Review Article

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A REVIEW OF DENTAL UNIT WATERLINES ASSOCIATED RISKS IN DENTISTRY

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ABSTRACT:

Dentist is among those professionals groups who are potentially exposed to harmful micro-organisms on daily basis. There are various routes by which micro-organisms spread in dental operatory i.e. through blood born route, direct contact, salivary route, infected equipments and droplet infection. In dentistry, water is used as coolant, as an irrigant and for rinsing. This water is supplied through DUWLs which are susceptible to biofilm formation and micro-organisms proliferation. If the same contaminated water is used for dental procedures, the aerosol produced can be a source of infection to both the patient as well as dental team. The concern related to DUWLs cross-infection has increased in recent times due to increased in the number of medically compromised patients. This review article discusses various aspects of biofilm formation, its harmful effects, guidelines and various methods available to disinfect the DUWLs.

Key Words- Dental unit water lines (DUWLs), dental chair unit (DCU), cross infection, biofilm

INTRODUCTION:

While working in a dental operatory, dentist along with whole dental team are exposed daily to harmful infectious micro-organisms. Source of these micro-organisms are usually the patients being treated but water used in dental units may also contribute to it. In dental office, microbial contamination can occur by four basic routes i.e. through blood born route (e.g. Hepatitis B and C viruses, HIV virus)[1,2], saliva contamination from infected patient (e.g. Herpes simplex virus)[3], through contaminated instruments or from handpiece emitted aerosol of dental unit.[4] Eliminating the risk of cross contamination or spread of infectious agents is the major concern of any health care setup and dentistry is no different in pursuing this agenda. Various protective methods like gloves, face mask, face shields, rubber dam, autoclaving of instruments etc. are been used to prevent the spread of infection by above mentioned first three modes but contamination of dental unit water lines (DUWLs) by micro-organisms is still a worrying factor. This review discusses causes of biofilm formation in DUWLs and available methods to reduce the spread of micro-organisms through DUWLs.

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Biofilm

Biofilm is the colonies of micro-organisms that adheres to the solid surface in the presence of adequate moisture and can be defined as a microbially-derived sessile community characterized by cells that are irreversibly attached to a substrate or to each other, are embedded in a matrix of extracellular polymeric substance that they have produced, and exhibit an altered phenotype with respect to growth rate and gene transcription.[5] The presence of contaminated water in dental units was first reported by Dr. G. C. Black in 1963 in Great Britain.[6] Biofilms can survive in extreme conditions and perhaps represents the most primitive form of life.[7]

Micro-organisms found in biofilm are generally bacteria but it may also contain fungi, protozoa, algae and amoeba. During the formation of biofilm a conditioning pellicle is formed first. This pellicle is composed of inorganic compounds which are derived from environment in which biofilm is forming (can be biotic or abiotic surface). Initial colonizers adheres themselves to the surface by reversible and weak van-der-waals forces. Later they adhere permanently following other cell adhesion methods. This initial pellicle along with its own growth provides various sites for other micro-organisms to adhere.[8,9] Most of the biofilms are covered in glycocalyx which is a polysaccharide slime layer. This glycocalyx prevents dessication and chemical insult of micro-organisms within the pellicle.[10] Biofilm helps microbial cells with exchange of genetic material, protects microbial cells against the nutritional excess and drying. It also helps in the accumulation of nutrition from the water phase.[11]

Dental chair units (DCU)

To practice dentistry, dental chair unit (DCU) is the most basic and significant equipment required. Present DCU have all operating essentials like air and water supply, suction units and instruments required for variety of dental procedures into one compact assembly.[12,13] Because DCU are used in the treatment of many patients every day, so they are regarded as medical devices.[14,15] Hence microbial contamination of any specific DCU part can act as a source of cross infection especially in patients with underlying disease and in immunocompromised patients.[15] DCU components like suction devices, dental hand pieces and ultrasonics that come in direct contact with patients should be of particular concern.

Dental unit waterlines (DUWLs) associated biofilms

Water is required for variety of DCU supplied instruments like handpieces, air/water syringes and ultrasonic scalers. Water is also required in dentistry to cool the heat generated during various dental procedures.[13] Water may be inhaled as aerosols, can be ingested during rinsing or can contaminate surgical wounds directly. This water entering patient's mouth is usually contaminated with 10^4-10^8 CFU/ml of micro-organisms.[16] If judged acc. to the standards of drinking water all over the world (Japan=100 CFU/ml, Europe≤ 200 CFU/ml and US≤ 500 CFU/ml) dental unit water is not at all acceptable for consumption.[17] Majority of solid surfaces which are in contact with water are home to biofilms, hence DUWLs provide ideal conditions for the growth of micro-organisms that enter DCU from municipal water supply.[18] Repeated formation of biofilm in DUWLs can be attributed to its structure. As DCUs are not continuously used throughout the day, it leads to water stagnation for extended period which in return promote microbial proliferation.[19] Secondly, the physics of laminar flow of water in DUWLs is such that the centre of the lumen has maximum flow and water flows at minimum rate at the periphery. This results in microbial deposition on the tubing surface which further promotes bacterial proliferation.[20,21] DUWLs consist of a network of narrow plastic tubings having length of nearly 6 m with 2 mm inner diameter along with brass and non-flexible plastic connections with 4 mm diameter. This results in high surface area to water volume ratio facilitating the biofilm formation.[19] Most of the DUWLs have an average temperature of 23^0c[22] which may encourage the microbial proliferation. For the comfort of the patient some DUWLs are fitted with heaters, in such units temperature can range in between 20-30^0c.[23] When compared with glass or steel, micro-organisms adhere rapidly to hydrophobic polymeric plastic tubings (e.g. polyvinylchloride or polyurethane).[19] Bacterial adhesion is also promoted as municipal water contains minerals like calcium carbonate which gets deposited on DUWLs surface.[10] When a new dental unit is connected to the mains water supply, even if not used, a biofilm can form within 8 hours and will show protective matrix with embedded micro-organisms within 6 days.[24,25] There are two main sources of microbial contamination of DUWLs i.e. due to saliva suck back of a patient which occurs when negative pressure is generated on stopping dental equipment. This is the reason why handpieces used in dentistry should be provided with integrated antiretraction valves to prevent backflow of fluids.[13,19] Second source of microbial contamination may be water from municipal system.[26] Biofilm formation is unavoidable and results in discharging the microbial cells to patient through DUW. The concentration of micro-organisms found in DUWLs is far above the standard guidelines resulting in increased potential for cross infection.

Micro-organisms associated DUWLs biofilm

DUWLs biofilms consist of bacteria, fungi and protozoa. Most frequent bacterial genera found are Pseudomonas, Legionella, Klebsiella, Moraxella, Escherichia, Flavobacterium or non tuberculous mycobacteria. Oral micro-organisms most frequently isolated from DUWLs belongs to genrae Lactobacillus, Actinomyces, Bacteroids, Streptococcus, Staphylococcus, Candida and Veillonela.[27]

Gram negative Legionella rods

DUWLs provide suitable environment for the proliferation of Legionella rods (L. Pneumophila etc.).[28] These bacteria are responsible for causing Legionellosis having varying clinical forms, most dangerous being pneumonia (Legionnaires disease) which is caused by Legionella pneumophila pneumoniae. An influenza-like variant of this disease is more common which is described as Pontiac fever.[29] The condition within the DUWLs is optimal for the development of Legionella rods and biofilm formation due to water stagnation, low chloride concentration and high water temperature. Amoebae contribute to the transmission of these bacteria as they develop inside the amoebic cell.[28] Atlas et al isolated Legionella genus bacteria from 78% of the dental unit samples in which 8% samples were found to contain Legionella Pneumophila Penumonia.[30] Williams et al found legionella species bacteria in 62% of DUW samples and in 90% of sample their concentration exceeded 100 CFU/ml.[31] Another study conducted in Poland found legionella species in 24.2% of DUW samples exceeding 1-200 CFU/ml and 30% strains belonged to Legionella Penumophila serotype 1 which is the most pathogenic strain.[32] High prevalence of legionella rods in DUWL renders the dentist and the whole dental team at the risk of inhaling water droplet aerosol contaminated with these bacteria.[28] This was confirmed by the research which showed that dental worker have shown high percentage of positive serological reaction to Legionella antigen compared to general population.[33] Non tuberculosis Mycobacteria can occur in DUWL biofilm and posess the hazards for infection in immunocompromised people.

Fungi

DUWL biofilms contain Candida parapsilosis (yeast). Mould fungi of Fusarium, Alternaria, Cladosporium, Scopulariopsis, and Penicillium can be found in DUWL which can be hazardous for immunocompromised people.[4]

Protozoa

Most commonly found free living amoeba in DUWL are Vahlkampfia species, Hartmanella species and Vanella species. They can cause infections in patients with compromised immunity.[4]

Risks associated with DUWLs

There is no mention of any public health problem in literature related to exposure to DUWLs but because the practice of infection control focuses on minimizing the exposure to known pathogens, contamination of DUWLs with micro-organisms cannot be ignored. It gained more importance in the recent times as the number of immunosuppressed patients due to steroids, drug therapy, alcohol or systemic diseases is increasing, making them more susceptible to opportunistic pathogens as found in DUWLs.[34] There are a few reports mentioned in the literature related to DUWLs. Literature mentions a case of prosthetic heart valve infection by Mycobacterium gordonae and two other cases mentioning the NTM cervical lymphadenitis after dental extraction.[35,19] Another mention is of P. aeruginosa contaminated DUWLs exposure of two patients with solid tumor leading to subsequent development of oral abscesses in both patients. Later same strain was recovered from DUWLs that was responsible for the abscesses.[36] Clark mentioned the nasal flora alteration in approximately 50% of dentists.[37] According to another report, dental team members were shown to be more susceptible to respiratory infections when compared with overall population and their medical colleagues.[38] Another case mentioned is of a dentist who suffered from fatal pneumonia caused by Legionella dumoffi due to daily exposure to contaminated water in DUWLs however evidence was only circumstantial.[39]

Recommendations

Centre for disease control (CDC) and prevention in 1993 recommended-

1. Practice for installing anti-retraction valves in dentistry
2. Waterlines flushing for several minutes daily and 20-30 sec. flushing in between patients
3. Use of sterile solution for bone cutting procedures

American dental association (ADA) in 1996 asked dental manufacturers to find methods to reduce biofilm formation in DUWLs. The goal was to reduce heterophillic bacterial count to ≤ 200 in unfiltered unit.

In 1996, Organization for Safety and Asepsis procedure supported CDC and ADA guidelines.[10] It was recommended that water supplying dental unit should comply with drinking water standards i.e. 200 CFU/ml. Draining down of waterlines by day's end was also recommended to reduce water stagnation. At present no regulation addresses the dental treatment water quality.[17]

DUWLs decontamination approaches

Since 1963, various methods have been investigated to make the DUWLs micro-organism free. Various approaches available include-

1. Flushing

Various agencies recommended several minute flushing of DUWLs at the start of clinical day to reduce microbial accumulation due to overnight water stagnation.[40] In between patient flushing is also recommended to remove materials which may have entered

DUWLs during treatment.[10] Flushing has temporary effect on reduction of micro-organisms in DUWLs and in completely ineffective against biofilm. As discussed earlier in this article due to physics of laminar flow of water in DUWLs, the layer in contact with the biofilm remains stationary even during flushing. Efficacy of flushing has been challenged by various authors saying that in case of flushing for less than 10 min. there was minimal and variable bacterial clearance. It has been recommended that flushing for 20 min. reduces bacterial count to zero.[41]

2. Independent reservoir

With the help of separate sterile water reservoir, municipal water supply can be bypassed. Another advantage of independent reservoir is that clinician can control water quality introduced into the system. Reservoir with sterile or boiled water which is allowed to cool in a sealed container should be used.[42] These systems are comparatively inexpensive to install.

3. Chemical treatment

Ideally, chemical agents used to control biofilm formation should be bactericidal but should be non toxic and non-irritating to humans. It should detach biofilm, prevent its reformation and should not damage or corrode DUWL's internal structure. It should be inexpensive to use and when used continuously in water treatment, it should not affect enamel and dentin bonding agents. These chemicals can be introduced into the DUWLs either continuously or intermittently. Major disadvantage of intermittent system is that biofilm organisms may rebound between treatments. Continuous delivery systems reduced the chances of micro-organisms re-colonization but as it is always present in the DUWLs, it may damage them. As chemical agent is always present, its chronic exposure to health care workers should be considered.[43,44] Various chemical agents used for this purpose are-chlorhexidine gluconate, gluteraldehyde, povidone iodine, hypochlorite and peroxides.[41] A dental unit water pre-treatment system that maintains the water quality below portable water standards has been described. It will also reduce the time required for DUWLs disinfection, reduces chemical handling and also reduces incidences of human error.[27]

4. Chlorination

Chlorine used as sodium hypochlorite is most common biocide used and is particularly effective against Legionella proliferation.[45] Chlorination is well known for maintaining drinking water standards in community water storage tanks.[46] According to some studies chlorination reduces bacterial count in DUWLs to a few hundered[47] where as other studies found it ineffective against L. pneumophila.[46] Gluteraldehyde is also used for this purpose with integral automated flush system with contact time of 7 minutes.[42] Biofilm bacteria are generally resistant to chemical treatment because-

A- Some bacterial cells in biofilm are starved or slow growing due to nutritional deficiencies. These non or slow growing cells are less sensitive to antimicrobial agents.

B-Exopolymers-Exopolysaccharides production prevents the penetration of various agents to full biofilm depth.

C- Within the biofilm some cells adapt protective biofilm phenotype which either deactivate some disinfectants or form a barrier against their diffusion.[25]

5. Filtration

Use of filters in DUWLs for elimination of bacteria was first described nearly 20 years ago.[48] In studies evaluating the micro-filtered water used in dentistry, found 80% output water samples bacteria free and among remaining samples none exceeded 200 CFU/ml of bacterial count.[49,50] Another study using 0.22 µm filters found few micro-organisms on SEM in post filtration tubing sections when compared with pre-filtration section.[51] Mayo and Brown found that no micro-organisms were detected from water samples taken close to 0.2 µm filters however as the distance from the filter increased levels of bacteria also increased, may be because of biofilm formation in post-filtration waterlines.[52] Advantages of filters include reduction or elimination of chemicals and hence reduction in damage to DUWLs and dental staff exposure to chemical residue, minimal cost and unit can use municipal water supply. DUWLs re-contamination can occur within 24 hours due to trapping and growth of bacteria on filters. Hence disposable filters with daily replacement are recommended.[10]

6. Peroxide, Ozone, UV light

Hydrogen peroxide and ozone can be introduced continuously into dental unit water even during treatment hence has the benefits of continuous delivery system.[53] UV radiation has been used alone or in combination with ozone and other biocides for water treatment. It is a non polluting alternative. UV radiation alone has significant effect on reducing microbial contamination.[54]

7. Autoclavable system

An autoclavable assembly of water reservoir, dental unit waterline tubing and fitting which can be sterilized in between patients has been cleared by FDA.[42]

None of the above mentioned methods can completely remove the biofilm and make DUWLs free of micro-organisms alone, so the combination of given methods should be used to make them more effective.

CONCLUSION:

The potential of DUWLs biofilms laden with micro-organisms for cross contamination in dental operatory cannot be denied. But adequate knowledge of the current concepts and use of various means available will definitely reduce the chances of cross contamination. Hence, every possible effort should be made to improve the quality of water used in dental units.

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