstract

Introduction: This study quantitively compared the efficiency of removing a novel radiopaque smear layer using different activation instruments.

Methods: 60 extracted human mandibular premolars with single canals were decoronated, accessed, instrumented with rotary files to the working length, and radiographed. The root canal was filled with a solution containing insoluble lead salts, in order to impregnate the smear layer, making it radiopaque. All teeth were radiographed to confirm the presence of a radiopaque smear layer. Activation of 6% NaOCl was completed using one of four techniques on 15 teeth each; (1) manual agitation, (2) EndoActivator (EA), (3) SmartLite Pro EndoActivator (SLPEA), and (4) an ultrasonic activator (UA) before taking final radiographs. Analysis of smear layer removal was performed radiographically using ImageJ for the entire canal, as well as its apical 3mm.

Results: Removal of the smear layer along the entire canal was significantly better for UA and manual agitation ($p<0.05$), 92% and 90% respectively. SLPEA was slightly better at removing smear layer (77%) than EA (71%), although this was not statistically significant. In the apical 3mm, no significant difference was observed in smear layer removal between all methods of activation.

Conclusion: Ultrasonic and manual agitation were significantly better at removing the smear layer along the entire canal than EA and SLPEA. In the apical 3mm, all irrigation techniques were equally effective at smear removal. Funding was provided by LSU Health Science Center.

Keywords: *Ultrasonic; Sonic; Activation; Radiopaque; Smear Layer*

Introduction

The main objective of endodontic treatment is to prevent and treat bacterial contamination inside of the root canal system in order to retain the tooth and its function [1]. Bacteria in the main portion of the root canal can be eliminated rather easily using instruments and solutions during the cleaning and shaping procedure. A problem lies when attempting to clear the smear layer from areas not touched by mechanical endodontic instruments. Isthmuses, lateral canals and apical ramifications are not cleaned easily.

The smear layer is a coating of bacteria and remnants of pulp tissue, odontoblastic processes, and debris from instrumentation that is packed on the walls of the canal. This smear layer can also block access to canal irregularities [2]. If thorough cleaning of the smear layer is not achieved, the contaminated areas that remain have been shown to retain the bacterial biofilm and can cause reinfection of a treated root canal [3,4]. Removal of the smear layer has also been shown to increase sealer adhesion due to dentinal tubule penetration and improve its bactericidal effects [5].

Several different solutions, such as sodium hypochlorite (NaOCl) and Ethylenediaminetetraacetic acid (EDTA) have been proven to remove the smear layer, kill microbes and dissolve tissue in the canal, thus decreasing the probability of reinfection [6,7]. Replenishing and agitating the cleaning solutions inside of the root canal, instead of just flooding it, is considered a more effective way of cleansing the canal. This promotes the exchange of fresh and active solution to reach throughout the complex anatomy of the entire root canal [2].

There are several ways that this agitation can be accomplished to increase the extent and effectiveness of the cleaning solutions [8,9]. Ultrasonic activating units utilize transmission of vibrations at a frequency of 40,000Hz from a non-cutting tip to provide two types of fluid movement: acoustic streaming and cavitation. Acoustic streaming is the rapid movement of the fluid in a vortex shape around the tip, whereas cavitation involves the expansion and contraction of microbubbles to create small shockwaves [10]. Currently, studies have determined that ultrasonic activation removes more of the smear layer than any other product [8,9]. SmartLite Pro EndoActivator (SLPEA) (Densply Sirona, Charlotte, North Carolina, USA) and its predecessor, EndoActivator (EA) (Densply Sirona, Charlotte, North Carolina, USA), use sonic technology transferred into its highly flexible polymer tips to agitate canal fluids. EA uses operating frequencies of 160, 175, and 190Hz which has been shown to lack cavitation or acoustic streaming [11]. SLPEA uses manufacturer stated frequency of 3,000-18,000 cycles per minute, which is equivalent to 50-300 Hz, and aims to provide cavitation and acoustic streaming to the irrigants. Unlike the activating units listed previously, SLPEA is a versatile product with the current abilities to not only activate irrigants, but also cure restorations and transilluminate teeth with their appropriate adapters allowing the practitioner to have an all-in-one instrument.

Evaluation and analysis of the smear layer in previous studies have been completed by a Scanning Electron Microscope (SEM) using a scoring system. There are drawbacks in using this system such as potential tooth destruction during tooth preparation, subjective nature of scoring, limited field of view of the canal wall, inability be replicated, and inability to determine smear layer thickness [12,13]. Currently there is no ideal experimental model used to evaluate the smear layer [12]. Development of a simple, replicable, quantifiable way to evaluate the smear layer is needed to allow for more accurate results.

Since the effectiveness of smear layer removal of SLPEA has not been compared to any other activation unit on the market, the aim of this study is to determine which product, SLPEA, EA, Ultrasonic activation (UA), or manual irrigation, is more effective at removing a newly developed radiopaque smear layer during root canal irrigation in the whole and apical 3mm of the root canal.

Materials and Methods

The study protocol approval (#5074) was obtained from the office of research services at the university and followed throughout research experiment.

Tooth Selection:

A total of 60 extracted mandibular premolar teeth with one canal were selected (15 per group). Bucco-lingual and mesio-distal radiographs were taken to verify the existence of only one canal. Inclusion criteria were permanent teeth, fully-developed apices, minimal restorations, and no previous root canal treatment.

Tooth Preparation:

All teeth were measured using calipers and marked at a length of 18mm. The occlusal surface of the teeth were then reduced with a flat disc diamond bur to maintain a constant working length (WL). All teeth were accessed with a highspeed round bur and the root canal orifice was expanded open with Vortex blue orifice opener (Densply Sirona, Charlotte, North Carolina, USA). Patency was determined utilizing a 10.02 K-file. Using a Global Dental Microscope (Global Surgical Corporation, St. Louis, Missouri, USA) (10x), the K-file was navigated into the canal until the tip of the file was seen at the anatomical apex to confirm patency and WL. All files were marked and all teeth were verified to maintain a WL of 17mm.

Each tooth was instrumented using Vortex Blue rotary files (Densply Sirona, Charlotte, North Carolina, USA) in sequence 20.04, 25.04, 30.04 to enlarge the canal while irrigating with 6% NaOCl in between each file. Root canals were dried with paper points. Bucco-lingual radiographs were taken of all teeth using a jig to maintain orientation.

Lead sulfide was prepared by grinding lead (II) sulfide (Sigma #372595) in a mortar and sieving the particles to less than 250 µm diameter. These particles were then suspended at 25% (vol:vol) within a 10% ovalbumin solution in phosphate buffered saline pH 7.4. Since the lead sulfide is insoluble in aqueous solutions the particles were suspended in solution by vigorous agitation prior to application to the canal. Using a micropipette, a lead sulfide slurry was inserted into the canal and integrated onto the wall of the canal using a 30.04 rotary file counterclockwise to the WL to incorporate the lead sulfide slurry into the smear layer. A 20.04 gutta percha cone was placed into the canal to the WL to maintain an open path for irrigants. The slurry was allowed to set at room temperature and humidity.

After the slurry was allowed to set, the gutta percha was removed. Using the jig, each tooth was radiographed from a bucco-lingual direction to determine the baseline smear layer using the lead carbonate slurry-induced radiopacity. Sticky wax was used to cover the apices of the teeth to seal the canal and simulate periodontal ligament during irrigation.

Smear Layer Removal:

All teeth were numbered and assigned to one the following irrigation groups using a random number generator (Google) (n=15 teeth each):

Group 1: Manual Irrigation (side-vented needle)

Group 2: EndoActivator (EA)

Group 3: SmartLite Pro EndoActivator (SLPEA)

Group 4: Ultrasonic activation (UA)

All teeth were cleaned with their respective instruments and 6% NaOCl. All debris rinsed from the canal was suctioned with high-speed surgical suction. Each irrigation technique was completed as follows:

Group 1: Side vented needle was placed into the canal 2mm from the WL. Needle tip was moved in short 2-3mm vertical strokes while expressing the 9ml 6% NaOCl continuously.

Groups 2 and 3: Canal chamber filled with 6% NaOCl. The activator tip was placed within 2mm of WL. The unit was placed on "high speed" setting and a pumping action was made to move the activator in short 2-3mm vertical strokes. NaOCl was activated in the canal for 30 seconds. After activation, loose debris in the canal was irrigated with NaOCl using a syringe with a side-vented needle until the fluid was clear of debris.

Group 4: The ultrasonic unit (Acteon) was set to 50% and canal chamber was filled with 6% NaOCl. An EndoUltra activator tip (Vista Apex, Racine, Wisconsin, USA) was moved using small 2-3mm vertical strokes while maintaining a distance of at least 2mm from WL. The NaOCl was activated in the canal for 30 seconds. After activation, loose debris in the canal was irrigated with NaOCl using a syringe with a side-vented needle until the fluid was clear of debris.

The teeth were dried with sterile paper points, sticky wax was removed, and a final radiograph of each tooth was taken with the same jig and orientation to visualize smear layer removal.

Data and Statistical Analysis:

All radiographic images were uploaded into ImageJ software. Values for the radiopacities of the smear layer were obtained for the pre- and post- irrigation radiographs for the whole and apical 3mm of all teeth. The differences in smear layer radiopacities were calculated and were analyzed for any statistical differences ($p<0.05$) using a t-test.

Results

A smear layer was established and cleaned for each irrigation method using the lead sulfide slurry as seen on the radiographs in Figure 1.

The percentage of smear layer removal for the whole canal is exhibited in Figure 2.

Ultrasonic activation removed most of the smear layer, followed by manual irrigation, SLPEA, then EA (92.0%, 90.3%, 77.1% and 71.4% respectively). Significant differences were noted between manual activation and both EA and SLPEA ($p<0.05$). Significant differences were also noted between ultrasonic activation and both EA and SLPEA ($p<0.05$). Although SLPEA was better at removing the smear layer, there was no significant difference between EA and SLPEA. There was also no significant difference between manual activation or ultrasonic activation.

The percentage of smear layer removal for the apical 3mm segment is exhibited in Figure 3. Manual activation removed most of the smear layer, followed by ultrasonic activation, SLPEA, then EA (44.6%, 36.8%, 26.8% and 22.8% respectively). There were no significant differences in smear layer removal between any of the activation methods in the apical 3mm ($p>0.05$).

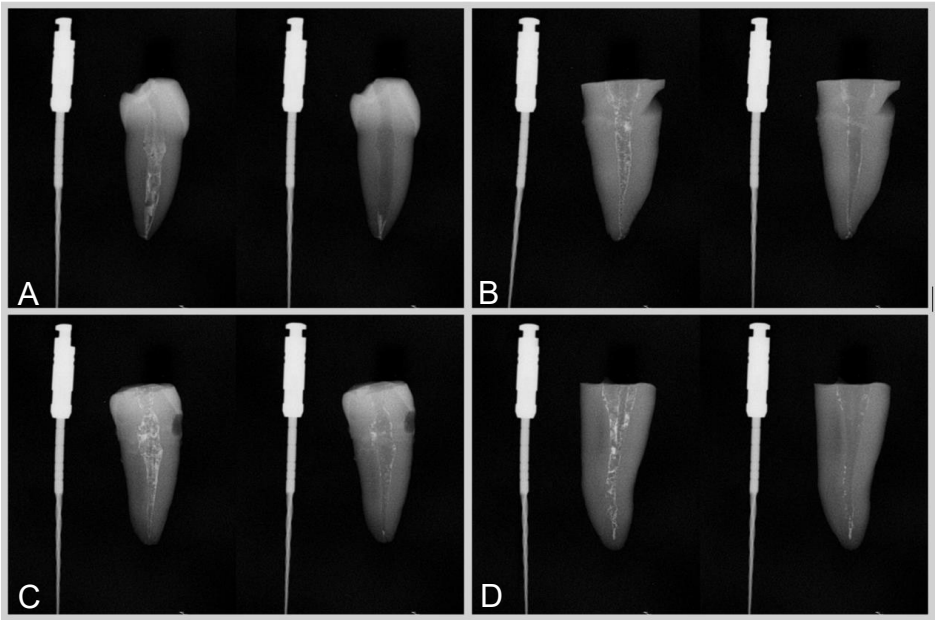

Figure 1. *Pre- and Post-Activation Using Different Methods (A: Manual, B: EA, C: SPLEA, D: UA)*

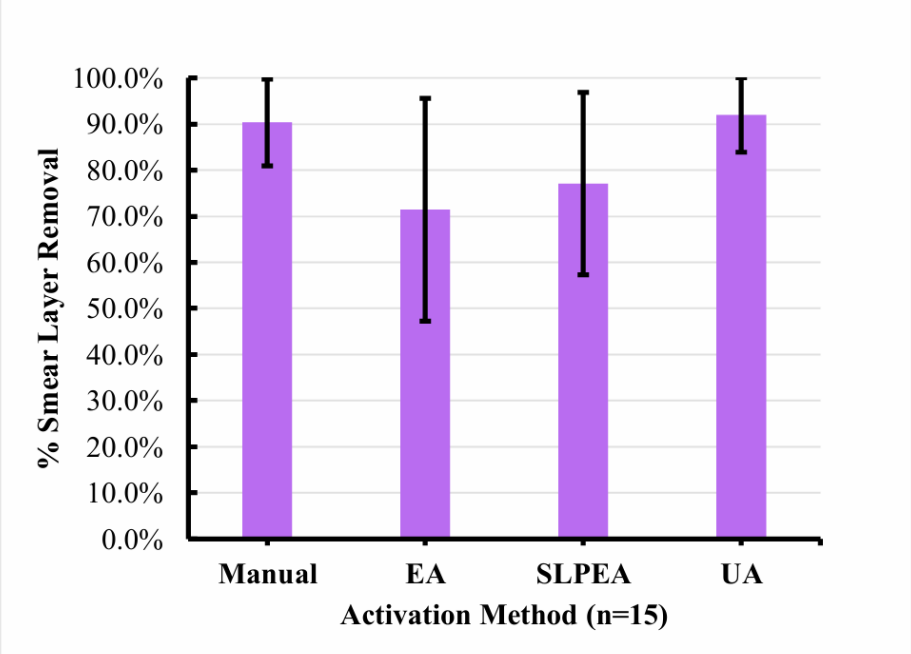

Figure 2. *Percentage of Smear Layer Removal in Whole Tooth*

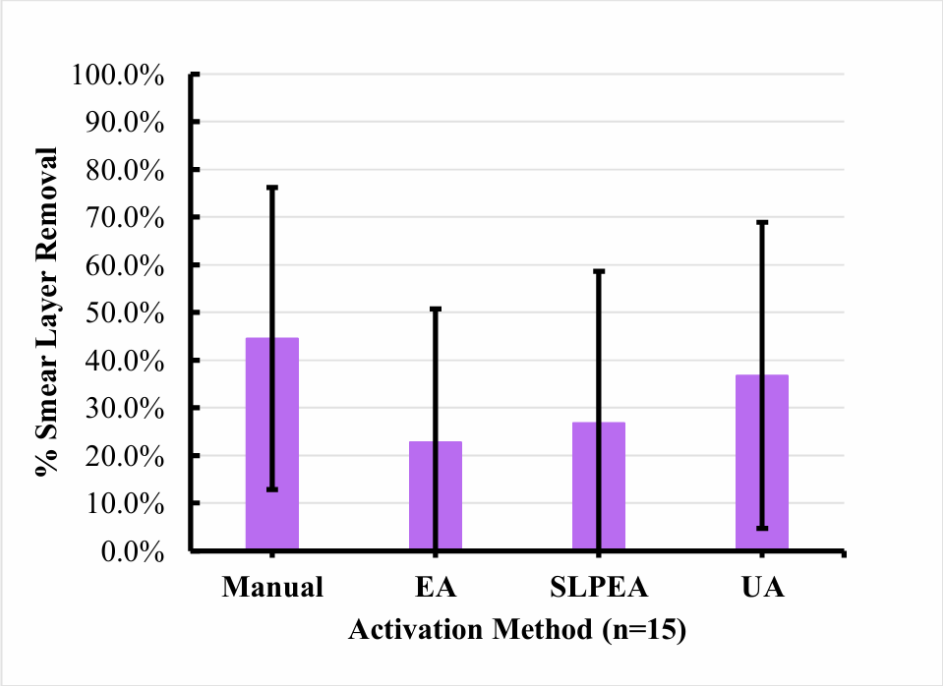

Figure 3. *Percentage of Smear Layer Removal in Apical 3mm.*

Discussion

Removal of all bacteria and the smear layer is important in the success of root canal treatment. If this layer is not removed, irrigants, medicaments and sealers are unable to penetrate the dentinal tubules [3,4]. The results from this study show that ultrasonic activation is better at removing the smear layer in the entire root canal with minimal NaOCl when compared to SLPEA and EA. Although SLPEA was slightly better at removing the smear layer, it was not significantly different than EA. This may influence existing users of the EA to continue utilizing this product instead of purchasing SLPEA.

The main focus during endodontic treatment is aimed at the apical third of the root canal. This area is where many of the canal ramifications retain bacteria and the smear layer. While ultrasonic and manual activation removed the most amount of debris in the apical portion of the root canal, none of the irrigation methods removed the entire smear layer consistently. This is most likely caused by the 'vapor lock effect' which makes fluid difficult to reach in the apical portion of the canal [4]. It was noted that larger and wider apical areas were able to be cleaned more effectively than more constricted canals and canals with fins. This suggests that larger apical preparations could allow for more effective irrigation of the apical portion of the root canal.

When looking at the results of the apical data, the standard deviations for each group were relatively large. This is thought to be due to inconsistent cleaning of instruments due to fluctuations in canal morphologies. While some of the canals were cleaned 95% to 100%, others were cleaned less than 1% in the same group leading to the large standard deviation.

Previously, the cleanliness of the root canal system after irrigation has been studied by SEM evaluation. This method leaves room for error due to its inability to examine the entire root canal system, observe the density of the smear layer, or quantify results [12]. In order to view the entire root canal system, the lead sulfide slurry allowed radiographic evaluation of the entire root canal, density of the smear layer, and quantification of smear layer removal. Proteins in the albumin of the lead sulfide slurry replicates a similar tenacity of the smear layer in a natural tooth during root canal treatment. This method of smear layer quantification is inexpensive and can be easily and quickly replicated allowing for countless applications to future smear layer studies.

When activating the root canal systems with EA and SLPEA, it was noted that there was a significant amount of vibration from the instruments. While the SLPEA had a less distinct vibration than the EA, it could possibly be uncomfortable to the patients compared to the ultrasonic and manual activation methods.

Since the manual irrigation performed similar to the ultrasonic activation, it can be suggested that the constant replenishing of NaOCl in the canal system is very important in smear layer and bacterial removal. In this study, a large amount of NaOCl (9ml) was used to irrigate the root canal system as compared to the less than 0.5 mL needed in ultrasonic, EA and SLPEA methods. This led to the high success of manual irrigation. It can be assumed that if the fluid was replenished in ultrasonic, EA and SLPEA methods, there would have been a higher percentage of smear layer removal for these methods as well. During manual irrigation, it was observed that the average amount of time that it took to continuously dispense 9ml of NaOCl in the canal system was 90 seconds. This is much more time needed as compared to ultrasonic, EA and SLPEA systems (typically 30 seconds). Further studies can be completed utilizing either less NaOCl with manual irrigation and/or more NaOCl with EA, SLPEA, and ultrasonic activating units to verify this assumption.

Conclusion

Removal of the smear layer during root canal treatment is a critical step for success. As compared to previous studies on root canal irrigant activation, all smear layer evaluations have been completed with SEM, leaving room for error due to its inability to examine the entire root canal system, observe the density of the smear later, or quantify results. This study has provided a new method of smear layer removal evaluation using a lead sulfide slurry. The density of the radiopacity allows for quantifiable analysis using an image processing software such as ImageJ. Using this method, ultrasonic activation and manual agitation were significantly better at removing the smear layer along the entire canal than EndoActivator and SmartLite Pro EndoActivator. In the apical 3mm, all irrigation techniques were equally effective at smear layer removal.

Acknowledgements

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Declaration of Interest

The authors declare no conflict of interest.

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