Waterborne Biofilms and Dentistry: The Changing Face of Infection Control

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Abstract

Interest in and concern about the biofilms that occur in dental equipment and waterlines have been increasing in recent years. Dental unit waterlines are ideal environments for the growth of microorganisms entering dental units from the municipal water supply. This article describes the conditions in waterline tubing that favour development of biofilms and discusses the level of risk that such microbial growth poses for both dental professionals and their patients. It is stressed that very few cases of infection have been linked directly to contamination in dental unit waterlines. Finally, potential solutions for minimizing risks are presented and discussed.

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Dental handpieces (specifically high-speed drills), air/water syringes, and ultrasonic scalers are connected to dental units by a network of small-bore plastic tubing through which water and air are propelled to activate or cool down the instruments. Hydrodynamics shows that the water column inside a small lumen moves in the centre of the tubing, leaving a thin layer of liquid virtually undisturbed along the walls. Coupled with recurrent long-term water stagnation (over nights, weekends and holidays) at warm temperatures, this physical state creates propitious conditions for water microflora to establish tenacious adherent communities. Some dental unit waterlines that have been in use for many years are coated with a biofilm that is visible to the naked eye, clogs the small-bore tubing and gives the water a foul odour.

Most dental units are connected directly to municipal distribution systems for potable water; even if chlorinated, this water hosts a diverse microflora of bacteria, yeasts, fungi, viruses, protozoa, unicellular algae and nematodes. Free-floating (planktonic) microorganisms are vulnerable to environmental stress, biocide activity and microscopic predators. However, once inside the dental unit, such microorganisms can settle on the inner tubing surface, initiating a chain of events that results in colonization, microcolony formation and, eventually, biofilm development.

Water with less than 1 fecal coliform/100 mL and less than 500 colony-forming units (CFU)/mL is considered potable. Because the detection of coliform bacteria is impaired by high bacterial loads, it has been argued that total bacterial counts higher than 500 CFU/mL might conceal the presence of some pathogens in a sample. Water delivered through dental handpieces does not usually meet potable water standards because it has much higher microbial counts, sometimes as high as 200,000 CFU/mL. One of the reasons for these high concentrations may be the high area-to-volume ratio of small-bore waterlines (6:1), which offers plenty of surface area on which the microorganisms can settle and a relatively small volume of liquid into which daughter cells can be shed.

Selection and Amplification of Pathogens by Waterborne Biofilms

Most of the bacteria detected in tap water are considered neither human pathogens nor opportunistic pathogens. The opportunistic pathogens may account for more than 30% of the total bacterial population in water distribution systems, but the human opportunistic pathogens found in water supplies (including *Pseudomonas aeruginosa*, *Legionella pneumophila*, nontuberculous mycobacteria and *Acanthamoeba* spp.) are found at very low concentrations. The presence of biofilms inside waterlines tends to be associated with higher baseline levels of the above opportunistic pathogens in the water exiting the waterline. *P. aeruginosa* may be isolated from 15% to 24% of samples of dental unit water at concentrations of up to 2 x 10^5 CFU/mL and may account for 75% to 100% of the cultivated flora in these units. *Legionella* spp. are regularly isolated from dental unit waterlines, where they can reach concentrations of 10^2 to 10^4 CFU/mL. The occurrence of these organisms could be due to the presence in waterlines of free-living amoebae, which are considered important hosts for *L. pneumophila* and other pathogenic bacteria, including

P. aeruginosa. Nontuberculous mycobacteria (including *Mycobacterium gordonae* and *Mycobacterium chelonae*) reach concentrations in dental unit water that are 400 times greater than those in tap water. Thus, biofilms may be an important site for the growth of aquatic mycobacteria.

Once a pathogen such as *P. aeruginosa* reaches the wall of the tubing, a colonization process begins whereby the bacteria grow and multiply in the biofilm. The colonization process is virtually impossible in the liquid phase. The formation of microcolonies increases the level of *P. aeruginosa* in the water that bathes the biofilm. However, the risk of infection lies in the bacteria that are shed from the biofilm and leave the waterline.

Risk of Infection from Dental Unit Waterlines

Dental unit water systems host many microorganisms, some of which are known human pathogens. However, few substantiated reports of disease linked to dental unit water can be found in the literature. A 1987 report published in the *British Dental Journal* is the reference on which most publications in this field rely. The paper presented 2 case reports in which medically compromised patients had been infected with *P. aeruginosa* originating from dental unit water supplies. In 1994, a dentist's death from pneumonic legionellosis was attributed to the inhalation of the pathogen during use of handpieces. Although it could not be proven definitively that the dental unit water was the culprit, suspicion ran high. Isolated cases of amoebic eye infection, brain abscess and gastrointestinal disorders have been reported, but strong evidence is lacking. Nonetheless, a lack of evidence does not constitute absence of evidence.

There are at least 4 ways in which waterborne microorganisms might cause infection in a patient undergoing dental work: hematogenous spread during surgical procedures, local mucosal (oral or conjunctival) contact, ingestion and inhalation. Hematogenous dissemination is considered theoretical but possible. Dental treatment can lead to transient bacteremia caused by oral streptococci. However, involvement of oral tissue is more likely, possibly through local infection after tooth extraction or periodontal intervention. Eye infection with *Acanthamoeba* spp. after accidental splatter has been reported. Gastrointestinal disorders caused by waterborne microorganisms, although possible, would be difficult to link to a dental unit.

The evidence suggests that dental personnel are continually exposed to waterborne microorganisms. For example, the prevalence of antibodies to *L. pneumophila* was significantly higher among dental personnel than in a control population (34% and 5% respectively), and the nasal flora of dentists may have a higher proportion of waterborne *Pseudomonas* spp. While there do not seem to have been any studies examining the presence of waterborne bacteria in the air of a dental clinic, some findings suggest that they may be present and viable, although not cultivable. There is thus a theoretical risk of infection associated with the microbial organisms found in dental unit waterlines.

Prevention of Negligible Risks

The chances of a patient experiencing an infection that can be linked to water used during a dental treatment are hard to estimate. The infective dose required to achieve infection in 50% of individuals exposed to a dental unit waterline pathogen can be as high as 1×10^{10} cells. The number of cells required to achieve an infective dose is unlikely to occur often, and the risk of infection is therefore exceedingly small.

Public awareness of microbial threats is now greater than in previous decades, thanks to better education and public television documentaries. The fear of microscopic "bugs" is fed by an industry that tries to introduce microbe-killing compounds into every aspect of our lives: the manufacturers of antimicrobial toys, socks and T-shirts, laundry and dishwashing soaps, sanitizing hand gels and so on. In its efforts to control infection, the dental profession spends billions of dollars on the purchase of gloves, masks, disinfectants, disposable devices and sterilizers and on the replacement of dental handpieces damaged by repeated sterilization. The contamination of dental unit waterlines is an issue that now concerns the dental profession on a number of levels. Researchers have identified and studied the problem and have published their results. Official organizations have reacted by issuing press releases and recommendations. In the meantime, dental companies have joined the fray, ensuring a proliferation of products designed to mitigate a problem that some feel is imaginary or artificially inflated.

Potential Solutions

The Canadian Dental Association has set guidelines for dental unit waterlines (Table 1). These recommendations can be easily adopted by dental personnel.

A growing number of dentists mistakenly believe that the use of distilled or sterile water in the dental unit minimizes the problem. It is important to remember that the tubing is probably already colonized by biofilms, so the distilled or sterile water will itself become contaminated as it passes through the lines. The use of distilled or sterile water is thus unjustified and probably useless, except in a self-contained system that is strictly maintained.

A number of products are available to help control the problem.

- Filters: When installed near the handpieces, filters offer a physical barrier to the passage of microorganisms. If used according to instructions, they perform well. Filters designed to purify water *before* it enters the dental unit can also be used. However, if the tubing is already colonized by biofilms, these filters will have only a minor influence on microbial output. Certain filters are impregnated with iodine, a strong antibacterial agent, which is gradually released into the water during the use of the handpieces. This measure will reduce bacterial counts. However, some patients may have an allergic reaction to iodine.
- Autoclavable systems: These independent water systems (in which each component can be sterilized) deliver sterile water if cleaned and used correctly. A disadvantage is the need for an autoclave with sufficient capacity to hold the system.

Table 1 CDA Guidelines On Dental Unit Waterline Maintenance

Dentists are encouraged to take steps to reduce any potential risk of dental unit waterline microorganisms causing infection through the following waterline maintenance procedures:

- Avoid heating water for the dental unit.
- At the beginning of each clinic day, purge all lines by removing handpieces, air/water syringe tips and ultrasonic tips and flushing thoroughly with water. The decrease in bacterial counts associated with such purging has been confirmed in two Canadian studies.[1,2] According to Barbeau et al[1]., 1996, and Whitehouse et al[2]., 1991, approximately a 5-8 minute purge is required to reduce bacterial counts to potable water standards (<500 cfu/ml).
- Run high speed handpieces for 20-30 seconds after each patient, to purge all air and water.
- Use sterile water or sterile saline when flushing open vascular sites and/or cutting bone during invasive surgical procedures.
- Follow manufacturer's instructions for daily and weekly maintenance if using bottled water or other special delivery system.

1 Barbeau, J., Tanguay, R., Faucher, E. et al. Multiparametric analysis of waterline contamination in Dental Units. *Appl Envrion Microbiol.* 62:3954-3959, 1996

2 Whitehouse R.L.S., Peters, E., Lizotte, J. et al. Influence of biofilms on microbial contamination in dental unit water. *J Dent.* 19:290-295, 1991

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- Chemical products (disinfectants): From a strictly microbiological point of view, most disinfectants reduce bacterial counts to an acceptable level, yielding the equivalent of potable water; however, they do not generate sterile water. Because some disinfectants are corrosive (e.g. bleach, which should never be used undiluted), the manufacturer of the dental unit should be consulted before any chemicals are introduced into the water system. In general, disinfectants are allowed to remain in the lines overnight, and are then flushed from the lines the next morning. If bleach is used, it should be left in the tubing for a short time only, and the system should then be rinsed with copious amounts of water and left to dry overnight.

Although the use of these products is not covered by any official recommendations, a dental practitioner may decide to adopt one of them. However, some of these products have not been independently tested, and their long-term effects on microbial communities are still unknown.

The following recommendations should help you, the dental professional, to select the best option for your situation. Do not make a rush decision on the basis of media reports, information from patients or pressure from salespersons — there is no obligation to buy any product. Take the time to evaluate your needs and your budget. Ask questions and ensure that the answers supply the information you require. Find out whether independent research has been done on the product. In the end, patient safety should be the main consideration; annual costs are also a factor, as is the time needed to change filters, fill bottles and autoclave equipment.

Water Testing

Pretesting dental unit water is virtually useless, as it is unlikely that water from any untreated dental unit will be free of microorganisms. However, after initiation of a treatment program, testing can be used to determine whether water quality is acceptable and whether the solution that has been adopted is worthwhile.

Conclusion

Improving the quality of dental unit water will have benefits not only in the present but also in the future. Most immunocompetent patients treated in the typical dental office are not at risk. However, the infective dose needed to establish infection in immunosuppressed, elderly and chronically ill patients is generally lower than for healthy children and adults. Therefore, any solution to this problem must be satisfactory for all patients, regardless of their health status. ◆

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