REVIEW ARTICLE

IMPORTANCE OF DECONTAMINATION IN DENTAL UNIT WATER LINES: A REVIEW

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ABSTRACT

Dentistry is unique because it is the only health care discipline that routinely uses water in the treatment of patients. Water goes into the dental units and then onto and through high speed hand pieces, three way (air-water) syringes, and power scalers, employing a system of very thin plastic tubing. The water then enters the patient's oral cavity and can become aerosolized or become a part of spatter, which could place practitioners and patients at a risk of occupational exposure. The goal of infection control in dentistry is to reduce or eliminate exposure of patients and dental team members to micro-organisms.

Dental unit water lines (DUWL) contain relatively small amounts of water much of which is in continuous contact with the inner surfaces of the tubing. Water entering dental units usually contains few microorganisms, however water coming out of the unit is often highly contaminated as the water is not in constant motion with the extended dormant periods causing DUWL to readily become colonized by a variety of micro-organisms. Most water borne organisms are of low pathogenicity or are opportunistic pathogens causing harmful infection only under special conditions or among immuno-compromised individuals. Microorganisms of greatest concern are the species of Pseudomonas, Legionella and Mycobacterium.

Biofilms form quickly and serve as a continuous source of contamination for DUWL water. Flushing of lines will temporarily reduce microbial emissions, but do not remove biofilm. Use of sterile water also doesn't reduce the level of microorganisms released. The only remedy is to effectively remove the biofilms through the routine use of certain chemicals which would eventually help retard biofilm development.

This review article highlights the relevance of decontamination of DUWS and importance of asepsis followed at each of the clove clinics, keeping in mind practitioners and patients health as our top priority.

Keywords: *dental unit water lines, biofilm, decontamination, Legionella, endotoxins*

INTRODUCTION

Dental unit water systems (DUWS) are used to irrigate the oral cavity during dental treatment. In dentistry, the dental chair unit (DCU) is the most essential item of equipment necessary for the practice of dentistry. Each DCU is equipped with an elaborate loom of interconnected narrowbore (i.e. mostly 2-3 mm internal diameter) flexible plastic tubing called dental unit waterlines (DUWLs) that supply water to all of the DCU- supplied instruments, cup-filler and bowl-rinse water outlets . In a typical DCU, the DUWL network can consist of many meters of tubing. Due to the texture and composition of the plastic tubing, microbial biofilms form readily, resulting in DCU output water that is frequently heavily contaminated with microorganisms of varied categories[6]. The purpose of this article is to succinctly review the problem of biofilm contamination in DUWLs, its causes, the approaches that have been used to control the problem, and their strengths and limitations, and to highlight recent progress in DCU design changes and advances in automated biofilm control systems that can provide long-term solutions to the problem.

DISCUSSION

Creation of biofilm in DUWL Biofilms are microbial communities that adhere to solid surfaces where ever there is sufficient moisture (including plants and animal tissues). Most plastic dental tubing have an inside diameter of 1/16th to 1/8 inch and thus have a very large surface area to volume ratio. The hydrophobic surfaces of water line promote the attachment and colonization of biofilm organisms. At peak usage, the flow rate in a dental hand piece can be between 2 to 10 ml per minute. In contrast, most household water pipe lines are made of ½ inch diameter with flow rates of about 15lts per minute; this is approximately 1000 times greater flow then through dental unit water lines. The water in dental lines is also completely stagnant on weekends and evenings. Thus the layered structure of

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biofilms (limited diffusion) combined with the low flow conditions renders these microbial colonies intrinsically resistant to many biocides and cleansing schemes. Active biofilm then becomes the primary reservoir for continued contamination of the system. Biofilms also provide an environment conductive to the proliferation of a wide variety of other microscopic life, including fungi, algae, protozoa and nematodes[7].

Causes of biofilm formation Narrow bore water lines: The flow of water in narrow-bore DUWLs is laminar. The velocity of flow varies from virtually zero at the lumen walls of DUWLs to a maximum along the center line of the waterline lumen. Thus a thin immobile layer of fluid, called the hydrodynamic boundary layer, exists at the interface of the lumen wall and the moving water within the DUWL8. Following connection to a water supply, a conditioning pellicle or a biofilm is formed. Consequently, DUWL biofilm functions as a reservoir for continuous contamination of DUWL output water as it forms a natural habitat for the microorganisms to grow. Microbial contamination of DUWL output water is a universal phenomenon in standard DCUs and all untreated DUWLs in DCUs will harbor resident biofilms and yield contaminated output water. Biofilms can form within the DUWLs of new DCUs within several hours of connection to a mains supply[9].

Water stagnation: Water stagnation in DUWLs, when DCUs are not in use, further encourages the growth of biofilm. Most DCUs are probably not used for more than 12 hours per day, five days per week and thus water stagnation is a significant contributory factor to DUWL output water contamination[10]. Heating of the DCU output water Individual DCU models may come equipped with a water heating unit which provides DUWL output water at a temperature that is comfortable for the patient. Heating DUWL output water to >20°C may selectively encourage the growth of particular bacterial species. Recent studies in the authors' laboratory indicate that the temperature of DUWL water in DCUs can rise significantly following several hours of continuous DCU use, probably due to heat transfer from both the dental clinic e environment and from internal DCU components (M. Boyle and D. Coleman, unpublished observations) which contributes to the formation of biofilm[11].

ANTI-RETRACTION VALVE FAILURE

Integrated anti retraction devices (usually valves) that prevent back flow of fluids from the oral cavity into DUWLs during instrument use. However, a number of studies have shown that oral fluids can be retracted into DUWLs during dental instrument use[12]. Furthermore, the detection of blood, oral bacteria and other microorganisms of human origin in DUWL output water has provided indirect evidence for anti-retraction valve failure[13]. Contaminated reservoir bottles Some DCUs use independent water reservoir bottles to provide water to the DUWLs. These bottles are manually filled with water (mains water, distilled water or sterile water) but can easily become contaminated with skin bacteria such as Staphylococcus epidermidis and S. aureus, the latter a common human pathogen, thus introducing additional human microorganisms into DUWLs[14].

DCU WATER SUPPLY

The quality of water supplied to DCUs from reservoir bottles is influenced by several factors, including the quality of the water itself and the presence of biofilms on the internal surfaces of reservoir bottles15. Furthermore, if reservoir bottles are supplied with distilled water, the microbiological quality will be influenced by the condition and cleanliness of the distilled water storage containers, on how long and under what conditions the water is stored prior to use and on the condition and cleanliness of the distillation unit. Heavily contaminated DUWL output water, containing up to 108 bacteria per ml, is not consistent with infection prevention and control best practice[16].

DISEASES CAUSED BY THE MICROORGANISMS PRESENT IN DUWL

Majority of microbial species found in DUWL output water comprise of gramnegative aerobic heterotrophic environmental species of low pathogenicity[17]. The environmental bacteria are of concern as they predominantly initiate biofilm formation and often are responsible for the excreted protective polymeric matrix which affords protection to more pathogenic species. They may also produce enzymes (e.g. catalase) or other substances that reduce the efficacy of disinfectants and over time, these populations may become selectively enriched18. Known human bacterial pathogens recovered from DUWL output water include Pseudomonas species, particularly Pseudomonas aeruginosa, Legionella species, particularly L. pneumophila and nontuberculosis Mycobacterium species[19, 20]

Legionella spp. (L. pneumophila and approximately 40 other spp.) are frequently present in man-made water distribution systems and can cause Legionnaire's disease (pneumonia resulting from inhalation) or Pontiac fever (a flu-like illness without pneumonia). Legionellae are intracellular parasites of a range of amoebae and protozoa that live in soil and water, often in conjunction with biofilms. Many reports have identified Legionella bacteria in DUWL output water[21]. A number of studies have indicated that occupational exposure of dental healthcare staff to aerosols of waterborne bacteria generated by dental instruments attached to DUWLs may lead to a higher prevalence of antibodies to Legionella. Fotos et al. reported that 23% of dental healthcare staff that worked in practice for more than two years was serum anti-L. Positive. In contrast, only 8% of subjects tested who had no clinical contact were anti-L. pneumophilia IgG antibodypositive[22]. Endotoxins: DUWL output water can be a major source of bacterial endotoxins (lipopolysaccharide (LPS)) released from the cell walls of Gram-negative bacteria). Levels up to 100,000 endotoxin units (EU) per milliliter have been reported in DUWL output water[15]. Inhaled endotoxin can exacerbate airflow obstruction and airway inflammation in individuals with allergic asthma and asthma severity is directly correlated with concentration of endotoxin23. In addition, data from a single, large, practice-based cross-sectional study reported a temporal association between occupational exposure to contaminated DUWL output water with aerobic bacterial counts of >200 colony-forming units per milliliter (cfu/ml) at 37ºC and development of asthma in a subgroup of dentists in whom asthma arose following the commencement of dental training[24].

In an attempt to address this issue, the American Dental Association (ADA) Council on Scientific Affairs set a goal for the year 2000 that water used for dental treatment should contain d"200 cfu/ml of aerobic heterotrophic bacteria25. Many experts in the field have endorsed this recommendation, but in fact it has not been widely achieved[1]5.

METHODS OF REDUCING MICROBIAL CONTAMINATION

Non chemical approaches (Table I): Flushing of the pipelines, Use of distilled water, Fitting microbial filters

Chemical approaches (Table II): DUWL biofilm treating agent: The use of chemical agents to control biofilm formation in DUWLs has potential for adverse effects on DCU components and instruments, on patient oral tissues and on dental restorative materials. This is particularly pertinent for residual treatment agents that are present in DUWL output water and which enter the patient's oral cavity and may also be swallowed or inhaled from aerosols generated by dental instruments. A study of DUWL disinfection using an alkaline hydrogen peroxide agent for periodic use reported obstruction of DUWLs by disinfectant deposits in three out of six DCUs tested. The problem became evident after four weeks of once-weekly treatment in the three DCUs, and in one of these, after 14 weeks the DUWL supplying the air/ water syringe DUWL became completely blocked[26].

PRETREATMENT OF DCU SUPPLY WATER

Some consideration should be given to pretreating DCU supply water for DCUs, particularly DCUs supplied with tank water such as in dental hospitals and dental clinics equipped with large numbers of DCUs 11.Commercially available filters can be utilized for dealing with specific problematic aspects of DCU supply water quality including sediment filters (remove suspended solid contaminants), activated carbon filters (remove organic contaminants), water softening units for use in hard water areas and Kinetic Degradation Fluxion (KDF) filters that remove some dissolved metals. Sediment filters should be fitted in-line with the incoming water supply before any other water filter or unit.

Sediment filters extend the working life of other types of filter by removing coarse contaminants and sediment particles that otherwise could reduce the efficacy of filters fitted downstream such as carbon filters and water softeners[6].

FACTORS CONTRIBUTING TO INADEQUATE

DUWL DISINFECTION

In 2007, a study by O'Donnell et al. investigated the long-term (21-months) effectiveness of the hydrogen peroxide and silver ion-containing DUWL disinfectant Planosil to maintain the quality of DUWL output water below the ADA recommended standard of d"200 cfu/ ml of aerobic heterotrophic bacteria using once weekly disinfection in 10 Planmeca Prostyle

Compact DCUs. In the first 9-month part of the study a high incidence (9.3%) of intermittent DUWL disinfection failure occurred. On investigation, several contributory factors were identified the first of which was low compressed air pressure that resulted in inadequate distribution of disinfectant throughout the DUWL network.

Other factors identified included operator failure to include one of the three-in-one air/water syringes in the disinfection cycle and corrosion of DCU components by the DUWL disinfectant[18].

Having identified these problems, corrective measures were put in place to prevent reoccurrence of intermittent DUWL disinfection failure due to these causes, including DCU component changes and ensuring strict compliance with the DUWL cleaning protocol. In the second part of the study a highly significantly increased prevalence of strongly catalase-positive Novosphingobium and Sphingomonas bacterial species ($P < 0.0001$) occurred in 4/10 DCUs, Catalase is an enzyme commonly produced by bacteria where it functions to catalyze the decomposition of hydrogen peroxide. The increased prevalence of these strongly catalase positive environmental bacterial species in DUWL output water following extended use of Planosil, one of the active ingredients of which is hydrogen peroxide, indicated selective pressure for retention of these species, which would have a survival advantage in DUWLs exposed regularly to hydrogen peroxide[10].

Table 1: Non Chemical Approaches

S. no	Method	Comment	References
1	Anti-retraction valves integrated into DCU-supplied instruments	They are used to prevent the back flow of the oral fluids into the tubings of the dental chair. However they fail frequently resulting in retraction of oral fluids into DUWLs. Flushing DUWL after each patient use is recommended.	[27]
2	Use of microbial filters at the ends of DUWLs near the instrument attachment sites or on DCU supply water lines	Can be effective in reducing microbial density in DUWL output water but has no effect on biofilm resident in DUWLs. They are prone to clogging and have to be replaced regularly. Some of the filters remove bacterial endotoxin from water	[28]
3	Draining or drying of DUWLs	Flushing of the DUWL for a time period of 30 seconds at the end of the day. It has little effect on improving DUWL output water quality as biofilm resident in DUWLs can resist desiccation.	[29]
4	Use of distilled water, deionized water, sterile water or pasteurized DUWL supply water provided from reservoir bottles	The effect depends on a lot of factors like the source of the distilled water, storage method, containers used, coolant water bottle units of the dental chair. In addition to that it has little effect on improving DUWL output water quality if biofilm is already resident in duels. Some of the new DCUs may come with biofilms formed during factory quality testing	[30]
5	Flushing of DUWLs with fresh water	Results in reducing the microbial density in DUWL output water, but not to acceptable levels. Has no effect on DUWL biofilm	[17]

Table 2: Chemical Agents Used

S.no	Materials	Comments	References
1	Chlorhexidine gluconate, Chlorhexidine gluconate and alcohol	Variable removal of DUWL biofilm. Effective at minimizing contamination of DUWL output water.	[31]
2	Activated chlorine dioxide, chlorine dioxide and sodium phosphate mouth rinse	Effective at minimizing contamination of DUWL output water	[31]
3	Glutaraldehyde Glutaraldehyde and quarternary ammonium salts	Variable efficacy at eliminating biofilm And reducing microbial density in DUWL output water. Highly toxic substance	[32]
4	Sodium hypochlorite	Variable efficacy at eliminating biofilm and reducing microbial density in DUWL output water	[33]
5	Sodium hypochlorite and citric acid	Effective at minimizing microbial density in DUWL output water	[33]
6	Hydrogen peroxide and silver alkaline peroxide	Effective at eliminating biofilm and minimizing microbial density in DUWL output water. Reports of clogging of DUWLs following repeated use of alkaline peroxide	[33]
7	Electro-chemically Activated solutions	Very effective at eliminating biofilm and minimizing microbial density in DUWL output water. pH range of products 2.0-7.4. pH neutral products are best as they do not show adverse effects on DCU components. Ecasol shown to lack cytotoxicity for human keratinocytes and reconstituted human oral epithelium.	[35]
8	Povidone-iodine	Effective at minimizing microbial density In DUWL output water	[36]
9	Sodium fluoride	Effective at minimizing microbial density In DUWL output water but only partial elimination of Biofilm	[30]
10	Sodium perborate	Variable efficacy at minimizing microbial Density in DUWL output water	[37]
11	Ethylenediaminetetraacetic acid	Effective at minimizing microbial density in DUWL output water and biofilm removal	[38]
12	Citric acid and sodiumptoluolsulponechloramide and Sodium ethylenediamine tetra acetic acid	Two-phase treatment product. Effective at minimizing microbial density in DUWL output water	[31]

DCUS WITH INTEGRATED DUWL DISINFECTION UNITS

Waterline Cleaning System: The WCS is a semi-automated DUWL cleaning system used in DCUs supplied with mains water in which all DUWLs are supplied with disinfectant from a central reservoir when the DUWL disinfection function is activated. Following overnight disinfection, DUWLs are automatically purged of disinfectant and flushed extensively with fresh mains water. During the disinfection cycle, all other DCU functions are inactivated until the disinfection cycle is completed[18].

The Water Management System: The WMS is an integrated DUWL cleaning system that requires minimal effort on the part of the user, is more advanced and automated than the WCS[39].

CONCLUSION

Microbial contamination in the dental unit water lines has been a problem faced in every clinic since the past 50 years and still is a problem. The current ADA recommendation quotes that the output water supply from the dental chair units at a consistent level should be d”500 cfu/ml of aerobic heterotrophic bacteria or better because of the increasing number of immunocompromised and other vulnerable patients seeking dental treatment. However, attaining this level of output water quality from DUWLs consistently has been difficult to achieve in practice for several reasons including the absence of specific quality standards and because DCU manufacturers have been slow to tackle the problem by redesigning DCUs. In recent years there has been constructive progress in this area with the development of validated, integrated and automated DUWL disinfection systems by some DCU manufacturers for use with specified chemical DUWL treatment agents that are consistently effective in the long term and compatible with their DCUs.

DCUs in clinics may also be supplied directly by mains water or indirectly by mains water from water storage tanks. Alternatively DCUs may be supplied by water from reservoir bottles. Pretreatment of supply water using a variety of filters customized to suit the water supply can be used to provide

DCU SUPPLY WATER OF CONSISTENT QUALITY.

Water supplied to DUWLs should not be heated to discourage the growth of more pathogenic microorganisms such as L. pneumophilia which grow preferentially at higher temperatures.

Most recently, the development of fully automated, centralized biofilm control systems for simultaneously controlling DUWL biofilm in many DCUs that can provide DUWL output water of consistently better quality than potable water in the longterm has provided a robust solution to the problem of DUWL biofilm for dental hospitals and large clinics equipped with many DCU. Finally as it has been stated by the studies and researches mentioned above it is very clear that it is the duty of dental staff to reduce the contamination in every possible way and we at Clove consider this as a top priority and follow a regular asepsis protocol, keeping patient and practitioners health as our prime concern.

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