Analysis of Heat Generation Using Ultrasonic Vibration for Post Removal

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Abstract

This study measured the temperature of the root surface and post during the application of ultrasonic vibration to cemented posts to simulate post removal procedure. Root canal therapy was performed on ten extracted maxillary incisors. A stainless steel Parapost was cemented into each prepared post space. Ultrasonic vibration was applied to the post and temperatures were recorded at the coronal post and the cervical root surface. Data were analyzed with ANOVA using the independent variables of (a) time of ultrasonic application (15, 30, 45 and 60 s) and 2) location (post and root surface). Greater temperature increase was observed at the post (52.6°C, SD 11.1; 82.6°C, SD 20.1; 111.0°C, SD 29.1; 125.3°C, SD 33.2) compared to the root surface (9.5°C, SD 4.6; 17.5°C, SD 4.8; 25.4°C, SD 7.3; 32.2°C, SD 8.1) for each time period, $P < 0.001$. Ultrasonic application to the post for longer than 15 s generates high temperature on the root surface.

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Many endodontically treated teeth have posts, which can be an obstacle if retreatment is needed (1, 2). Ultrasonic instrumentation is commonly used for post removal (3, 4) but it does have inherent risks, one of them being increased temperatures transmitted to the surrounding periodontium and alveolar bone.

The effect of iatrogenic heat on bone and periodontal tissues is well-documented (5, 6). The threshold for heat-induced bone necrosis is 10°C above normal body temperature of 37°C sustained for 1 min. Fatty necrosis of bone occurs and new bone will not regenerate under these conditions. Little information is available concerning the effect of heat on the periodontal ligament or cementum but Atrizadeh et al. (7) found osteoclastic activity, bone resorption, and ankylosis after applying an electrosurgery tip to the cementoenamel junction of squirrel monkeys for 1 s. In a later study Line et al. (8) inserted the tip of a soldering iron into a prepared root canal of a squirrel monkey for 2 s and ankylosis was later observed at five of the six root surfaces.

Ultrasonic instruments produce sound-like mechanical waves at a frequency of 25 kHz to 30 kHz. Ultrasonic energy is produced by the conversion of one form of energy to another. Magnetostrictive ultrasonic instruments work by applying an alternating current to the ferromagnetic wire coils in the handpiece causing it to vibrate. Piezoelectric instruments work by vibrating quartz plates in the handpiece. The ultrasonic vibration generates heat (10). Sparse information exists in the literature regarding the amount of heat generated during ultrasonic instrumentation. Abrams et al. (9) measured temperature increases of up to 12°F in the pulpal walls of extracted premolars and incisors following 60 s of light ultrasonic scaling. Nicoll and Peters (11) demonstrated in vitro temperature increases from 4°C to 35°C on dentinal surfaces using ultrasonic scaling procedures.

An in vitro study by Johnson et al. (12) compared the amount of time and the tensile force needed to remove cemented posts with ultrasonic vibration and found 16 min to be an effective time. Six to 41.2 min of vibration was required for post removal using different ultrasonic instruments evaluated by Buoncristiani et al. (13). Neither study described whether the ultrasonic vibration was continuous or intermittent or if coolant was used.

While ultrasonic instrumentation is a commonly used method for post removal in endodontics, the degree of temperature increase that may be transmitted to the surrounding tissues is not known. To date there is no information in the literature regarding the amount of heat generated with ultrasonics when used for endodontic procedures. This study was designed to answer the question regarding temperature changes occurring along the post and the root surface with the use of ultrasonic instrumentation for post removal.

Methods and Materials

Root Canal Preparation and Obturation

Ten maxillary central and lateral incisors that were extracted for prosthetic or periodontal reasons were placed in 10% formalin for 1 wk. Teeth with root caries, restorations, abrasions, erosions, craze lines, fractures or marrings from the extraction were excluded. The teeth selected had roots at least 15 mm in length and measured at least 3 mm in diameter at a point 5 mm from the anatomic apex. They were sectioned 1 mm coronal to the buccal cemento-enamel junction. A size 10 endodontic file was inserted into the canal until it exited the apical foramen. The working length was established 1 mm short of this distance.

The canals were prepared with a crown down technique using nickel titanium rotary files to produce an apical preparation size of a #7 (0.465 mm) Profile instrument (Dentsply Corp., Tulsa, OK). Canal Lubricant (Roydent Inc.) and 2.6% sodium hypochlorite solution were used during canal preparation. A size 45 master cone was modified as needed to achieve "tug-back" and fit the apical preparation of the canal. Root canal sealer (Roth 801, Roth Corp., Chicago, IL) was placed on the master cone and inserted into the canal. Using lateral condensation (D11T, Premier Corp.) additional medium-fine accessory cones (Hygienic Corp.) were placed until the spreader tip could penetrate no more than 4 mm into the canal. The excess gutta-percha was then removed (Touch-N-Heat; Analytic Technology, Redmond, WA). The coronal surface of each root was then trimmed perpendicularly to produce specimen 13 mm in length. Cavit (ESPE, Germany) was used to seal each coronal orifice. The teeth were then stored in 100% humidity for 1 wk.

Post Space Preparation

A post space was prepared with a #5 Parapost drill (Coltene/Whaledent) to a depth of 7 mm. A # 5 stainless steel Parapost was trial fitted into the prepared post space then trimmed so that 2 mm of post extended beyond the coronal root surface for ultrasonic application.

Post Cementation

The posts were cemented with zinc phosphate cement (SS White Co., Philadelphia, PA) and held under continuous pressure for 10 min. Excess cement was removed and the specimens were placed in 100% humidity for 30 days.

Testing Procedure

Type K chromel/alumel thermocouples (Omega Engineering, Inc., Stamford, CT) were attached with cyanoacrylate cement at the exposed post and to the root surface 2 mm apical to the cemento-enamel junction (11, 14–17). The opposite ends of the thermocouple wires were connected to a laptop computer. To keep the tooth moist during the experiment, a hole was punched in the center of a rubber dam thereby exposing the coronal post for ultrasonic application and leaving the tooth covered under the rubber dam. Next, each tooth was encased in a holding block and clamped to a vertical restraining rod. A piezoelectric ultrasonic handpiece (Spartan, Fenton, MO) with a CPR 1-C ultrasonic post removal tip (Dentsply; Tulsa Dental, Inc.) was secured to another vertical restraining rod with the ultrasonic tip positioned on the top of the post in an axial direction with a static 500 g force for 1 min at maximum amplitude. No water coolant was used. The temperature at each thermocouple was recorded on the computer at 15 s intervals. The data were analyzed using SPSS statistical software. ANOVA was used to analyze the temperature recorded with the independent variables: length of ultrasonic application (15, 30, 45, 60 s) and location (post, root surface).

Results

Table 1 shows the mean temperature changes at each location and time period. The temperature at the post rose 52.6°C, SD 11.1 at 15 s; 82.6°C, SD 20.1 at 30 s; 111.0°C, SD 29.1 at 45 s and 125.3°C, SD 33.2 at 60 s. The temperature at the cervical root surface rose 9.5°C, SD 4.6 at 15 s; 17.5°C, SD 4.8 at 30 s; 25.4°C, SD 7.3 at 45 s and 32.2°C, SD 8.1 at 60 s. There was a significantly greater temperature increase observed at the post surface than at the root surface ($P < 0.001$). There was a significant temperature increase at both the post and root surface as the length of time of ultrasonic vibration increased ($P < 0.001$). Figure 1 shows the graphic representation of mean temperature changes.

Discussion

Ultrasonic instruments vibrate at a frequency of 25 to 30 kHz. The ceramic plates of the piezoelectric handpiece are designed to provide minimal noise and require little or no water coolant compared to the magnetostrictive ultrasonic instruments (10). Nevertheless, the high frequency vibration does generate frictional heat (10). Abrams et al. (9) and Nicoll and Peters (11) showed in vitro temperature increases on dentinal surfaces during ultrasonic periodontal scaling procedures. Other dental procedures have demonstrated a temperature rise at the root surface associated with warm obturation techniques (14–16, 18, 19), crown preparation (17) and post space preparation (20). But there is no information in the literature regarding the amount of heat generated using ultrasonic instruments for endodontic procedures.

Most ultrasonic studies in the dental literature applied the instrument manually or measured the applied force (9, 11–13, 21, 22). All efforts were made to standardize the procedures and reduce experimental and operator variability in this study. Investigator variability was minimized by using a custom-made holding apparatus for the ultrasonic handpiece. The holding apparatus provided reproducible force and direction of the ultrasonic tip to each post for each test procedure. A preliminary study by the investigators determined 450 to 500 g as the manual force used to apply ultrasonic vibration to the post. It was also found when the ultrasonic handpiece was secured in the holding apparatus 500 g force provided the most control and stable position for the ultrasonic tip on the post during the vibration procedure.

Walmsley et al. (23) found a 200 g force for 2.5 min simulating silver point removal caused the tip to bend. It should be noted that the ultrasonic tip used in their study had a large curved shape with a thin, narrow point unlike the thick CPR 1-C tip used in our study. Further studies are needed to determine the proper amount of force needed for the safe and effective use of ultrasonic instrumentation.

Vibration energy dissipates from the ultrasonic tip to the post and is absorbed through the dentin. Higher temperatures were recorded at the post surface compared to the root surface. Heat transmission through the post and dentin still resulted in temperature increases approaching 10°C in as little as 15 s along the external root surface and continued to rise for the duration of ultrasonic application. This is the critical temperature at or above which irreversible bone injury can occur.

The temperature changes produced by the ultrasonic in this study may be enough to cause damage to the periodontal tissues, especially in the areas that are in close proximity to the ultrasonic application. Dentin is a poor thermal conductor and a small difference in dentin thickness may have a large effect in heat conduction. Teeth with thin roots and large posts could be more susceptible to the heat generation from ultrasonic application during post removal.

TABLE 1 Mean temperature increase in centigrade (with standard deviation) from baseline at the post and root surface for each time period

Location	15 sec.	30 sec.	45 sec.	60 sec.
Coronal post	52.6 ± 11.1	82.6 ± 20.1	111.0 ± 29.1	125.3 ± 33.2
Cervical root	9.5 ± 4.6	17.5 ± 4.8	25.4 ± 7.3	32.2 ± 8.1

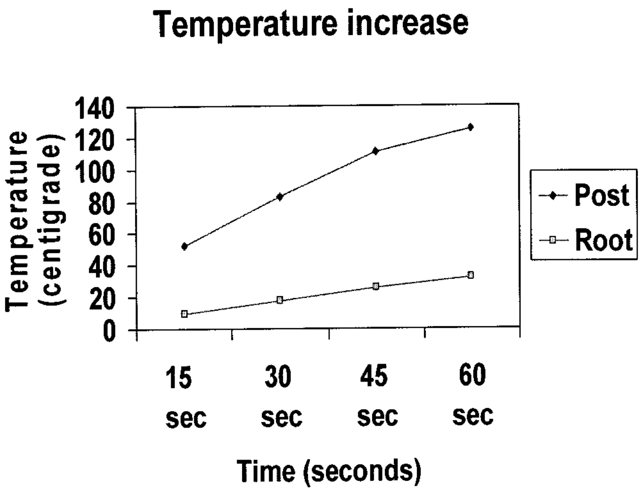

Figure 1. Mean temperatures recorded over time.

This in vitro study was conducted under a set of reproducible conditions, investigating one post type, cemented at one depth into similar sized maxillary incisors using one type of cement. It is unknown if this temperature insult to the root surface and periodontal tissues has a deleterious effect, especially under different clinical conditions. In vivo temperature changes may also be different than those found in this study because thermoregulatory mechanisms such as capillary blood flow and tissue metabolism may help dissipate heat along the root surface.

Despite some recommendations that piezoelectric ultrasonic energy can be used without coolant, this study suggests that brief application of ultrasonic energy can generate considerable heat at the post and root when used with coolant. Further research in this area should be pursued.

References

1. Eckerbom M, Magnusson T. Restoring endodontically treated teeth: a survey of current opinions among board-certified prosthodontists and general dental practitioners in Sweden. Int J Prosthodon 2001;14:245–9.
2. Hussey DL, Killough SA. A survey of general dental practitioners' approach to the restoration of root-filled teeth. Int Endod J 1995;28:91–4.
3. Stamos DE, Gutmann JL. Survey of endodontic retreatment methods used to remove intraradicular posts. J Endod 1993;19:366–9.
4. Krell KV, Jordan RD, Madison S, Aquilino S. Using ultrasonic scalers to remove fractured root posts. J Prosthet Dentistry 1986;559:46–9.
5. Eriksson RA, Adell R. Temperatures during drilling for placement of implants using the osseointegration technique. J Oral Maxillofacial Surg 1986;44:4–7.
6. Eriksson RA, Albrektsson T. Temperatures threshold levels for heat-induced bone tissue injury: a vital-microscopic study in the rabbit. J Prosthetic Dentistry 1983;50: 101
7. Atrizadeh F, Kennedy J, Zander H. Ankylosis of teeth following thermal injury. J Periodon Res 1971;6:159–67.
8. Line SE, Polson AM, Zander HA. Relationship between periodontal injury, selective cell repopulation and ankylosis. J Periodontol 1974;45:725–30.
9. Abrams H, Barkmeier WW, Cooley RL. Temperature changes in the pulp chamber produced by ultrasonic instrumentation. Gen Dentistry 1979;27:62–4.
10. Spangberg L. In: Cohen S, Burns RC, eds. Pathways of the pulp, 8th ed., Chapt. 14. Instruments, materials and devices. St. Louis, Mosby, 2002;535–7.
11. Nicholl BK, Peters RJ. Heat generation during ultrasonic instrumentation of dentin as affected by different irrigation methods. J Periodontol 1998;69:884–8.
12. Johnson WT, Leary JM, Boyer DB. Effect of ultrasonic vibration on post removal in extracted human premolar teeth. J Endod 1996;22:487–8.
13. Buoncristiani J, Seto BG, Caputo AA. Evaluation of ultrasonic and sonic instruments for intraradicular post removal. J Endod 1994;20:486–9.
14. Weller NR, Jurcak JJ, Donley DL, et al. A new model system for measuring intracanal temperatures. J Endod 1991;17:491–4.
15. Floren JW, Weller NR, Pashley DH, et al. Changes in root surface temperatures with in vitro use of the System B heatsource. J Endod 1999;25:593–5.
16. Jurcak JJ, Weller NR, Kulild JC, et al. In vitro Intracanal temperatures produced during warm lateral condensation of gutta-percha. J Endod 1992;18:1–3.
17. LaForgia PD, Milano V, Morea C, et al. Temperature change in the pulp chamber during complete crown preparation. J Prosthet Dent 1991;65:56–61.
18. Lee FS, Van Cura JE, BeGole E. A comparison of root surface temperatures using different obturation heat sources. J Endod 1998;24:617–20.
19. Romero AD, Green DB, Wucherpfennig AL. Heat transfer to the periodontal ligament during root obturation procedures using an in vitro model. J Endod 2000;26:85–7.
20. Tjan AH, Abbate MF. Temperature rise at root surface during post-space preparation. J Prosthet Dent 1993;69:41–5.
21. Altshul JH, Marshall, Morgan L, et al. Comparison of dentinal crack incidence and of post removal time resulting from post removal by ultrasonic or mechanical force. J Endod 1997;23:683–6.
22. Dixon EB, Kaczkowski PJ, Nicholls JI, et al. Comparison of two ultrasonic instruments for post removal. J Endod 2002;28:111–5.
23. Walmsley AD, Lumley PJ, Johnson WT, et al. Breakage of ultrasonic root-end preparation tips. J Endod 1996;22:287–9.