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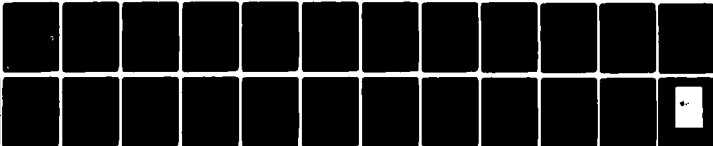
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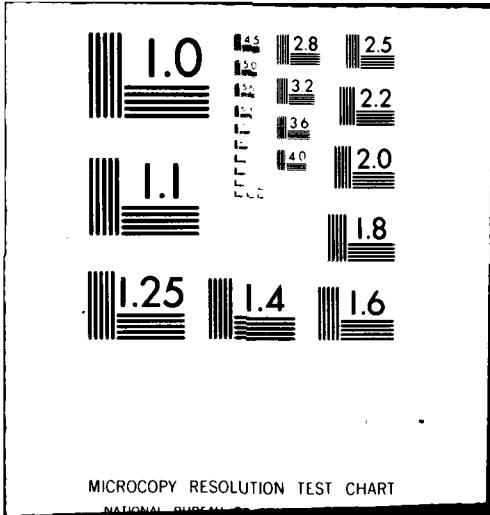
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Three cold tests - ice, skin refrigerant, and CO₂ snow - were compared for their ability to decrease intrapulpal temperatures in vitro. A 5-second CO₂ snow application resulted in a statistically greater decrease than ice or skin refrigerant in both virgin and in crowned teeth. Although the amount of temperature change a pulp can withstand is not known, the 4 to 8F° decrease produced by the CO₂ snow did not seem extreme. Temperature transfer between teeth in proximal contact was shown to be relatively insignificant. Advantages of CO₂ snow based upon clinical experience are discussed.

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(6) IN VITRO EFFECTS OF ICE, SKIN REFRIGERANT,
AND CO₂ SNOW ON INTRA-PULPAL TEMPERATURE.

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ABSTRACT

Three cold tests - ice, skin refrigerant, and CO₂ snow - were compared for their ability to decrease intrapulpal temperatures in vitro. A 5-second CO₂ snow application resulted in a statistically greater decrease than ice or skin refrigerant in both virgin and in crowned teeth. Although the amount of temperature change a pulp can withstand is not known, the 4 to 8F⁰ decrease produced by the CO₂ snow did not seem extreme. Temperature transfer between teeth in proximal contact was shown to be relatively insignificant. Advantages of CO₂ snow based upon clinical experience are discussed.

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INTRODUCTION

A reliable and yet practical vitality test would be a welcome adjunct to aid in the evaluation of the pulpal status of teeth. The three popular tests today are thermal, electrical, and test cavities. Test cavities underscore the difficulty experienced by practitioners in arriving at a diagnosis.

A vitality test exists which has been popular in many parts of the world but which is largely untried in the United States. It is a cold test utilizing dry ice in the consistency of compacted snow referred to alternatively as carbon dioxide snow (CO₂ snow).

Early use of dry ice in dentistry can be traced to 1936.¹ More recently, Obwegeser and Steinhauser² modified the apparatus into a clinically usable CO₂ pencil form. Liquid CO₂ under pressure is converted to CO₂ snow when the pencil is filled from the tank of CO₂ (Fig 1). Tests on 1000 teeth indicated the CO₂ snow as 97.5% accurate as compared to 97.2% accuracy for electrical pulp testing.³ Another study comparing vitality tests⁴ showed CO₂ snow to be 96.6% accurate, while electrical and heat tests were 90% and 87.6% accurate, respectively.

Seltzer, Bender, and Ziontz⁵ showed that both electrical pulp tests and thermal tests using ice or ethyl chloride were unreliable based upon subsequent histological findings in the pulp. They found that 53% of teeth with partial or total pulp necrosis responded to the electrical pulp tester. Endodontic therapy or extraction is indicated for such teeth, however, underscoring the

the misdiagnosis which can result from reliance on electrical pulp tests. The most reliable application of the tester is when no response is obtained since 97.7% of these teeth have at least partial necrosis. From 11% to 33% of teeth with partial or total necrosis responded normally to ice or ethyl chloride, while 27% to 50% of teeth not requiring endodontic treatment gave an abnormal response or no response.

In addition to its apparent accuracy, other advantages of CO₂ pencil vitality test are the speed and ease of application, since isolation of the teeth is unnecessary.² A full compliment of teeth can be tested in 2 to 3 minutes. As such, the CO₂ snow test would be a practical addition to the routine examination. CO₂ snow is also recognized as effective in testing through gold crowns.² Schiller⁶ showed histologically, as early as 1937, that the test was not only easy and sure, but safe for the pulp.

Given the apparent usefulness of the CO₂ pencil vitality test, it seemed appropriate to determine its effect on intrapulpal temperature. White and Cooley⁷ applied several thermal tests to a tooth in vitro and measured intrapulpal temperature changes. They found that skin refrigerant produced a greater temperature decrease than either ice or an ice water bath, and recommended its use based upon convenience. However, clinicians find skin refrigerant a very slow test if multiple teeth are to be evaluated because it loses effectiveness after one tooth is tested.

The purpose of this investigation was to quantitatively compare

intrapulpal thermal changes produced in vitro by ice, skin refrigerant, and CO₂ snow. The experiment was designed to measure both temperature change within the tooth tested, and within adjacent teeth in proximal contact.

Materials and Methods

Three diagnostic cold tests were applied to the crowns of 13 extracted human mandibular molars and intrapulpal temperature decreases were recorded and compared. Six of the teeth studied had non-carious and non-restored crowns (virgin teeth), on five teeth full crown preparations were made and full gold crowns were fabricated and cemented. The remaining two teeth received Class II preparations; one received a dycal base, copalite, and an amalgam, and the other copalite and amalgam.

Three cold tests, ice, skin refrigerant, and CO₂ snow were used in this study. Ice was made in anesthetic carpules with an internal diameter of 7 mm. The skin refrigerant was applied using two #0 cotton pellets held in the beaks of cotton pliers and sprayed with the refrigerant until crystals formed. The carbon dioxide snow at the tip of the CO₂ pencil was 3.5 mm in diameter.

The study was divided into three parts. For all three parts of the study, the cold tests were applied five times to the same spot on teeth at body temperature. All tests were applied to the buccal surface in the center mesiodistally and 2 mm occlusal to the cervical line or gold crown margin. The intrapulpal temperature change produced by the cold tests was measured by a needle thermistor

probe.* Each cold test application was 5 seconds and intrapulpal temperatures were monitored for 90 seconds. The intrapulpal temperature was allowed to return to body temperature for the start of each test.

A modification of White and Cooley's⁷ method was devised to maintain the teeth at body temperature⁸ (Fig 2). The roots were resected from all teeth 2 to 4 mm apical to the cemento-enamel junction to give direct access to the entire pulp chamber (Fig 3). Teeth were mounted in proximal contact in pairs in self-cured acrylic jigs, simulating tooth-to-tooth contact in the mouth. The occlusals of the teeth were imbedded in the acrylic at 45 degree angle with the exposed pulp chambers facing out (Fig 3). These jigs were mounted on an aluminum plate (10.4 cm x 6.3 cm x 0.6 cm) on the top of a metal box[†] (10.4 cm x 6.7 cm x 4.2 cm) containing a heating unit.[‡] This system supplied heat to maintain the acrylic jigs and the teeth at body temperature. The temperature of the aluminum plate holding the acrylic blocks, and of the acrylic blocks themselves, was monitored. A metal dial thermometer was placed inside the metal box to monitor its temperature. The temperature of the acrylic jig was measured by a thermal probe[#] placed on the jig next to the teeth and connected to a scanning tele-thermometer.⁰

To measure the intrapulpal temperature, the needle thermistor probe, 42 mm long with a diameter of 0.4 mm, was connected to a tele-thermometer.⁺ Temperatures were measured to 0.1 F⁰ accuracy. The thermistor probe was insulated from drafts with a 1 mm thick polyvinyl

tube leaving only the tip of the thermistor exposed. The tip of the thermistor probe was placed intrapulpally next to the dentin, directly under the spot where cold tests were applied, to allow temperature monitoring. The pulp chamber was filled with silicone heat transfer compound.[±] Silicone oil has been shown to have approximately the same thermoconductivity as dentin.⁹

By monitoring both systems, the teeth were maintained at body temperature. The heating unit, stage, and jigs with the teeth were covered by a clear polyvinyl bag to keep any changes in room temperature, or drafts, from effecting the results. Testing agents were inserted through a small opening at the top of the bag.

The power to the heating unit was supplied by a variable auto-transformer^x plugged into a 115v A.C. electrical outlet. This allowed fine control of the power being supplied to the heating unit, and therefore the temperature of the system. The current from the transformer to the heating iron was read on a 0.10 milliamperere D.C. logging meter^y (Fig 3).

PART ONE

In part one, the transference of cold produced by ice, skin refrigerant,^φ and CO₂ snow^θ was studied. The cold tests were applied independently to the six virgin teeth with intact crowns and to the five teeth with gold crowns. Intrapulpal temperature changes were measured within the teeth to which the cold test was applied. The testing sequence for each tooth was randomized.

Part Two

For part two of the study, cold transference from one virgin tooth to a virgin neighbor in proximal contact, or from gold crown to gold crown, was measured. Silicone heat transfer compound was placed on the proximal contact area to insure contact and cold transfer between teeth. Only CO₂ snow was used in part two, and it was applied to one tooth with the thermistor probe located intrapulpally in the adjacent tooth.

Part Three

In part three, temperature transference was measured between unlike teeth in contact. Specifically, CO₂ snow was applied to virgin teeth contacting crowned teeth, with the thermistor probe in the crowned teeth. The probe was then placed in the virgin teeth to measure temperature transfer when the CO₂ snow was applied to the crowned teeth. This procedure was repeated with teeth restored with C1 II amalgams contacting either virgin teeth or crowned teeth.

Statistical Methods

The mean temperature decreases and standard errors were calculated for the five test applications of each agent on each tooth.¹⁰

In addition, for part one the average standard error of the means for each test agent was calculated, and the test agents were compared to each other using paired t-tests.¹⁰

RESULTS

Part One

Resultant intrapulpal temperature decreases produced when the

three cold test agents were applied to virgin, intact crowns or to teeth with gold crowns are summarized and depicted in Table 1 and Figure 4.

For virgin teeth, a five second application of CO₂ snow produced a mean intrapulpal temperature decrease of $4.01 \pm s.e. 0.13$ F⁰. Skin refrigerant produced a mean drop of $2.06 \pm s.e. 0.07$ F⁰ and ice a mean decrease of $1.05 \pm s.e. 0.06$ F⁰. It is evident that the results are consistent, with CO₂ snow always producing a greater effect than skin refrigerant, which produced a greater effect than ice.

Carbon dioxide snow applied five seconds to gold crowns produced a mean intrapulpal temperature decrease of $8.21 \pm s.e. 1.23$ F⁰. Skin refrigerant was less effective than ice on gold crowns and produced a mean drop of $2.61 \pm s.e. 0.17$ F⁰. Ice dropped the mean intrapulpal temperature $3.70 \pm s.e. 0.42$ F⁰. Again, the results are very consistent.

Figure 2 shows the intrapulpal temperature decreases over time. The maximum temperature change for virgin, intact crowns occurred 20 to 25 seconds after the test was begun, regardless of which cold test was applied. For gold crowns, maximum temperature changes were recorded between 30 and 45 seconds after the start of the tests.

Part Two

Table 2 summarizes the temperature transference data for CO₂ snow applied to one virgin, intact crown or gold crown with the intrapulpal temperature decrease measured in like teeth in proximal contact. The average temperature decrease figures represent the mean temperature drop for five CO₂ snow tests on all combinations of teeth.

When CO₂ snow was applied for 5 seconds to one virgin, intact crown and the intrapulpal temperature measured intrapulpally in its contacting neighbor, the mean temperature decrease for all pairs was 0.22±s.e. 0.03 (Table 2).

The mean temperature decrease for all pairs measured intrapulpally in one gold-crowned tooth when the CO₂ snow was applied to the contacting gold crown was 1.98±s.e. 0.37 (Table 2).

The broken lines in Figure 2 represent the temperature transfer data for part two. For virgin teeth, intrapulpal temperature decreased an average of 0.2 to 0.3 F⁰ between 15 and 25 seconds. Temperature transfer between gold-crowned teeth resulted in a decrease of 1.0 F⁰ by 30 seconds and 1.9 F⁰ by 90 seconds.

Part Three

Table 3 summarizes the data for temperature transference between unlike teeth.

When CO₂ snow was applied for 5 seconds to virgin teeth contacting teeth with gold crowns, the mean intrapulpal temperature decrease in the crowned teeth was 0.08 to 0.14 F⁰. Crowned teeth-to-virgin teeth produced a 0.56 to 0.60 F⁰ decrease, and crowned teeth-to-teeth with C1 II amalgams transferred 2.38 to 2.98 F⁰. Applied to the buccal of teeth with C1 II amalgams, the mean intrapulpal temperature in adjacent crowned teeth decreased 0.42 to 1.02 F⁰.

DISCUSSION

To measure intrapulpal temperature decreases produced by cold tests, two major modifications were made to White and Cooley's

technic. The heating unit was incorporated to maintain teeth at body temperature since it was felt that tests should be applied under conditions similar to those in vivo. Every test in this study was conducted on teeth which were at body temperature. The second modification was that the roots were resected from all experimental teeth. A pilot study revealed that improved access to the pulp chamber allowed more accurate placement of the thermistor temperature probe and resulted in more consistent readings.⁸ Trowbridge and others¹¹ also resected the roots from teeth in an experiment in which the speed of temperature transference was evaluated. Their method of maintaining teeth at body temperature differed in that a water bath at 34°C was used. A water bath was considered for this study, but it was felt the large volume of water around the crown would be less representative of the in vivo situation where the tooth is in a moist environment, but not submerged. It was also felt that the large volume of water might dissipate the temperature more rapidly than in the clinical situation.

Results of this study indicate that intrapulpal temperature changes produced in vitro by CO₂ snow are within a physiologic range. This has been of major concern since the CO₂ snow is -119°F. In a pilot study, CO₂ snow applied directly to a temperature probe at 73°F was only capable of reducing the temperature to 5°F in 2 seconds, -3°F in 5 seconds, and -17°F in 10 seconds. Ice and skin refrigerant produced only about one-half the response of CO₂ snow. A 5 second CO₂ snow application decreased intrapulpal temperature only 4.01±s.e. 0.13°F for virgin teeth and 8.20±s.e. 1.23°F for crowned teeth. Clinically, 2

seconds are generally adequate to produce patient response for a vital tooth.

Based solely upon the relative temperatures of ice, skin refrigerant, and CO₂ snow, the relative intrapulpal temperature decreases produced in virgin teeth (Figure 1) are not surprising. However, Figure 1 further reveals that in crowned teeth, ice produced a greater effect than skin refrigerant. The reason for this apparent paradox was evident when applying the tests. When the cotton pellets saturated to crystallization with skin refrigerant were applied to the gold crowns, an audible sizzle was frequently noted and the crystals immediately melted. Although the cotton pellets were held in contact with the gold crowns for the standard 5 seconds, it is likely that the cold was quickly dissipated such that there was no further cooling effect beyond perhaps the first 1 or 2 seconds. When ice was applied to gold crowns, the ice melted rapidly and the resultant cold water had to be absorbed to prevent it from flowing over the test area. This is precisely what occurs clinically. However, the ice was not exhausted during the 5-second test and therefore, in contrast to skin refrigerant, exerts its cooling effect throughout the test.

Individual differences among the teeth in the magnitude of temperature decrease is likely due to the varying thicknesses of enamel and/or dentin (as well as the cement layer for the crowned teeth). Figure 4 and Table 1 show that the insulating effects resulted in predictably consistent relative temperature changes for the three cold-test agents. Teeth I and II consistently registered less change, however. Examination

of both chambers revealed them to be extensively obstructed by secondary dentin. Similar variability is seen clinically in teeth with advanced secondary dentin formation.

The greater intrapulpal temperature decrease noted in the crowned teeth, regardless of the cold test, indicated that the gold acted as a reservoir or temperature-sink for the cold. This is further reflected in Figure 2, which shows that the maximum temperature decrease for crowned teeth was reached at 30 to 45 seconds following cold application while for virgin teeth it was reached at 20 to 25 seconds. This does not appear to be merely slower conduction through gold and cement because at 20 to 25 seconds the temperature decreases were greater in all cases than in the virgin, intact teeth.

For part two of the study, only CO₂ snow was used as a cold test. The CO₂ snow was selected because it produced the greatest temperature changes. Some clinicians who use cold tests to help diagnose pulpal status are concerned that the cold might be transferred to neighboring teeth resulting in false interpretations. The data gathered here indicates that between contacting virgin teeth, when CO₂ snow is used, little temperature (mean 0.22F⁰) is transferred (Table 2). This study was in vitro, and all tests were applied to the teeth at body temperature. Although possible, it seems unlikely that the in vivo use of CO₂ snow on virgin teeth would produce results which differ significantly. In a pilot study to determine the effect of merely holding the CO₂ snow adjacent to but not touching teeth, the pooled average (33 tests on 7 teeth) when holding the snow 3 mm from the

buccal surfaces of the teeth was an intrapulpal temperature decrease of $0.21F^{\circ}$. The results were the same whether the thermistor probe was within the tooth directly under the CO_2 snow or within the adjacent tooth. This finding indicates that the effect of having the CO_2 snow near virgin teeth is comparable to the temperature transmitted between them when one is tested. Since, clinically, teeth do not respond when the CO_2 snow is passed close to them, it is doubtful that temperature transfer between virgin teeth clouds results.

For gold-crowned teeth in contact, CO_2 produced a greater temperature transfer (mean $1.98F^{\circ}$) between teeth (Figure 5) than in virgin teeth. It is of interest to note that a 5-second CO_2 snow application to one crowned tooth is sufficient to create a relatively large intrapulpal temperature decrease in a contacting tooth. The magnitude of the response, as evident in Figure 2, could reasonably be assumed capable of producing a pulpal response. However, the time lag would likely prevent misinterpretation. Ehrmann also commented on this observation.¹² Clinically, a 2-second CO_2 snow application is adequate to produce response, and after a 10-second application the tooth is considered non-responsive to cold. Figure 5 clearly shows that a $1 F^{\circ}$ change in temperature requires 30 seconds. By that time, the test has been concluded or other teeth are being tested. It, therefore, seems unlikely that results could be misinterpreted.

Part three of the study must be viewed as preliminary findings due to the relative paucity of data and combinations tested. The results are consistent with parts one and two, however. The tooth

to which the CO₂ snow was applied seems to govern the magnitude of the temperature transfer, based upon the results of part two. That is, since virgin tooth to virgin tooth temperature transfer was very low, it would be expected that virgin tooth to gold crown transfer would be low. The 0.08±s.d. 0.04 F⁰ to 0.14±s.d. 0.05 F⁰ temperature decreases for those combinations are consistent with the results of part two and of similar magnitude to the controls where the CO₂ snow was held 3 mm from the teeth. Teeth with C1 II amalgams produced a temperature transfer greater than when the CO₂ snow was applied to a virgin tooth, but less than when applied to a gold crown. This finding is reasonable since the cold would be relatively insulated by the buccal tooth structure, but then transferred more significantly by the amalgam (Table 3). No definitive statement can be made concerning the insulating effects of cement bases under amalgam restorations. A study to evaluate the thermal insulating effect of cement bases under amalgam restorations is currently underway.

Although this was not a clinical study, it is appropriate to correlate the findings with clinical observations. The CO₂ snow test produces in vitro temperature changes which do not appear to be beyond a physiologic range. And again, it should be emphasized that a 2-second application (rather than the 5-second test used) is generally sufficient to produce a response. Clinical use of CO₂ snow has verified the findings of this study and Ehrmann's comments that the cold test can be used through gold crowns^{2,12} and is a time saver in that a full dentition can be tested in less than two

minutes.¹² Ehrmann also noted accurately that CO₂ snow is not effective for calcified pulps, representing its only recognized shortcoming.

Findings presented in this paper underscore the usefulness and probable safety of CO₂ snow as the vitality cold test of choice. Further tests currently underway include the comparative effects of ice and CO₂ snow on human enamel integrity, and on the pulps of dogs.

CONCLUSIONS:

1. When applied to either virgin or crowned teeth in vitro, CO₂ snow produced a statistically greater intrapulpal temperature decrease than either ice or skin refrigerant.
2. When significant temperature transfer occurred between teeth in contact, the transfer was so slow that misinterpretations of vitality would be unlikely.
3. Compared to ice and skin refrigerant, the effectiveness and superiority of the CO₂ pencil for testing crowned teeth was clearly demonstrated.
4. Temperature changes produced intrapulpally by the CO₂ pencil (approximately 4 to 8F⁰) do not seem to be extreme when considering the integrity of the pulp.
5. These findings are consistent with what is clinically observed with use of the CO₂ pencil.

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- * Thermistor, Cole-Parmer Instrument Co., No. 8455, Chicago, Ill 60648
- ‡ Pomona Box Model 3301, Pomona Electronics Co., Inc., Pomona, CA
- ¶ Ungar S. Iron Heating Unit, Ungar Corp., PO Box 6055, Compton, CA 90220
- # Thermal Probe for Scanning Tele-Thermometer, Y.S.I. Model 47, Yellow Springs Inst. Co., Inc., Yellow Springs, Ohio 45387
- o Scanning Tele-Thermometer, Y.S.I. Model 47, Yellow Springs Inst. Co., Yellow Springs, Ohio 45387
- + Tele-Thermometer, Y.S.I. Model 43TF, Yellow Springs Inst. Co., Inc., Yellow Springs, Ohio 45387
- ± GC Silicone Compound Z-S, GC Electronics, Rockford, ILL 61101
- x Powerstat^(R) Variable Autotransformer (Variac), The Superior Electric Co., Bristol, Conn.
- y 0-10 Milliampere D.C. Logging Meter, API Inst. Co., 3 Greenfield Rd., PO Box 750, St. Albans, Vt.
- φ Skin Refrigerant, Dichlorotetra-Fluoroethane, N.F. Aerosol Service Co., Inc., 4255 9th Ave., City of Industry, CA 91746
- ø Odontotest^(R), Union Broach Corp., 36-40 37th Street, Long Island City, NY 11101

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TABLE 1 Mean intrapulpal temperature decreases in $F^0 \pm SD$ (part one of study)

tooth	V I R G I N T E E T H			C R O W N E D T E E T H			
	c o l d t e s t			c o l d t e s t			
	ice	skin refrigerant	CO ₂ snow	tooth	ice	skin refrigerant	CO ₂ snow
1	1.26±0.23	1.84±0.05	4.50±0.52	I	3.72±0.22	2.46±0.18	6.88±0.55
2	0.94±0.17	2.08±0.13	3.57±0.27	II	2.72±0.89	2.22±0.39	4.18±0.89
3	1.08±0.26	1.88±0.42	4.22±0.27	III	3.98±0.35	3.23±0.26	11.32±0.47
4	0.90±0.14	2.13±0.56	3.74±0.34	IV	2.96±0.31	2.44±0.31	9.18±0.55
5	1.17±0.33	2.28±0.60	4.00±0.16	V	5.12±0.52	2.73±0.42	9.48±0.66
6	$\frac{0.98 \pm 0.23}{1.05 \pm 0.06^*}$	$\frac{2.16 \pm 0.42}{2.06 \pm 0.07}$	$\frac{3.90 \pm 0.55}{4.01 \pm 0.13^*}$		$\frac{3.70 \pm 0.42^*}{2.61 \pm 0.17^*}$	$\frac{2.61 \pm 0.17^*}{8.21 \pm 1.23^*}$	

*Treatment mean \pm SE

Paired t-tests for virgin teeth:

ice significantly different from skin refrigerant,

p<.0005, df=5

ice significantly different from CO₂ snow,

p<.0005, df=5

skin refrigerant significantly different from

CO₂ snow, p<.0005, df=5

*Treatment mean \pm SE

Paired t-tests for crowned teeth:

ice significantly different from skin refrigerant,

.010<p<.025, df=4

ice significantly different from CO₂ snow,

.0025<p<.005, df=4

skin refrigerant significantly different from

CO₂ snow, .001<p<.0025, df=4

Table 2. Temperature transference between like teeth (part two of study)

<u>from virgin tooth to virgin tooth</u>		<u>from crowned tooth to crowned tooth</u>	
<u>teeth</u>	<u>temperature decrease*</u>	<u>teeth</u>	<u>temperature decrease*</u>
1 to 2	0.24±0.05	I to II	0.94±0.34
2 to 1	0.24±0.05	II to I	1.42±0.19
2 to 3	0.14±0.05	III to IV	2.05±0.35
3 to 2	0.32±0.13	IV to V	2.44±0.43
3 to 4	0.16±0.05	V to IV	3.06±0.40
4 to 3	0.24±0.09		<u>1.98±0.37**</u>
	<u>0.22±0.03**</u>		

*mean ± SD in F⁰ for five repetitions

**mean for all pairs ± SE

Table 3. Temperature transference between unlike teeth (part three of study)

	<u>Temperature decrease*</u>
From Virgin to Crowned Combination 1	0.14±0.05
Combination 2	0.08±0.04
From Crowned to Virgin Combination 3	0.56±0.09
Combination 4	0.60±0.12
From Crowned to Amalgam Combination 5	2.38±0.13
Combination 6 (base under amalgam)	2.98±0.16
From Amalgam to Crowned Combination 7	1.02±0.18
Combination 8 (base under amalgam)	0.42±0.08

*mean ± SD in F⁰ for five repetitions

Legends

Figure 1 CARBON DIOXIDE SNOW COLD TEST EQUIPMENT:

- A. Carbon dioxide tank.
- B. Adapter and valve for filling pencil.
- C. Plastic tube for CO₂ snow forming.
- D. Carbon dioxide pencil in which CO₂ snow is compacted.
- E. Plunger to compact CO₂ snow in pencil.

Figure 2 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.
teeth.

Figure 3 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 4 INTRA-PULPAL TEMPERATURE DECREASES.

Figure 5 INTRA-PULPAL TEMPERATURE DECREASES OVER TIME.

Solid lines represent intra-pulpal temperature decreases for part one of study, and broken lines for part two.

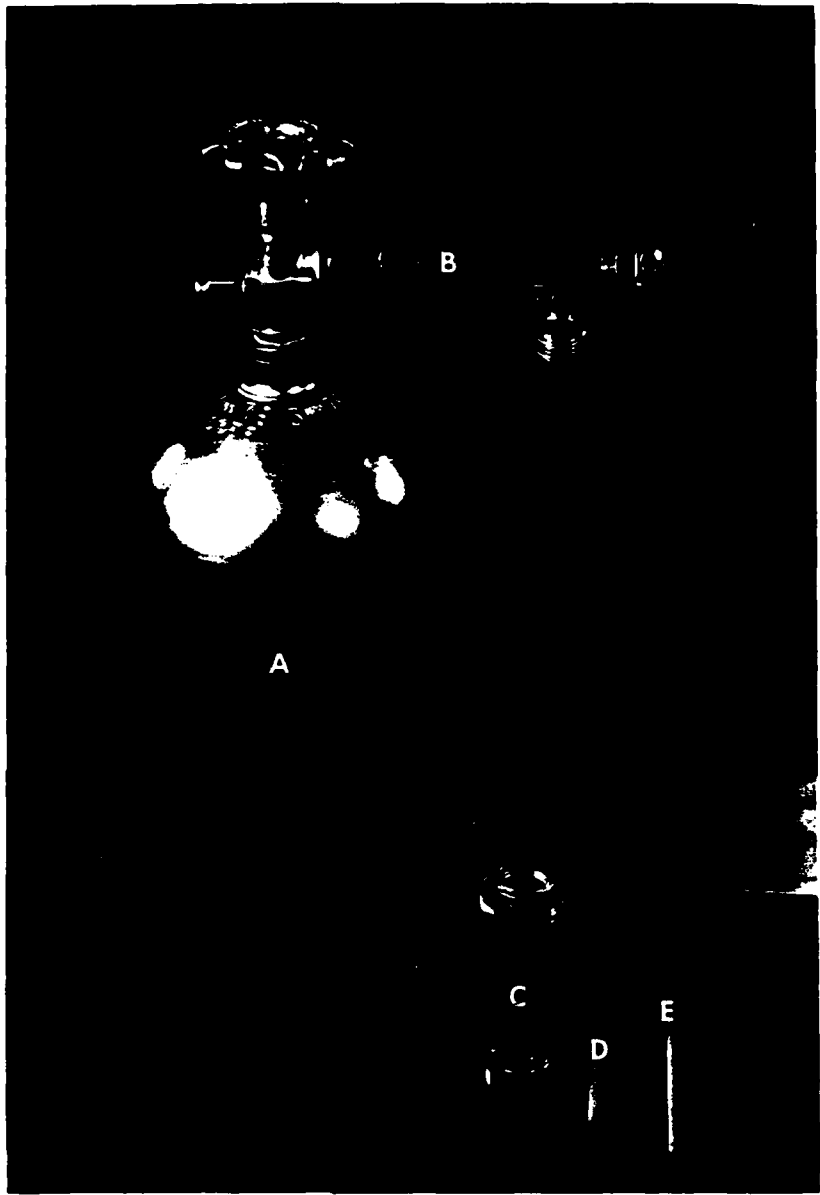


FIGURE 1

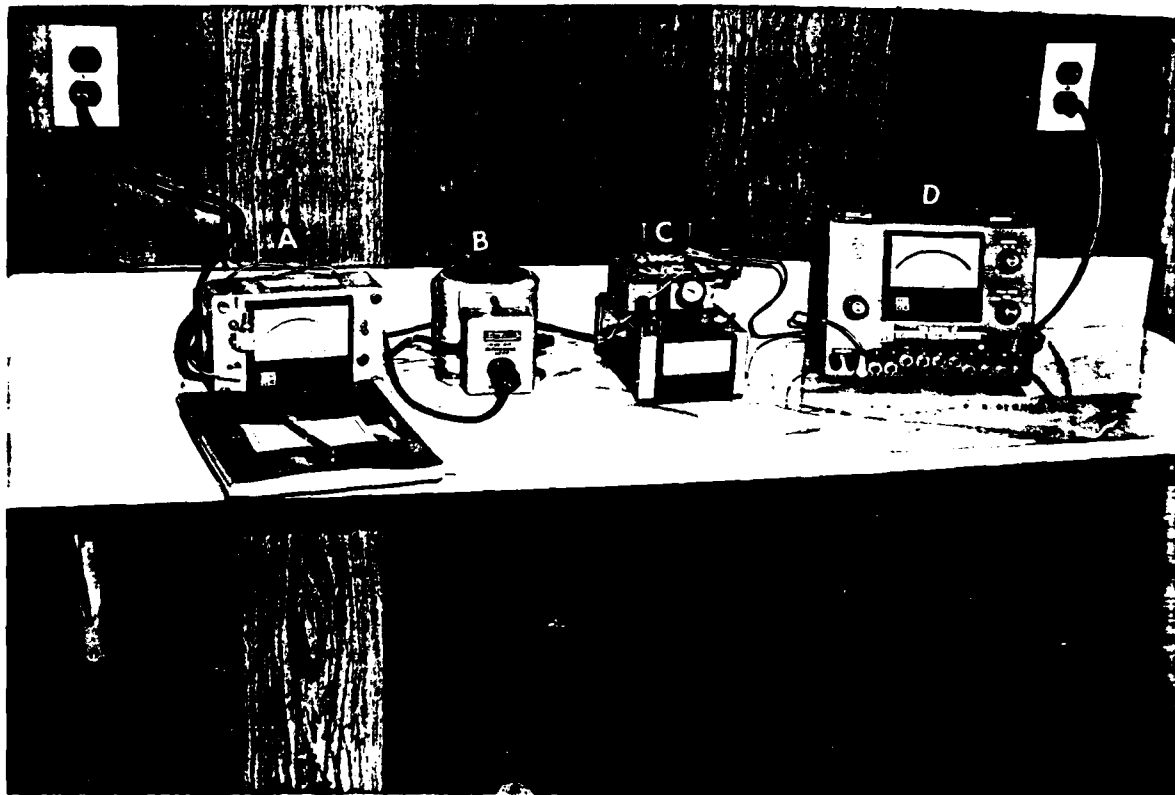


FIGURE 2

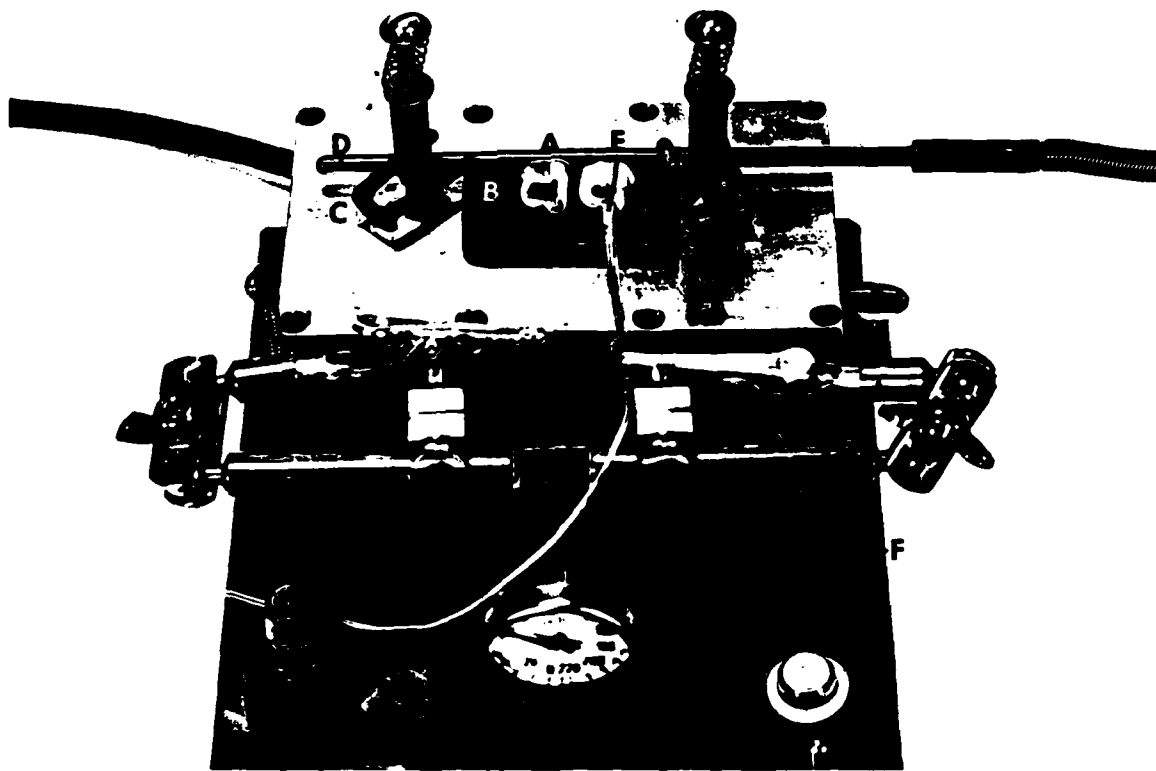


FIGURE 3

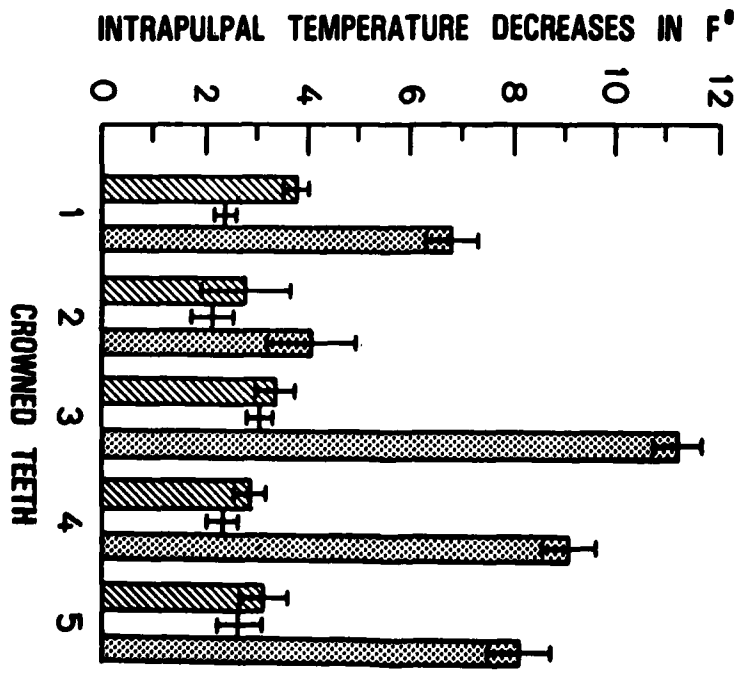
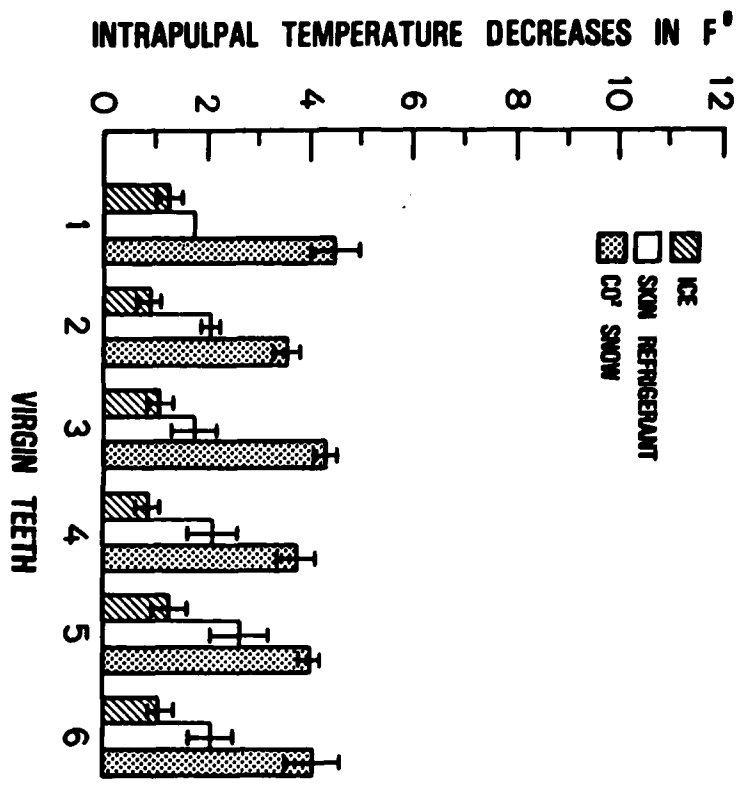


FIGURE 4

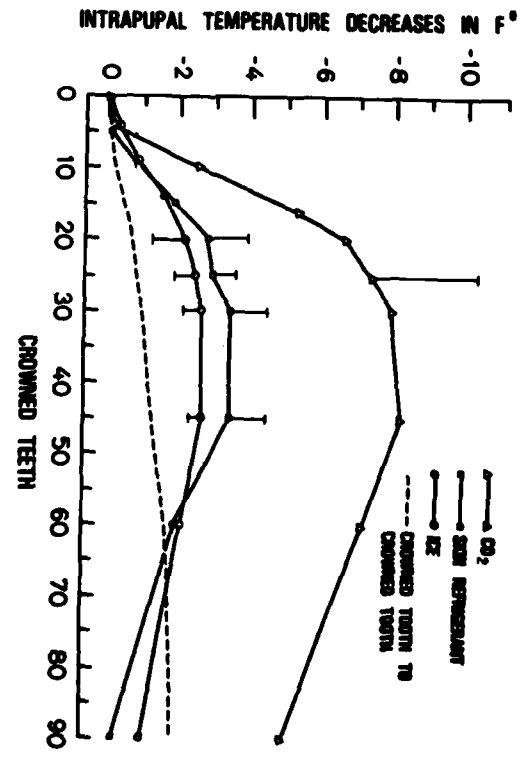
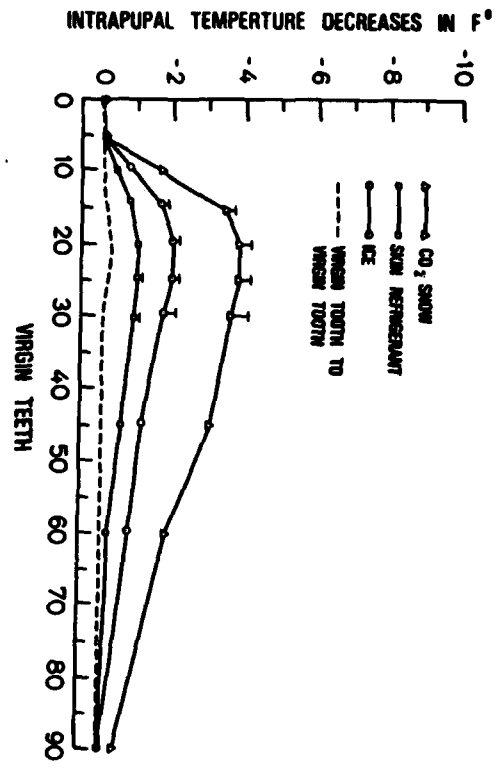


FIGURE 5