The Effect of Ultrasonic Post Instrumentation on Root Surface Temperature

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Abstract

This study measured root surface temperature changes when ultrasonic vibration, with and without irrigation, was applied to cemented endodontic posts. Twenty-six, extracted, single-rooted premolars were randomly divided into two groups. Root lengths were standardized, canals instrumented, obturated, and posts cemented into prepared spaces. Thermocouples were positioned at two locations on the proximal root surfaces. Samples were embedded in plaster and brought to 37°C in a water bath. Posts were ultrasonically vibrated for 4 minutes while continuously measuring temperature. Two-way ANOVA compared effects of water coolant and thermocouple location on temperature change. Root surface temperatures were significantly higher ($p < 0.001$) when posts were instrumented dry. A trend for higher temperatures was observed at coronal thermocouples of nonirrigated teeth and at apical thermocouples of irrigated teeth ($p = 0.057$). Irrigation during post removal with ultrasonics had a significant impact on the temperature measured at the external root surface. *(J Endod 2006;32:1085–1087)*

Key Words

Heat-induced bone degeneration, post removal, root surface temperature changes, ultrasonics

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Manipulation of tooth structure through preparation, ultrasonic scaling, rotary instrumentation, obturation, and post space preparation techniques raise the temperatures of dental tissues (1–7). If a sufficient amount of heat is transferred to supporting tissues, thermal injury may result (8).

Several studies have investigated the temperature at which damage to bone is initiated. Sauk et al. found that exposing the periodontal ligament to a temperature of 43°C resulted in protein denaturation and elaborated that ankylosis and bone resorption may develop (9). Atrizadeh et al. delivered heat through an electrosurgery tip to prepared root canals in monkeys and found localized areas of necrosis within the periodontal ligament at 3 days. After 6 months, resorption and ankylosis were noted (10). Line et al. activated a soldering iron for 2 seconds in root canals of squirrel monkeys. The elevated temperature induced osteoclastic bone resorption at 6 days, bone and root resorption at 21 days, and repair, as demonstrated by ankylosis, at 31 days (11). Matthews and Hirsch discussed in vitro inactivation of bone alkaline phosphatase at 56°C and considered this the critical temperature for bone injury (12).

In a study preceding their work on heat-induced bone degeneration, Eriksson et al. observed blood flow stasis in bone 2 days after a 1-minute exposure to a temperature of 53°C (13). The followup study measured threshold levels required to induce bone injury (14). Bone injury in two of five rabbits occurred after a 1-minute exposure to 47°C, whereas the remaining rabbits showed no bony resorptive activity deviating from normal. Damage to fat cells was observed in all five animals. The affected bone and fat tissues were resorbed without signs of subsequent regeneration. Bony healing after thermal injury appeared to induce connective tissue rather than hard tissue formation. These results suggested a critical temperature for bone injury could be as low as 47°C and is time-dependent.

Ultrasonic instrumentation without irrigation has been recommended for removing canal obstructions. Garrido et al. stated the use of a coolant during ultrasonic post removal interferes with disrupting the adhesive bond of resin cements (15). For post removal, it was recommended that nonsurgical ultrasonic work be performed dry to optimize vision (16). More recently, however, it has been advocated that the field should be frequently flushed with water to decrease heat buildup and the potential for dangerous heat transfer to the attachment apparatus when performing ultrasonic procedures for longer periods of time and against larger conductive metal posts (17, 18).

A literature search for temperature increases associated with ultrasonic vibration of posts produced only a few articles. Satterthwaite et al. found in their in vitro study of heat production when intraradicular posts were subjected to ultrasonics, that temperatures increased an average of 18.7°C when vibrated for 30 minutes (19). Temperature elevations of 125.3°C on the post and 32.2°C on the root surface were reported by Dominici et al. when ultrasonic energy was applied to cemented posts for 1 minute (20). Budd et al. used infrared thermography to determine temperature rise on the root surface caused by ultrasonic post removal using piezoelectric and magnetostrictive devices and four coolant parameters. They found significant differences in temperature rise related to the ultrasonic device, location on the tooth, and cooling methods used (21). The study designs did not account for the heat-sink capacity of periodontal vascularity. Fors et al. suggested that temperature changes occurring on root surfaces during in vitro studies may be less pronounced in vivo because of the vascularity of the periodontal ligament (22).

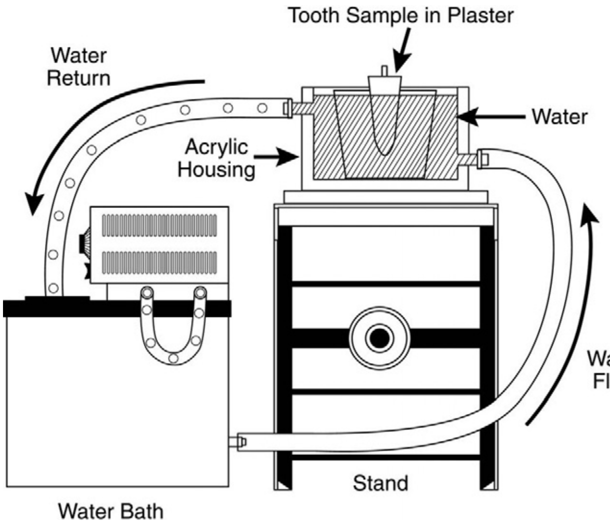

Figure 1. Apparatus used for maintaining samples at 37°C during testing.

A simulated biologic model was used in this study to evaluate temperature changes induced on the supporting structures of teeth subjected to ultrasonic instrumentation for post removal. The purpose of this study was to measure external root-surface temperature changes when ultrasonic vibration, with and without irrigation, was applied to cemented posts.

Materials and Methods

Twenty-six extracted, human, single-rooted maxillary and mandibular premolars were randomly divided into two groups. All instruments and materials were used according to manufacturer's instructions. Root lengths were standardized by sectioning each tooth perpendicular to its long axis below the cemento-enamel junction, producing samples 13 mm in length. All canals were instrumented at a working length of 12 mm to a #35 master apical file using a crown-down technique with Profile 0.04 taper nickel titanium rotary instruments (Dentsply/Tulsa Dental Products, Tulsa, OK). Canals were irrigated with 6.0% by mass NaOCl between each sequential file size. After drying canals with paper points, they were obturated using cold lateral compaction of gutta-percha and AHPlus sealer (Dentsply/DeTrey GmbH, Konstanz, Germany). Gutta-percha was removed using a System B unit (Analytic Technology, Redmond, WA) set at 93.3°C (200°F), leaving 5 mm gutta-percha in the apical part of the canal. Samples were stored in 100% humidity for 7 days to allow the sealer to set.

Post spaces were prepared 7 mm into the canals using a #5 ParaPost drill (Coltene/Whaledent, Mahwah, NJ). Stainless steel posts standardized to 11 mm (#5 ParaPost, Coltene/Whaledent) were cemented into the canals with Panavia F 2.0 (Kuraray Medical, Okayama, Japan) polymeric composite cement. Excess cement was removed from the decoronated surface completely exposing 4 mm of post.

Two, PFA Teflon insulated T-type thermocouples (Part # 5SRTC-TT-T-30-36, OMEGA Engineering, Stamford, CT) with a wire diameter of 0.25 mm and an approximate 0.03 second conduction rate were positioned on the proximal root surfaces at 2 mm and 7 mm below the coronal height of the root. A thermal conducting epoxy resin (SE 4451 A and SE 4451 B, Dow Corning, Midland, MI) with good dielectric properties was mixed in equal parts, applied to the thermocouple and adjacent root surface, and allowed to set for 4 hours. To firmly secure the thermocouples, an epoxy resin (GOOP SuperMend, Eclectic Products, Pineville, LA) was mixed in equal parts, applied over the set conductive resin, and allowed to set for 4 hours. Each root was embedded in 28 mm of plaster leaving the coronal end slightly exposed to allow application of a rubber dam retainer. The height of the plaster allowed the sample to be immersed in a temperature-controlled water bath without being submerged.

Before testing, each sample was equilibrated to 37°C. The water bath consisted of a cylindrical acrylic housing (30 mm tall) with influent and effluent ports connected to an external heat source by surgical tubing. A constant temperature environment was maintained by a continuous cycle of heated water around the plaster-embedded sample (Fig. 1). The flow rate was unknown. A rubber dam isolated each sample with a metal retainer, keeping the dam above the circulating water level. A grounding wire attached to the rubber dam retainer prevented electronic noise from interfering with the thermocouple readings. To stabilize the ultrasonic tip, a piece of vinyl tubing (3M Electronics/Electrical, Austin, TX) was placed around the top 1.5 mm of the exposed post. A VT-S tip (Sybron Dental Specialties, Glendora, CA), in a Suprasson P-5 BOOSTER ultrasonic generator (Satelec/Acteon, Bordeaux, France) set at a power of 11, was placed into the open end of the vinyl tubing in contact with the top of the post and activated for 4 min. Instrumentation of each sample was performed by one operator with or without water irrigation from the ultrasonic handpiece according to the study group designation.

External root surface temperatures were measured beginning 1 minute before the initiation of ultrasonic vibration and continuing for 1 minute after termination of the procedure. Temperature measurements were made at an interval of 1.14 seconds as permitted by the computer software. Electromagnetic interference, such as lighting, was not measured or compensated for. A two-way ANOVA compared the effects of irrigation and thermocouple location on temperature.

Results

The peak temperature increase for irrigated samples was (5.9 ± 3.8°C) (mean ± standard deviation) at the apical thermocouple and (3.2 ± 3.9°C) at the coronal thermocouple. The peak temperature elevation for nonirrigated samples was (15.2 ± 4.9°C) at the apical thermocouple and (17.6 ± 5.9°C) at the coronal thermocouple (Table 1). The standard deviations are presented as the estimated standard uncertainty of the experimental measurements. Root surface temperatures were found to be significantly higher ($p < 0.001$) when posts were instrumented without irrigation. Temperature changes detected between coronal and apical thermocouples alone were not significant ($p = 0.900$); however, a trend for higher temperatures was observed at the coronal thermocouples of nonirrigated teeth and at the apical thermocouples of irrigated teeth ($p = 0.057$). No significant change in temperature was observed within the water bath of the apparatus.

Discussion

A pilot study determined that a near plateau in temperature change occurred once peak temperatures were reached. All samples in the pilot study arrived at, and remained at peak temperature for greater than 1 minute during the 4-minute study time. When post vibration ceased, all measurement points returned to baseline temperature within a few minutes.

TABLE 1. Maximum change in temperature measured by thermocouples in °C after 4 min of ultrasonication

	Wet °C	Dry °C
Coronal	3.2 ± 3.9	17.6 ± 5.9
Apical	5.9 ± 3.8	15.2 ± 4.9

Standard deviations are presented as the estimate of the standard uncertainty of the measurements (mean ± SD, $n = 13$).

The temperature changes generated when vibrating posts without irrigation surpassed a 10°C increase in temperature for periods greater than 1 minute in all samples. The use of irrigation during instrumentation maintained external root-surface temperature changes below 10°C in all samples. These findings are in agreement with Satterthwaite et al. (19) and Dominici et al. (20).

Temperature differences, although not significant, were observed both with and without irrigation between the coronal and apical regions. Coronal thermocouples detected greater temperature changes for dry than for wet samples because irrigation and high evacuation suction draws heat from the instrumented post and adjacent coronal tooth tissue, resulting in lower coronal temperatures. The greater apical temperature increase of the irrigated group might be explained by heat conduction of the stainless steel post. Whereas heat is conducted away from the external surface of the exposed post by irrigation and suction at the coronal end, the core of the metal post may continue to deliver heat to the apical dentin.

Thermal conductivity (as a function of time and temperature) and thermal diffusivity (as a function of thickness and time) of dentin and enamel were studied by Brown et al. (23). They stated that dentin is a poor thermal conductor, suggesting that dentin thickness will insulate the periodontal tissues from potential heat damage. Varying thickness of dentin between tooth types as well as within the same tooth may affect the quantity of heat transferred to the external root surface.

The findings of this study indicate that the ultrasonic technique used for post removal can generate temperatures that can be detrimental to the periodontium and lead to bone resorption and ankylosis. However, more variables need to be studied before general conclusions can be drawn regarding clinical ultrasonic vibration of posts. These variables include: post type, cement type, onset of damaging temperatures, ultrasonic power setting, type of ultrasonic tip used, canal configuration, dentin thickness, length of the exposed post, and the effect of instrument pressure applied during ultrasonic use.

Under the conditions used in this study, irrigation during post removal using an ultrasonic instrument had a significant impact on the heat measured at the external root surface. Therefore, the risk of thermal injury to the surrounding periodontium and bone is potentially minimized when ultrasonic instruments are used with irrigation.

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