



Use of chlorine dioxide to disinfect dental unit waterlines

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Summary This paper describes a trial of chlorine dioxide in dental unit waterlines to produce potable quality water. Four treatment protocols using 50 ppm activated chlorine dioxide solution were tested. Each caused a short-term (<48 h) decline in total viable counts but did not provide potable quality water. Inter-mittent use of chloride dioxide is thus not suitable for long-term decontamination of dental unit waterlines. Units should be redesigned to discourage biofilm formation, and more research into practical methods of achieving potable water is required in the interim.

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Introduction

The water quality regulations^{1,2} provide a legal definition of the 'wholesomeness' of potable water, and include a number of chemical and microbiological parameters. Water-borne pathogens such as *Legionella* sp., and *Escherichia coli* should always be absent. As a general guide for potable water, the number of bacterial colony forming units (cfu) is <10 when tested as 37°C, and <100 at 22°C.¹ For over 30 years, water from dental unit waterlines (DUWLs) has been known to be heavily contaminated with micro-organisms. High levels of contamination, including the presence of *Legionella*, have been found in general dental practice and hospital departments in our unpublished studies, and those of others.^{4–11}

Bacterial contamination of DUWLs is thought to follow development of biofilms on their inner

surface. The bacteria may be derived from the water supply, or by retrograde spread during dental treatment.¹¹ The contact time required for chlorine to kill organisms in the biofilm may be hundreds or even thousands of times greater than that required to produce an equivalent kill on organisms suspended in water. This reduction is caused by the biofilm structure which results in reduced penetration, or absorption of disinfectant, and changes in bacterial structure. The aim of this study was to investigate the efficacy of chlorine dioxide in improving the quality of water emerging from DUWLs.

Methods

Disinfectant

At the start of each experiment, 100 L of activated 50 ppm chlorine dioxide solution (Purogene, Vernacare, Bolton, Lancashire, UK) was prepared (according to manufacturer's instructions) in a water tank. Concentrations of chlorine dioxide in the tank were measured at the start and end of each experiment using the manufacturer's assay kit.

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Test units

Seven dental units in a clinic of a dental teaching hospital were tested. The units (Castellini Manta—c.10 years old) were selected because they shared a water supply that could be replaced by that containing the chlorine dioxide, which was pumped into the units at a pressure of 30–46 psi (2–3 bar). Before each experiment, the mains water was disconnected, and all outlets in the dental units and taps were drained. Chlorine dioxide was then pumped into the system, and flushed through for 2 min. Water from two randomly selected outlets was assayed to confirm the chlorine dioxide concentration. After each experiment, the chlorine dioxide tank was disconnected, and the mains water reconnected. Each unit was flushed for several minutes, and the water from two randomly selected outlets was assayed to confirm the absence of residual chlorine dioxide.

Sample collection and analysis

Samples were collected according to recommended procedures¹ and transported at once to the laboratory at 4°C. Water from all the units was tested unless otherwise indicated, together with water from a randomly selected tap from a hand basin in the clinic. Total viable counts (TVCs) at 22 and 37°C were performed using the standard pour-plate method.¹

Experimental interventions

1. Each DUWL was flushed with chlorine dioxide for 2 min, and left to soak for 60 min. Counts were performed 48 h later.
2. Each DUWL was flushed with chlorine dioxide for 4 min, and left to soak for 60 min. Each line was then flushed with the chlorine dioxide solution for 4 min prior to reconnection of the mains water. Counts were performed 48 h later.
3. Each DUWL was flushed with chlorine dioxide for 4 min and left to soak for 75 min, then flushed with chlorine dioxide for 4 min prior to reconnection of the mains water. Counts were performed 48 h later.
4. One DUWL was flushed with chlorine dioxide for 7 h. At 2-hourly intervals, the disinfectant concentration was checked. The unit was then left to soak overnight with chlorine dioxide, before being flushed with mains water. Counts were performed at 48, 96 and 144 h.

Results

The counts are shown in Tables I and II. Baseline TVCs at 22 and 37°C from each unit were in excess of that for potable water, and all were significantly greater than those from the washbasin taps ($P = 0.02$, one-sample Wilcoxon test).

Table I Summary of the use of chlorine dioxide to decrease the total viable counts (TVCs) in dental unit waterlines (DUWLs)

	Median DUWL TVCs (cfu/mL) at 37°C (range)	Median DUWL TVCs (cfu/mL) at 22°C (range)	Tap water TVCs (cfu/mL) at 37°C	Tap water TVCs (cfu/mL) at 22°C
Baseline counts	3.52×10^2 ($0-5 \times 10^4$)	1.0×10^5 ($5 \times 10^4-1.0 \times 10^5$)	0	2.3×10^2
Intervention 1 (48 h)	1×10^5 ($0-10 \times 10^5$)	1.0×10^5 ($1.0 \times 10^5-1.0 \times 10^5$)	1	1×10^5
Intervention 2 (48 h)	10 ($0-4 \times 10^2$)	8×10^2 ($38-1.0 \times 10^5$)	2	6
Intervention 3 (48 h)	1×10^5 ($61-1.0 \times 10^5$)	1×10^5 ($1.0 \times 10^5-1.0 \times 10^5$)	2	2.06×10^3

Table II Prolonged use of chlorine dioxide to decrease the total viable counts (TVCs) in a dental unit

	DUWL TVCs (cfu/mL) at 37°C	DUWL TVCs (cfu/mL) at 22°C	Tap water TVCs (cfu/mL) at 37°C	Tap water TVCs (cfu/mL) at 22°C
Intervention 4 (48 h)	1	9.68×10^2	1	4.69×10^2
Post-intervention 4 (96 h)	5.8×10^2	1×10^5	4	1.60×10^2
Post-intervention 4 (144 h)	6.0×10^2	1×10^5	1	66

DUWL, dental unit waterlines.

Interventions 1 and 3 showed no reduction over the baseline counts, while Intervention 2 showed a reduction at both temperatures, and interestingly enough a reduction in the 22°C tap water sample. Intervention 4 gave a more acceptable result in the 48 h sample; however, after 96 h, counts had risen to baseline levels (Table II).

Discussion

This work highlights the difficulties associated with the decontamination of intricate medical devices which are heavily biofouled. Whilst chlorine dioxide has been successfully used for the control of *Legionella* sp. in hospital water supplies,^{12–14} the unique engineering conditions associated with dental units, conspire to make complete disinfection a difficult task. The flow of water through the extensive network of narrow bore plastic tubing creates a laminar flow system encouraging biofilm build-up. The high surface area to volume ratio of narrow bore tubing will further encourage biofilms. Free chlorine and chlorine dioxide may not penetrate into all areas of a biofilm.¹⁵

There have been several attempts to address the problem of microbial contamination of DUWLs, including autoclaving of handpieces, handpiece replacement between patients, flushing of the unit prior to use, 'anti-contamination' devices to prevent retrograde aspiration of oral secretions into the water supply line, connection to a separate water supply (e.g. connection to bottles of distilled water), chemical disinfection of waterlines, ultra-violet radiation disinfection and the use of in-line water filters.^{6,16–18} The most commonly used procedure of flushing the handpiece with water prior to use may lower bacterial counts in the outflow^{9,19} but high levels of microbial contamination can still persist.^{9,19,20} Nevertheless, the British Dental Association (BDA)²¹ and Centers for Disease Control (CDC)²² recommend that all waterlines should be allowed to run and discharge water for several minutes at the beginning of each day, and for a shorter interval between patient appointments. Unfortunately, flushing merely eliminates suspended (planktonic) organisms with little effect on the residual biofilm. We suspect that this is due mainly to the complex design of dental chair equipment, resulting in the stagnation of water within the equipment lines and build-up of biofilm.

There is little epidemiological evidence that microbial contamination of DUWLs constitutes a significant risk of infection to either patients or their

dentists, although this may be due to difficulties in collecting the appropriate data. Among immunocompromised individuals, however, there is undoubtedly a potential for infection.²³ Therefore, every effort should be made to ensure that water of potable quality emerges from dental unit handpieces. Chlorine dioxide appears to have limited benefit in this situation, and long-term solution will require redesign of the dental unit system to eliminate stagnation of water and reduce the formation of biofilms.

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