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In vitro evaluation of temperature changes in the root canal induced by ultrasonic scalers

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Van der Velden UKoster TJGFeilzer AJTimmerman MFVan der Weijden GA. *In vitro* evaluation of temperature changes in the root canal induced by ultrasonic scalers.

Abstract: *Objective:* To evaluate *in vitro* the thermal effects induced by four different ultrasonic scalers on the temperature in the root canal during ultrasonic scaling. *Methods:* An extracted lower central incisor provided with a thermocouple in the root canal and a tube, entering the tooth incisally and exiting it apically to simulate an artificial bloodstream, was placed in a model of the lower jaw with soft artificial gingiva. Tested ultrasonic scaler systems included: EMS PM-600, Satelec P-max, Dürr Vector and Dentsply Cavitron. The tooth was scaled with each system at full water supply of 21°C. Furthermore, the amount of water supply was determined to maintain during scaling a constant temperature in the root canal. Finally, thermal changes due to scaling without water were assessed. *Results:* Except for the Vector all scaler systems showed a temperature decrease in the root canal. The Vector with water/polish suspension showed a trend towards an increase in temperature. To maintain a constant temperature in the root canal the Cavitron needed twice the amount of water compared with PM-600 and P-max. Without water, all scaling systems induced a temperature increase. *Conclusion:* For safe ultrasonic scaling, care should be taken that the cooling water has room temperature and that, dependent on the scaler system, the proper amount of water is supplied.

Key words: cooling water; root canal; temperature; ultrasonic scaling

Introduction

Traditionally manual scalers have been used to remove supra- and subgingival deposits from teeth. However, during the last decades, it has been shown that ultrasonic scalers are comparably effective (1). The removal of attached deposits by an ultrasonic instrument is achieved primarily through the vibratory action of the tip, aided by cavitation effects of the associated cooling water (2). The mechanical treatment of the root surface with ultrasonic and sonic instruments is a repetitive process, which generates frictional heat at the contact point between the tip of the instrument and the tooth surface (3, 4). The amount of heat generation varies with the pressure that is used and the frequency, amplitude and mode of action of the instrument.

The proposed effect of heat generation resulting from the use of ultrasonic instruments on the pulp is based mainly on experiments with rotating instruments. Knapp and Bernier (5) were the first to investigate the effect of ultrasonic vibrations on the pulp tissue after cavity preparation by means of an ultrasonic instrument in dogs. They observed a reduction in the height and number as well as disorganization and vacuolization of odontoblasts resulting in an inflammatory response of the pulpal tissues. In order not to cause damage to pulpal tissues by ultrasonic scaling, the cooling water supply should not be below 20 ml min^{-1} (6). However, the Vector ultrasonic system (a piezoelectric unit) uses, according to the manufacturer, 3.3 ml min^{-1} of cooling water (7). The horizontal vibration of this device is converted by a resonating ring in a vertical vibration (25 kHz), resulting in a parallel movement of the working tip to the tooth surface. The water is supplied with intermittent pulsation and is fixed hydrodynamically along the insert of the instrument by the linear ultrasonic movement (8). There are, however, no data available to support that the 3.3 ml min^{-1} of water supply is enough to avoid a rise in temperature (9). Furthermore, it was shown by Koster *et al.* (9) that in case of the EMS P-max ultrasonic system, the combination with the perio maintenance tip and full water supply also resulted in less cooling water than the advised 20–30 ml min^{-1}. Therefore, it may be hypothesized that scaling procedures using the optimal scaling conditions in terms of water supply and power settings according to the manufacturers' instructions could yet result in a temperature rise in the root canal with possible negative effects on the pulpal tissues. Therefore, the purpose of this study was to evaluate *in vitro* the thermal effects induced by four different ultrasonic scalers on the temperature in the root canal.

Material and methods

Scaler systems

For this study, four scaler systems were selected:
1 EMS Piezon Master 600 (PM 600), 24–32 kHz piezoelectric generator (Electro Medical Systems, Nyon, Switzerland).
2 Satelec P-max (P-max), 27–33 kHz piezoelectric generator (Satelec-Acteon group, Bordeaux, France).
3 Dürr, Vector ultrasonic system (Vector), 25 kHz piezoelectric generator (Dürr Dental GmbH & Co. KG, Bietigheim-Bissingen, Germany) in combination with the scaler and perio handpiece.
4 Dentsply, Cavitron Select SPS (Cavitron), 30 kHz magnetostrictive generator (Dentsply, York, PA, USA).

Each scaler system was tested with four different tips. Depending on their shaft size, these tips can be divided into four groups: (i) standard tip, (ii) perio tip, (iii) slim perio tip and (iv) perio maintenance tip. Table 1 shows the tip selection for each scaler system as chosen from the available manufacturers tip collection. The PM 600 and P-max had a tip corresponding with each of these four categories. The Cavitron had three tips matching the standard, perio and slim perio types, whereas for the Vector, only the standard and perio maintenance tip matched.

All four scaler systems were 'stand-alone units'. Consequently, they were not connected to running water but obtained the water from a small tank which is located either underneath or on top of the unit. The PM 600, P-max and Cavitron had an adjustable water supply system, whereas the Vector had an unchangeable fixed amount of water supply which can be used with and without the addition of polishing fluid to the cooling water. In this study, the Vector was used both with water alone as well as with the water/polish suspension both of which are applied by intermittent pulsation. In Table 2, the optimal scaling conditions are presented in terms of full water supply and matching power settings according to the manufacturers' instructions.

Table 1. **Tip types used with the four different scaler systems according to the shaft size**

	Type of the scaler systems			
Tip type	PM 600	P-max	Cavitron	Vector
Standard	A	1	FSI 1000	Scaler
Perio	P	1S	SLI-10S	–
Slim perio	PS	10Z	SLI-10R	–
Perio maintenance	PL-3	TK1-1S	–	Straight perio

Test Model set-up

One intact extracted human lower incisor that was free of obvious defects and stored in physiologic saline solution with 5% formalin was selected for this study. To gain proper access to the root canal, the pulp chamber was opened from the incisal edge and a small apical segment of the root was removed. The tooth was washed in water, and the pulpal content was removed by means of an endodontic file with a diameter of 0.5 mm (flexofile; Dentsply Maillefer, Ballaigues, Switzerland) creating a space in the root canal of 0.65 mm mesiodistally and 1.3 mm buccolingually. To simulate the blood flow, which *in vivo* may drain the produced heat in the tooth, a metal tube with a diameter of 0.64 mm (Ismatec SA, Glattbrugg, Switzerland) was inserted into the pulp chamber via the incisal entrance into the lingual space in the root canal, exiting the tooth at the apex. Water drainage, simulating the blood flow through the tube, went from an incisal to apical direction. In the buccal part of the space in the root canal, a standard

Table 2. **Optimal scaling condition for the various systems according to the manufacturer's instructions with respect to full water supply and matching power setting**

Scaler system	Water supply (ml min^{-1})	Power setting
EMS, Piezon Master 600 (PM 600)	50	70%
Satelec, P-max (P-max)	40	Blue 8*
Dürr, Vector ultrasonic system (Vector)	3.3	70%
Dentsply, Cavitron Select SPS (Cavitron)	55	Blue 10*

*The blue zone of P-max and Cavitron identifies the power range for scaling procedures.

thermocouple (K-type), at the end of the wire with a diameter of 0.6 mm and a length 0.6 mm, was inserted at the apical entrance of the tooth up to 2 mm apical from cement–enamel junction. The incisor, containing both thermocouple and tube, was embedded at the position of the 41 in a model of the lower jaw with soft artificial gingiva and removable teeth (Frasaco model, Sachs, Tettnang, Germany). The apical part of the root was embedded in the artificial bone of the model up to 4 mm apical of the cement–enamel junction leaving a 4 mm subgingival space between the soft artificial gingiva and the tooth. This simulated a 4-mm periodontal pocket in which a scaling procedure could be carried out. The tooth was fixated in the artificial bone with composite (Z100l; 3M ESPE, St. Paul, MN, USA) leaving a space open for the apical tube and the thermocouple wire. To simulate an artificial body temperature, the jaw model, including the fixed experimental tooth, was placed in an isothermic bath in such a way that the artificial gum was above the surface of the water. The bath was set at a constant temperature of 39°C, which resulted in a resting mean temperature in the root of the test tooth of 32°C (which is an estimated mean tooth temperature based on the study of Fanibunda (10), who showed a range from 28 to 35°C. The tube at the apical side of the tooth exited into the thermobath, and the tube that entered the incisal side of the tooth was connected to a water rotation pump (Reglo-CPF digital, type ISM833A; Ismatec SA, Glattbrugg, Switzerland) creating a circulating flow with a rotation speed 0.07 ml min^{-1}. The latter is an estimated mean blood flow rate in the tooth as calculated by Kim *et al.* (11) and Ciucchi *et al.* (12). The thermocouple was connected to an electronic transducer TC-08 (Pico Technology Limited, Cambridgeshire, UK) passing a signal to a computer. The temperature measurements, continuously registered during 90 s at 0.5 s cycles, were calculated with the PICO computer program (Pico Technology Limited).

Experimental design

In this study, one unit of each scaler system was tested. Each unit and tip combination was used in triplicate in the experimental model as described above and operated by one and the same operator (TGJK). In the first experiment, water supply and power setting of each scaler system were used under the optimal scaling conditions according to the manufacturers' instructions (Table 2). A temperature of approximately 21°C was used for the water supply, similar to what is used in daily practice. During all scaling procedures, the tip of the scaler was held in continuous contact with the root surface of the tooth, moving it back and forth with a continuous sweeping motion parallel to the tooth axis (13). Light pressure was applied, and a scaling procedure was performed during 90 s. After each scaling procedure, a rest period was introduced until both the ultrasonic scaler unit and the test tooth had regained the baseline temperature. Thereafter, the experiment was repeated twice in the same way. A second experiment was performed to establish the amount of water supply needed to maintain the root canal temperature close to the baseline temperature before start of the scaling procedure. Using the manufacturer's optimal power settings, decreasing amounts of water were applied during scaling. As soon as the temperature started to drop or to rise, the water supply was adjusted until a stable temperature was obtained close to the baseline value. This experiment was also repeated twice. This experiment did not include the Vector system, as the amount of water supply with this unit could not be adjusted. A third and last experiment was performed to assess the thermal changes without the use of water supply during 90 s of scaling at the same optimal power settings. After the test tooth had regained the baseline temperature, the experiment was repeated twice in the same way.

Statistical analysis

The thermal data were transposed from the Pico program (Pico Technology Limited) to the SPSS program (SPSS Inc., Chicago, IL, USA). For all threefold measurements, mean values and standard deviations were calculated. The temperature at start, minimum and maximum temperature, and differences between minimum and maximum were calculated. In the experiment with the maximum amount of cooling water, the temperature dropped reaching a plateau value after 30 s. Therefore, the temperature as a result of the scaling procedures was calculated as the mean temperature of assessments between the time points 30–90 s (T30/90). Temperature changes caused by the use of the four scaler systems were tested using a repeated-measures analysis of variances (ANOVA) between temperature at baseline and the mean difference in temperature of the used tip types at T30/90, or Tmax in case of the experiment without water supply. Next post hoc testing was performed by comparing each possible pair of PM 600, P-max Vector and Cavitron. Changes in temperature from baseline to T30/90 were analysed for each scaler/tip-type system by mean of a paired sample *t*-test. Differences in temperature changes within each scaler/tip system were again analysed by means of repeated-measures ANOVA. Mauchly's tests showed that variances of differences were in no case significantly different. Concerning amounts of water supply to maintain constant temperatures, a univariate analysis of variance was used, entering water supply as the dependent variable and scaler system and tip type as fixed factors. In all analyses, post hoc testing using a Bonferroni approach was performed to determine the source of the differences between groups. Differences were considered as statistically significant at $P < 0.05$.

Results

Temperature effects under optimal scaling conditions

Before the start of the experiment (T0), the temperature in the root canal varied on average between 31.4 and 32.6°C. In Table 3, the temperature changes are presented for the four scaler systems that were used in the experiment. Following scaling with water supply, all four units showed a decrease in

Table 3. **Mean temperatures in the root canal under optimal scaling conditions according to the manufacturers' instructions: temperature at baseline (T0), temperature between time span 30 and 90 s (T30/90) and the temperature difference between T0 and T30/90. Standard deviations in parentheses**

Scaler system	Tip type	T0 °C	T30/90 °C	T0–T30/90 °C	*P*-value
PM 600*	Standard	32.1 (0.8)	25.6 (0.2)	−6.5 (0.9)	<0.001
	Perio	31.7 (0.5)	25.7 (0.1)	−6.0 (0.4)	<0.001
	Slim Perio	32.3 (0.5)	26.0 (0.4)	−6.2 (0.3)	<0.001
	Perio maintenance	32.6 (0.2)	25.9 (0.2)	−6.7 (0.1)	<0.001
P-max	Standard	32.1 (0.7)	26.1 (0.3)	−6.0 (0.5)	<0.001
	Perio	32.1 (1.2)	26.2 (0.5)	−5.1 (0.4)	<0.001
	Slim Perio	31.6 (0.5)	26.2 (0.1)	−5.4 (0.4)	<0.001
	Perio maintenance	31.9 (0.3)	30.2 (0.5)	−1.7 (0.6)†	0.04
Vector‡	Standard	31.4 (0.2)	30.4 (1.3)	−1.0 (1.3)	0.31
	Perio maintenance	31.9 (0.7)	29.8 (0.8)	−2.2 (0.9)	0.06
	Standard§	32.1 (0.5)	33.1 (1.0)	1.0 (1.2)	0.29
	Perio maintenance§	31.4 (1.1)	34.3 (1.0)	2.9 (1.3)	0.06
Cavitron¶	Standard	32.3 (0.6)	26.8 (0.1)	−5.5 (0.6)	<0.001
	Perio	31.7 (0.3)	28.9 (0.4)	−2.8 (0.5)	<0.001
	Slim Perio	32.2 (0.9)	27.5 (0.3)	−4.7 (0.8)	<0.001

*PM 600 significantly different from Vector and Cavitron ($P < 0.001$), but not from P-max ($P = 0.12$).
†Within P-max, the drop in temperature for Perio maintenance is significantly less compared with the other tip types ($P < 0.001$).
‡Vector significantly different from PM 600, P-max and Cavitron ($P < 0.001$).
§Water/polish suspension with the Vector.
¶No significant difference between Cavitron and P-max ($P = 0.32$).

temperature which was statistically significant for the PM 600, P-max and Cavitron. When using the standard tips, this decrease was 6.5°C, 6.0°C and 5.5°C, respectively. The drop in temperature was the largest by the PM 600 and the least by the Vector. Within each scaler system, the temperature drop was not different between the tip types with the exception of the P-max in combination with the perio maintenance tip. This combination induced a significantly lower temperature drop as compared to the other three tips. When using the Vector system in combination with polishing fluid, even a trend for an increase in temperature was found (Table 3).

Isothermic cooling water supply

The procedure to maintain a stable temperature in the root canal during scaling procedures resulted in fluctuations of the temperature just below or just above the baseline starting temperature. However, the ranges were small and varied between 1.1°C and 2.1°C for the various scaler/tip systems (Table 4). The amount of water supply necessary to keep the temperature in this range varied significantly for the three scaler systems used. The P-max needed the least water supply ranging from 7.9 to 12.6 ml min^{-1} followed by the PM 600. In all cases, the combination of a scaler system with the standard tip needed more water supply than the other tip types. The Cavitron needed approximately twice the amount of water supply as the PM 600 and P-max ranging from 20.3 and 24.1 ml min^{-1}.

No water supply

Table 5 shows the change in temperature in the root canal without the use of water supply during 90 s of scaling. All scaler systems induced a significant rise in temperature ranging from 4.9°C to 10.4°C. No significant differences between the four scaler systems as well as the various tip types could be assessed.

Discussion

The present study was initiated to evaluate temperature changes in the root canal after instrumentation with different ultrasonic scaler systems employed with different amounts of water supply and to assess whether they are safe to use, also on the most vulnerable teeth. Therefore, this study was designed as a 'proof of safety' study and investigated the maximum influence of scaling procedures on the temperature in the root canal of a tooth. It has been shown that the impact of temperature decreases with increasing thickness of the dentin between root canal and root surface (14). Therefore, all assessments of this study were carried out on a lower incisor of which the dentin thickness as measured at 5 mm from the apex is the smallest of all teeth, that is, 0.5 mm (15). *In vivo*, due to the blood flow through the root canal and the diffusion of heat into the surrounding bone, the anticipated root canal temperature changes as a reaction on external temperature changes might be dampened (16). Therefore, in the present study, a model was used that included an artificial bloodstream as well as body temperature, mimicking as much as possible the *in vivo* situation. The results showed that after 30 s of scaling with the three piezoelectric systems at full water supply of 21°C, the temperature in the root canal dropped to a plateau value ranging from 25.6°C to 30.2°C dependent on the scaler system used. This suggests that the artificial bloodstream with a temperature of 39°C does contribute to the final temperature in the root canal.

Table 4. **Mean temperatures in the root canal with isothermal cooling water supply: temperature at baseline (T0), minimum (Tmin) and maximum (Tmax) temperature change during instrumentation, differences between Tmin and Tmax and mean amount of water supply necessary for isothermal cooling. Standard deviations in parentheses**

Scaler system	Tip type	T0 °C	Tmin °C	Tmax °C	Tmin–Tmax °C	Water supply setting (ml min^{-1})
PM 600*	Standard	32.2 (0.2)	30.9 (0.3)	32.5 (0.4)	1.6 (0.1)	12.1 (0.6)†
	Perio	31.4 (0.2)	30.6 (0.4)	31.8 (0.4)	1.1 (0.3)	10.2 (0.1)
	Slim Perio	31.2 (0.3)	30.9 (0.2)	33.0 (0.5)	2.1 (0.5)	10.4 (0.2)
	Perio maintenance	31.4 (0.5)	31.0 (0.4)	32.3 (0.5)	1.3 (0.5)	10.8 (0.2)
P-max	Standard	31.9 (0.6)	31.4 (0.4)	32.8 (0.4)	1.4 (0.3)	12.6 (0.1)†
	Perio	32.0 (0.2)	31.8 (0.2)	33.0 (0.1)	1.2 (0.3)	9.5 (0.9)
	Slim Perio	31.1 (0.3)	30.6 (0.1)	32.2 (0.5)	1.6 (0.5)	8.9 (0.9)
	Perio maintenance	31.8 (0.2)	31.2 (0.4)	32.4 (0.3)	1.2 (0.4)	7.9 (0.4)
Vector‡						
Cavitron§	Standard	32.2 (0.3)	30.9 (0.7)	32.5 (0.9)	1.7 (0.5)	24.1 (0.2)†
	Perio	31.7 (0.6)	30.9 (0.8)	32.2 (1.0)	1.3 (0.3)	21.0 (0.2)¶
	Slim Perio	31.7 (0.3)	30.2 (0.6)	31.7 (0.3)	1.6 (0.8)	20.3 (0.2)

*PM 600 needed more water supply than P-max ($P < 0.001$).
†In all scaler systems, the standard tip needed more water supply than the other tip types ($P < 0.006$).
‡Data on Vector are not included since it only allowed a full water cooling supply setting.
§Cavitron needed more water supply than PM 600 and P-max ($P < 0.001$).
¶In case of the Cavitron, the perio tip type needed more water supply than the slim perio tip ($P = 0.001$).

Table 5. **Temperatures without cooling water supply: mean temperature at baseline (T0), maximum temperature (Tmax), difference between T0 and Tmax. Standard deviations in parentheses**

Scaler system	Tip type	T0 °C (SD)	Tmax °C (SD)	T0–Tmax °C (SD)*
PM 600	Standard	31.9 (0.5)	39.5 (2.5)	7.6 (2.5)†
	Perio	31.9 (0.3)	40.8 (2.8)	8.9 (2.5)
	Slim Perio	32.3 (0.4)	42.6 (3.4)	10.3 (3.4)
	Perio maintenance	31.5 (0.9)	40.3 (1.8)	8.8 (1.8)
P-max	Standard	32.3 (0.5)	37.8 (.08)	5.5 (0.3)†
	Perio	31.5 (0.9)	41.9 (7.4)	10.4 (6.7)
	Slim Perio	32.4 (0.1)	39.3 (2.2)	6.9 (2.2)
	Perio maintenance	31.7 (0.9)	36.6 (2.2)	4.9 (1.3)
Vector	Standard	32.0 (0.6)	37.8 (0.3)	5.8 (0.8)†
	Perio maintenance	32.1 (0.3)	41.7 (5.0)	9.6 (4.6)
Cavitron	Standard	31.7 (0.1)	39.6 (2.6)	7.9 (2.6)†
	Perio	32.1 (0.3)	41.8 (3.1)	9.7 (3.0)
	Slim Perio	31.1 (0.7)	37.9 (2.0)	6.8 (1.3)

*All scaler systems induced a significant rise in temperature ($P < 0.001$), but no significant differences were present between the four scaler systems.
†No significant differences were present between the tip types.

It is obvious and confirmed in the present study that if no water cooling is used, the temperature in the root canal will rise. In the present study, water supply with a temperature of 21°C was used. Previous *in vitro* studies using cooling water of higher temperatures showed conflicting results. Kocher and Plagman (3), using an amount of cooling water supply of 30 ml min^{-1} with a temperature of 35°C, showed an increase of 4°C during scaling on the opposing dentine walls of 0.5 mm thickness during scaling. Nicoll and Peters (17) reported an increase of 7°C of dentine slabs of 0.5 mm thickness when using 30 ml min^{-1} of cooling water supply with a temperature of 26°C. In both studies, a scaling procedure of 30 s was employed. Most likely the discrepancy in results is due to the different *in vitro* models used. However, to avoid a rise in temperature in the root canals, it may be better to use cooling water at room temperature as in the present study. Nevertheless, if too little cooling water is used, a rise of the temperature in the root canal could be still possible. To study this possibility, the isothermic experiment was carried out to assess at which water supply setting of the four devices with the various tips no change in temperature in the root occurred when using water at room temperature. The results of this study that could only be carried out for the PM 600, P-max and Cavitron showed that for all three devices, lower water supply settings can be used than the advised full amount. Still, the exact amount of water is not known because results of a previous study showed that the water supply setting of a device does not necessarily reflect the amount of water that is actually supplied (9). Nevertheless, using less water may be beneficial for the operator's visibility. Therefore, in case of the PM 600 and P-max, this study indicates a water supply setting of approximately 12 ml min^{-1} may be advised, whereas the Cavitron needs approximately the double amount. In case of the Vector, which allows only the maximum setting of water supply and using a polish suspension, a risk of an increase in temperature in the root seems to be present. The reason why the Cavitron needs twice as much water cooling supply as the PM 600 and the P-max is probably related to the working mechanism. The Cavitron is a magnetostrictive ultrasonic scaler, whereas the other two are piezoelectric ultrasonic scalers. With magnetostrictive ultrasonic scalers, cooling water is required for both the transducer and the tip. As vibrations of the metal strips in the stack of the Cavitron device produce heat, the cooling water is therefore necessary to prevent overheating of the handle. Consequently, the effluent cooling water reaching the tip of the instrument will thus be of a higher temperature than at the entrance of the handpiece, and therefore, more cooling water is needed to maintain a constant temperature in the root canal during scaling as compared to the other instruments.

If heat reaches the pulp during dental procedures, it can lead to vascular injury and tissue necrosis. In a study in Macaca rhesus monkeys, it was found that minimal intrapulpal chamber pathological lesions will develop if the pulp temperature increases 2.2°C (18). A pulp temperature rise of 5.5°C led to necrosis in 15% of the cases, whereas an 11.1°C rise resulted in necrosis of the pulp in 60% of the cases, and 100% with an increase of 16.6°C. However, more recent work by Baldissara *et al.* (19) did not support these data. They found that after heat application on the crown, resulting in an increase of 11.2°C in the pulp chamber, no damage to the pulp tissues was induced, as no signs of inflammation and no reparative processes were detected. The discrepancy between the results of the two studies is most likely due to the difference in teeth that were used. In the latter study, human premolars and molars were used of subjects aged 10–25 years. Probably, the larger volume of the pulp chambers of human teeth makes them more resistant to heat damage due to more blood supply. However, it must be realized that in these two studies, the histological changes in the pulp chamber were evaluated, whereas heat produced during scaling will result in a rise of temperature in the root canals. In the light of the above-mentioned studies, it is likely that the tissues in the relatively small root canals may be less resistant to heat damage than the pulpal chamber tissues. Therefore, it seems the safest if the temperature in the root canal does not rise during scaling which especially for the Vector used with polish suspension may be difficult.

Conclusion

For safe ultrasonic scaling, care should be taken that the cooling water has room temperature and that, dependent on the scaler system, the proper amount of cooling water is supplied. This is accomplished if the manufacturer's instructions are followed. Magnetostrictive units need approximately double the amount of water supply as compared to standard piezoelectric scalers. The water temperature and amount of water supply are important variables in order to maintain a constant temperature within the root canal.

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Conflict of interest and source of funding statement

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