# THERMAL ENERGY TRANSFER THROUGH ALL CERAMIC RESTORATIONS

by

Sarah E. Troisi
Lieutenant, Dental Corps
United States Navy

A thesis submitted to the Faculty of the
Comprehensive Dentistry Graduate Program
Naval Postgraduate Dental School
Uniformed Services University of the Health Sciences
in partial fulfillment of the requirements for the degree of
Master of Science
in Oral Biology

June 2018

Naval Postgraduate Dental School
Uniformed Services University of the Health Sciences
Bethesda, Maryland

CERTIFICATE OF APPROVAL

---

MASTER'S THESIS

---

This is to certify that the Master's thesis of

Sarah E. Troisi

has been approved by the Examining Committee for the thesis requirement for the Master of Science degree in Oral Biology at the June 2018 graduation.

Research Committee: [redacted]

Ye, Ling, D.D.S., Ph.D.
CDR, DC, USN
Manuscript Supervisor, Dental Research Department
Research Committee Chair

[redacted]

Avillo, Andrew, D.D.S., M.S.
CAPT, DC, USN
Program Director, Comprehensive Dentistry Department

[redacted]

Hartzell, David, D.D.S., M.S.
CAPT, DC, USN
Comprehensive Dentistry Faculty

The author hereby certifies that the use of any copyrighted material in the thesis manuscript titled:

"THERMAL ENERGY TRANSFER THROUGH ALL CERAMIC RESTORATIONS"

is appropriately acknowledged and, beyond brief excerpts, is with the permission of the copyright owner.

RESIDENT SIGNATURE

[redacted]

Sarah E. Troisi
Comprehensive Dentistry Graduate Program
Naval Postgraduate Dental School
June 2018

NAVAL POSTGRADUATE DENTAL SCHOOL
SARAH E. TROISI

2018

## ABSTRACT

THERMAL ENERGY TRANSFER THROUGH ALL CERAMIC RESTORATIONS
SARAH E. TROISI
M.S., COMPREHSIVE DENTISTRY, 2018

Directed by: Ye, Ling, D.D.S., Ph.D.
CDR, DC, USN
Manuscript Supervisor, Dental Research Department
Naval Postgraduate Dental School

INTRODUCTION: As all ceramic restorative materials for indirect dental restorations become more widely used, providers must be able to accurately diagnose the pulpal status of restored teeth. It has been shown that thermal testing, specifically cold testing, can be conducted through metal ceramic restorations, all metal restorations, and all ceramic restorations using traditional ceramics. However, no study to date has been performed to examine the feasibility of cold testing through novel, chairside milled ceramic materials.

MATERIALS AND METHODS: Thirty extracted human premolars were mounted in acrylic and sectioned 5mm from the cementoenamel junction (CEJ), perpendicular to the long axis of the tooth. Pulpal tissue was removed, a thermal conductive medium was placed, and a thermocouple probe was inserted into pulp chamber of each tooth. Thermal testing was conducted on each tooth by placing a #2 cotton pellet saturated with 1,1,1,2-tetrafluoroethane (TFE) on the facial surface for 60 seconds. The intrapulpal temperature change was measured at ten second intervals to establish the baseline for natural teeth. Teeth were then reduced by 1.5mm on the facial surface to simulate a preparation for an all-ceramic restoration. Milled blocks of lithium disilicate, zirconia, and feldspathic porcelain 1.5mm in thickness were fabricated. Then, ten milled blocks from each material were cemented to prepped teeth and intrapulpal temperature change was measured. A non-linear mixed effects model, specifically a three-parameter exponential decay model, was used to analyze data.

RESULTS: Three test materials and natural teeth displayed similar rate of temperature change, although the feldspathic samples had a lower initial temperature compared to natural teeth, while both the feldspathic and zirconia samples had a higher asymptotic temperature compared to natural teeth.

CONCLUSIONS: Thermal testing is a viable option for determining pulpal status through an all-ceramic restoration.

TABLE OF CONTENTS

LIST OF GRAPHS

## LIST OF FIGURES

# CHAPTER I: INTRODUCTION

In dentistry, the trend of full coverage restorations that are being delivered is rapidly changing. Historically, metal ceramic restorations (MCR) have been the standard in fixed prosthodontics and have been the primary restorative choice for most dentists (Kelly, 2011). In the past twenty years, MCRs have fallen from over 70% of all crowns delivered to about 30% (Christensen, 2011). All ceramic restorations (ACR) now account for more than 50% of crowns placed (Christensen, 2012). These novel, high-strength ceramics are esthetic and can be manufactured in the dental office with CAD/CAM technology (Lawson, 2016, Aldegheishem, 2017). Machined ACRs have better physical properties than conventional powder/liquid ceramics (Giordano, 2010), and have been accepted as alternatives to MCRs (Sailer, 2015). Loss of tooth vitality is one of the predominant biologic complications for single crowns (Cheung, 2005, Valderhaug, 1997), with a 5-year complication rate of 1.8% (Sailer, 2015). It has been shown in the literature that pulp sensibility testing can be performed through MCRs, all metal restoration (AMR), and feldspathic porcelain ACRs (Miller, 2004). With the advent of new ACRs, the need to be able to predictably evaluate the pulpal status of restored teeth is apparent. No information to date has been published to establish guidelines for thermal testing through chairside milled ACRs. The purpose of this study is to determine the thermal conductivity of new chairside milled all ceramic materials.

# CHAPTER II: MATERIALS AND METHODS

The methods for this study were adapted and modified from the design used in Miller, et al., 2004. Thirty caries-free, non-restored extracted human premolars were collected from the Walter Reed National Military Medical Center and stored in a 0.2% sodium azide solution.

Radiographs were used to verify adequate space in the pulp chamber for the placement of a thermocouple probe with a diameter of 0.5mm, and to verify that all teeth were caries- and restoration-free. The teeth were then mounted in acrylic base using clear orthodontic resin with the lingual half of the tooth secured (Figure 1). The roots were sectioned perpendicular to the long axis of the tooth at a point 5 mm apical to the cementoenamel junction (Figure 2). All pulpal material was removed with barbed broaches. A thermocouple probe (Type T, Omega Engineering) was placed in the pulp chamber of each tooth, and radiographs were taken to verify that the probes could be seated to the most coronal extent of the pulp-dentin surface opposite the facial testing surface up to the roof of the chamber. The probes were then removed, and the teeth were filled with a thermal conductive medium (Omegatherm "201" High Temperature High Thermal Conductivity Paste, Omega Engineering, Stamford CT) using a stainless steel hand file. Then, the thermocouple probes were fully seated in the pulp chamber and secured with sticky wax. Radiographs were taken to confirm the placement of the probes (Figure 3).

Initial thermal tests were completed at room temperature. Baseline temperature for each sample was established using a water bath set to 37 degrees Celsius, simulating the intraoral environment. Tetrafluoroethane (TFE) was chosen as the cooling agent in this study (1,1,1,2-tetrafluoroethane, Hygenic Endo-Ice Green, Coltène Whaledent, Cuyahoga Falls, OH). A #2 cotton pellet was saturated with TFE for three seconds while it was held with Kelly straight hemostats (Hu-Friedy, Chicago, IL) at a distance of 2 inches from the nozzle. Testing was conducted on the middle third of the facial surface of each tooth for 60 seconds, and the intrapulpal temperature change was measured at 10 second intervals with a logging thermometer (HH2002AL, Omega Engineering). Each of the 30 intact premolar crowns were tested three times before being prepared for testing with restorative material.

In order to prepare the experimental samples, the facial height of contour of each tooth was reduced by one and a half millimeters using a modified flat end cylinder bur (NeoDiamond #0614.8C, Microcopy, Kennesaw, GA) on a high-speed handpiece. Ten samples measuring 6.4mm (length) by 5.4mm (width) by 1.5mm (thickness) were designed and milled via CAD/CAM (InLab, Sirona Dental Systems, Long Island City, NY) for each of three different restorative materials, including lithium disilicate (IPS e.max CAD, Ivoclar Vivadent, Amherst, NY), feldspathic ceramic (CEREC Bloc C, Sirona Dental Systems, Long Island City,NY), and monolithic zirconia (inCoris TZI C, Sirona Dental Systems, Long Island City,NY).

The thirty samples were randomly placed in one of three groups corresponding to each restorative material. In group 1, lithium disilicate blocks were bonded to the prepared teeth using resin cement, per manufacturer's instructions (Multilink Automix, Ivoclar Vivadent, Amherst, NY). In group 2, feldspathic ceramic bocks were bonded to ten prepared teeth using resin cement. In group 3, zirconia blocks were conventionally cemented to ten prepared teeth using a glass ionomer luting cement (Ketac Cem Maxicap, 3M ESPE, St. Paul, MN). The same protocol was followed for testing experimental samples that was used for baseline samples. Sixty second thermal testing cycles were conducted on all 30 of the bonded samples, which were repeated 3 times per sample (Figure 4).

A non-linear mixed effects model was used to analyze the data. The data was fitted to a curve of exponential decay. The function includes three parameters, which are initial temperature, rate of change, and asymptotic, or final temperature.

## CHAPTER III: RESULTS

In this study, the temperature change over a course of a minute was examined for all samples, both control and experimental. One hundred and eighty total tests were performed. Graph 1 is a visual representation of all of the data. In graph 2, the mean of all data is shown. In order to perform a statistical analysis, the data was fitted to a curve of exponential decay, which was a way in which to represent a cooling model. The function used to model the data is shown in Graph 3. After the data for each sample were fitted to an exponential decay curve (Graph 4), three different parameters were examined, including initial temperature, asymptotic temperature, and rate of change.

The first parameter, initial temperature, was analyzed (Graph 5). The feldspathic porcelain sample showed a statistically significant lower initial temperature by 1.83°C ($p = 0.002$, 95% CI). The lithium disilicate and zirconia samples showed no difference compared to the control. The second parameter analyzed was asymptotic temperature (Graph 6). This is the temperature that the sample approaches, but never reaches. Both feldspathic porcelain and zirconia samples were higher than the control by 2.92° ($p = 0.001$) and 1.80° ($p = 0.04$), respectively. The analysis of the third parameter, the rate of change, yielded no differences between the experimental samples and the control samples (Graph 7).

## CHAPTER IV: DISCUSSION

Lithium disilicate most closely resembled the properties of enamel, while feldspathic porcelain showed the most deviation from the control. There was no significant difference in rate of change between the samples, even when differences in initial and asymptotic temperature were taken into account, which is strongly suggestive of no difference across materials. Although the feldspathic samples showed a statistically significant difference in both initial and asymptotic temperature, it is not clinically relevant. Since an overall net decrease in temperature was seen, it is reasonable to assume that cold testing is possible through feldspathic porcelain.

A non-linear mixed effects model was used for the analysis in this study. Because the model's nested random effects, it is able to account for differences across teeth and materials, such as tooth anatomy. Despite trying to achieve uniformity between samples by choosing only non-restored, non-carious extracted human premolars, each tooth had a different thickness of enamel, dentin, and size of pulp chamber.

## CHAPTER V: CONCLUSION

As trends are shifting in dentistry and patients are demanding highly esthetic, durable restorations, chairside milled ACRs are going to continue to prevail. In order to provide patients with appropriate care and correctly treat disease processes, the pulpal health of teeth must be able to be determined through a variety of restorative materials. The results from this experiment showed that using a commonly used method, cold testing, to evaluate pulpal health is feasible. In conclusion, thermal testing is a viable option for determining pulpal status through all ceramic restorations.

## REFERENCES

Aldegheishem A, Ioannidis G, Att W, Petridis H. Success and Survival of Various Types of All-Ceramic Single Crowns: A Critical Review and Analysis of Studies with a Mean Follow-Up of 5 Years or Longer. Int J Prosthodont. 2017;30(2):168-181.

Cheung GS, Lai SC, Ng RP. Fate of vital pulps beneath a metal-ceramic crown or a bridge retainer. Int Endod J. 2005;38(8):521-30.

Christensen GJ. The all-ceramic restoration dilemma: where are we?. J Am Dent Assoc. 2011;142(6):668-71.

Christensen GJ. Indirect restoration use: a changing paradigm. J Am Dent Assoc. 2012;143(4):398-400.

Giordano R, Mclaren EA. Ceramics overview: classification by microstructure and processing methods. Compend Contin Educ Dent. 2010;31(9):682-4, 686, 688 passim.

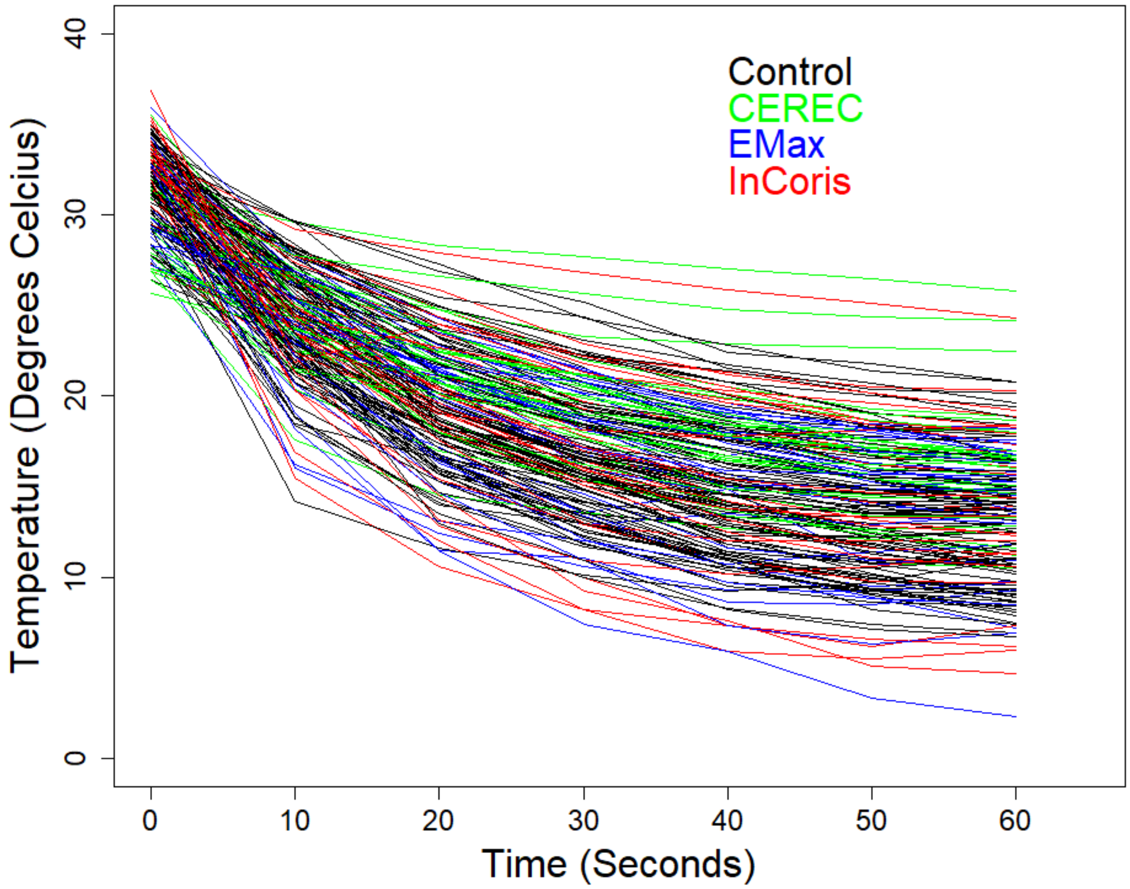
Kelly JR, Benetti P. Ceramic materials in dentistry: historical evolution and current practice. Aust Dent J. 2011;56 Suppl 1:84-96.

Lawson NC, Bansal R, Burgess JO. Wear, strength, modulus and hardness of CAD/CAM restorative materials. Dent Mater. 2016;32(11):e275-e283.

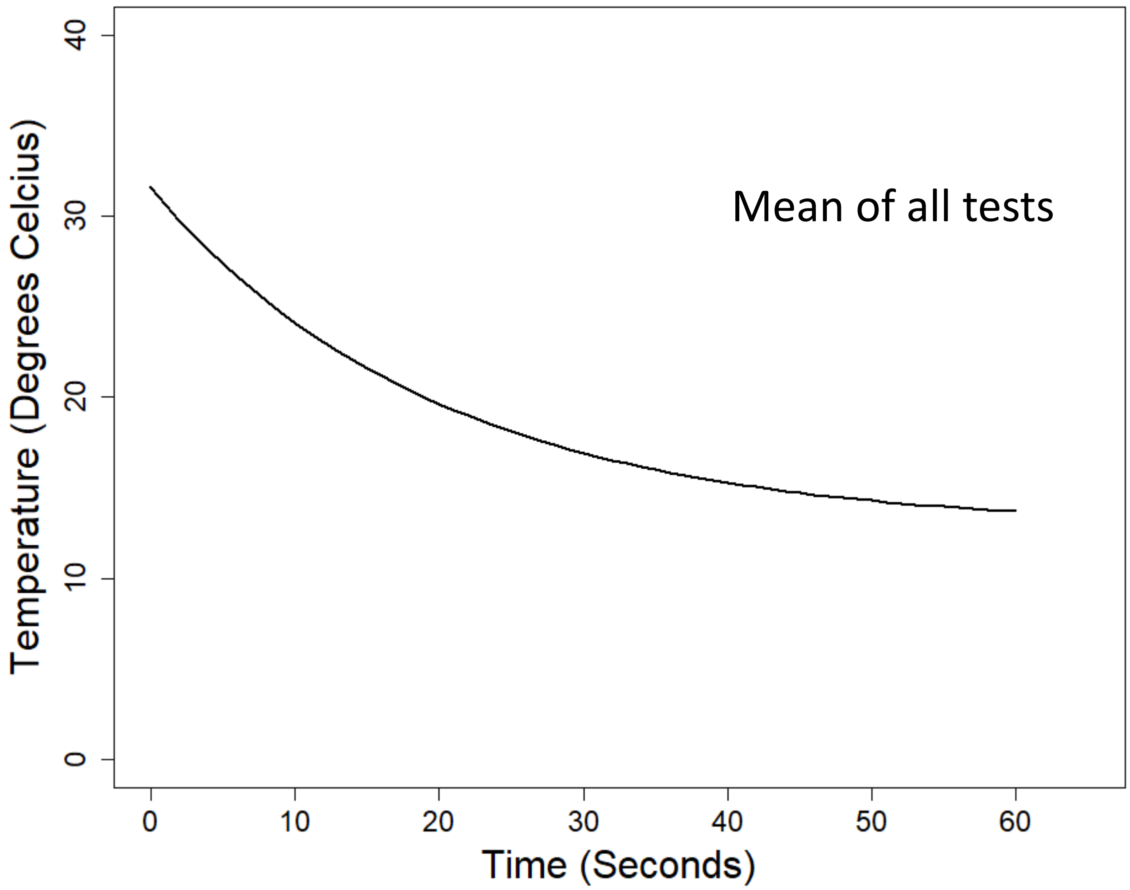
Miller SO, Johnson JD, Allemang JD, Strother JM. Cold testing through full-coverage restorations. J Endod. 2004;30(10):695-700.

Sailer I, Makarov NA, Thoma DS, Zwahlen M, Pjetursson BE. All-ceramic or metal-ceramic tooth-supported fixed dental prostheses (FDPs)? A systematic review of the survival and complication rates. Part I: Single crowns (SCs). Dent Mater. 2015;31(6):603-23.

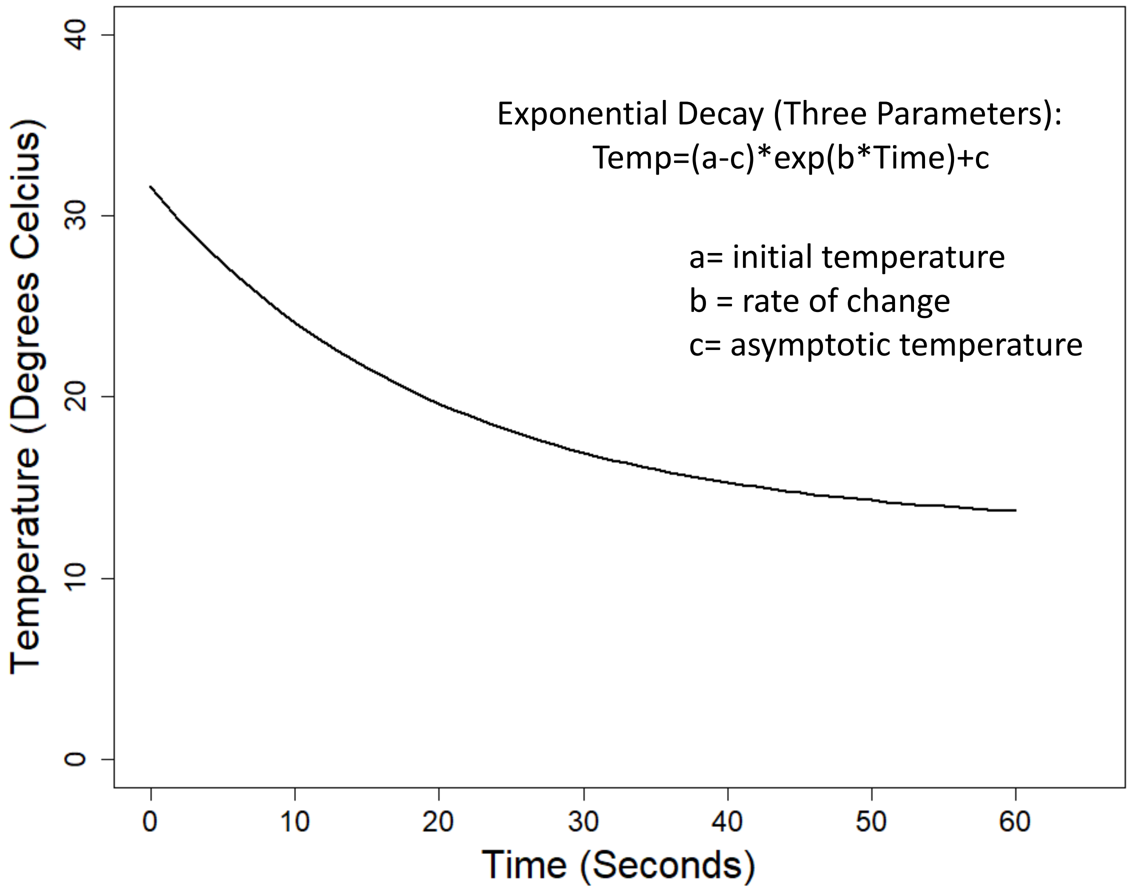
Valderhaug J, Jokstad A, Ambjørnsen E, Norheim PW. Assessment of the periapical and clinical status of crowned teeth over 25 years. J Dent. 1997;25(2):97-105.



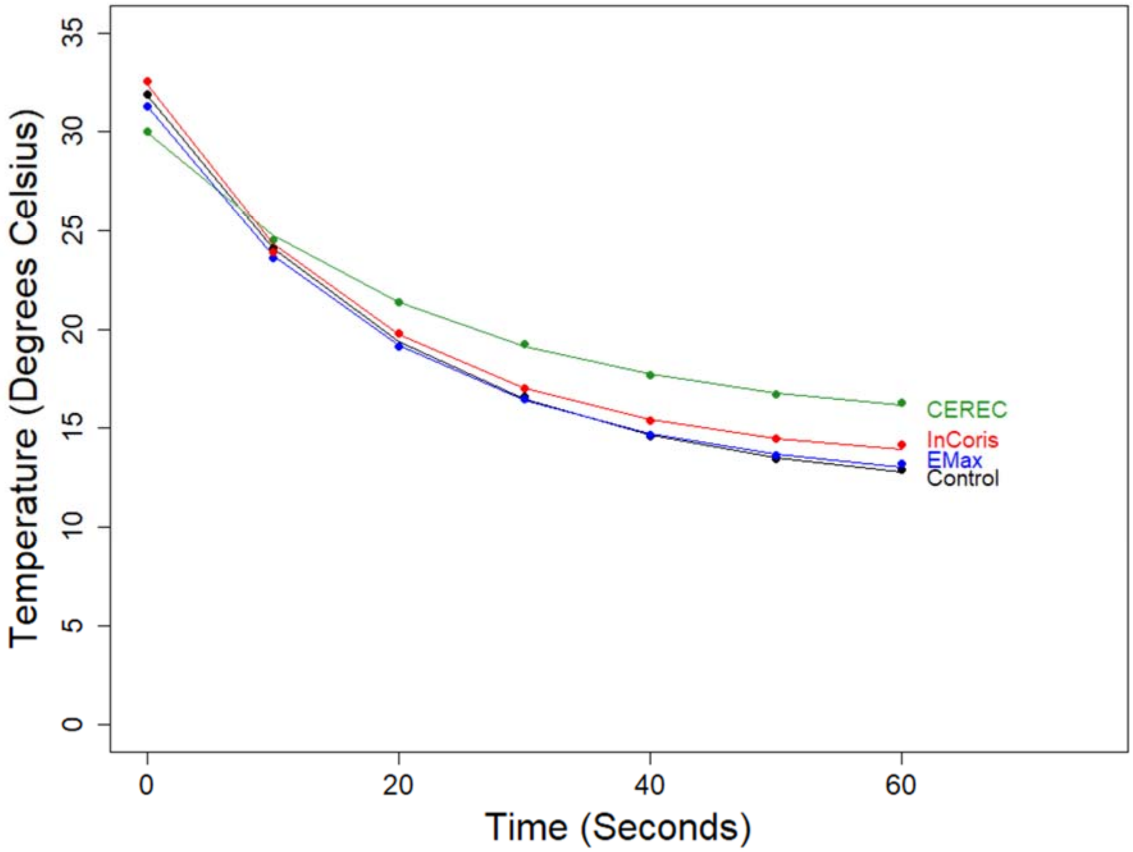

**Graph 1**: Graphic compilation of all data



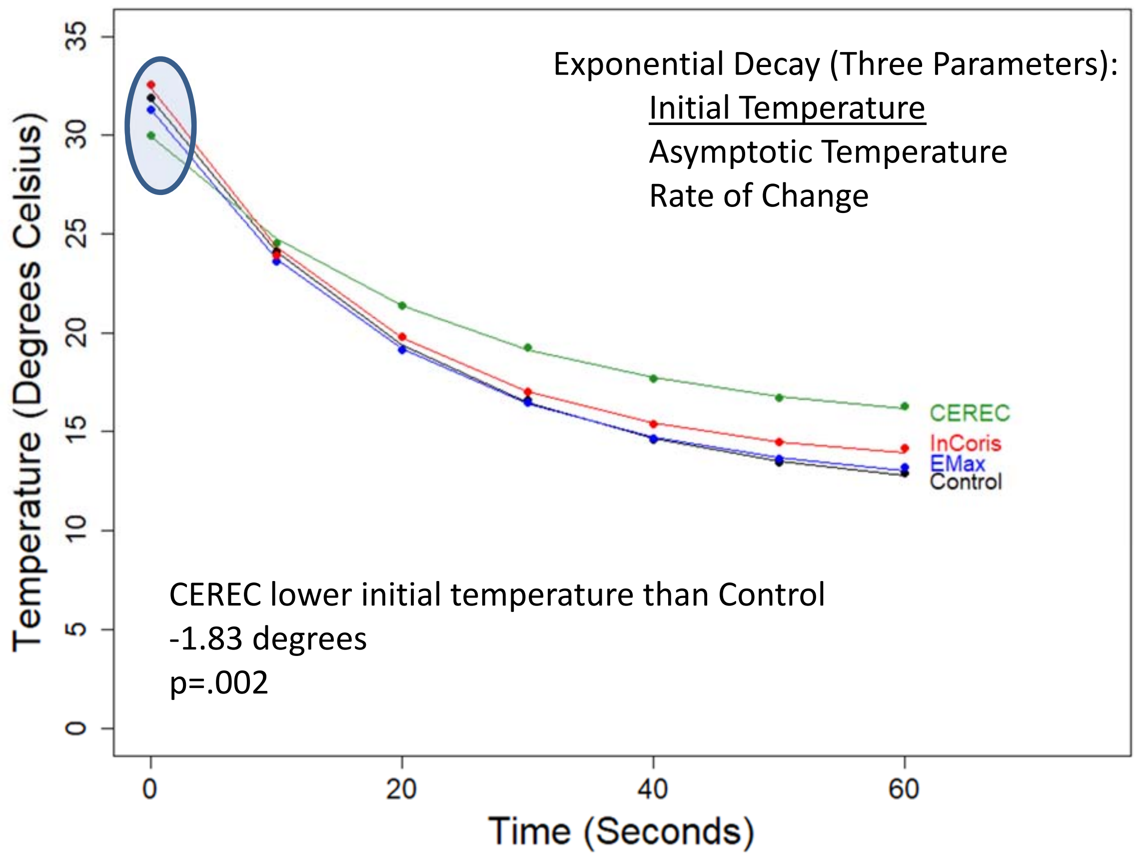

**Graph 2**: Mean of all data, including control and experimental samples



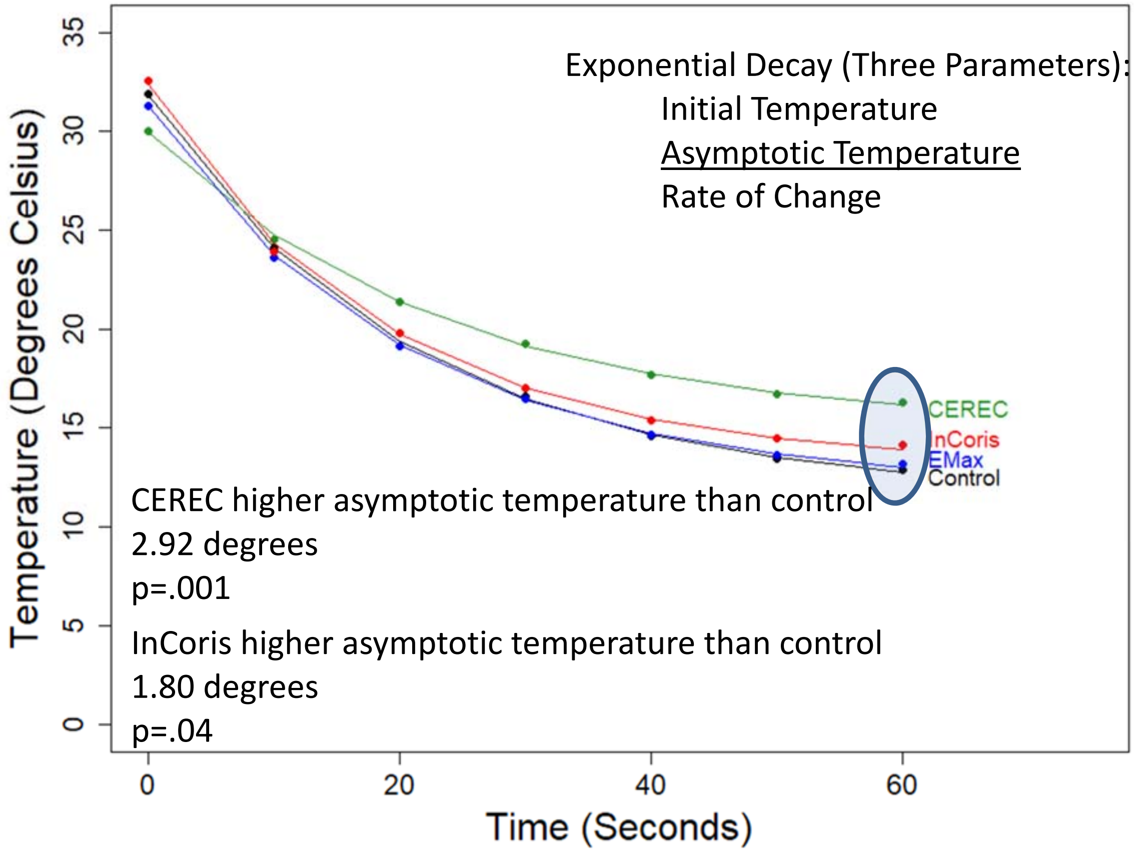

**Graph 3**: Exponential decay model



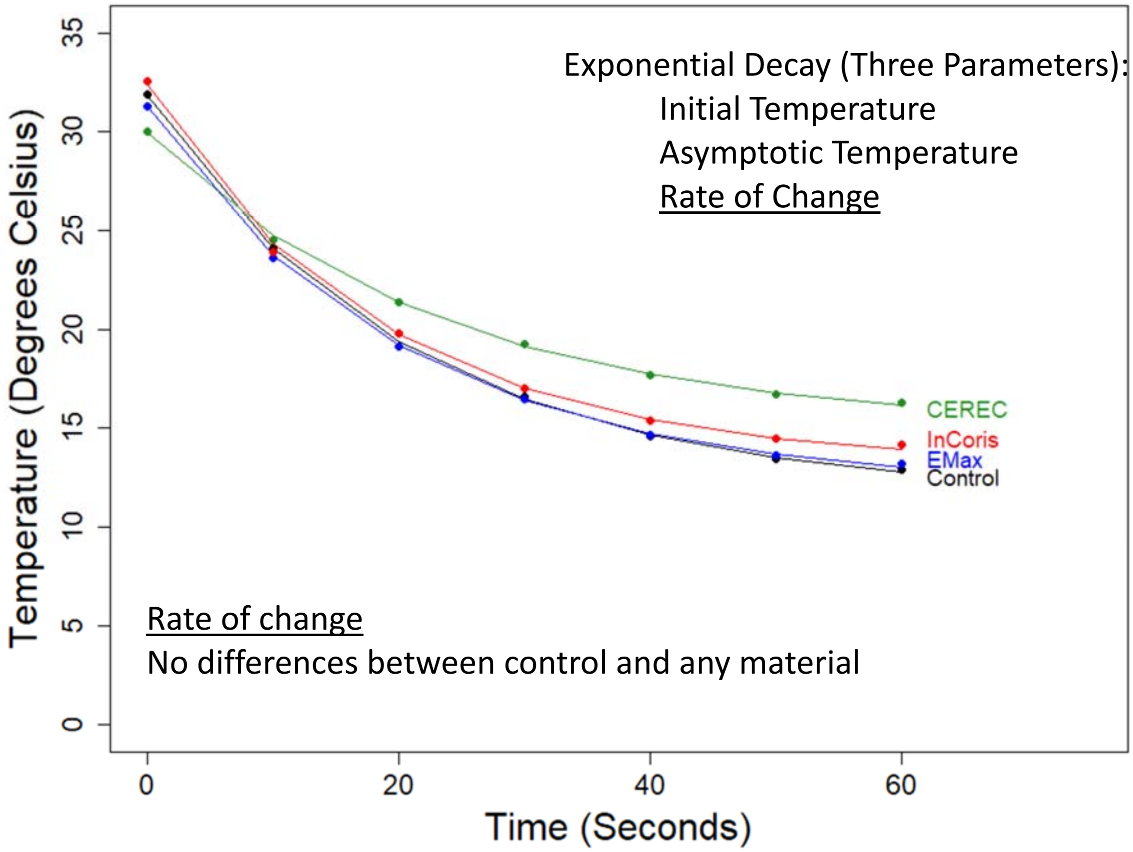

**Graph 4**: Means of data for control and experimental groups




**Graph 5**: Analysis of parameter 1 (initial temperature)




**Graph 6**: Analysis of parameter 2 (asymptotic temperature)




**Graph 7**: Analysis of parameter 3 (rate of change)


**Figure 1**


**Figure 2**

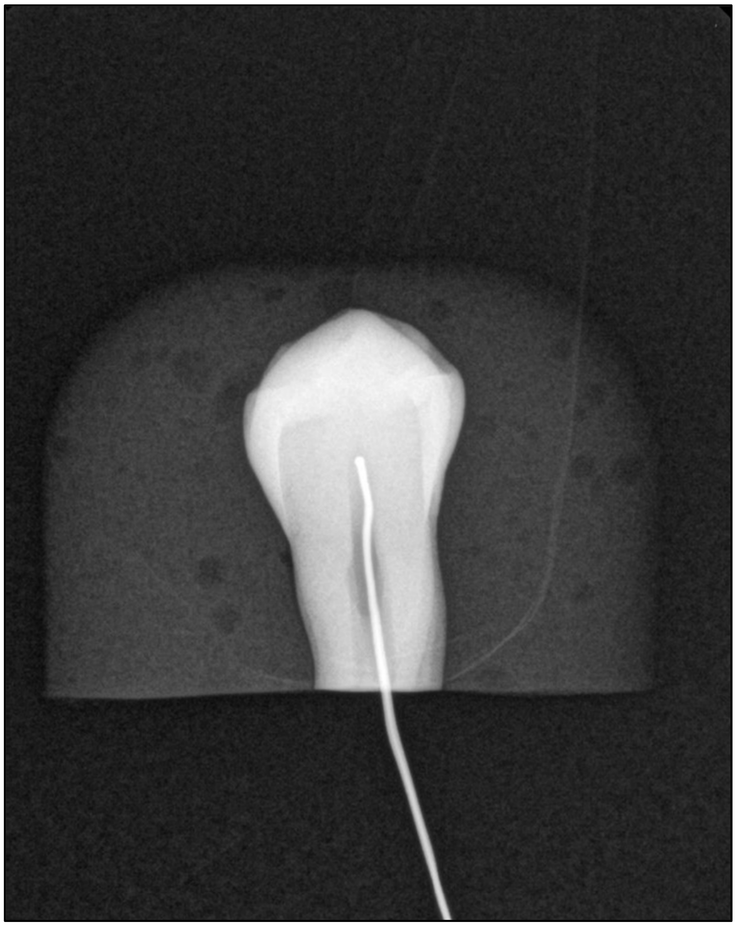


**Figure 3**

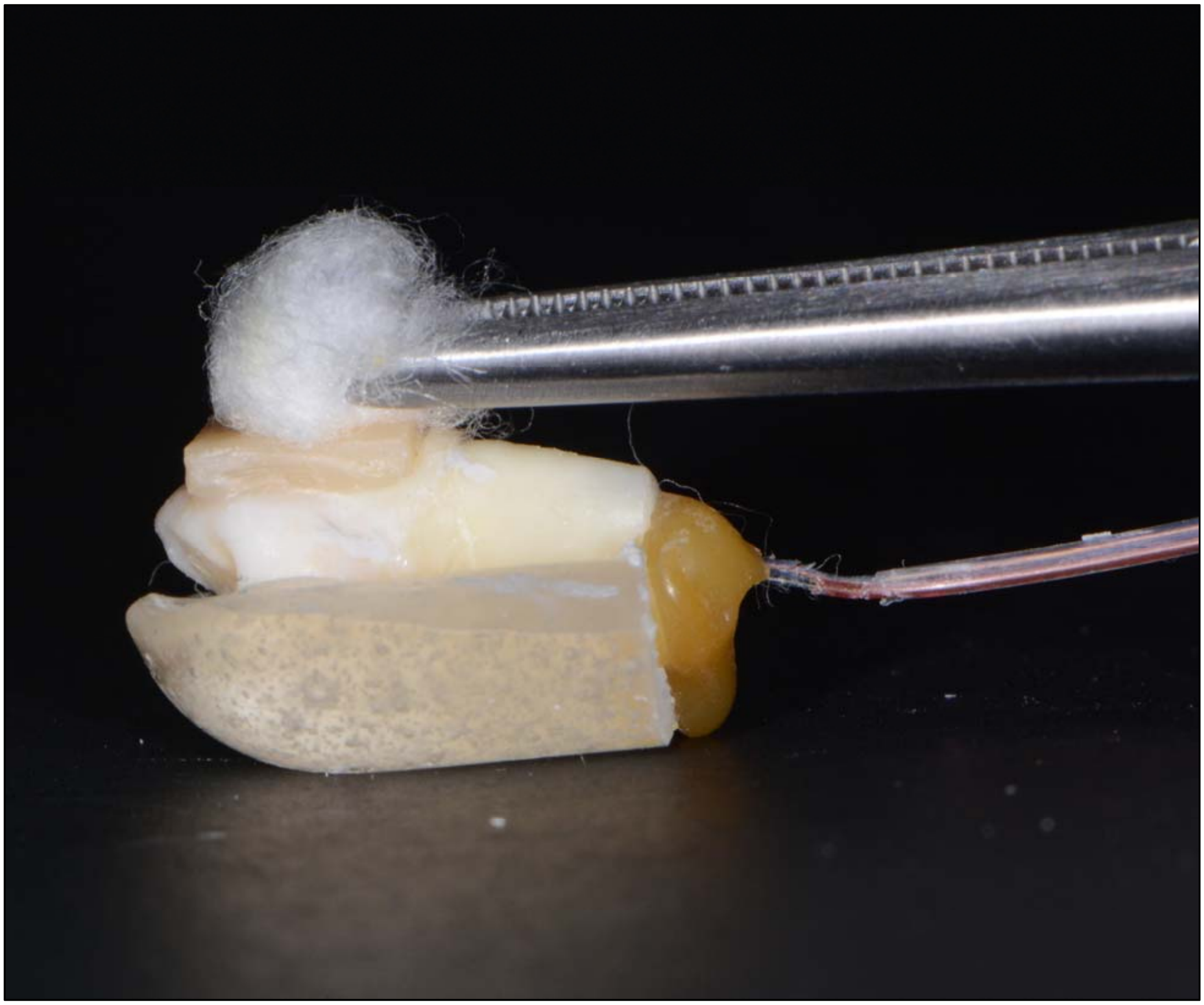


**Figure 4**