Volume 9 · Issue 2
2014

ADA Professional Product Review®

A Publication of the Council on Scientific Affairs

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In This Issue:

Letter from the Editor – David C. Sarrett, DMD, MS

All good publications do routine evaluations to determine how to best serve their readers, and the ADA Professional Product Review is no exception. Feedback comes to me from many sources—fellow faculty and deans, dental students and others. And, we routinely survey groups of ADA members to get input about topics the newsletter should pursue. Based on that feedback, we are expanding our content to provide a variety of information on dental equipment, materials, occupational safety and health issues and other areas that affect your daily practice.

For this issue, we interviewed Dr. Shannon Mills and Dr. John Tullner for the article, "Surface Disinfectants: What dentists and their staff need to know." Disinfectant products have been around for decades, but you may be surprised to hear what they have to say about contact time and efficacy. In a new feature, Mailbox, we'll be answering some of the many questions that ADA members pose to the ADA's Division of Science, such as "Must I bag all instruments? What if I use them as soon as they have been autoclaved? Can I bag instruments after sterilization? Can I wear a short sleeve lab jacket when it's hot?"

The ADA Laboratory also did two evaluations for this issue—one on dental unit water treatment systems and one on temperature rise in electric handpieces, which can produce burns. And, if you're thinking of buying or updating your electronic health records system, you'll want to read the article by Mike Uretz that looks at things to consider before moving forward.

I'd like to hear from you. What topics would you like to see covered in future issues? Contact me at ppreditor@ada.org.

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ISSN 1930-8736

Disease Transmission Through Dental Unit Water: An Update

Stephen E. Gruninger

For the past 20 years, standard precautions have included a recommendation intended to limit dental unit water microbial contamination. It is inconsistent to ignore dental unit water quality, while strictly adhering to the use of personal protective equipment, immunizations, surface disinfection, sterilization of instruments, biohazard waste handling, avoidance of percutaneous injuries, and appropriate use of disposable supplies.[1] Intuitively, keeping microbial numbers as low as possible is logical. But where is the evidence that disease is transmitted by contaminated dental unit water to patient or provider?

We have some insight to that question in a 2012 case report in *The Lancet*.[2] The report described an elderly woman in Italy who acquired Legionella pneumophila infection after two visits to her dentist and subsequently died. *Legionella pneumophila*, subtype 1, was found in both the patient and in the dentist's high-speed handpiece waterline. Measured microbial numbers in the waterline were 62,000 CFU/mL, more than 120 times higher than the current CDC and ADA recommendation of 500 CFU/mL.[1] Many studies have shown that different species of legionella can be identified in dental unit water, but this was the first documented Legionella pneumophila fatality related to dental unit water.

You might speculate that if *L. pneumophila* can be in dental unit water, then dentists could acquire Legionella pneumophila occupationally. The ADA Health Screening Program (HSP), held at various cities during the ADA's annual convention, began looking at this issue about 10 years ago, ending in 2012. HSP participants' blood was assayed for the presence of *L. pneumophila* antibodies, subgroups 1-6. The results were surprising. *L. pneumophila* antibody prevalence among these dentists ranged from a low of 4.6% at the HSP held in Honolulu to a high of 22% at the HSP held in Philadelphia. The average prevalence over 10 years was about 11%. This is much higher than the current dentist antibody prevalence for the bloodborne pathogens, HBV, HCV and HIV. However, a small control group of non-dentists surveyed at the same time showed approximately the same prevalence as dentists.[3] Although *L. pneumophila* antibody prevalence was high, evidence for occupational exposure was not strong. Further analyses showed that exposure is unrelated to how often dentists monitored the microbial numbers in their dental unit waterlines, or whether or not they reported cleaning their waterlines by one or more methods. However, *L. pneumophila* exposure was strongly correlated with where a dentist lived. Furthermore, *Legionella pneumophila* antibody prevalence did not differ significantly between multiple visits to the same HSP location separated by at least four years. This fact gives additional support to a geographical bias for the observed *L. pneumophila* antibody prevalence among locations across the United States.[4]

So what does this tell us? If we accept that *L. pneumophila* is ubiquitous throughout the environment, then dentists can come into contact with the bacterium like any other non-dentist. The source of exposure could be from a home shower head or water faucet, public drinking fountains, garden hoses or any other source where a fine spray or mist of warm water could be inhaled or otherwise aspirated. Of course, the source could also be from untreated dental unit water.

While *L. pneumophila* in dental unit water may not be a significant source of disease transmission, the Italian case report certainly shows that transmission can occur, especially in elderly and other immunocompromised patients. Furthermore, there are a multitude of microbes, some pathogenic, capable of forming biofilms in dental unit water. Many of these microbes can present an infectious hazard in immunocompromised patients. Good infection control practices demand that dental unit water be as free from infectious contaminants as possible.

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A Laboratory Evaluation of Dental Unit Water Treatment Systems

The U.S. Environmental Protection Agency's (EPA) Safe Drinking Water Act allows a maximum limit of 500 colony forming units per milliliter (CFU/mL) heterotrophic bacteria.[1] However, it is not uncommon for water from dental units to contain as much as 100,000 CFU/mL, greatly exceeding the maximum allowed for potable water.[2-4] The U.S. Centers for Disease Control and Prevention's Guidelines for Infection Control in Dental Health-Care Settings recommend that water exiting the dental unit (treated water) has no more than 500 CFU/mL bacteria, which reflects the EPA's maximum safe level of heterotrophic bacteria in drinking water.[5,6] The American Dental Association's Council on Scientific Affairs' "Statement on Dental Unit Waterlines," updated in 2012, notes that "dental unit waterlines must be maintained regularly to deliver water of an optimal microbiologic quality." Thus, every dental office infection control plan should include a process for maintaining dental unit water quality.[6]

Dental unit waterlines are considered an ideal substrate for biofilms, which thrive in an aqueous environment characterized by frequent periods of stagnation. The small volume of water that passes through tubing with a relatively large surface area (interior tubing diameter is typically 1.5 – 2 mm) creates a large volume-to-surface area ratio, where decreased laminar flow at the tubing wall increases the potential for biofilm formation. If left unmanaged, organisms can proliferate to several hundred times their original concentration. Minerals from tap water deposit onto the tubing wall and become attachment sites for bacteria. Dead bacteria and other organic matter reinforce bacterial growth on the interior tubing wall, forming a dense, protective matrix that hinders biofilm removal. The matrix encourages biofilm maturation and thickening, narrows the tubing channel, restricts water flow, and provides the foundation for rapid microbial re-colonization when only disinfecting methods are used for control.[3]

Disinfecting dental unit waterlines can be challenging because the tubing is not easily accessible. Measures to control build-up of biofilm in the tubing typically focus on the treatment of incoming water, or the introduction of chemical disinfectants via a reservoir bottle before delivery to the patient. Treatment of incoming water from the main municipal supply at the operatory level can be accomplished by water purification, ozone treatment, ultraviolet radiation, and/or filtration methods, which can be expensive, but generally require less frequent maintenance than the intermittent or continuous use of chemical disinfectants, which are relatively inexpensive and seemingly straightforward. While the cost of chemical treatments can be just pennies per use, these products must be delivered according to a set schedule to be effective. Maintenance solutions are placed in the reservoir bottle each time it is filled, followed by the delivery of shock solutions on a weekly or monthly basis, according to the manufacturer's instructions.

While the initial investment for devices that treat incoming water is greater at the outset (Table 1), less expensive chemical disinfectants present more opportunities for human error, such as neglecting to apply a chemical treatment according to schedule. (See Cost Considerations on page 10 for more information about cost.)

The ADA Laboratory staff purchased and evaluated eight dental unit waterline treatment devices and one independent sterilizable water delivery system to determine which products deliver water that meets the EPA standard for potable water. The devices evaluated here do not remove established biofilm, and therefore are intended for use in either brand new installations, or existing dental unit waterlines that have been treated to remove biofilm. These devices treat water before it enters the unit to prevent the introduction of microbes and eventual establishment of biofilm. Routine chemical treatment of the waterlines is not required by the manufacturer when one of these devices is used. We also evaluated one portable dental unit with reservoir bottles and sterilizable tubing (AquaSept Heat Sterilizable Independent Water Delivery System; AquaSept, Hudson, Wis.). In addition to providing information on the efficacy of these products, it is our goal to address practical issues especially since the initial investment in these products may be substantial.

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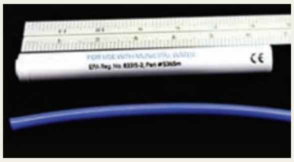
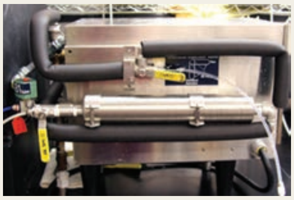
Table 1. Product Features, According to Manufacturer.

Device Name and Manufacturer	Dimensions		Cost Considerations
AquaSept Heat Sterilizable Independent Water Delivery System (Cart) AQUASEPT LLC Hudson, WI 888-539-3907 www.Aquasept.com	Control box: 12" W x 4" H x 3" D Cart: 20" W x 29" H x 10" D (extends to 40" H)		$3,307.00 for cart, one handpiece line (excludes handpiece) and one syringe line§
DentaPure DP365B Dental Unit Water Purification Cartridge MRLB INTERNATIONAL, INC. Fergus Falls, MN 800-972-3543 www.dentapure.com	6 ¾" H x 3/4" D		$249.95
Sterisil Straw for Municipal Water (S365M) STERISIL, INC. Palmer Lake, CO (719) 622-7200 www.sterisil.com	6.5" H x 0.625" D		$150.00
Sterisil Straw for Distilled Water (S365) STERISIL, INC. Palmer Lake, CO (719) 622-7200 www.sterisil.com	6.5" H x 0.625" D		$150.00
DentaPure DP365M Dental Unit Water Purification Cartridge MRLB INTERNATIONAL, INC. Fergus Falls, MN 800-972-3543 www.dentapure.com	6 ¾" H x 2 1/4" D		$249.95
Sterisil Cartridge* STERISIL, INC. Palmer Lake, CO (719) 622-7200 www.sterisil.com	15.5" H x 2.5" D		CV-SK installation kit for $64.00 CV-20 (source water >150 ppm) $160.00 CV-10 (source water 76-150 ppm) $130.00 CV-8 (source water 0-75 ppm) $110.00
Sterisil System STERISIL, INC. Palmer Lake, CO (719) 622-7200 www.sterisil.com	17.5" W x 17" H x 6.5" D		$5,275.00
VistaClear 1000 VISTA RESEARCH GROUP, LLC Ashland, OH (Distributed by Pelton & Crane) 800-659-6560 www.VistaResearchGroup.com	8" W x 10" H x 5" D		VistaClear 1000 has been discontinued and is replaced by multi-chair VistaClear 2000 Model, which retails for $5,999.00 The mode of operation is identical for both models.
Waterclave Water Purifier Model WCJ64-40 WATERCLAVE, LLC Overland Park, KS (913) 312-5860 www.Waterclave.com	18" W x 20" H x 27" D		$10,995.00

The manufacturer's suggested retail price is as of February 2014. Actual price may vary.

§ Price includes cart, one handpiece line and one syringe line. Must purchase additional handpiece and syringe lines to accommodate procedure load between autoclave cycles. Cost of each additional handpiece and syringe line is $695.00.

* The in-line cartridge fits in the junction (floor) box of the dental unit, while the valved cartridge is cabinet-mounted. Appropriate model is based on Total Dissolved Solids (TDS) measurement of your office tap water using a TDS-3 Handheld meter (Sterisil, Inc.). The CV-20 Model was recommended by Sterisil based on TDS level of source water used in this evaluation (~300 ppm). Contact Sterisil to select the right cartridge based on the TDS level of your water.

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Table 2. Product Features

Water Treatment Device	AquaSept Heat Sterilizable Independent Water Delivery System	DentaPure DP365B Purification Cartridge	Sterisil Straw for Distilled Water (S365)	Sterisil Straw for Municipal Water (S365M)	DentaPure DP365M Purification Cartridge	Sterisil Cartridge	Sterisil System	VistaClear	Waterclave Water Purifier
Intended Use	Delivers sterile water for dental procedures	Replaces pick up straw in reservoir bottle; treats bottled source water	Replaces pick up straw in reservoir bottle; treats bottled water <100 ppm TDS	Replaces pick up straw in reservoir bottle; treats municipal tap water >100 ppm TDS	Treats municipal tap water	Treats municipal tap water	Centralized system supplies water for 1-100 dental units	Treats municipal tap water	Supplies sterile water to up to 60 dental units
Mode of Action/Active Ingredient(s)	Reservoir bottles, control heads and tubing are sterilized in a steam autoclave after each patient	Continuously elutes 2-6 ppm iodine into treatment water	Releases antimicrobial (silver) into treatment water	Releases antimicrobial (silver) into treatment water	Continuously elutes 2-6 ppm iodine into treatment water	Removes TDS and releases antimicrobial (silver) into treatment water	Filters particulates, removes ions and organics, and disinfects deionized water with UV irradiation and silver	Physical filtering process and chemical reaction imparting a bacteriostatic effect	Heats water to 188°F - 190°F with pressure
Recommended Operating Air Pressure	60 psi	45 psi	40 psi	40 psi	45 psi	45 psi	75 psi	40 psi	20-90 psi
Recommended Flow Rate	Not specified	Not specified	25 mL/min	25 mL/min	Not specified	25 mL/min	100 mL/min	0.76 L/min 0.20 gallons/min	Not specified
Capacity (volume of water)	N/A	240 L	240 L	240 L	240 L	Varies; depends on TDS in water	1,000 L per year €	567 L	Purifies 15 gallons per hour
Indicator Threshold	N/A	Iodine must be > 0.5 ppm	N/A	N/A	Iodine must be > 0.5 ppm	TDS must remain below 10 ppm	TDS must remain below 10 ppm	N/A	N/A
Recommended Shock Treatment	N/A	Not specified	Built-in shock treatment	Built-in shock treatment	Not specified	Built-in shock treatment	Citrisil by Sterisil, Inc.	VistaTab for initial shock	Sterilex Ultra Liquid by Sterilex Corp.
Power Requirements	None	None	None	None	None	None	Must be installed near an electrical outlet	None	Must install near electrical source having appropriate voltage (208 or 240 V)
Audible/ Visible Alarm	No	No	No	No	No	No	Yes	No	Yes
Ongoing Maintenance Costs	None	No	No	No	No	Multiple cartridges per year	$ 1,052 for filter replacement cost	VistaClean cleaning solution	None
Installation Service Available	Yes, via phone	No	No	No	Yes	Yes	Yes	Yes	Yes
Replacement Parts and Accessories	16 oz. bottles, or adapters various size sterilized water bottles; sterilization cassette	Iodine test strips sold separately	N/A	N/A	Iodine test strips sold separately	N/A	N/A	N/A	Reverse osmosis filters, chemical shock accessories, etc.

€ Systems are available that will treat 3,000, 7,000, and 10,000 liters of water annually. This information was collected from the manufacturers' directions for use, product packaging and information the manufacturer submitted on the ADA Laboratory's technical product table form.

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Dental Unit Water Test System Design

The ADA Laboratory staff developed test equipment to evaluate the DentaPure DP365M, DentaPure DP365B (MRLB International, Inc., Fergus Falls, Minn.); Sterisil Straw S365m for municipal water, Sterisil Straw S365 for distilled water, Sterisil Cartridge, Sterisil System, (Sterisil, Inc., Palmer Lake, Colo.), and VistaClear (Vista Research Group, LLC, Ashland, Ohio) (Table 1). The test equipment was equipped with drive air pressure, pressure gauges and regulators to supply air and water as specified by the manufacturer; flow meters and solenoid valves to control flow rate through dental unit tubing, and reservoir bottles to simulate a delivery system using parts commonly available from dental and industrial supply companies. The Waterclave Water Purifier (Waterclave, LLC, Overland Park, Kan.) received water using a peristaltic pump and flow meter. And as its name states, the AquaSept Heat Sterilizable Independent Water Delivery System is an independent water delivery system.

Water Source

Chemical properties of municipal water vary widely across the United States. The term "total dissolved solids" (TDS) is a measure of mineral, salt, and metal ions that can deposit on dental waterline tubing and ripen conditions for biofilm establishment. Total dissolved solids can range from less than 120 ppm to greater than 350 ppm in surface waters across the United States. While municipal water with TDS near 300 ppm may be unlikely, it is possible.[8] The laboratory-formulated tap water represents more challenging conditions than water with low TDS. Products intended for use with tap water (Sterisil Straw S365m, DentaPure DP365M, Sterisil Cartridge, Sterisil System, VistaClear, AquaSept system, and the Waterclave) were supplied with water formulated in the ADA Laboratory to impart a hardness of 160 – 180 mg/L $CaCO_3$ (classified as "hard" by the U.S. Geological Survey), pH 6.5 - 7.8, and 270 - 300 mg/L total dissolved solids (near the top of the U.S. range for municipal supply water). Treatment devices that are intended for use with deionized water (DentaPure DP365B and Sterisil Straw S365) were supplied with deionized water of pH 5.5 - 6.0.

This evaluation did not use water formulated to represent private well water.

Testing

All dental unit waterline treatment devices were challenged with a mixture of equal volumes of *Pseudomonas aeruginosa and Klebsiella pneumoniae* that had been isolated from fresh water environments. Laboratory staff members inoculated each water source (that is, test and control) at 500 CFU/mL to represent the maximum amount of bacteria supplied by a municipal tap water supply. Products intended for use with deionized water were supplied with the same inoculation prepared in deionized water. Although deionized water is unlikely to contain this level of bacteria, the goal was to challenge each device with the worst case scenario, as well as keep the test parameters consistent between the devices.

System Operation

Systems operated at a flow rate of 25 mL/minute for eight hours a day, five days a week (Table 3). Per the manufacturer, the Sterisil System, which had the greatest filter capacity to accommodate multiple dental operatories, was operated at 100 mL/minute to efficiently move water through the five filter cartridges. (Note: Sterisil also stated that the flow rate sensor is not sensitive at 25 mL/minute.) Manufacturers determine cartridge capacity (liters of water treated) by estimating the volume of water a dentist uses in daily practice over a given period of time. In most cases, this volume is estimated to be equivalent to one year of cartridge life.

Manufacturers use slightly different scenarios to report cartridge capacity such as "240 L or one year," or "567 L or one year." The ADA Laboratory estimated the average flow rate of a dental handpiece to be about 25 mL/minute. For example, a 750 mL reservoir bottle that operated at a flow rate of 25 mL/minute for 1 minute on and then 3 minutes off would be completely used in 2 hours. Hence, a dentist could use up to 4 reservoir bottles per day. However, if the flow rate is slowed to 10 mL/minute and the intermittent cycle changes to 1 minute on followed by 9 minutes off, a single 750 mL reservoir bottle may last an entire day.

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Table 3. Experimental Operating Parameters

Water Treatment Device	Flow Rate (mL/minute)	Filter Capacity* (L)	Operating Cycle	Testing Interval
AquaSept Heat Sterilizable Independent Water Delivery System	25	N/A	5 minutes on / 5 minutes off	After each sterilization cycle¥
DentaPure DP365B Water Purification Cartridge	25	240	1 minute on / 3 minutes off	Daily
Sterisil Straw S365 for Distilled Water	25	240	1 minute on / 3 minutes off	Daily
Sterisil Straw S365M for Municipal Water	25	240	1 minute on / 3 minutes off	Daily
DentaPure DP365M Water Purification Cartridge	25	240	continuous	Daily
Sterisil Cartridge	25	~67§	continuous	Daily
Sterisil System	100	1000	continuous	Daily
VistaClear	25	567	continuous	Daily
Waterclave Water Purifier	25	N/A	continuous	Once weekly for 12 weeks

* According to the manufacturer
§ Calculated with the Cartridge Calculator on www.sterisil.com.
¥ AquaSept's operating instructions state that the bottles and tubing must be autoclaved within 4 hours of use. Three hours after operation, the test bottle, control head, and tubing were placed in a sterilization pouch and sterilized in a pre-vacuum chamber steam sterilizer at 132°C for 15 minutes. Following sterilization and cooling, the test and control bottles were filled with sterile deionized water.

Treatment devices intended for use within reservoir bottles (that is, DentaPure DP365B, Sterisil Straws S365 and S365M) were operated intermittently for 1 minute on followed by 3 minutes off to mimic dental unit water delivery during patient treatment. The investigators operated the DentaPure DP365M, Sterisil Cartridge, Sterisil System, VistaClear and Waterclave continuously. They operated the AquaSept system for 5 minutes on, followed by 5 minutes off, until it had expelled 8 oz. (236 mL) of water.

The investigators tested water samples collected from the treated water supply at regular intervals (Table 3). AquaSept operated for 103 use/sterilization cycles and was tested after each cycle. Investigators tested Waterclave weekly over 12 weeks as its operation is not limited by volume. Treated water samples from the remaining devices were tested daily and the volume of water treated by each device was recorded throughout the evaluation. As indicated in Table 2, the DentaPure DP365B and DentaPure DP365M Purification Cartridges release iodine to disinfect the water. For these products, the investigators routinely measured iodine levels to determine when the device was nearly depleted of iodine and would require cartridge replacement. The Sterisil products, on the other hand, remove TDS and release silver ions that kill bacteria in the water. The TDS level was measured daily, as rising TDS levels signal depletion and the need for cartridge replacement. Each evaluation remained active until the manufacturer-stated maximum amount of water treated was reached, or the TDS or iodine threshold was reached (Table 2).

Ten-fold serial dilutions of 50 mL water samples were plated in triplicate using low-nutrient, Reasoner's 2A (R2A) agar, incubated at room temperature for seven days, and enumerated to determine an average heterotrophic plate count (HPC) as CFU/mL.[7] Investigators deemed the water treatment device was effective as long as HPC of water exiting the treatment device was less than 500 CFU/mL. HPC levels exceeding this maximum limit indicated product failure. The volume of treated water at which another performance indicator (TDS or iodine concentration) reached a threshold level is also reported.

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Table 4. Summary of Results

Water Treatment Device	Average HPC at Capacity		TDS/Iodine at Capacity		Overall Performance	Comment
AquaSept Heat Sterilizable Independent Water Delivery System	<10 CFU/mL	✓	N/A		✓	
DentaPure DP365B Water Purification Cartridge	<10 CFU/mL	✓	>1.5 ppm Iodine	✓	✓	
Sterisil Straw S365 for Distilled Water	<10 CFU/mL	✓	N/A		✓	
Sterisil Straw S365M for Municipal Water	>500 CFU/mL	✗	N/A		✗	Immediate failure with source water of 300 ppm TDS[7]
DentaPure DP365M Water Purification Cartridge	<10 CFU/mL	✓	>1.0 ppm Iodine	✓	✓	
Sterisil Cartridge	<10 CFU/mL	✓	>10 ppm TDS	✗	✓	TDS >10 ppm at 61 L and HPC >500 CFU/mL at 66 L; allowing ~1 week window for replacement
Sterisil System	<10 CFU/mL	✓	4.0 ppm TDS	✓	✓	Effective for >250 mL beyond capacity
VistaClear	>500 CFU/mL	✗	N/A		✗	Source water was pH 6.5-7.8, in accordance with the manufacturer-stated optimal range of 6.5-8.5. Redox reaction, however, most likely absent with source water of pH <8; device most likely more effective with water of pH >8, which is impractical for most municipal water supplies
Waterclave Water Purifier	<10 CFU/mL	✓	N/A		✓	

✗ Fails to meet the performance criterion based on experimental conditions
✓ Passes the performance criterion based on experimental conditions

Results

Evaluation results are summarized in Table 4. Detailed information and other laboratory observations are described for each device following Table 4.

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The **AquaSept Heat Sterilizable Independent Water Delivery System** effectively treated water throughout the evaluation. The water exiting the test handpiece line was consistently less than 10 CFU/mL over 103 use/sterilization cycles, compared to the untreated control line, which averaged 10,000 CFU/mL. AquaSept estimates the life of the sterilizable components to be 100 sterilization cycles. After 103 use/sterilization cycles, the water outlet tubing of the test bottle exhibited tears in the medical-grade silicone tubing rendering it unusable (Figure 1). In clinical use, the AquaSept tubing will most likely require replacement after about 5 months of daily sterilization.

The **DentaPure DP365B Water Purification Cartridge** (replaces straw within reservoir bottle of delivery system) effectively filtered 240 L water and maintained less than 10 CFU/mL throughout the evaluation. The control line HPC averaged 96,000 CFU/mL. Additionally, the iodine level, as measured with iodine test strips, was greater than 1.5 ppm throughout the evaluation, providing adequate disinfecting power.

The **Sterisil Straw S365 for Distilled Water** (replaces straw within reservoir bottle of delivery system) effectively filtered 240 L water and maintained less than 10 CFU/mL throughout the evaluation. The control line HPC averaged 96,000 CFU/mL.

There was inadequate disinfectant capability of the **Sterisil Straw S365M for Municipal Water** (replaces the pick-up straw within reservoir bottle of delivery system) when used with source water having nearly 300 ppm TDS. Heterotrophic plate counts of the treated water rose immediately and averaged 1060 CFU/mL, while the untreated control line averaged 302,000 CFU/mL. Although still within the stated acceptable range, source water with 300 ppm TDS depleted the ionizing resin that directly affects the release of the antimicrobial agent. For example, Sterisil states on their product packaging that the Municipal Straw S365M is intended for use with municipal water having TDS greater than 100 ppm and to "confirm that the water quality is good". However, we discovered that the manufacturer's website terms "good quality water" as water with an upper limit of 300 ppm TDS. This upper limit is not explicitly stated on the packaging, and we observed that the straw for municipal water was not effective in reducing microbial numbers when TDS is at the upper limit. This level of TDS in municipal water might be exceptional, but it does occur, as water chemistry varies

Figure 1

Tear in AquaSept tubing after 103 use/sterilization cycles.
(Note: The manufacturer recommends 100 use/sterilization cycles, corresponding to about 5 months of use.)

widely across the country. Sterisil will test a customer's dental office water and advise on the best device for that dental office's specific water chemistry. A dental office with water of approximately 300 ppm TDS may not be able to take advantage of the convenience of the Municipal Straw. In this case, a dentist may get better results with another device, such as the Sterisil System or Sterisil Cartridge, but they may require plumbing modifications.

The **DentaPure DP365M Water Purification Cartridge** (installed in or near junction box after the water pressure regulator) was highly effective throughout the evaluation with an average HPC less than 10 CFU/mL for treated water and 46,000 CFU/mL for the control line. In addition, despite the stated capacity of 240 L for the water purification cartridge, 645 L water was effectively treated before the filter clogged. Also, DentaPure instructs dentists to monitor available iodine levels as part of the water monitoring regimen and to change the purification cartridge when the iodine level reaches 0.5 ppm. Through the use of iodine test strips, investigators determined that the iodine level never dropped below 1.0 ppm throughout the evaluation, including after filtering a total of 645 L water.

Sterisil states an ideal capacity of 100 L water, or 5 months of clinical use for the **Sterisil Cartridge, CV-20 Filter**. However, under the operating conditions and water hardness levels employed in this evaluation, it was estimated that the cartridge could effectively treat approximately 67 L of water. Experimentally, a

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total of 61 L water was effectively treated before the TDS reached a measurement greater than 10 ppm. After treating 66 L of water, the HPC jumped to greater than 500 CFU/mL and the cartridge emitted a fish-like odor, which signaled total depletion of the deionizing material. The additional 5 L of effectively-treated water corresponds to about one week of use, allowing enough time to replace the cartridge once the TDS measurement rises above 10 ppm signaling the device is no longer effective. Hence, the Sterisil Cartridge and corresponding manufacturer recommendations were deemed very accurate. As such, users may have better results if they change the cartridge when the TDS reading rises above 10 ppm, rather than waiting until a rise in microbial counts or an odor occurs. Following the manufacturer's recommendations and its online Cartridge Calculator will result in the most effective use of this product. Based on the Cartridge Calculator and our laboratory tests, it appears that the lower the TDS of the dental office water, the longer the working life for this device.

The **Sterisil System** maintained effectiveness throughout the duration of the evaluation with HPC less than 10 CFU/mL, while the control line reached 46,000 CFU/mL. The Sterisil System treats municipal water by reducing TDS in order to supply an entire office with water having less than 10 ppm TDS. More specifically, the Stage 3 reverse osmosis filter removes 85% of TDS and is followed by another deionizing filter to reduce the TDS to a negligible level. Finally, the water travels through an ultraviolet (UV) lamp and a silver-releasing Stage 5 cartridge for disinfection. The device monitors the deionizing filter and the reverse osmosis filter performance, which can be easily read on the display.

According to the manufacturer, the product will effectively treat about 1,000 L water. According to their findings, the investigators determined that the device had effectively treated 1,277 L water, the final water sample was measured to have 4 ppm TDS, and all filters appeared to be functioning without the need for replacement. To investigate and confirm continued disinfection, we unplugged the UV lamp to verify that the silver-releasing Stage 5 antimicrobial cartridge was effectively functioning. Similarly, the Stage 5 cartridge was exchanged for a blank cartridge to verify that the UV lamp was still functioning. In both cases, HPC of the water remained below 10 CFU/mL, demonstrating the individual effectiveness of both the Stage 5 cartridge and the UV lamp.

In each of the three laboratory trials, the **VistaClear** system did not maintain counts below 500 CFU/mL for more than 24 hours. Besides mechanical filtration, the VistaClear system contains a resin within the cartridge to facilitate a bacteriostatic reduction-oxidation chemical reaction above pH 8 (personal communication with VistaClear). As the pH of our source tap water ranged from 6.9 - 7.8, it is likely that the reduction-oxidation reaction never occurred, causing the dental unit waterline treatment system to fail. This system does not appear to work with water sources lower than pH 8.0, although the manufacturer states an optimum working range of 6.5-8.5 pH for source water.

During the 12 weeks of operation, water treated by **Waterclave Water Purifier** was less than 10 CFU/mL compared to the untreated control, which averaged 200,000 CFU/mL. As long as the temperature is monitored to ensure the unit is operating between 180-190°C, the unit will likely function properly.

Cost Considerations

The ideal time to consider implementing a dental unit waterline treatment device is when you are building a new office or remodeling. In general, most modern dental units are equipped with a reservoir bottle. Alternatively, older delivery units can be updated to accommodate various forms of water treatment. For example, an existing dental unit can be retrofitted with a reservoir bottle and toggle switch to supply treated water from the main water supply and disinfectant solutions via the reservoir bottle. Such an approach is estimated at about $500.00 per unit. An additional cost to a retrofitted system is the need to shock the existing waterlines with a chemical cleaner until appropriate monitoring procedures indicate the accumulated microbes reach an acceptable level. The approximate annual cost of chemical waterline treatment per dental unit fitted with a 0.7 L reservoir bottle ranges from $87.75 to $277.00, depending on the product. In addition, if a new building or remodel is not in the foreseeable future, the cost to plumb or modify a dental office's current plumbing scheme to accommodate a specific dental unit waterline treatment device should be considered.

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For some of the devices evaluated here, power consumption costs are another consideration. For example, the Waterclave Water Purifier requires 4 kWh electricity per hour. Assuming a cost of $0.056 per kWh, the annual cost to supply power to the Waterclave is about $421.00 ($35.00 per month). Alternatively, the annual cost to supply power to the Sterisil System is about $63.00 ($5.00 per month).

Another point for consideration is that some of the devices, such as the DentaPure DP365B Water Purification Cartridge for bottled water and the Sterisil Straws for both deionized and municipal water sources, offer 90-day and 365-day models. The purchase of a 365-day device will cost about 20% less than purchasing four 90-day devices.

Brief Summary of Results

- The AquaSept Heat Sterilizable Independent Water Delivery System treated water effectively throughout the evaluation. Disinfecting and sterilizing the inoculated bottle did not produce any colonies on agar throughout the evaluation.

- The DentaPure DP365B and the Sterisil Straw S365 filtered 240 L of water effectively maintaining HPCs of less than 10 CFU/mL throughout the evaluation.

- When used with source water having nearly 300 parts per million TDS, the Sterisil Straw S365M provided inadequate disinfectant capability. There was a marked rise in HPCs of the treated water shortly after testing commenced and they averaged 1060 CFU/mL, while the untreated control line averaged 302,000 CFU/mL.

- The DentaPure DP365M Water Purification Cartridge was highly effective throughout the evaluation, with an average HPC of less than 10 CFU/mL, whereas the untreated control line averaged 46,000 CFU/mL.

- The Sterisil System maintained effectiveness throughout the evaluation, averaging less than 10 CFU/mL, whereas the control line averaged 46,000 CFU/mL.

- In each of the three trials, VistaClear did not maintain HPCs below 500 CFU/mL for more than 24 hours.

- During the 12 weeks of operation, water treated by Waterclave Water Purifier had HPCs of less than 10 CFU/mL compared to the untreated control which averaged 200,000 CFU/mL.

The Bottom Line

Dentists and their staff members should monitor microbiological quality of dental unit water regularly. In the ADA Laboratory's evaluation, all of the dental unit waterline treatment devices were effective except for the VistaClear and the Sterisil Straw S365M. Furthermore, it is important to assess the quality of the source water (i.e. hardness, total dissolved solids, pH, etc.) before purchasing and installing a dental unit waterline treatment system.

ADA Laboratory researchers who participated in this evaluation include Stephen E. Gruninger, Kristy L. Vogt, and Rashad Vinh.

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