

# Effects of Thermal Vitality Tests on Human Dental Pulp

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**Experiments were conducted to determine the effects of thermal pulp testing agents on the human dental pulp. Histological evaluation of the pulps of premolar teeth to which heated gutta-percha had been applied for up to 10 s revealed no evidence of injury. Teeth to which carbon dioxide (CO<sub>2</sub>) snow was applied for as long as 5 min were found to have structurally intact pulps. When the thermal testing agents were applied to teeth in vitro, temperature in the region of the pulpodentinal junction did not reach noxious levels. This study indicates that assessment of tooth vitality with either heated gutta-percha or CO<sub>2</sub> snow does not jeopardize the health of the pulp.**

Thermal stimulation is a standard means of assessing the vitality of teeth. Various methods of applying heat and cold are available, but heated gutta-percha, ice, and ethyl chloride have traditionally been the most popular. More recently dichlorodifluoromethane and carbon dioxide (CO<sub>2</sub>) snow have been shown to be more reliable than either ice or ethyl chloride (1).

Since the temperature of heated gutta-percha may be as high as 76°C when applied to the tooth (2), and the temperature of CO<sub>2</sub> snow is -78°C, concern has been expressed that tests involving such high or low temperatures may damage an otherwise healthy pulp (3). Therefore, the objectives of this investigation were to (a) determine whether these thermal testing agents are capable of damaging the pulp, and (b) assess the degree of temperature change occurring at the pulpodentinal junction (PDJ) during the application of heated gutta-percha and CO<sub>2</sub> snow to the tooth surface.

## MATERIALS AND METHODS

Nine subjects, four males and five females, who were scheduled to have clinically intact premolar teeth extracted for orthodontic purposes were selected for this study. The subjects ranged in age from 11 to 22 yr. Thermal vitality tests were conducted on a total of 32 clinically sound teeth, as shown in Table 1. Controls consisted of four premolars that were not subjected to thermal testing. In vitro assessment of temperature changes occurring at the PDJ was conducted on

four additional premolar teeth obtained from orthodontic patients.

Each of the test agents was applied to the mid-buccal surface of the crowns of the teeth. The patients were instructed to indicate by hand signal the moment they perceived sensation, at which time the test agent was removed from the tooth.

In order to study the effect of prolonged testing, some teeth were anesthetized with 3% carbocaine prior to application of the test agent.

A total of eight teeth in three patients were tested with heated gutta-percha. The gutta-percha (The Hygenic Corp., Akron, OH) was in the form of a stick having a diameter of 3.5 mm. The end of the stick was heated in an alcohol flame until it became soft and just began to "smoke," according to the method of Grossman (4). Prior to testing, the tooth surface was coated with petroleum jelly to prevent gutta-percha from sticking to the enamel. The duration of each test, i.e. the length of time the gutta-percha was in contact with the tooth, varied from 1 to 10 s.

Twenty-six teeth in six patients were tested with a CO<sub>2</sub> snow pencil. Pencils approximately 3.5 mm in diameter were prepared in a special plastic adapter (Odontotest; Fricar AG, Zurich, Switzerland).

Following thermal testing the teeth were extracted under local anesthesia at posttest intervals ranging from less than 1 h to 2 wk. Immediately after extraction the lower third of each tooth was cut off, and the tooth was placed into 10% neutral-buffered formalin. Following fixation the teeth were decalcified in 0.5 M EDTA and embedded in paraffin. Serial sections were cut through the pulp in a mesial-distal direction and the sections were stained with haematoxylin and eosin for light microscopy.

To assess temperature changes occurring at the PDJ opposite the site of application of the thermal test agents, in vitro tests were conducted on two maxillary and two mandibular premolar teeth. A thermister probe was inserted into the pulp chamber and positioned against the dentin opposite the test site on the tooth surface, as described previously (1). Temperatures were recorded during simulated clinical vitality testing with each of the test agents.

## RESULTS

### Histological Evaluation

Examination of the serial sections of experimental and control teeth revealed that all teeth had structurally intact

**TABLE 1. Summary of teeth tested, duration of stimulation, and posttest extraction intervals**

Test Modality	Duration of Stimulation	No. of Teeth Extracted	
		<1 h posttest	4-14 days posttest
Gutta-percha	1-10 s	5	3
CO <sub>2</sub> snow	1-10 s	3	5
	15-40 s	3	2
	60-90 s	3	2
	5 min	3	3
		Total 17	15

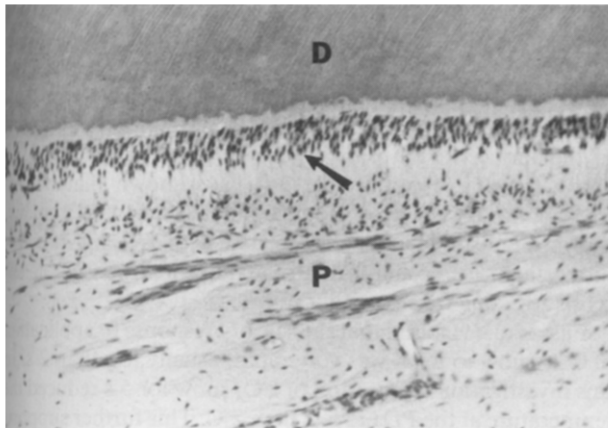


FIG 1. Section of pulp of maxillary second premolar extracted 1 h after 10-s application of heated gutta-percha. *D*, dentin; arrow, odontoblast layer; *P*, pulp (original magnification  $\times 56$ ).

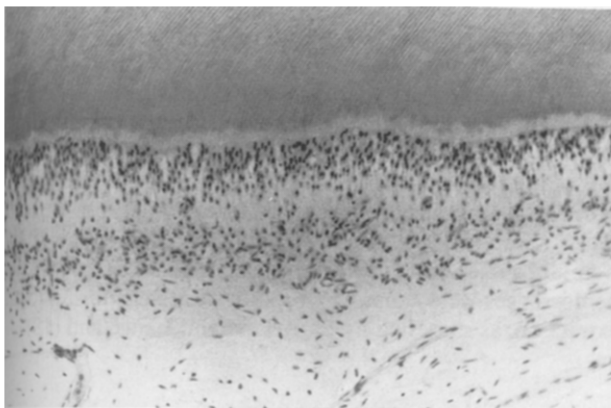


FIG 2. Section of pulp of mandibular first premolar extracted 1 wk after 10-s application of heated gutta-percha (original magnification  $\times 56$ ).

pulps (Figs. 1 to 4). There were no pathological alterations in any of the experimental teeth that could be attributed to the application of heated gutta-percha or CO<sub>2</sub> snow. However, several of the experimental and control teeth exhibited pulp calcifications, reparative dentin formation, and small areas of hemorrhage (Fig. 5).

**In Vitro Temperature Recordings**

Temperature changes occurring at the PDJ following application of thermal test agents to teeth are shown in Table 2.

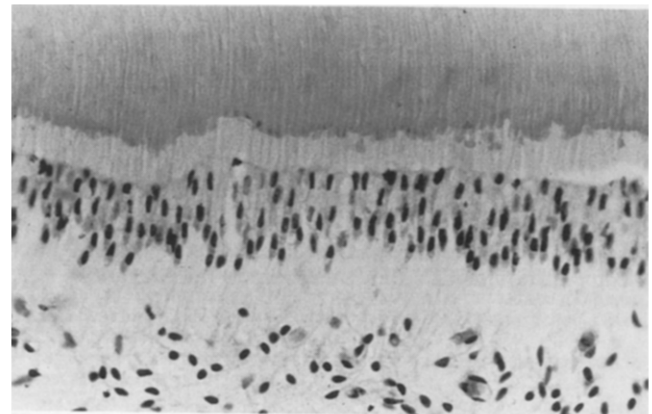


FIG 3. Section of pulp of mandibular second premolar extracted 1 h after application of CO<sub>2</sub> snow for 5 s (original magnification  $\times 80$ ).

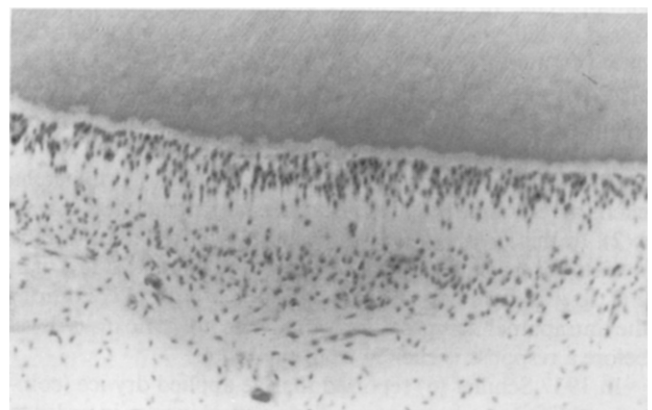


FIG 4. Section of pulp of maxillary second premolar extracted 12 days after application of CO<sub>2</sub> snow for 5 min (original magnification  $\times 56$ ).

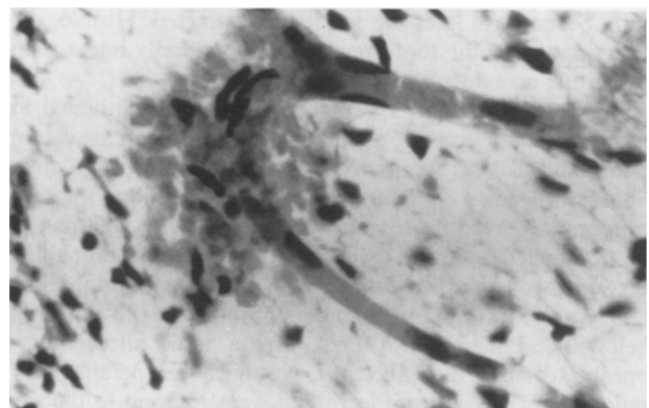


FIG 5. Section of mandibular first premolar from control group showing localized area of intrapulpal hemorrhage (original magnification  $\times 220$ ).

**TABLE 2. Mean temperature (°C  $\pm$  SD) at the PDJ following application of pulp testing agents to teeth (n = 4)**

Agent	Time following application of heat or cold			
	0 s	5 s	10 s	5 min
Gutta-percha	35.0	36.4 $\pm$ 0.6	39.9 $\pm$ 1.5	—
CO <sub>2</sub> snow	35.0	34.1 $\pm$ 0.5	31.3 $\pm$ 1.3	09.5 $\pm$ 3.4

As can be seen, a 5-s application of gutta-percha increased the temperature from 35°C to  $36.6 \pm 0.6^\circ\text{C}$  (SD). A 10-s application of gutta-percha caused the temperature to rise to  $39.9 \pm 1.5^\circ\text{C}$  (SD).

Application of CO<sub>2</sub> snow to teeth for 5 s caused the temperature to drop to  $34.1 \pm 0.5^\circ\text{C}$  (SD); a 10-s application caused it to drop to  $31.9 \pm 1.3^\circ\text{C}$  (SD). Continuous application for 5 min resulted in a drop in temperature to  $9.5 \pm 2.4^\circ\text{C}$  (SD). This temperature was reached approximately 75 s after the application of CO<sub>2</sub> snow, whereupon it leveled off.

## DISCUSSION

When used as a vitality test agent, gutta-percha is usually heated over an alcohol flame. One disadvantage of this method is that it is difficult to control the temperature of the gutta-percha. In testing intact anterior teeth, Mumford (5) found that if the gutta-percha was held in the flame for 2 s only 14% of the teeth gave a positive response. Trowbridge et al. (2), using the Grossman (4) method of heating gutta-percha that was used in the present study, found that all intact premolars tested gave a positive response.

Previously it has been shown that heated gutta-percha elicits a very rapid response from teeth, generally less than 2 s (2). In this investigation application of heated gutta-percha to teeth for 5 s increased the temperature of the PDJ less than 2°C, so it is extremely unlikely that under clinical conditions the intrapulpal temperature would rise to a noxious level before a response is elicited from the tooth.

In 1937 Schiller (6) reported that he applied dry ice (compressed CO<sub>2</sub>) to a human maxillary central incisor in order to determine its effect on the pulp. The first test consisted of a 2-min application under local anesthesia. After 1 wk, the tooth was asymptomatic and dry ice was again applied, this time for 3 min. The following week dry ice was applied for 5 min. Seven days later the tooth was extracted. Histological examination of the tooth revealed a structurally intact pulp exhibiting no evidence of injury.

With the advent of cryosurgery, studies were initiated to determine the effects of extreme cold on the dental tissues. Langeland et al. (7) applied a cryoprobe containing circulating liquid nitrogen ( $-196^\circ\text{C}$ ) to the crown of a cuspid tooth for 3 min and observed necrosis of the coronal pulp. Heitman et al. (8) applied a similar cryoprobe to the interdental papilla between two teeth with vital pulps in dogs and found that the temperature in the pulp chambers of the teeth did not drop below 0°C. Pollen et al. (9) also used a liquid nitrogen cryoprobe to study the effect of cryosurgical temperatures on pulp tissue. The pulps of teeth that were adjacent to the site of surgery were reported to be hyperemic (dilated blood vessels), but neither pulpitis nor necrosis was observed. Shepherd (10) applied a cryoprobe having a surface temperature of  $-50^\circ\text{C}$  to the dental tissues of rats. Reduction of intrapulpal temperature to  $-13^\circ\text{C}$  resulted in destruction of the odontoblast layer and fibrosis of the pulp. More recently, Dowden et al. (11) used an experimental cryosurgical unit to apply temperatures below  $-80^\circ\text{C}$  to intact monkey teeth for periods of 1, 2, and 3 min. They found that when the intrapulpal temperature reached  $-10^\circ\text{C}$  or below, pulpal injury resulted. Although they observed destruction of odontoblasts and dam-

age to the microvascular system in the coronal pulp, the radicular pulp remained intact.

The advantages of CO<sub>2</sub> snow vitality testing over other cold agents and electrical pulp testing devices have been delineated by Fulling and Andreassen (12), Ehrmann (13), and Fuss et al. (1). Consequently, it is important to determine whether CO<sub>2</sub> snow can be utilized without jeopardizing the health of the teeth being tested. Augsburg and Peters (14) studied intrapulpal temperature changes following a 5-s application of CO<sub>2</sub> snow to extracted human mandibular molar teeth and observed a decrease of only about 2°C. Ingram and Peters (15) found that the application of CO<sub>2</sub> snow to dog teeth for as long as 2 min produced no pulpal damage. Results of the present investigation are in agreement with these studies, as no evidence of pulpal injury was observed following application of CO<sub>2</sub> snow for up to 5 min. This is not surprising, as results of our *in vitro* temperature tests indicate that even during prolonged application of CO<sub>2</sub> snow the temperature of the surface of the pulp adjacent to the test site remains above freezing. Frank et al. (16) have shown that only if freezing occurs will cold produce pulpal injury. Presumably, the mechanism of injury associated with freezing involves intracellular ice crystal formation coupled with ischemic necrosis resulting from vascular injury.

Fuss et al. (1) found that the sensory response to application of CO<sub>2</sub> snow to teeth was very rapid, usually less than 2 s. In this investigation application of CO<sub>2</sub> snow for 5 s reduced the temperature at the PDJ to less than 2°C. This further supports the hydrodynamic theory concerning the sensory response of teeth to thermal stimulation (17). According to this theory application of heat or cold results in rapid movement of fluid in the dentinal tubules that mechanically stimulates the sensory nerve terminals located in the region of the PDJ.

Since small areas of intrapulpal hemorrhage were observed in both experimental and control teeth, they could not have been produced by the vitality testing procedures. In histological studies hemorrhage is often cited as evidence of pulpal injury, yet its cause has not been established with certainty. It is of interest that Langeland and Langeland (18) frequently observed extravasated erythrocytes in histological sections of intact unerupted teeth. Since the control teeth in this study were not subjected to any form of trauma, it may be that the hemorrhages were caused by rupture of vessels during tooth extraction, as suggested by Langeland and Langeland (18).

## CONCLUSIONS

Histological assessment of the pulps of teeth that had been tested with heated gutta-percha or CO<sub>2</sub> snow revealed no evidence of tissue injury.

*In vitro* application of heated gutta-percha to the surface of human premolar teeth for intervals of up to 10 s did not cause the temperature at the underlying PDJ to rise to a noxious level. During the application of CO<sub>2</sub> snow, the temperature at the PDJ did not fall below freezing.

The use of heated gutta-percha and CO<sub>2</sub> snow to assess the vitality of teeth does not jeopardize the health of the pulp.

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The informed consent of all human subjects who participated in the experimental investigation reported or described in this article was obtained after the nature of the procedures and possible discomforts and risks had been fully explained.

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