Curriculum Vitae

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Education

University of Maryland Dental School Endodontic Residency — Fall 2017-Present
Certificate of Endodontics Candidate
Master of Science Candidate

University of Maryland School of Dentistry — June 2015
AEGD Resident

University of Maryland School of Dentistry — May 2014
Doctor of Dental Surgery

University of Maryland, College Park — Spring 2009
General biology; Bachelor of Sciences

Montgomery College — Spring 2006
AA degree

Professional Experience

Chief dentist at Access Carroll Integrated Healthcare — 2015-2017
- Clinical patient care
- Supervised dental students and hygiene students on externship

Teaching Resident – University of Maryland — Spring 2017 – Present
- Pre-clinical Endodontics lab teaching assistant
- Supervised 3rd and 4th year dental students with clinical endodontics

Pediatric Clerkship – University of Maryland — Fall 2013-2014
• Focus on pediatric treatment with didactic seminars, clinical patient treatment, hospital rotations, and journal clubs

Research Experience

Post graduate Endodontic Resident, University of Maryland Fall 2017-Present

- Extensive reading of the literature

- Table clinic presentation at AAE 2018
  - Clinical Applications of 3D Digital Visualization in Endodontics

- Table clinic presentation at AAE 2019
  - Nanotechnology and Endodontic Imaging: The Next Generation

Dr. Daniel C. Stein Laboratory University of Maryland College Park 2007-2009
- Studying the effects of *mutL* and *mutS* genes on mutation frequency in *Neisseria gonorrhoeae* FA1090.

Poster Presentation 2009
- HHMI Undergraduate Research Symposium
- Presentation on: *Neisseria gonorrhoeae* DNA Repair Pathways

Honors and Awards

The Gorgas Odontological Honorary Society 2012-2014
Howard Hughes Medical Institute Fellowship 2008

Professional Membership

American Association of Endodontists 2017-Present
Edward C. Penick Endodontic Study Club 2017-Present
American Dental Association 2010-Present

Abstract

Comparison of Setting Expansion of White MTA and Endosequence Root Repair Material Putty Fast Set

Seyedeh Pegah Ghiasi Afjeh, Master of Science 2020

Dissertation Directed by: Dr. Priya Chand, BDS MS (Director of ASE Endodontics Residency Program)

The purpose of root end filling material in endodontic surgery is to provide a seal to prevent the ingress and egress of bacterial toxins into the periapical area. One reason for the sealing ability of these materials is their expansion upon setting. The aim of this study was to compare the percent linear setting expansion of WMTA and ERRM putty fast set using a linear voltage displacement transducer (LVDT) under controlled temperature of 37° Celsius. Materials were prepared according to the manufacturer's instructions and packed into the hollow hydrophilic porous tubing. Approximately 200 μL of HBSS was added to the porous tube in order to initiate the setting reaction. Expansion changes were measured until it appeared to have plateaued. ERRM putty showed a significantly greater mean percent expansion compared to the MTA ($P \leq 0.005$). MTA expanded an average of 0.109% (0.08%-0.20%) while ERRM putty expanded an average of 6.63% (2.93%-8.89%).

Comparison of Setting Expansion of White MTA and Endosequence Root Repair Material Putty Fast Set

by
Seyedeh Pegah Ghiasi Afjeh

Thesis submitted to the Faculty of the Graduate School of the
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Silicon dioxide (SiO2)

Calcium oxide (CaO)

Magnesium oxide (MgO)

Potassium sulfate (K2SO4)

Sodium sulfate (Na2SO4)

Grey MTA (GMTA)

White MTA (WMTA)

Resilon/Epiphany system (RES)

Endosequence Root Repair Material (ERRM)

Cone-beam computed tomography (CBCT)

Computed tomography (CT)

International Organization for Standardization (ISO)

Hank's balanced salt solution (HBSS)

Linear Voltage Displacement Transducer (LVDT)

Outside diameter (OD)

Inside diameter (ID)

Comparison of Setting Expansion of White MTA and Endosequence Root Repair Material Putty Fast Set

Introduction:

The goal of endodontic treatment is to perform adequate debridement and sealing of the root canal system to allow healing of peri-radicular infection. However, this may not be achievable in every case. Surgical endodontics is indicated in cases where non-surgical retreatment has failed or is not possible (1). New advances in endodontic surgery including the introduction of the surgical microscope, ultrasonics, and new root-end filling materials have made modern surgical endodontics far more predictable than in the past (2).

Surgical Endodontics:

Endodontic surgery accounts for about 3% to 10% of all endodontic procedures in practice (3). According to a web-based survey, 91% of endodontists perform some type of surgery, and majority of them use a surgical operating microscope and ultrasonics (4). While endodontists perform most of the surgical root canal treatments (78%), 22% of surgeries are done by general dentists and other specialists (5). Endodontic surgery accounts for about 5.5% of all endodontic procedures (6). The aim of endodontic surgery is to resolve the persistent inflammatory process that cannot be treated using non-surgical therapy. It is also performed to treat procedural mishaps, such as root perforation due to canal instrumentation or post-space preparation (7). The steps of peri-radicular surgery include: peri-apical curettage, resection of the apical third of the root, preparation of the root end using ultrasonic instrumentation and filling of the root end using a biocompatible material (8). The goal is removal of the region where most apical

ramifications and persistent bacteria are found and to seal the root end to entomb remaining bacteria in the canal. This prevents the egress of bacteria from the canal into the periapical region promoting healing (9).

The ideal endodontic repair material should be biocompatible, non-resorbable, resistant to dissolution in tissue fluids, dimensionally stable, radiopaque, able to adapt to dentinal walls and should have good handling characteristics (10,11). Numerous materials have been used for this purpose including cavit, amalgam, composite resin, super EBA, zinc oxide eugenol cements and glass ionomer cements. However, none of these materials possess all of these characteristics (7,10,11).

Traditionally, amalgam was used as the filling material of choice, however it has many disadvantages such as, mercury toxicity, corrosion, leakage and its ability to cause tissue tattoos (1). IRM and Super EBA and intermediate restorative material (IRM) have shown better success rates compared to MTA, however these also have their own disadvantages. These include sensitivity to moisture, tissue irritation and difficulty in handling (2). Similarly, moisture sensitivity of composite resins has limited its used as a root-end filling material since achieving a dry field during surgery is not possible. Even though glass ionomers are able to bond chemically to tooth structure and are dimensionally stable, their solubility prevents them from becoming the ideal filling material (2).

Mineral Trioxide Aggregate (MTA):

Mineral trioxide aggregate (MTA) is a biomaterial that was introduced in 1993 by Dr. Torabinejad (12). It was approved for endodontic use by the U.S. Food and Drug Administration in 1998 and was commercialized as ProRoot MTA (Dentsply Tulsa Dental, Tulsa, OK; 7,12). MTA material is derived from portland cement and contain small amounts of Silicon dioxide (SiO2), Calcium oxide (CaO), Magnesium oxide (MgO), Potassium sulfate (K2SO4), and Sodium Sulfate (Na2SO4) (7). Bismuth oxide is added as a radiopacifier (13). The Portland cement component consists of dicalcium silicate, tricalcium silicate, tricalcium aluminate, tetracalcium aluminoferrite and Gypsum (14-16). Compared to portland cement, MTA has a smaller particle size, a longer working time and a smaller amount of heavy metals. MTA also undergoes additional processing and purification before distribution to dentists (7,17).

There are two types of ProRoot MTA available on the market today: a gray-colored and a white-colored formula. White MTA (WMTA) was introduced in 2002 by Dentsply Tulsa Dental to address esthetic concerns because the earlier gray colored MTA was prone to staining the tooth structure (16). The main difference between the two varieties is a smaller concentration of tetracalcium aluminoferrite and a smaller particle size in white MTA (16,18).

MTA is a powder that forms a colloidal gel in the presence of water. It sets within three to four hours into a hard cement (12). Since its introduction, MTA has been used in various endodontic procedures, such as repair of root perforations, apexification, apexogenesis, pulpotomy, pulp capping, internal resorption repair, as a barrier for internal bleaching, and as a root end filling material during endodontic surgery (19).

Biocompatibility/Bioactivity:

Currently, MTA is the material of choice and the gold standard as a root-end filling material during endodontic surgery. Biocompatibility and bioactivity of MTA has been proven in both in vitro and in vivo studies (7). In research by *Torabinejad et al*, tissue reaction of implanted super-EBA and MTA in the mandible of guinea pigs was examined. The results showed biocompatibility of both materials with mild or no inflammation in the MTA group. Bone formation adjacent to the implanted MTA was also observed (20). In another study, *Keiser et al* compared cytotoxicity of MTA compared to super-EBA and amalgam using human PDL fibroblasts and a cell viability assay for mitochondrial dehydrogenase activity. In both the freshly mixed and 24-hour set samples, MTA was shown to have the least cytotoxicity. This supported the use of MTA as a root-end filling material (21). *Gandolfi et al* showed the ability of MTA to form a superficial layer of apatite in a phosphate containing solution (22).

Leakage:

Dye and bacterial leakage studies have shown greater sealing ability of MTA compared to amalgam and super EBA. *Torabinejad et al* used rhodamine B fluorescent dye and a confocal microscope to evaluate the sealing ability of amalgam, super EBA and MTA as root end filling materials in vitro. MTA showed significantly less leakage compared to amalgam and super EBA (23). In another study, *Aqrabawi* looked at the depth of methylene blue dye penetration using a stereomicroscope, in extracted teeth, after retrograde root filling with MTA, amalgam and EBA. He found that MTA provided a better seal compared to amalgam and EBA (24). In a bacterial leakage study, 3 mm of MTA as a root end filling material showed significantly less leakage of *Staphylococcus*

epidermidis compared to amalgam, super EBA and IRM. While MTA showed no leakage after 90 days, other samples filled with amalgam, super EBA and IRM began leaking at 6-57 days (25). In another in vitro study, *Maltezos et al* found that MTA and the Resilon/Epiphany system (RES) showed significantly more resistance to leakage using *Streptococcus salivarius* compared to Super EBA (26).

Antibacterial properties:

High Alkalinity and the ability to release calcium hydroxide after hydration are among other advantages of MTA that make it a desirable material (27,28). Both MTA and Portland cement consist of calcium oxide which gets converted to calcium hydroxide in solution. Calcium hydroxide dissociates into calcium and hydroxyl ions increasing the PH and providing an unsuitable environment for bacterial growth (29).

Disadvantages:

Despite MTA's superior biocompatibility and sealing ability, the difficult handling properties of MTA have been a concern of many clinicians (30). According to the manufacturer's recommendations, MTA is mixed in a 3:1 powder to water ratio. After mixing, a colloidal gel is formed which later solidifies in the presence of moisture (31). However, maintaining the consistency of MTA during surgical and non-surgical procedures is difficult. This creates a problem during the placement of the MTA (32). The long setting time of MTA (three to four hours) is another area of concern during procedures where setting is important in preventing the wash out of the material and providing a hermetic seal (33). Different variations of MTA, such as MTA Angelus have

been formulated to overcome these difficulties. MTA Angelus lacks the calcium sulphate phase which results in a shorter setting time compared to MTA (34).

Endosequence root repair material (ERRM):

Endosequence root repair material (ERRM; Brasseler, Savanah, GA) is a calcium silicate phosphate cement that was introduced to overcome the limitations of MTA. It consists of calcium silicate, calcium phosphate, zirconium oxide, tantalum oxide and fillers (31). The material comes in an injectable syringe in a putty or paste format. These two differ only in particle size. This water-miscible (ability to mix with water) but non-aqueous carrier allows storage of these premixed cements without hardening (35). Since the material is premixed, it can be placed directly into the working area using intra-canal tips which can be easily bent or other instruments of choice (31). According to Brasseler, the manufacturer, it is hydrophilic and sets in the presence of the moisture provided by the periapical region and the dentinal tubules. Dentin contains about 20% water by volume which is presumably responsible for its setting (36). The nanosphere particles allow the material to enter and interact with the moisture present in the dentinal tubules. This creates a mechanical bond after setting (37). The material is white and radiopaque which makes it easy to visualize on radiographs. It is dimensionally stable with no shrinkage after setting (37). ERRM putty has a working time of 30 minutes and setting time of 4 hours (34). Recently, a fast set version of ERRM putty (ERRM fast set) has been introduced with a working time of 30 min and setting time of 20 minutes; however, setting time may be longer in drier conditions (38).

Biocompatibility:

ERRM has a high pH with a strength of 70-90 MPa (31). The pH of the material reaches 12.8 during placement and steadily decreases during the next seven days. This high pH contributes to its antibacterial properties and biocompatibility (37). In vitro biocompatibility of ERRM has been investigated by several studies. *Ma et al* compared the biocompatibility of ERRM and MTA using human gingival fibroblasts. ERRM showed similar cell viability and cell adhesion to MTA (39). In another study by *Willerhausen et al*, using human periodontal ligament fibroblasts and osteoblasts, no significant difference was found between the proliferation rates of control cells and those in contact with the ERRM, suggesting the biocompatibility of this material (40).

Antibacterial properties:

In a study by *Lovato et al*, a direct contact test was used to determine the antibacterial properties of ERRM putty and ERRM paste against *E. faecalis (*present in root canal infections) as compared to MTA. Results showed that there was no significant difference between the antibacterial efficacy of the three tested materials. They all showed lower viable counts compared to the negative controls (41). *Alsalleeh et al* furthermore showed comparable antifungal biofilm activity of ERRM and MTA against cultures of *C. Albicans* (42).

Cytotoxicity:

Cytotoxicity of ERRM has also been compared to that of MTA. In a Study by *AlAnezi et al*, no significant difference was seen in the cell viability of mouse fibroblasts in samples treated with GMTA, WMTA, and ERRM putty. The Cell viability of AH 26

(positive control) was lower than the other groups (31). *Hirschman et al* found no significant difference in cytotoxicity between ERRM putty and MTA using human dermal fibroblasts (43). However, *Damas et al* showed significantly less cell viability of human dermal fibroblasts treated with ERRM putty compared to WMTA, MTA-Angelus and ERRM paste (37). *Ciasca et al* and *Llerena et* al showed similar cytotoxicity of ERRM putty and MTA using human osteoblast cells and human periodontal ligament fibroblasts (44,45).

Bioactivity:

Bioactivity of ERRM putty has also been studied. A bioactive material is capable of interacting with tissues and ultimately results in formation of a hydroxyapatite layer at the interface of the material and the tissue. *Shokouhinejad et al* showed the formation of this apatite layer in the presence of ERRM putty exposed to simulated tissue fluid. This apatite layer increased with time (46).

Chen et al studied, using periapical radiographs, cone-beam computed tomography (CBCT), micro computed tomography (CT), and histology, the healing of the periapical area after endodontic surgery in dogs using MTA and ERRM putty as root end filling material. Six months after surgery, both materials induced minimal or no inflammation; however, the group treated with putty showed significantly more root-end surface area covered with bone, cementum-like and periodontal ligament-type tissues. Both CBCT and micro CT showed significantly better healing in the ERRM putty group compared to the MTA group (47).

Leakage:

The purpose of endodontic surgery is to eliminate disease and to produce a hermetic seal to prevent the egress of toxins into periapical tissue (48). This makes the sealing ability of the root end material an important characteristic which has been investigated in several in vitro studies. These studies produced conflicting results possibly due to differences in methodology. In vitro leakage studies by *Nair et al* and a bacterial nutrient leakage study by *Antunes et al* showed that there was no significant difference between the sealing ability of white MTA and ERRM in vitro (8,48). However, another study by *Hirschberg et al* showed that the ERRM group showed significantly more leakage compared to the MTA group when used as a root end filling material in vitro (49).

Setting expansion:

Another possible explanation for the sealing ability of MTA is its expansion upon setting. Studies by *Islam et al* and *Chng et al* determined the dimensional change of MTA using the method specified for root canal sealing materials by the International Organization for Standardization (ISO) 6876:2001 (12). The setting expansion of GMTA and WMTA were found to be 0.28% and 0.3% respectively (17). In a study by *Storm et al*, using a novel linear expansion measuring device, it was concluded that grey MTA (GMTA) showed significantly more expansion (1.02%) compared to white MTA in water (0.08%) or Hank's balanced salt solution (HBSS) (0.68% GMTA, 0.11% WMTA; 12). However, no recent studies have compared the expansion of bioceramic root end filling materials (ERRM Putty) with the gold standard, MTA.

Advantages of ERRM are easy storage and handling, dimensional stability, ability of being easily visualized on the radiograph, short setting time, and insensitivity to moisture compared to MTA. However, there have been no published articles on the setting expansion of putty.

Purpose:

The purpose of this study was to compare the percent linear setting expansion of WMTA and ERRM putty fast set using a linear voltage displacement transducer (LVDT).

Hypothesis:

The following are the null and research hypotheses for this study:

Null hypothesis: there is no significant difference in maximum percent setting expansion of ERRM compared to WMTA.

Research hypothesis: there is a significant difference in the maximum percent setting expansion of ERRM and WMTA.

Material and Methods:

Experimental set-up:

A device based on an LVDT (linear voltage displacement transducer) was designed to measure axial displacement (i.e., expansion) of a material during curing while in the presence of an aqueous fluid (e.g., water or normal saline) at a controlled temperature (37 ^{o}C).

The major components of the device are depicted in Figure 1. Temperature is controlled by placing the sample assembly in a metallic heating block (Heating Block with Temperature Controller, FOSS NIR Systems) connected to a digital temperature controller. Displacement of the sample during curing is measured using a Miniature LVDT (Omega Model LD400-5) which provides nearly frictionless motion and the ability to detect small displacements. The voltage output from the LVDT is captured using a computer-based data acquisition system (USB Data Acquisition Module, Omega OMB-DAQ-54 with Personal Daq Acquisition Software).

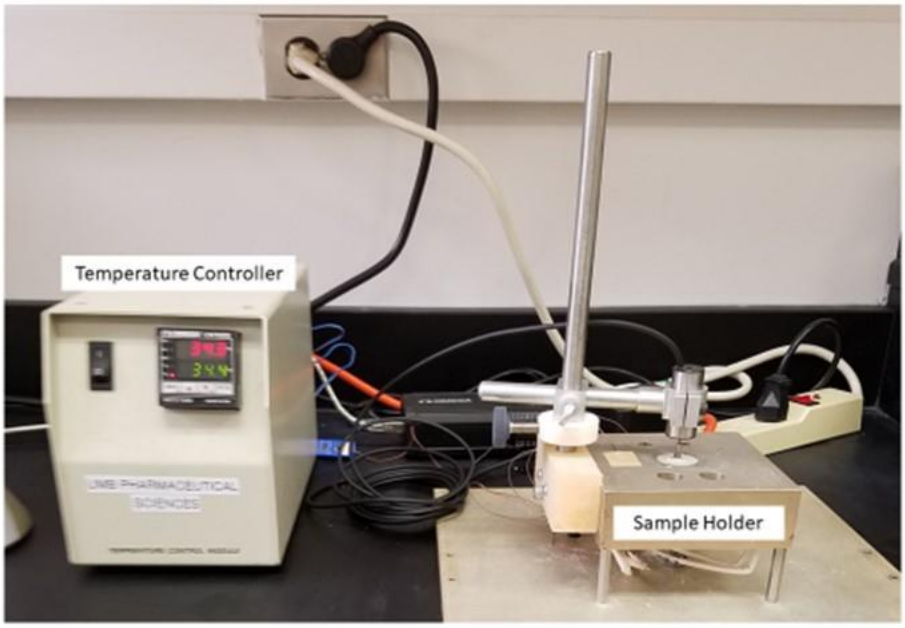

Figure 1. System Components

A specially designed sample holder (Figure 2) was machined from an inert plastic rod (Delrin). The outside diameter (OD) of the sample holder is 1” and it fits securely into the large cavity in the heating block. The inside diameter (ID) of the sample holder is 0.5” so that it can accommodate a segment of porous tubing (0.250” ID x 0.500” OD Porous Tube, Hydrophilic 50 Micron, Scientific Commodities, Inc.). The porous tubing absorbs and retains moisture providing an environment with high water activity for the material that is being examined.

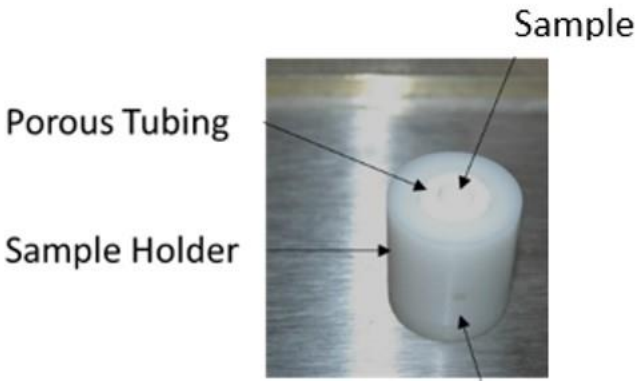

Figure 2. Sample Holder

Figure 3 shows the configuration of the sample and LVDT during measurement. When a measurement is to be made, the sample material itself is packed into the inside of the porous tubing. The tip of the LVDT core is placed on top of the material after packing to permit calculation of the initial height to monitor subsequent dimensional changes. Also attached to the block is a Type T thermocouple. The thermocouple provides a direct temperature reading that corresponds to the state of the system at a particular timepoint. This additional sensor was included to determine if variation in temperature is associated with observed variation in displacement. Electrical outputs from the LVDT and the thermocouple are digitized and captured using a software program (Omega Personal Daqview). The time interval for data collection is set at 1 min. Thus, a simultaneous temperature and displacement output is collected and stored every minute.

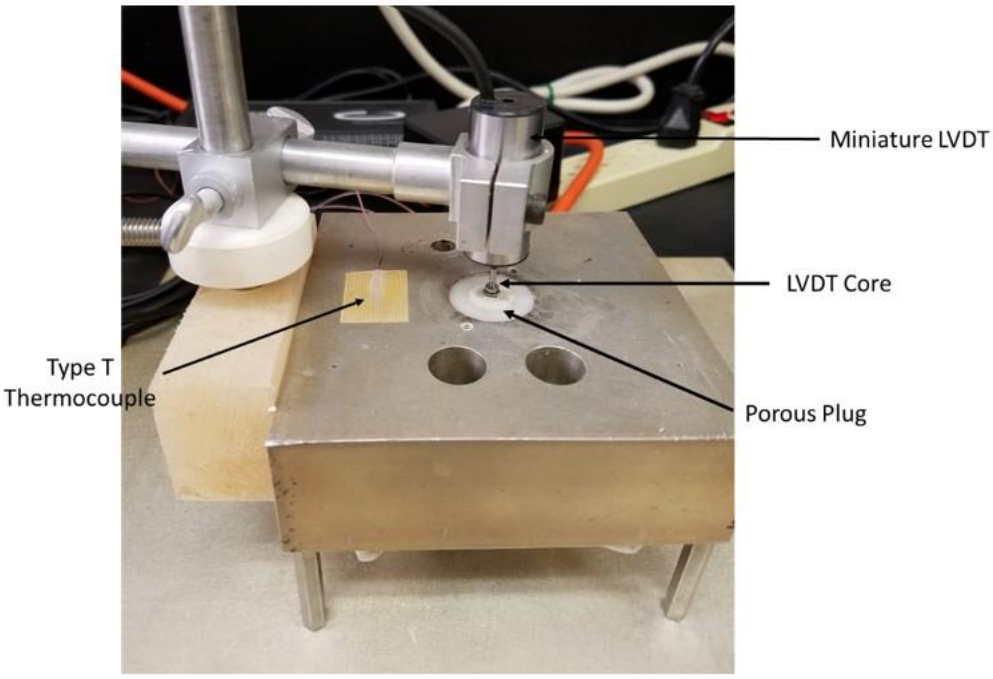

Figure 3. Assembly During Measurement

Experimental Procedure:

- Calibrate the LVDT (see discussion later)
- Configure the data acquisition system to collect and save voltage output every one minute.
- Turn on the temperature controller and allow sufficient time for the temperature to reach 37^{o}C. Allow at least 90 minutes of warm up period until the temperature stabilizes
- Place the empty sample holder into the heating block.
- Place a segment of the porous tubing into the heating block.
- Prepare sample and collect data.

Data collection using ERRM:

- Prepare the sample according to manufacturer's instructions.
- Introduce approximately 0.3 g of ERRM fast set putty (contents of one syringe) into the sample holder using the syringe and pack down gently.
- Place the core of the LVDT directly on top of the sample.
- Collect data for Five minutes
- Introduce approximately 200 uL of HBSS (Hanks balanced salt solution) to the hydrophilic tube using a micropipette.
- Continue to collect data
- When expansion appears to have plateaued, save the data to an ASCII file and then import it into Excel to translate the voltage data into the desired displacement units (um).

Data collection using MTA:

- Mix one pack of ProRoot MTA with the ampule provided in the pack according to instructions on the packet.
- Introduce the sample into the tubing using a small spatula (MTA) and pack it down gently.
- Place the core of the LVDT directly on top of the sample.
- Collect data for five minutes
- Introduce 200 uL volume of HBSS to the hydrophilic tubing using a micropipette.
- Continue to collect data
- Save the data to an ASCII file and then import it into Excel to translate the voltage data into the desired displacement units (um).

LVDT Calibration:

- The LVDT is calibrated using two gauge blocks of known dimensions. The relationship between displacement and voltage is shown in figure 4.
- In this example, with the tip of the LVDT core in contact with the block surface, the initial voltage output was 1.3127 V
- When the first gauge block (1.15 mm in thickness) was placed between the block surface and tip of LVDT core, the voltage output increased to 2.7548 V.
- When the second gauge block (1.17 mm in thickness) was added, the voltage increased to 4.0582 V.
- The slope of this black line in figure 4 (1.1832 V/mm) provides a calibration factor that can be used to convert voltage to displacement.

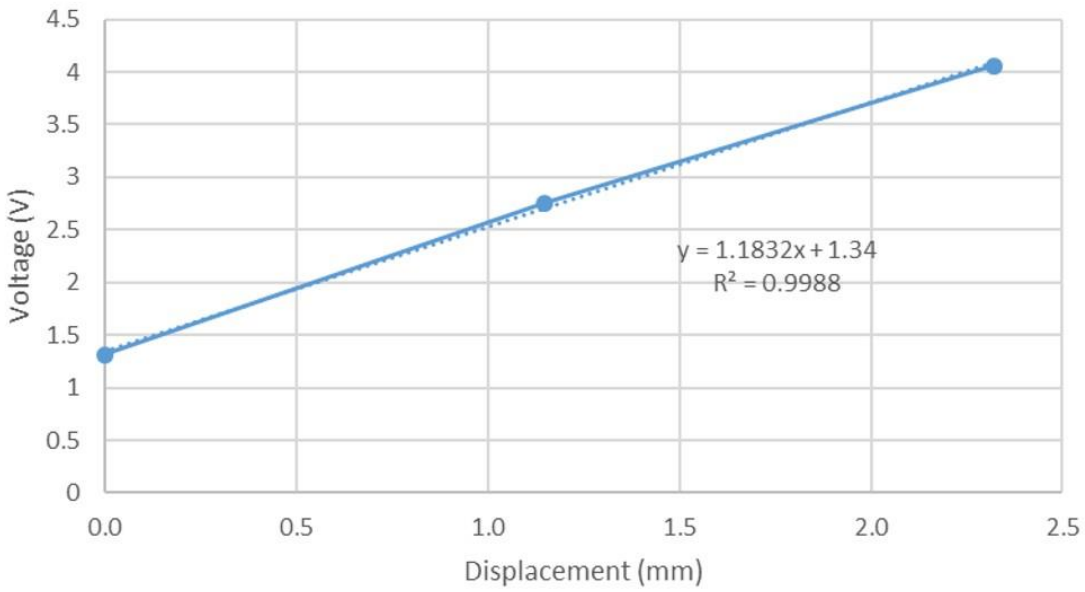

Figure 4. Calibration of The LVDT (Showing the Relationship Between Displacement and Voltage)

Example of data processing for putty expansion:

Table 1 shows an example of the raw data and mathematical processing for a sample of ERRM putty.

Table 1. Raw Data/Mathematical Processing for a Sample of ERRM Putty

time (min)	Temp (oC)	LVDT (V)	Material Expansion		
			Voltage Change	Displacement	
Base of the cylinder		-4.42678	(V)	(μm)	%
0	37.0	2.9435	0.0000	0.0	0.00%
1	36.9	2.9431	-0.0003	-0.3	0.00%
2	36.9	2.9428	-0.0007	-0.6	-0.01%
3	37.0	2.9428	-0.0006	-0.5	-0.01%
4	37.0	2.9427	-0.0007	-0.6	-0.01%
5	37.0	2.9427	-0.0007	-0.6	-0.01%
6	36.9	2.9445	0.0010	0.8	0.01%
7	37.0	2.9748	0.0314	26.5	0.43%
8	36.8	3.0014	0.0579	48.9	0.79%
9	36.9	3.0242	0.0807	68.2	1.10%
10	36.9	3.0430	0.0996	84.2	1.35%
11	36.9	3.0601	0.1166	98.6	1.58%
12	37.0	3.0746	0.1311	110.8	1.78%
13	36.9	3.0875	0.1440	121.7	1.95%
14	36.9	3.0996	0.1562	132.0	2.12%
15	37.0	3.1114	0.1679	141.9	2.28%
16	36.8	3.1227	0.1792	151.5	2.43%
17	36.8	3.1334	0.1899	160.5	2.58%
18	36.9	3.1431	0.1996	168.7	2.71%
19	37.0	3.1525	0.2090	176.7	2.84%
20	36.9	3.1610	0.2176	183.9	2.95%
21	36.8	3.1694	0.2259	190.9	3.07%
22	36.9	3.1768	0.2333	197.2	3.17%
23	36.9	3.1842	0.2408	203.5	3.27%
24	36.9	3.1913	0.2478	209.4	3.36%
25	36.8	3.1981	0.2547	215.2	3.46%
26	36.8	3.2051	0.2616	221.1	3.55%

Table 1 demonstrates the initial 30-minute portion of data collection starting after introduction of the putty into the sample holder and locating the LVDT core on top of the material. The time=0 point occurs after the warmup period. The voltage with the core of the LVDT located at the base of the cylindrical opening in the sample chamber is identified and entered into the spreadsheet. After that, temperature and LVDT voltage data starting at time=0 are copied into the identified columns. The voltage change is calculated as the difference between the LVDT output voltage at a particular time and the voltage at time=0. The voltage change is converted to a displacement using the calibration factor. In the final column, expansion is calculated as a percentage of the initial height of the compacted material.

Statistical Methodology:

Results of power analysis:

Ten samples of ERRM and seven samples of MTA were tested using the two-sample t-test.

Statistics:

Samples were statistically compared using the two-sample t-test. The significance level was set at $p \leq 0.05$.

Results:

The maximum percent expansion of ERRM fast set putty and MTA were identified from the displacement vs. time profiles. The results of statistical analysis are shown in table 2. The maximum expansion of ERRM putty ranged from 2.93-8.89% with a mean of 6.63% and SD of 1.82%. The maximum expansion of WMTA ranged from 0.06%-0.20% with a mean of 0.11% and standard deviation (SD) of 0.05%. There was a significant difference between the maximum expansion of the two groups ($p \leq 0.005$, Fig. 5). A graph of all runs for both Putty and MTA groups are shown in figures 6 and 7 (Note: different Y-axis scale to better illustrate expansion profile of each material).

Table 2. Maximum Percent Expansion

Sample Runs	**ERRM Putty**		**MTA**	
		Lot		Lot
1	7.19%	A	0.20%	A
2	7.22%	A	0.15%	A
3	8.89%	A	0.06%	B
4	6.30%	A	0.06%	B
5	6.44%	A	0.11%	B
6	4.21%	A	0.11%	B
7	7.02%	A	0.08%	B
8	2.93%	B		
9	7.93%	B		
10	8.21%	B		
Average	**6.63%**		**0.11%**	
Standard deviation	**1.82**		**0.05**	
$p \leq 0.005$ $t=5.067$				

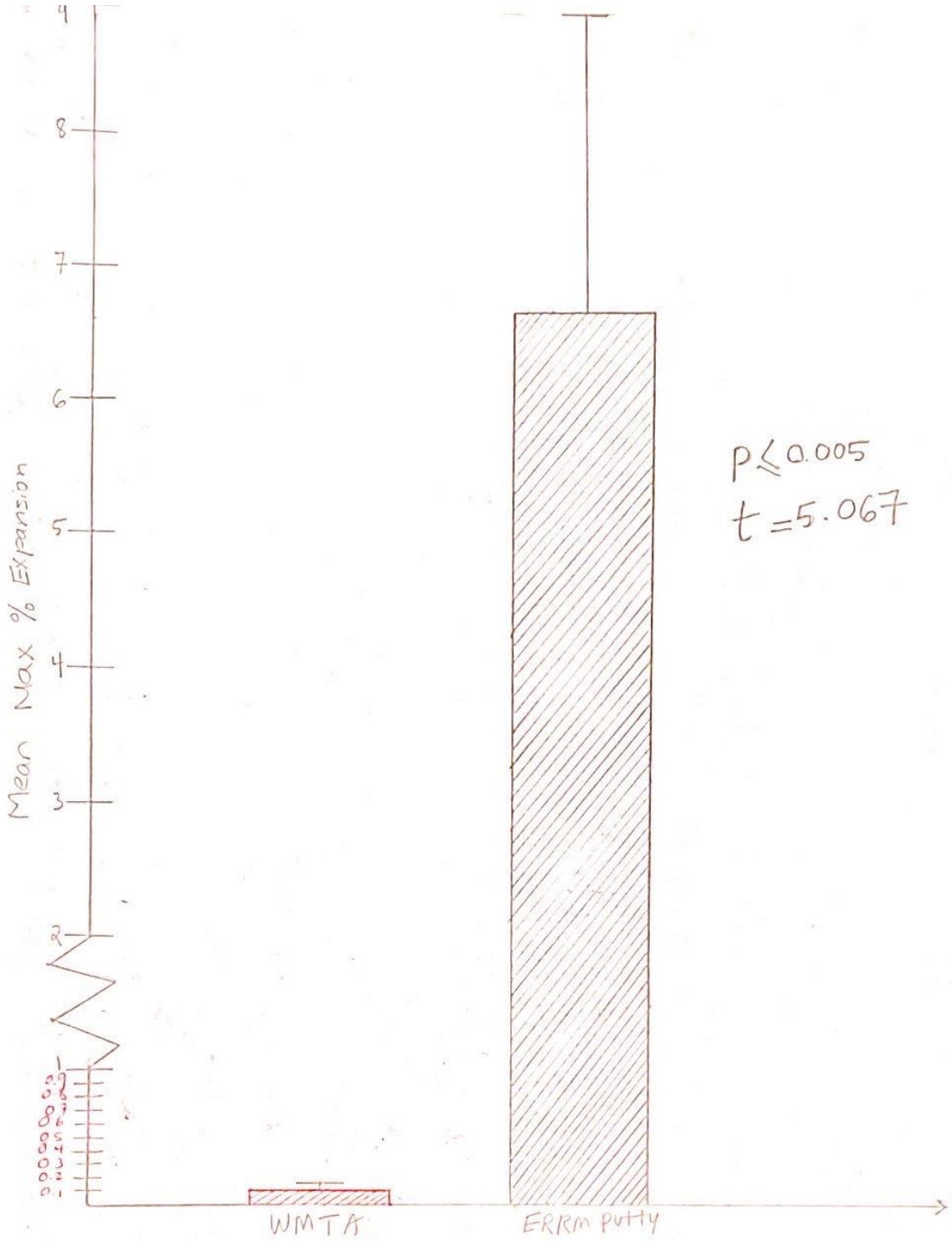

Figure 5. Mean Maximum Percent Setting Expansion

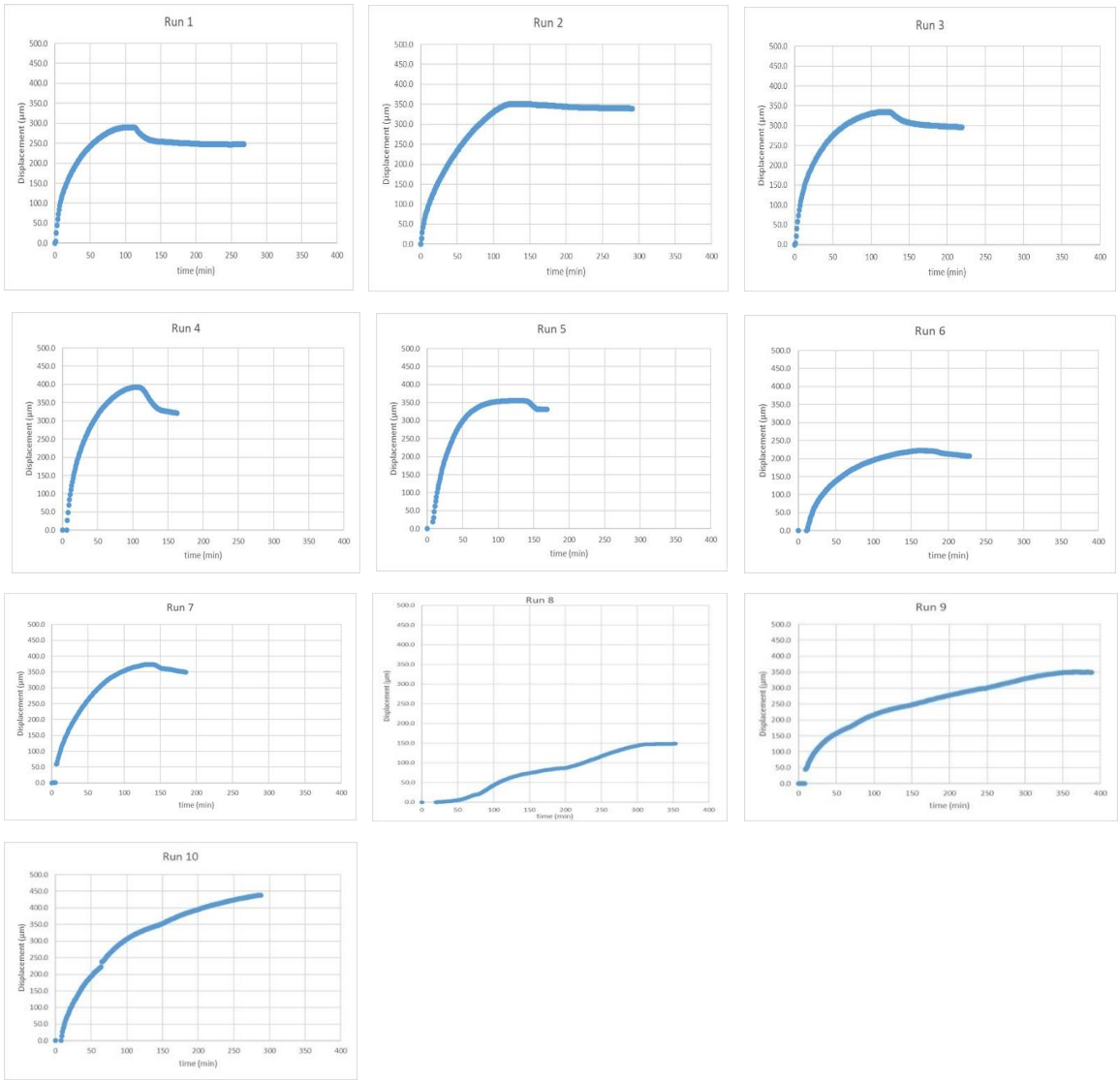

Figure 6. Displacement of EERM Putty as a Function of Time (Mean Expansion Rate of 6.63%)

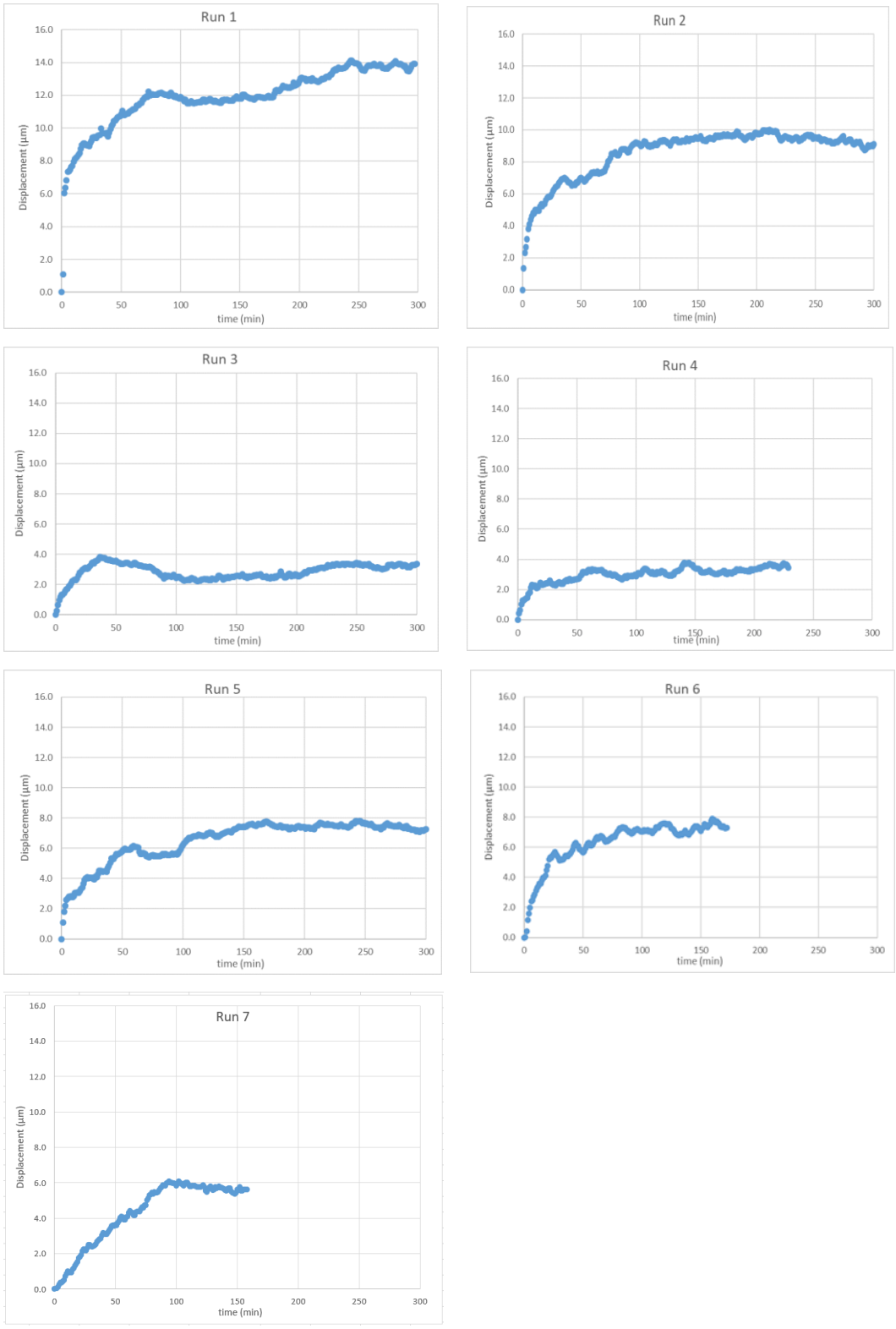

Figure 7. Displacement of <u>MTA</u> as a Function of Time (Mean Expansion Rate of 0.11%)

Each individual profile in figure 6 is presented with a consistent displacement and time axis so that it is easy to observe the rate and extent of expansion observed. Figure 6 shows the displacement of ERRM. As shown, no displacement is observed before HBSS is introduced. After introduction of HBSS, there is rapid expansion of the material which then slows down in an exponentially decreasing manner reaching a plateau. The shrinkage seen in putty in some of the runs (Example: Figure 6, Run 1) may be attributed to the system drying out since a specified amount of liquid was added at the beginning of the experiment, however this is not seen in every sample. Even though the maximum expansion among all samples is in the range of 6-8%, the rate is quite different across different runs. Figure 7 shows displacement of MTA. A similar approach is used as in Figure 6, yet the displacement axis is much smaller. Mean maximum expansion of MTA samples is 0.11% which is much less than that of ERRM Putty (6.63%).

Discussion:

The objective of this study was to measure and compare the maximum expansion of ERRM putty fast set and the gold standard, MTA. In order to mimic in vivo conditions, a unique device was designed and constructed where temperature was controlled and there was access to moisture to initiate setting of the material. A Temperature of 37° Celsius and HBSS were selected in order to more closely simulate the environment where MTA and Putty are used during surgical procedures. HBSS has an osmolality of approximately 280% mOsm/Kg H2O, which is similar to that of blood, 270-300 mOsm/Kg H2O (12).

Under in vivo conditions, the materials are exposed to constant moisture and humidity. However, in our study, after conducting a large number of experiments and method modifications, a decision was made to add approximately 200 uL of HBSS to the hydrophilic tubing. Due to the texture of the putty, immersing the sample in solution would make the material very runny and create difficulty in placing the LVDT core on top of the material. 200 uL of HBSS was sufficient to saturate the hydrophilic tubing without immersing the putty in "free" liquid. It also allowed us to control the amount of liquid added. Shrinkage of materials in some of the runs may be attributed to the sample drying out. In addition, despite our efforts to direct the liquid entirely into the tubing, frequently some of the volume entered the opening in the top of the cylinder.

Our research hypothesis was that there is a significant difference in the maximum percent setting expansion of ERRM and WMTA. In our study, we found a large difference between expansion of ERRM putty and MTA. The degree of expansion of MTA was found to be significantly less than that seen for the putty. These small

measurements challenged the capability of our LVDT device. Despite many design modifications of our device, conducted in an effort to get consistent results with the putty samples, we found a large variability in the performance of the material itself under the conditions employed. Considerable differences in the rate and extent of expansion were observed. This could be due to a lack of control of an as yet unidentified experimental variable or to differences in the material itself. Two different lots of putty were used in our study, however similar results were seen (see table 2). This sample size was adequate to find a significant difference between the two groups. Due to the significant difference ($p \leq 0.005$), the unequal sample size will not make a difference in the statistical outcome.

Previous studies by Islam et al and Chng et al found the setting expansion of GMTA and WMTA to be 0.28% and 0.30% respectively, using the method specified for root canal sealing materials in the International Organization for Standardization (ISO) 6876:2001 (17). However, the study by Storm et al used an LVDT device and found the setting expansion of WMTA to be 0.11% in HBSS. Our finding of 0.11% expansion of WMTA is consistent with this previous study. However, there are differences in our methodology. In the study by Storm et al, the samples were immersed in HBSS and were let to run for 24 hours. However, in our study a controlled amount of HBSS was added due to the reasons described earlier. The samples were also run until they appeared to have plateaued. This was done to prevent shrinkage of material which was seen due to the samples drying out. Constant presence of moisture may have resulted in a higher expansion than we saw in our experiment.

Limitations:

This study was conducted in vitro and despite our efforts to mimic in vivo conditions, the results may vary under clinical conditions. We were not able to have constant moisture and humidity (present in a clinical setting) throughout the experiment. We also did not allow the samples to run for 24 hours since we were not able to provide the moisture necessary during that time. The weight of LVDT core could have inhibited the expansion to some degree. Materials may expand more under clinical condition. Another limitation of our study was that we only measured the expansion in one dimension, and three-dimensional expansion measurement was not feasible with only one LVDT or with our experimental design.

Future Directions:

The purpose of root end filling material is to seal the apex to prevent the ingress or egress of bacteria and toxins into the periapical tissue. Dimensional stability and expansion of dental materials play a role in sealing ability (13). According to ISO 6876.2:1999, root canal sealers should not have a linear expansion of more than 0.1% and shrinkage of more than 1%. However, there are no ISO standards set for root end filling materials. Future studies can further confirm the setting expansion of ERRM putty using other methods, such as, Electronic Speckle Pattern Interferometry (ESPI) and to study the effect of expansion on microcracks on dentin. It will also be of importance to know the force of expansion, particularly the force exerted when the material is under constraint.

Conclusion:

Retrofill material is an important part of successful endodontic surgery. Under the conditions of our study, the linear setting expansion of ERRM putty fast set was greater than MTA. Considerable differences in the rate and expansion of putty were observed despite controlling for identified factors. The results of this study should be interpreted with caution since it is not known what results will be found under clinical settings.

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