Journal of Clinical Periodontology

Official Journal of The European Federation of Periodontology

Founded by the British, Dutch, French, German, Scandinavian, and Swiss Societies of Periodontology

J Clin Periodontol 2009; 36: 127–131 doi: 10.1111/j.1600-051X.2008.01349.x

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Water coolant supply in relation to different ultrasonic scaler systems, tips and coolant settings

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Koster TJG, Timmerman MF, Feilzer AJ, Van der Velden U, Van der Weijden FA. Water coolant supply in relation to different ultrasonic scaler systems, tips and coolant settings. J Clin Periodontol 2009; 36: 127–131. doi: 10.1111/j.1600-051X.2008.01349.x.

Abstract

Objective: This study evaluated ''in vitro'' the consistency of the water coolant supply for five ultrasonic scaler systems in relation to the tip type and different coolant settings.

Material and Methods: The systems were: EMS PM-400, EMS PM-600, Satelec P-max, Dürr Vector and Dentsply Cavitron. For each system, three units were used and on each unit various tips were tested. The tips were run unloaded for 1 min. at full and medium water supply setting.

Results: At full water coolant setting, the PM-400, PM-600 and Cavitron supplied on average >45 ml/min. of water coolant (51.5, 46.3 and 46.9 ml/min., respectively). The P-max supplied 25 ml/min. and the Vector supplied 4.9 ml/min. At medium setting, the PM-400 and PM-600 supplied approximately 50% of the volume given at the full coolant setting (25.0 and 26.3 ml/min., respectively). The Cavitron supplied approximately 40% at medium setting (18.2 ml/min.) and the P-max supplied approximately 25% (5.7 ml/min.).

Conclusion: The coolant control system of the different units did not provide a reliable indication of the water flow. Also, some perio tips gave less water coolant as compared with other tips of the same brand. Consequently, a change of tips during treatment may require adjustment of the water coolant supply.

Key words: coolant; in vitro; periodontal treatment; ultrasonics

Accepted for publication 13 October 2008

Ultrasonic instruments convert electrical energy into mechanical energy in the range of 18,000–50,000 vibrations per second (Van der Weijden 2007). Zinner (1955) showed that ultrasound instrumentation could be used to remove plaque and calculus from the teeth. Already in the 1960s, the instruments became an acceptable alternative to hand scalers as they were found to be as effective in the removal of calculus (McCall & Szmyd 1960). The use of an ultrasonic scaler will produce an increase in temperature of the dental and surrounding tissues. This is the result of frictional heating due to contact between the scaler and the tooth. Despite the small area of contact and the large acoustic mismatch between the steel scaling tip and the dental tissues, some ultrasound energy is still transmitted into the tooth. Absorption of this acoustic energy alone can result in an elevation in tooth temperature in vitro of up to 2°C (Walmsley et al. 1986). Under normal scaling conditions, with a water coolant supply set at 20 ml/min., the increase in temperature in the tooth should not exceed 8°C (Walmsley et al. 1986). In vitro data using dentine slabs show that when using sonic scalers, without a water coolant, the temperature of the dentine could increase by 35°C. In the presence of a water coolant (with a supply of 30 ml/min.), an increase of only 4–5°C was observed (Kocher & Plagmann 1996, Nicoll & Peters 1998).

It is understood that the application of a water coolant additionally has a beneficial effect. Cavitation occurs when the water contacts the vibrating tip, creating minute bubbles that collapse and release energy. This cavitation activity in the cooling water passed over the scaler tip can also be involved in the removal of plaque and stain from the tooth surface (Walmsley 1988).

Based on the available evidence, Trenter & Walmsley (2003), in their review, concluded that sonic and magnetostrictive ultrasonic-powered scaling

Conflict of interest and source of funding statement

The authors declare that they have no conflict of interests.

This study was self-funded by the authors and their institution.

should not be operated without irrigation. The amount of water coolant should be at least 20–30 ml/min. In contrast to these data, the Dürr Company, which markets the Vector ultrasonic scaler (VUS) (a piezoelectric unit), claims that 3.3 ml/min. of water coolant is sufficient. The horizontal vibration of this device is converted by a resonating ring into a vertical vibration (25 kHz), resulting in a parallel movement of the working tip to the tooth surface. The coolant is applied by intermittent pulsation and held hydrodynamically on the instrument by the linear ultrasonic movement (Hahn 2000, Slot et al. 2008). There are, however, no scientific data available to support this working mechanism. For the clinician, the manufacturers only provide information about the maximum amount of water coolant given per minute by the different scaler systems available in the market. The effect of water coolant supply settings of ultrasonic scaler systems and type of instrument (especially the tips) in relation to the amount of water coolant is unknown. It was, therefore, the aim of the present study to test ''in vitro'' the consistency of the water coolant supply for different commercially available ultrasonic units in relation to:

(1) ultrasonic tip type and
(2) different water coolant supply settings.

Material and Methods

Five scaler systems, being the most common brands sold in the Netherlands, were selected for this study (Table 1):

(1) EMS Piezon Master 400 (PM-400), 27–30 kHz piezoelectric system (Electro Medical Systems, Nyon, Switzerland) (Fig. 1a),
(2) EMS Piezon Master 600 (PM-600), 24–32 kHz piezoelectric system (Electro Medical Systems) (Fig. 1b),
(3) Satelec P-max (P-max), 27–33 kHz piezoelectric system (Satelec, Acteon group, Bordeaux, France) (Fig. 1c),
(4) Dürr, Vector (Vector), 25 kHz piezoelectric system (Dürr Dental GmbH & Co. KG, Bietigheim-Bissingen, Germany) in combination with the scaler and perio hand piece (Fig. 1d), and
(5) Dentsply, Cavitron Select SPS (Cavitron), 30 kHz magnetostrictive system (Dentsply, York, PA, USA) (Fig. 1e).

Table 1. Scaler systems, maximum water coolant supply and optimal power state according to the manufacturer

Scaler system	Water coolant supply (ml/min.)	Power state
EMS, Piezon Master 400 (PM-400)	50	70%
EMS, Piezon Master 600 (PM-600)	50	70%
Satelec, P-max (P-max)	40	Blue 8
Dürr, Vector (Vector)	3.3	70%
Dentsply, Cavitron Select SPS (Cavitron)	55	Blue 10

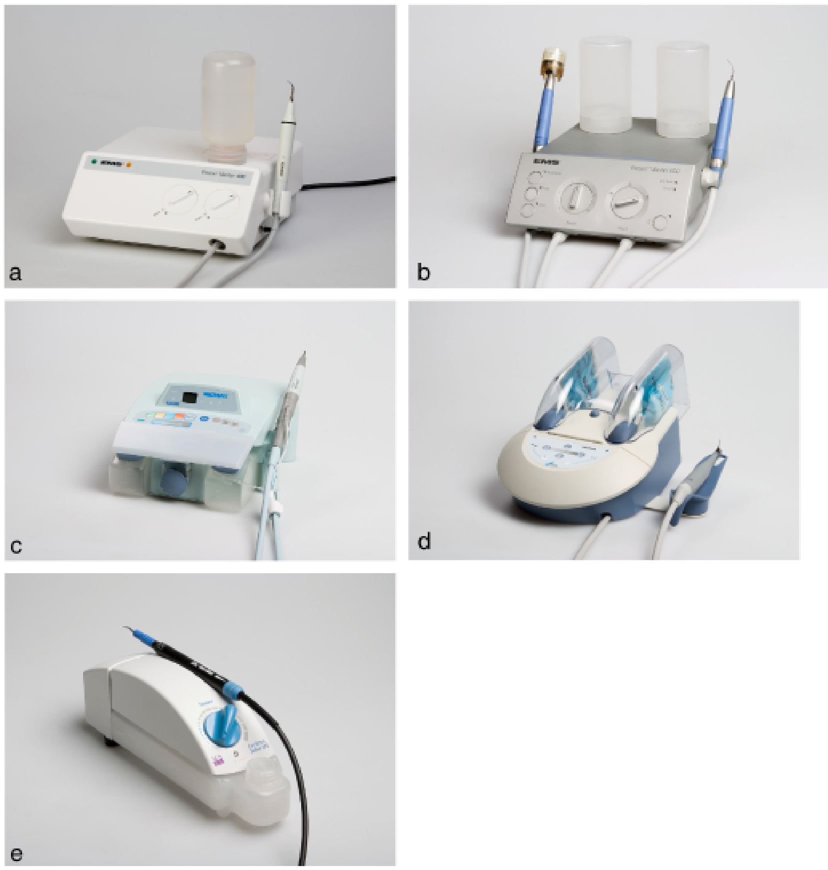

Fig. 1. (a) The PM-400 unit. (b) The PM-600 unit. (c) The P-max unit. (d) The Vector unit. (e) The Cavitron unit.

All five units were ''stand-alone units''. Consequently, they were not connected to the water mains. They draw water from a small tank that is located either underneath or on top of the unit. Water supply is therefore unit dependent.

For each type of scaler system, three different units were tested, thus controlling for the intra-system variability. Each scaler system was used with different tips. These tips can be categorized into four groups depending on their shaft size (1, standard; 2, perio; 3, slim perio; and 4, perio maintenance). Table 2 shows the tip selection for each scaler system as chosen from the available manufacturers' tip collection. The PM-400, PM-600 and P-max had a tip corresponding for each of these four categories. The Cavitron had three tips matching the standard, perio and slim perio types. The Vector had a standard and a perio maintenance tip.

The water coolant supply of each unit of the different scaler systems was tested as follows: the power was adjusted to the optimal scaling efficiency state according to the manufacturer (Table 1). This power state was maintained throughout the experiment. Tips were run unloaded for 1 min. at full and medium water supply settings. The Vector unit formed an exception,

Table 2. The tips used with the different scaler systems could be divided into four groups depending on the shaft size

Tip type	PM-400/PM-600	P-max	Vector	Cavitron
Standard	A	1	Scaler	FSI 1000
Perio	P	1S	–	SLI-10S
Slim perio	PS	10Z	–	SLI-10R
Perio maintenance	PL-3	TK1-1S	Straight perio	–

because it only allowed full water cooling supply setting. However, the water cooling supply could 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. In all cases, the water coolant/suspension was collected in a high (17.5 × 9 cm) standardized container (Schott Duran, Mainz, Germany) in order to gather the water coolant including spray/mist. The volume was determined by assessing the fluid weight on a precision scale (Mettler-Toledo, PM 4600 Delta Range, Columbus, OH, USA). For testing the consistency of the water supply, measurements with each tip for each unit were repeated five times.

Data analysis

For all fivefold measurements, mean values and standard deviation were calculated. Differences between units and tips used in each unit were tested using a three-level repeated measures analysis with post hoc testing. The levels of repeated measures were: fivefold repetition of each particular combination of tip type, unit type and individual unit (fastest changing level), the change of tip types within each type of unit and individual unit (the medium changing level) and the change of individual unit (three specimens of each individual unit type, the slowest changing level). Effects for tip types, unit types and interactions between these two could be recognized. Post hoc testing was performed to discern the origin of the differences found. Differences were considered as statistically significant at $p<0.05$.

Results

In Table 3, the mean amount of water coolant supply for each scaler system with their various tip types, at full and medium water coolant settings, is shown. Also, the overall mean per scaler system is illustrated. At full water coolant setting, the PM-400, PM-600 and the Cavitron supplied on average more than 45 ml/min. of water coolant (51.5, 46.3 and 46.9 ml/min., respectively). The P-max supplied 25 ml/min. and the Vector supplied 4.9 ml/min. The five different scaler systems supply different amounts of water coolant ($P_{\mathrm{ANOVA}}<0.0001$).

When adjusting the amount of water coolant from the full to the medium setting, the PM-400 and PM-600 supplied approximately 50% of the volume given at the full coolant setting (25.0 and 26.3 ml/min., respectively). The Cavitron supplied approximately 40% at the medium setting (18.2 ml/min.) and the P-max supplied approximately 25% (5.7 ml/min.). With the perio maintenance tip, the P-max unit had a lower volume of 11.2 ml/min. on the water coolant output setting as compared with the 29.3–29.7 with the other three tips ($P_{\mathrm{ANOVA}}<0.0001$). With the perio tip the Cavitron produced 36.0 ml/min., which was also lower as compared with 50.1 and 54.6 for the other two tips ($P_{\mathrm{ANOVA}}<0.0001$).

The within-fivefold-measurement standard deviations for each of the three units can be considered as a measure for the reproducibility of the amount of water coolant. Table 4 shows the mean of these standard deviations for each tip type per scaler system. The lower the mean standard deviation, the smaller the variations in the coolant supply of each unit. The Vector showed the lowest standard deviation, with a range from 0.1 to 0.2. The intermediate standard deviation was observed for the P-max (0.3 and 0.7) and the Cavitron (0.3–1.0). The highest standard deviation was observed for the PM-400 (0.9–2.8 ml/min.) for the different tip types, and for the PM-600 (0.4 and 1.6).

Discussion

During normal operation, the dental scaler tips of ultrasonic instruments have a continuous stream of water flowing over them, which is important for a safe and effective use. A water coolant with magnetostrictive ultrasonic units is required for both the transducer and the tip. A piezoelectric transducer may work without water such as for crown removal; however, it is beneficial if water flow is used as the tip will generate frictional heat generated at the tip/tooth interface. As the water flows over the surface of the tooth, the heat generated is conducted into the water and carried away by the bulk fluid movement. An increase in water flow over the scaler tip generally leads to a reduction in the maximum temperature attained (Lea et al. 2004). In addition to cooling, the water aids in increasing visibility by flushing the field of blood and other debris and irrigates sulci and periodontal pockets. The water lavage that accompanies dental deposit removal allows for a favourable tissue response (Bowen 2003).

Limited information is available about the amount of water coolant being flushed down to the very tip of the instrument when working in a periodontal pocket. Normally, the ultrasonic instrument is inserted to the base of the periodontal pocket to disrupt the microflora, debride the root surface and provide subgingival lavage. The heat generated in this process should be reduced by a constant stream of water originating from the base of the tip. It can be questioned whether irrigation during subgingival ultrasonic scaling is efficient while the surrounding periodontal tissues and narrow pocket lumen affect cooling of the scaler tip (Nicoll & Peters 1998). Research has shown that the water coolant of the ultrasonic unit indeed does extend apically as far as the ultrasonic tip, thereby providing coolant at the very tip of the instrument. However, beyond the path of the ultrasonic tip, there is limited dispersion of the coolant (Nosal et al. 1991). The water flow and generator power appear to be important parameters in this respect. At higher power settings, the water tends to be thrown off as aerosol before it reaches the working end of the tip (Lea et al. 2002) and so provides no heat regulation. Jahn (2006) stated that an amount of 14–23 ml/min. (mean of 17.5 ml/min.) of cooling agent appears to be sufficient to prevent thermal damages in periodontal pockets, as the penetration of the water coolant used

Table 3. Mean amount of water coolant in ml/min. presented by scaler system and tip, with the water coolant supply at full and medium settings and the overall mean per scaler system

Tip type	Mean amount of coolant at full water supply setting (SD)	Mean amount of coolant at medium water supply setting (SD)
PM-400		
Standard	51.7 (5.2)	33.0 (13.5)
Perio	52.1 (4.5)	22.5 (17.2)
Slim perio	55.7 (6.4)	29.8 (16.6)
Perio maintenance	46.5 (16.6)	14.8 (4.0)
Overall mean (ml/min.)	51.5	25.0
PM-600		
Standard	44.1 (8.9)	20.6 (15.8)
Perio	47.0 (5.7)	27.8 (15.0)
Slim perio	49.1 (5.3)	27.3 (17.7)
Perio maintenance	44.3 (9.1)	29.4 (17.3)
Overall mean (ml/min.)	46.3	26.3
P-max		
Standard	29.7 (1.3)	6.0 (0.5)
Perio	29.3 (1.0)	6.2 (0.6)
Slim perio	29.7 (1.9)	6.2 (0.7)
Perio maintenance	11.2 (2.4)[a]	4.4 (1.6)
Overall mean (ml/min.)	25.0	5.7
Vector*		
Standard	4.1 (0.2)	–
Perio maintenance	4.1 (0.1)	–
Standard[†]	5.7 (0.4)	–
Perio maintenance[†]	5.8 (0.1)	–
Overall mean (ml/min.)	4.9	
Cavitron		
Standard	50.1 (2.1)	18.3 (6.9)
Perio	36.0 (0.5)[b]	17.1 (6.2)
Slim perio	54.6 (0.5)	19.2 (7.6)
Overall mean (ml/min.)	46.9	18.2

*The Vector unit only allowed a full water cooling supply setting.
[†]Water coolant/suspension with the Vector.
[a]The perio maintenance tip is significantly different from the other three tips ($P_{ANOVA} < 0.0001$).
[b]The perio tip is significantly different from the other two tips ($P_{ANOVA} < 0.0001$).
Standard deviations in parentheses.

correlates well with the depth of the pocket treated. This amount was confirmed by three investigators, who were asked to adjust the ultrasonic scaler to a level of coolant water flow that they felt was ideal for routine clinical use (Harrel et al. 1996). For routine ultrasonic scaling, 20–30 ml/min. provides an adequate flow of water for safe operation of the unit Trenter & Walmsley (2003).

The present study was initiated to evaluate the amount of water coolant produced by the different brands of ultrasonic scaler systems. As discussed above, three of the scaler systems supplied approximately twice as much as the 20–30 ml/min. water coolant (i.e. PM-400, PM-600, Cavitron). One system supplied the advised amount (P-max), with the exception of one out of the four tips. Only the Vector produced <25% of the advised amount. On comparing the mean output levels for the different scaler systems with the manufacturer's specification (Tables 1 and 3), the PM-600, P-max and Cavitron did not reach the amount of water coolant as stated by the manufacturer in their product information. The present data also show that adjusting the water coolant supply to medium setting did not automatically result in a 50% decrease of the maximum amount of water coolant. The P-max and Cavitron units produce approximately 25% of the maximum water coolant supply at medium setting. It is also apparent that the overall variation between units is higher than the variation within each unit because the standard deviation of the mean in Table 3 is larger than the mean standard deviation in Table 4. Therefore, the water supply control system for the various units did not prove to provide a reliable indication for the actual flow of water coolant. In addition, both with the P-max as well as with the Cavitron, there were also tips (perio maintenance and perio, respectively) that gave less water coolant as compared with other tips of the same brand. Consequently, a change of tips during treatment may require adjustment of the water coolant supply.

The present study used for each ultrasonic scaler system one tip of each tip type on the three different units. There may be variation in water coolant supply among tips of the same type. This factor was not addressed in the present study design. Although not directly studied as such, one can deduce from the Lea et al. (2002) study that this may be an issue. These authors assessed the displacement amplitude of five tips at three different power settings and showed considerable variation among these tips. The displacement amplitude is affected by the water flow rate over the tip, which results in a damping effect. The variation observed among tips could therefore be a reflection of differences in water supply.

In summary, the results of the present study have shown:

(1) All units tested, except the Vector and the P-max with the perio maintenance tip, produced more than the advised 20–30 ml/min. coolant at full water supply setting.
(2) The water coolant supply control system did not provide a reliable indication of the amount of water coolant produced by the different units.
(3) Different tips of the same brand sometimes gave different amounts of water coolant when using with the same unit.

In conclusion, in order to provide a safe working environment for ultrasonic scaling, manufacturers should work on the indication of the flow of water so that it is clear for the clinician how much water coolant is supplied. If the water flow is inadequate, there may be discomfort to the patient or potential damage to the tooth. Also, some perio tips (perio maintenance and perio) gave less water coolant as compared with other tips of the same brand. Consequently, a change of tips during treatment may require adjustment of the water coolant supply.

Table 4. Mean SD of the within-fivefold-measurement standard deviations for each tip type per scaler system for the water coolant supply at full and medium settings

Tip type	The mean SD at full water supply setting (ml/min.)	The mean SD at medium water supply setting (ml/min.)
PM-400		
Standard	0.9	1.7
Perio	1.8	3.8
Slim perio	1.7	3.5
Perio maintenance	2.8	2.9
PM-600		
Standard	1.6	2.2
Perio	0.6	0.6
Slim perio	0.4	1.3
Perio maintenance	1.4	0.8
P-max		
Standard	0.6	0.1
Perio	0.7	0.1
Slim perio	0.5	0.2
Perio maintenance	0.3	0.1
Vector*		
Standard	0.2	–
Perio maintenance	0.1	–
Standard†	0.1	–
Perio maintenance†	0.1	–
Cavitron		
Standard	0.3	0.2
Perio	0.5	0.1
Slim perio	1.0	1.0

*The Vector unit only allowed a full water cooling supply setting.
†Water coolant/suspension with the Vector.

Acknowledgements

The authors wish to thank the Dutch representatives of the five ultrasonic scaler systems under investigation for lending the units.

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Clinical Relevance

Scientific rationale for the study: A water coolant is essential during ultrasonic instrumentation in order to reduce increase in temperature within the tooth and the surrounding tissues. Little is known about the actual water coolant supply of units available in the market. The existing literature suggests a minimum supply of 20–30 ml/min.
Principal findings: All units tested, except for the Vector, provided at full water supply setting the suggested 20–30 ml/min. The water coolant supply control system did not provide a reliable indication of the amount of water coolant supplied by the unit. Also, the different tip types did not provide comparable amounts of water coolant.
Practical implications: this information should stimulate manufacturers to clearly indicate to the clinician the flow of water so that it provides a safe working environment for ultrasonic scaling. It is also important for the professional in daily use of the ultrasonic unit. Compared with other tips of the same brand, some ''perio'' tips, which are intended for deep subgingival debridement, gave less water coolant. Therefore, a change of tips during treatment may require an adjustment of the water coolant supply for the operator.