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ARMY INST OF DENTAL RESEARCH WASHINGTON DC
IN VITRO MODEL SYSTEM TO EVALUATE INTA-PULPAL TEMPERATURE CHANG--FTC
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
	DA OH 6038 AD-A087582	
4. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED
In Vitro Model System to Evaluate Intra-Pulpal Temperature Changes		Submission of paper Mar 1980 - June 1980
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s)
Donald D. Peters and Robert A. Augsburger		
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
US Army Institute of Dental Research Walter Reed Army Medical Center Washington, DC 20012		62775A 3S762775A825 00 006
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE
US Army Medical Research & Development Command HQDA-IS Fort Detrick, MD 21701		June 1980
		13. NUMBER OF PAGES
		19
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report)
LEVEL II		UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)		
This document has been approved for public release and sale; its distribution is unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
pulp testing, carbon dioxide testing		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		
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⑨ Rept. for Mar-Jun 1962

⑥ In Vitro Model System to Evaluate Intra-Pulpal
Temperature Changes.

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Abstract:

A dry ice (carbon dioxide) cold test was applied to four extracted teeth and the intra-pulpal temperature change was measured using a thermistor probe. A model system was developed to maintain the teeth at body temperature. In order to establish a fast efficient experimental methodology for future studies, temperature changes were compared prior to and after root removal. The average temperature changes with roots ranged from $3.48 \pm \text{s.d. } 0.33^{\circ}\text{F}$ to $5.96 \pm \text{s.d. } 0.48^{\circ}\text{F}$. After roots were sectioned from their crowns, the average temperature changes were $6.30 \pm \text{s.d. } 0.20^{\circ}\text{F}$ and $7.42 \pm \text{s.d. } 0.33^{\circ}\text{F}$. The probable reason for the difference, and its significance, is discussed.

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Several studies have evaluated the immediate temperature changes due to operative procedures.¹⁻³ In an in vitro study White and Cooley⁴ recorded temperature changes within the pulp chamber of a tooth using various hot and cold tests. They removed the pulp, injected silicone heat transfer compound into the pulp space, and threaded a thermistor through the root into the pulp chamber. Silicone oil has been shown to have approximately the same thermoconductivity as dentin.⁴ The tooth was maintained at room temperature and subjected to hot and cold tests. The temperature changes within the pulpal space were recorded by the thermistor.

In designing a system to measure intra-pulpal temperature changes, two modifications of White and Cooley's study seemed appropriate. First, it was felt that cold tests applied to teeth at body temperature would be more clinically relevant. The second change concerned a proposed removal of the roots to facilitate accurate placement of the thermistor probe. The effect of root removal on intra-pulpal temperature change was unknown.

The purpose of this study was therefore threefold: first, to devise a model system which would maintain the teeth at body temperature; second, to test teeth with a thermistor threaded through the roots versus having the roots removed; third, to correlate the data and determine the value of this system for more extensive studies.

METHODS AND MATERIALS

The complete experimental armamentarium is seen in Figure 1, while the actual temperature monitoring unit is shown in Figure 2.

Four single canal extracted human anterior teeth were selected. The pulps were removed from an apical approach via the canals, and enlarged to a size which allowed placement of a needle thermistor[‡] 0.4 mm in diameter and 42 mm long (Fig 3). Cold cure acrylic was poured into a plastic form (55 mm x 43 mm x 5 mm) and the teeth mounted with mesiodistal contacts. Silicone heat transfer compound,^y which has the consistency of vasoline, was injected into their chambers and canals using a syringe with a 19 gauge needle. The jig with the teeth was clamped onto the aluminum plate (10.4 cm x 6.3 cm x 0.6 cm) mounted on a metal box^{*} (10.4 cm x 6.7 cm x 4.2 cm) containing a heating unit.⁺ This supplied heat to maintain the aluminum plate at a constant temperature. The box temperature was monitored by a dial thermometer.[±] Temperature of the acrylic jigs was monitored by a probe 113 mm in length and 3 mm in diameter attached to a scanning tele-thermometer.["] By monitoring both systems, the teeth placed on the plate could be maintained at a constant temperature. The temperature within the pulp chamber was monitored by the needle thermistor connected to a second tele-thermometer.[#] The thermistor was placed through the pulp canal into the pulp chamber. The teeth were maintained at body temperature. The current to the heating unit was monitored by a 10 milliamper D.C. logging meter^o and controlled by a variable autotransformer^x plugged into a 115v A.C. electrical outlet. The temperature monitoring unit with the jig and teeth in place were covered by a clear polyvinyl bag to keep drafts from effecting the results. Tests were made through a small opening in the top of the bag.

Each tooth had a CO₂ pencil[®] placed on the buccal surface in the center mesiodistally and two millimeters occlusal to the cervical line. The carbon dioxide was dispensed at the tip of the CO₂ pencil in the consistency of condensed snow with a diameter of 3.5 mm (Fig 4). The pencil was placed for 5 seconds and the pulpal changes recorded over 90 seconds. Each test was repeated 5 times.

Next, the roots were resected 2-4 mm apical to the cervical line and the silicone heat transfer compound replaced in the chambers (Fig 5). All but 1 mm of the tip of the thermistor was covered with a polyvinyl tube with a diameter of 1.1 mm. This insured against recording any temperature changes except at the working tip. The tip was then placed next to the dentin opposite the area to be tested, and the tests repeated as before.

RESULTS

Table 1 shows the results for the four teeth with the probe threaded through the roots into the chamber. The average temperature change of five tests on each tooth ranged from 3.48 to 5.97 F[°] occurring over 15 to 25 seconds. The range of standard deviations for the temperature change in each tooth for the five tests ranged from 0.33 to 0.48. The average of the standard deviations was 0.410. The average of the coefficient of variations was 8.76.⁷

Table 2 shows the results for the four teeth with the roots removed and the probe placed in a specific area in the chamber. The range of the average temperature change for the four teeth (five tests for each tooth) was from 6.30 to 7.42 degrees. Again, the maximum change in

temperature occurred between 15 to 25 seconds. Time data was unaffected by presence or absence of roots and consistent for each tooth. The range of standard deviations for the temperature change in each tooth for the five tests ranged from 0.20 to 0.33. The average of the standard deviations being 0.26. The average of the coefficient of variations was 3.94.⁷

Table 3 shows that with the roots removed the average temperature change increased from 1.35 to 2.88 degrees.

DISCUSSION

The model system used worked excellently for maintaining the teeth at body temperature. Maintaining the teeth at body temperature during testing may be of value for several reasons. First, any changes that occur in the pulpal space should relate well to what occurs clinically. Second, after a response occurs the reversal of effect should occur at much the same rate as occurs clinically. Third, the input of body heat occurring clinically in vital teeth is simulated.

Testing a tooth through the enamel and dentin and recording temperature change in the chamber space gave consistent results whether the root was present or not. Since the standard deviation was less for each tooth without the roots, it appears that the root may contribute to inconsistency in testing. To statistically evaluate the consistency of reading before and after removal of the roots, a coefficient of variations was calculated. The lower the coefficient of variation, the smaller the measurement error in comparison to the magnitude of measurement.⁷ Therefore, the measurement error was much less after root removal (3.95) than before root removal (8.76) even though readings

on individual teeth were different from each other both before and after removal.

The change in temperature without the roots was always greater than with the roots. Two explanations for this appear possible, First, without the root there is less volume to release heat allowing more effect on the probe. Second, without the roots, instead of just placing the probe haphazardly within the pulp chamber, it was possible to visually place it next to the dentin directly below where the test was made. This would appear to be more clinically significant since the tissue closest to where the test was made would be the first affected. Also, this second reason seems to more completely explain the inconsistency of temperature ranges. The individual teeth with and without roots had a range difference of 2.88 to 1.46 degrees. If only a loss of a cold sink was involved, some correlation to original change might be expected but did not occur. Second, the tests of the group of teeth with roots varied 2.46 degrees and without roots only 1.14 degrees. The 1.14 degrees may relate more directly to variation in thickness of enamel and dentin while the 2.46 degrees may add the inconsistent placement of the probe. Finally, the visual placement of the probe may better explain the decrease in standard deviation seen in the rootless teeth.

It would appear by the consistency of results, in magnitude and over time, that testing either with or without the roots is a valid procedure. However, testing without the roots was more consistent. The greater accuracy in visual versus tactile placement of the thermistor

probe appears to account for this difference. Since testing without roots is easier, faster, and more consistent, future studies using this model system will be performed on teeth with their roots removed. The system will be used to evaluate the intra-pulpal temperature changes produced by various cold tests, and to evaluate temperature transference via restorations with and without bases.

CONCLUSION

A cold test using dry ice (carbon dioxide) was conducted on four teeth in vitro with and without their roots. The following observations were made when intra-pulpal temperature changes were measured:

1. The temperature changes and the time in which they occurred were consistent for all the teeth tested.
2. The range of temperature change was always greater, but more consistent on the teeth without roots.
3. Using teeth without roots gives results equal to or better than those derived with the roots present.
4. Using teeth without roots is an easier testing procedure.

- * Pomona Box Model 3301, Pomona Electronics, Co., Inc., Pomona, CA
- † Thermistor Model 8455, Cole-Parmer Inst. Co., Chicago, Ill 60648
- y GC Silicone Compound E-Z, GE Electronics, Rockford, Ill 61101
- + Ungar S. Iron Heating Element, Ungar Corp, PO Box 6005, Compton, CA 90220
- ± Metal Thermometer, Stortz Corp., Perkasie, PA
- " Scanning Tele-Thermometer, Y.S.I. Model 47, Yellow Springs Inst. Co., Inc., Yellow Springs, Ohio 45387
- # Tele-Thermometer, Y.S.I. Model 43TF, Yellow Springs Inst. Co., Inc., Yellow Springs, Ohio 45387
- o 0-10 Milliampere D.C. Logging Meter, API Inst. Co., 3 Greenfield Rd., PO Box 750, St. Albans, VT
- x Powerstat^(R) Variable Autotransformer (Variac), The superior Electric Co., Bristol, Conn.
- o Odontotest^(R), Union Broach Corp., 37-40 37th Street, Long Island City, NY 11101.

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Commercial materials and equipment are identified in this report to specify the investigation procedures. Such identification does not imply recommendation or endorsement, or that the materials and equipment are necessarily the best available for the purpose. Furthermore, the opinions expressed herein are those of the authors and are not to be construed as those of the Army Medical Department.

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The authors wish to express their sincere appreciation to Mrs. Ailene Otterstedt for her extensive help in manuscript preparation.

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Table 1. Maximum Fahrenheit degree (F°) temperature changes and time for occurrence following a five second CO₂ test prior to root removal.

[illegible]

Table 2. Maximum Fahrenheit degree (F°) changes and time for occurrence following a five second CO₂ test after root removal.

Tooth #	1	2	3	4
	Temp F° changes	temp F° changes	temp F° changes	temp F° changes
	seconds	seconds	seconds	seconds
	time	time	time	time
	seconds	seconds	seconds	seconds
test 1	7.0	6.3	6.6	8.0
	20	20	20	15
test 2	7.6	6.7	6.4	7.4
	20	20	20	15
test 3	7.7	6.1	6.1	7.2
	20	20	20	15
test 4	7.3	6.4	6.4	7.2
	25	20	20	15
test 5	7.6	6.0	6.6	7.3
	20	20	20	15
mean	7.44	6.30	6.42	7.42
	21	20	20	15
standard deviation	0.29	0.27	0.20	0.33
coefficient of variation	3.90	4.29	3.12	4.45
				3.94

Table 3. Average increase in Fahrenheit degree (F°) temperature change for each tooth after removal of the roots

Tooth #	1	2	3	4
	F° Change	F° Change	F° Change	F° Change
with root	4.56	3.48	5.08	5.96
without root	7.44	6.30	6.42	7.42
temp. difference	+2.88	+2.82	+1.35	+1.46

Legends

Figure 1 - Complete experimental apparatus:

- A. Tele-thermometer monitoring temperature intra-pulpally.
- B. Variable autotransformer
- C. Temperature control unit.
- D. Tele-Thermometer monitoring temperature of acrylic jigs and teeth.

Figure 2 - Temperature control unit:

- A. Teeth
- B. Acrylic jig for teeth
- C. Aluminum stage
- D. Probe to monitor temperature of acrylic jig
- E. Needle thermistor probe to monitor intra-pulpal temperature
- F. Box containing heating element
- G. Thermometer to monitor stage temperature
- H. Milliampere D.C. logging meter

Figure 3 - Needle thermistor probe with plastic sleeve used to protect against non-experimental temperature changes.

Figure 4 - Carbon dioxide apparatus:

- A. Assembled snow former.
- B. Outer plastic tube.
- C. Carbon dioxide pencil. Pellet at end is exact replica of carbon dioxide testing surface placed against tooth.
- D. Plunger to condense carbon dioxide snow.

Figure 5 - Four anterior teeth mounted in jig after removal of roots.



FIGURE 1

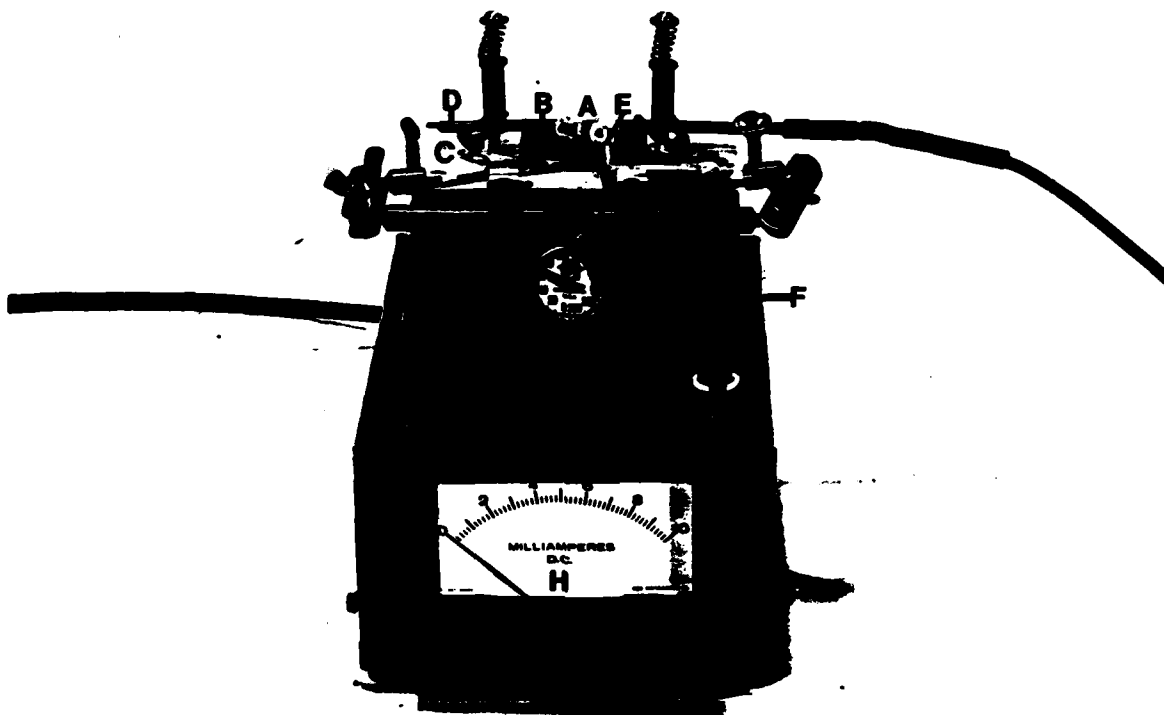


FIGURE 2



FIGURE 3

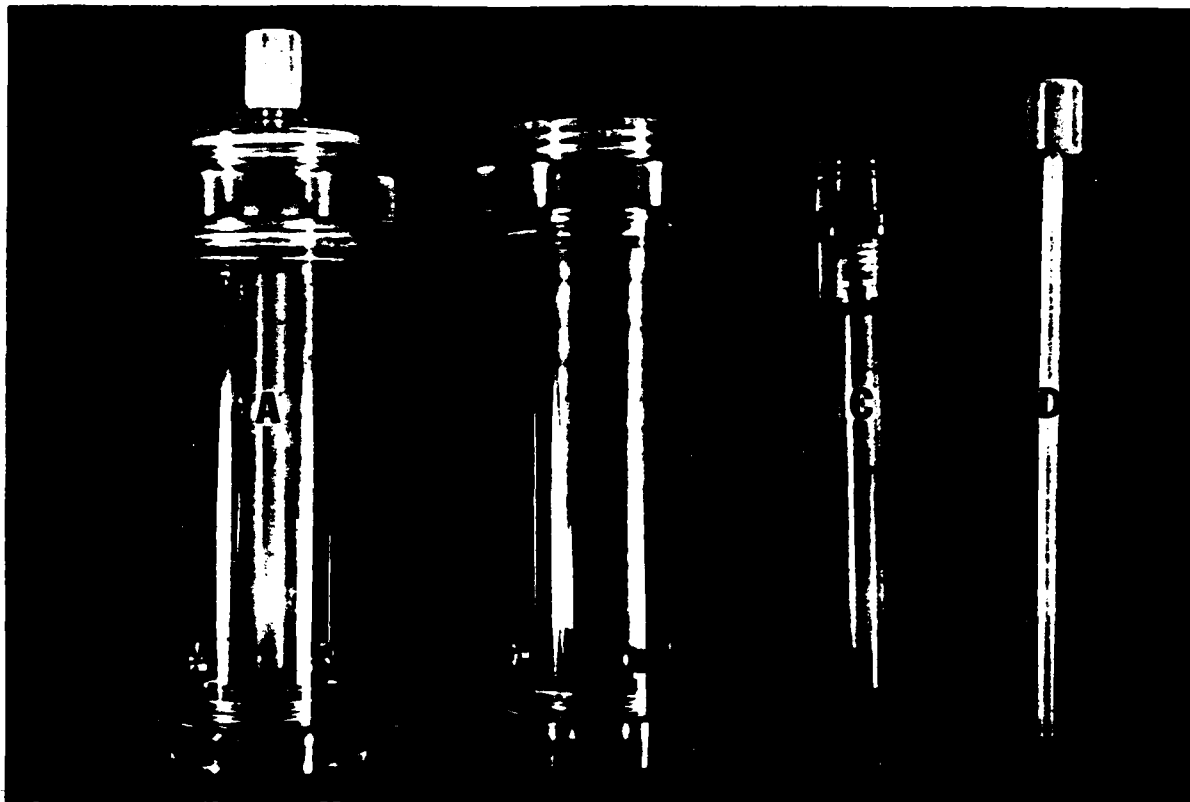


FIGURE 4

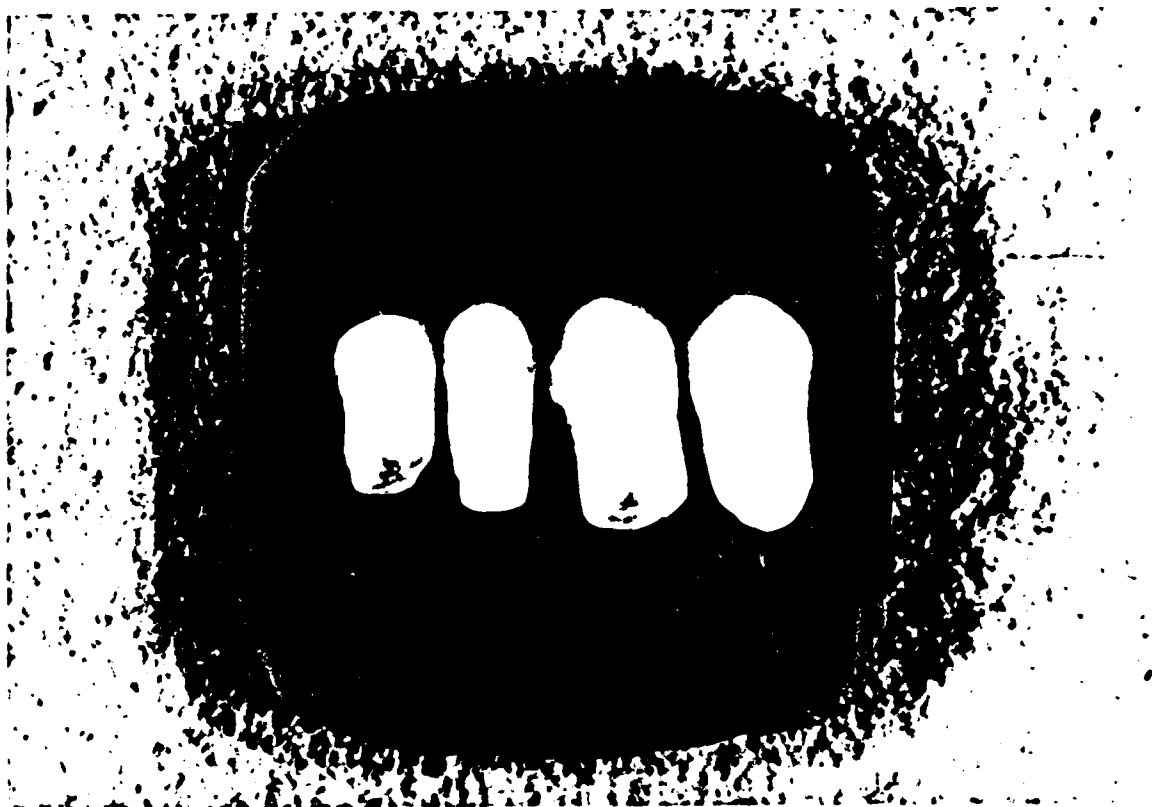


FIGURE 5