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RESEARCH ARTICLE

DENTAL UNIT WATER PIPELINE CONTAMINATION: A LITERATURE REVIEW

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ABSTRACT

Background: This article mainly focuses on the causes, the organisms involved and the protocols of disinfection of the water-pipelines of the dental units. **Aim:** The aim of this article is to review different herbal irrigants used in the field of endodontics. **Materials and methods:** A literature review is conducted using electronic databases "PubMed", "Google Scholar" and "Scopus", using keywords "dental chair contamination", "Micro-organisms", "water-pipelines", "dental water units", "Biofilms". Out of 107 articles, only 35 articles were relevant for this study. **Conclusion:** To conclude from this review DUW contamination is now more clearly defined, changes can be made by dental manufacturers and the scientific community in approaches to prevention and control.

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INTRODUCTION

The dental unit water (DUW) quality has always been of considerable importance to patients and dental staff as they are regularly exposed to water and aerosols generated from the dental unit. This water from the units are considered to be hosts of a diverse microflora of bacteria, yeasts, fungi, viruses, protozoa, unicellular algae and nematodes (Walker et al., 2000). There is a possibility that the water units may also become heavily contaminated with opportunistic respiratory pathogens such as Legionella spp. And Mycobacterium spp. Bacterial load in DUW should be kept at or below recommended guidelines for drinking water (Walker, 2003; O'Donnell, 2006; Williams, 1995). Previous studies have proven that, 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 (Leggat, 2001). The ADA established a goal for the year 2000 of 200 colony-forming units (cfu) per mL of aerobic heterotrophic bacteria for DCU output water.

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However, this standard has not been widely achieved, indicating the extent of this problem. The current Centres for Disease Control and Prevention (CDC) guidelines for infection control in dental healthcare settings recommend that DCU output water should contain 500 cfu/mL of aerobic heterotrophic bacteria (Harrel, 2004; Pankhurst, 2017; Yoon, 2015; Watanabe et al., 2016; Clesceri, 1952; Kettering, 2002; American Dental Association, 1996; American Dental Association Council on Scientific Affairs, 1999).

Literature review

About the dental unit piplines: The role of dental chair units supply water as a coolant and irrigant to turbine and conventional handpieces, ultrasonic scalers, three-in-one air/water syringes, as well as providing water for the patient rinse cup filler via an intricate network of interconnected narrow bore tubes (DUWLs). Water supplied to DCUs are usually provided either in independent bottle reservoirs or directly or indirectly from a municipal mains water supply. In Dental Hospitals and in some large dental clinics equipped with many DCUs, water supplied to DCUs often comes from large holding tanks supplied with mains water, whereas in smaller clinics DCUs may have individual mains connections. In the European Union, the majority of DCUs are supplied with municipal mains water. Pressure variations in the mains supply could conceivably cause retraction or backflow of water from DCUs into the mains if the pressure in the mains supply drops below that in DUWs. To circumvent this possibility, the water distribution network in some DCU models contains an air gap system that physically separates the water within the DUWs from the supply water, thus preventing backflow of potentially contaminated DCU water into the supply water network. It seems prudent that DCU manufacturers should include, as standard, an integrated air gap system within the waterline network in all DCU models (Kohn, 2003).

Biofilms in the DWU: Biofilms in DUW Bacteria in aquatic environments interact with surfaces to form a biofilm. Biofilms aid survival and to optimise available nutrients. The physics of laminar flow of DUW passing through the waterlines results in maximum flow at the centre of the lumen and minimal flow at the periphery, encouraging deposition of organisms onto the surface of the tubing. Intermittent use patterns of dental lines leads to stagnation of the entire water column within the waterlines for extended periods during the day, thus promoting further undisturbed bacterial proliferation. Bacteria adhere more readily to hydrophobic polymeric plastic tubing of the type used in dental equipment such as polyvinyl chloride, polyurethane than to those composed of glass or steel. Susceptibility of medical equipment such as catheters to biofilms has been reduced by coating with heavy metals or incorporating biocides into the fabric of the tubing that inhibit bacterial growth. Organisms in DUW biofilm are predominantly derived from the incoming mains water. Once a new DUW system is connected to mains water supply, even when it is not used for patient treatment, a biofilm will form within 8 h.19 The biofilm will develop to reach a climax community of microcolonies embedded in a protective extracellular amorphous matrix by six days.[26] Bacteria shed from the biofilm during use maintain the bioburden of planktonic (suspended) organisms detected in DUW. Greater resistance to surfactants, biocides and antibiotics than organisms floating freely in fluids are shown by biofilms in the Dental water units (O'Donnell, 2006; O'Donnell, 2007; Atlas, 1995).

Risks to patients: The goal of infection control is to minimise the risk from exposure to potential pathogens and to create a safe working environment in which to treat patients. The ever-increasing number of patients who are either immunocompromised or immunosuppressed due to drug therapy, alcohol abuse or systemic disease has produced a cohort of patients susceptible to environmental waterborne opportunistic pathogens such as those prevailing in DUW. The organisms recovered from DUW vary with geographic location. They include fungi, freeliving amoebae, protozoa and nematodes as well as the consistently reported recovery of saprophytic and opportunistic Gram-negative pathogens such as Pseudomonas spp., Klebsiella spp. and Flavobacterium spp. Of particular concern are the primary respiratory environmental pathogens found in DUW that can cause pneumonia, milder flu-like respiratory infection and, less commonly, wound infections, e.g. Legionella pneumophila and non-pneumophila Legionella spp. as well as Mycobacterium spp. including Mycobacterium avium-intracellulare. Mycobacterium avium-intracellulare can cause disseminated infection in HIV-seropositive patients following ingestion and High numbers of non-tuberculous mycobacteria may be swallowed, inhaled or inoculated into oral wounds during dental treatment with the potential for colonisation, infection or immunisation. Priming of the immune system by exposure to environmental NTM helps to maintain the anti-tuberculin immune response. These organisms are reputed to cause amoebic keratitis in contact lens wearers who clean their lenses in tap water. It is unknown whether they present a risk in the dental setting, but routine use of protective eye wear by both the dental team and patients should shield the eyes from any possible exposure (Abdouchakour et al., 2015).

Pseudomonas aeruginosa: This can be highly resistant to biocides, including antibiotics, and can grow in dilute disinfectants such as chlorhexidine and iodophors. It is able to thrive in low nutrient environments such as distilled water, which is often used by dentists in bottled-water systems. The infective dose for colonisation in healthy human volunteers is $>1.510^{6}$cfu/mL. Such high concentrations are rarely encountered in DUWs (Walker, 2003). Antibiotic treatment makes patients more susceptible to opportunistic pathogens and markedly lowers the required infectious dose. The estimated risk of colonisation by daily exposure to water with low levels of Pseudomonas aeruginosa is 1.7. Therefore, the risk of a healthy person becoming colonised is vanishingly low. The only proven evidence was published in 1987 (Pankhurst, 2017; Khosravi, 2016). Two patients with solid tumours were unwittingly exposed to DUWs contaminated with P. aeruginosa. Both patients subsequently developed gingival abscesses which, as later confirmed, were caused by the same strain of P. aeruginosa as that isolated from the turbine waterlines. In a prospective study, other non-compromised patients treated in one of six P. aeruginosa-contaminated dental units were transiently colonised for three to five weeks with P. aeruginosa, but no infection ensued (Pankhurst, 2007; Rusin, 1997).

Non-tuberculous Mycobacteria spp. (NTM): These are opportunistic pathogens causing pneumonia, cutaneous and disseminated disease. There is little evidence for person-to-person transmission and the organisms are transmitted from environmental sources by ingestion, inoculation or inhalation. Worldwide, there is an increasing incidence of infection by NTM in immunocompetent patients, which is thought to be acquired from environmental sources such as drinking water.31 Strains of Mycobacterium spp. have been isolated from infected AIDS patients and their home coldwater drinking water tap (Chobot, 1997). Fortunately, most NTM infection is asymptomatic as studies suggest that w12% of the population in the USA has been colonised by the NTM Mycobacterium aviumintracellulare (Montecalvo, 1994). In hospital outbreaks of NTM infection, the source of the organism has been tracked back to contaminated taps and showerheads. NTM are isolated in low numbers from municipal water supplies, the prevalence rate varies from 1% up to 50% depending upon the exact geographical location. It follows that their presence in DUWLs fed by mains water also reflects local geographical variations (Pankhurst, 1990; Rangel-Frausto, 1999). Only a small number of published studies evaluate the prevalence or health risk from NTM in DUWLs. NTM are commonly isolated from DUWLs, e.g. in England and parts of Europe, and have been shown to proliferate in the biofilm (Pankhurst, 2007; Rusin, 1977).

The numbers of non-tuberculous mycobacterium in DUWLs exceeded that of drinking water by a factor of 400 (Schulze-Robbecke, 1995). The obvious concern is that large numbers of NTM may be swallowed, inhaled or alternatively inoculated into oral wounds during dental treatment with the potential for colonisation and infection. Gargling with water containing NTM resulted in respiratory colonisation. Prosthetic heart valve infection with M. gordonae and another two cases of NTM cervical lymphadenitis following dental extractions has been reported. Low-level exposure of dentists to DUWLs could have a positive effect. Priming of the immune system by exposure to environmental NTM is thought to be beneficial as it helps to maintain the bacilli CalmetteeGuerin vaccine (anti-tuberculin) immune response (Khosravi, 2016; Pankhurst, 2007).

Legionella spp: Six to thirty percent of domestic hot water systems harbour legionellae (Health and Safety Commission, 2000; Strauss, 1996). In order to multiply in the DUWL, legionellae require other micro-organisms, particularly amoebae, a supply of nutrients and temperatures in the range of 20-45.Concentration of Legionella spp. in DUWL is reported to be in the range of 10^2 to10^5cfu/ mL. However, once established, legionella colonisation may persist in waterlines for years. Legionellae suspended in aerosols at 65% relative humidity can survive in laboratory conditions for 2 h.50 Legionellosis can present either as an atypical pneumonia or as a milder flu-like illness, known as Pontiac fever. Although more than half of the >46 species that comprise the family Legionellaceae have been linked to disease, the vast majority of reported cases of Legionnaires' disease are caused by L. pneumophila serogroup 1.51. The prevalence of legionella in DUWL varies widely from 0 to 68% depending, in part, on the isolation procedures (Pankhurst, 1990; Rangel-Frausto, 1999).

Risk factors include male sex, age >45 years, smokers, alcoholics, diabetics and people with chronic respiratory or renal disease and cancer.54 Many serological surveys for legionellosis among dental personnel have been conducted, and we could find no study involving the dental patients. An outbreak of Legionnaires' disease was reported from Stafford District General Hospital: 68 patients were found to be seropositive among whom 22 died. The source of infection was identified as the chiller unit of the air-conditioning plants. Two studies have shown that legionella antibody was more prevalent amongst dental clinic staff than in non-clinical staff working in the same premises." Antibody titres correlated directly with the duration of exposure to clinical work. A survey carried out by the Central Public Health Laboratory, London, found no evidence that previous dental treatment was a risk factor in patients with legionellosis. However, there are no large prospective or retrospective studies of respiratory infections in dental staff or patients, and it is most unlikely that sporadic cases of infection would be linked with dental treatment at a clinic where there was poor water quality in the dental units. At least one dental hospital felt it necessary to close temporarily because L. pneumophila serogroup 1 was found in the dental water supply, although there were no clinical cases. This raises questions about the advisability of looking for such organisms unless a specific problem is identified. In the UK, the Department of Health (DoH) advises that in hospitals 'Routine sampling to detect the presence of L. pneumophila in hot and cold water systems is not recommended unless it is suspected that they are the source of hospital-acquired legionella infection.

If samples reveal the presence of Legionella in low concentrations, there should be no grounds for alarm because the PHLS survey showed that Legionella can be found in most water systems (Schulze-Robbecke, 1995; Yoon, 2015; Tall, 1995).

Water-borne pathogens: An assessment of the various waterborne organisms that occur in dental units, their respective infective doses and the degree of exposure that occurs during dental surgery suggests that transmission of these opportunist pathogens cannot be excluded, particularly in the higher-risk immunocompromised individual. For example, children with cystic fibrosis receive dental surgery and are susceptible to infections with Gram-negative bacilli such as P. cepacia whose epidemiology is poorly understood (Chobot, 1997).

Risks to dental operator: Considerable attention has focused on the plight of the susceptible patient but the clinical members of the dental team inhale aerosols generated by dental equipment on a daily and long-term basis. Abnormal nasal flora in dental personnel has been linked to water system contamination.[32] The clinical dental team experience an increased prevalence of respiratory infections compared to the general population or their medical colleagues.Employing polymerase chain reaction methodology, Legionella spp. have been detected in 68% of DUW samples and L. pneumophila in 8%. Comparable prevalence rates were observed in potable water samples but e significantly from a public health standpoint e none of the potable samples had counts of >10 000 legionella/mL whereas 19% of the DUW samples were in this category. The magnitude of legionella antibody titres correlated directly with the duration of time spent carrying out clinical work, suggesting that aerosols generated from DUW are the likely source. Conversely, a survey carried out by the Central Public Health Laboratory, London found no evidence that previous dental treatment was a risk factor in patients with legionellosis. A dentist suffered from in which L. dumoffi and other Legionella spp. Were found from his surgery waterlines. Unfortunately, the isolates were not available for molecular typing which would have confirmed the link to the source. However, the possibility still remains that DUW-associated infections have gone unrecognised or unreported because of the failure to associate exposure to DUW or aerosols with the development of specific infections. Sporadic infections such as Pontiac fever, also caused by Legionella spp., are less likely to be investigated or notified to health authorities. Risk factors identified in domestic acquisition of Legionnaires' disease are of relevance in preventing infection in the dental surgery. Multivariate analysis showed an increased risk of infection following recent plumbing repairs, the use of an electric rather than a gas water heater, smoking, and working >40 h per week (Schulze-Robbecke, 1995; Davies, 1994).

Treatment of DUWs: Different types of chemical products are available for treating dental unit water. Due to the issues of materials compatibility, practitioners must consult the manufacturer of their DUWs before introducing any chemical substance, as this may otherwise invalidate their warranty. Dental chair manufacturers may recommend certain specific products to be used in dental equipment. Chemicals can be delivered continuously or intermittently. A recent study investigated the feasibility of treating between each patient rather than waiting until the evening or weekend, was efficacious in the control of both microbial contamination of dental treatment water and dental water line biofilms. Many chemical treatment processes claim to remove and kill biofilms, and manufacturers provide supporting evidence. Certain products that may remove biofilm, do not sufficiently disperse the biofilm and or dissolve the calcified products. This can cause occlusion and blockage of the dental water unit tubing. The common products are based on compounds like sodium hypochlorite, chlorine dioxide, chlorhexidine, peroxides, peracetic acid and citric acid. Other chemicals including electrochemically-activated water have also been investigated and have demonstrated potential for microbial control.The following agents can be used for management.

Alpron: The Alpron disinfectant system consists of three component system specifically designed for the elimination and control of biofilms within the narrow bore plastic water tubes of a dental unit. The initial biofilm removal solution consists of a sodium hypochlorite solution 1–2% applied to the DUWLs at an initial temperature of 50°C for 30 minutes. This is followed by a second solution consist of alkylamines, ten sides, complexing agents and defoamers applied to the DUWS at an initial temperature of 60°C for 30 minutes. The third solution, a 1% solution of sodium-p-toluolsulfonechloramide and sodium ethylenediamine tetra actetic acid (1% Alpron) was added to the reservoir that supplies the water to the dental hand pieces and triple syringe. Alpron has been tested in a number of studies. Smith et al.57 found that Alpron successfully reduced the total viable counts (TVCs) to a level similar to that of drinking water when used continuously over a period of 6–13 weeks. The active agents are sodium hypochlorite, sodium-p-tolulsulfonechloramide and EDTA 1–2%. The mode of delivery is continuos. Biofilms were also significantly reduced when measured before and after eight weeks of disinfection with Alpron (Walker, 2007; Smith, 2002).

Oxygenal: It relied on hydrogen peroxide. Its efficacy is based onsynergetically reinforced by silver ions ("OXYGENAL 6"). Numerous tests and laboratory investigations have demonstrated its very good material compatibility. When used in application concentrations, it does not pose a hazard to patients and personnel and it decomposes without residues into water and oxygen. Oxygenal shows a 99.2% reduction of biofilm coverage of dental tubing while no TVC was detected in the out flowing water after a single treatment. Active agent is hydrogen peroxide 0.4% (Smith, 2002).

Bio Blue: It consists of Chlorhexidine 0.12%, glycerol0.12% and alcohol based. Kettering et al tested Bio Blue and concluded that it was notable to reduce the TVC to below 200 cfu/ml when used in combination with tap water. The active agents are Chlorhexidine 0.12%, glycerol0.12% and alcohol based (O'Donnell, 2007; Walker, 2007).

Dentosept: Dentosept has active agent in the form of 1%Hydrogen peroxide. Dentosept has been shown to be highly effective in reducing TVCs and maintaining the microbial laod to level below 200 cfu/ml. the active agent is hydrogen peroxide 1%. The mode of delivery is intermittent. Dentosept gave the most consistent and substantial antimicrobial effect over time (Khosravi, 2016; Davies, 1994).

Sanosil and Sterilex Ultra: Hydrogen peroxide, silver ions as active agents. Tuttle bee et al evaluate and compared Sanosil (5 to 8 weeks) and Sterilex Ultra (7 to 20 weeks) in dental hospitals using once weekly disinfection of the DUWs, and both decreases TVCs significantly to below the ADA guideline of <200 cfu/ml. A significant reduction in biofilm coverage has also been observed using microscopy imaging techniques. In some studies, Sterilex Ultra initially minimized bacterial counts to levels below the ADA guideline, but failed to maintain low TVCs during week follow-up. The active agents are Hydrogen peroxide, silver ions and Alkaline peroxide 5% respectively. The both are having intermittent approach (Montecalvo, 1994; Smith, 2002).

Tetra-sodium EDTA: Tetra-sodium EDTA is a latest product that is effective against microbial biofilms and is compatible with a wide range of materials use in DUWs. In a study once weekly application of 4% (w/v)tetra-sodium EDTA was able to minimize the microbial counts of flowing water initially to <10 cfu/ml, but microbial counts retuned to base-line levels by the end of the working week. Increasing the concentration of tetra-sodium EDTA upto 8% enhanced the longevity of the reduction in viable microbial counts.[7]

Conclusion

Since from this review DUW contamination is now more clearly defined, changes can be made by dental manufacturers and the scientific community in approaches to prevention and control. Due to the multiple ports of entry to the DUW system for microbes, no single method or device will completely eliminate the potential for cross-infection. All the inlet systems of the dental water units require strict adherence to maintenance protocols to perform to their full potential. Future research are needed to help prevent contamination and disinfection of the dental water units.

REFERENCES

Abdouchakour F., Dupont C., Grau D., Aujoulat F., Mournetas P., Marchandin H., Parer S., Gibert P., Valcarcel J., Jumas-Bilak E., 2015. Pseudomonas aeruginosa and Achromobacter sp. clonal selection leads to successive waves of contamination of water in dental care units. *Applied and environmental microbiology*. Nov 1;81(21):7509-24.

American Dental Association Council on Scientific Affairs, 1999. Dental unit water lines: approaching the year 2000. J Am Dent Assoc, 130:1653-1664.

American Dental Association. 1996. ADA statement on dental unit waterlines. *J Am Dent Assoc.,* 127:185-186.

Atlas RM., Williams JF., Huntington MK. 1995. Legionella contamination of dental-unit waters. Applied and environmental microbiology. 1;61(4):1208-13.

Chobot S., Malis J., Sebakova H. et al., 1997. Endemic incidence of infection caused by Mycobacterium kansasii in the Karvina district in 1968e1995 (analysis of epidemiological data e review). *Cent Eur J Public Health.,* 5:164-217

Clark A. 1974. Bacterial colonisation of dental units and the nasal flora of dental personnel. Proc R Soc Med;67:29-30.

Clesceri LS., Greenberg AE., Eaton A., Closer L. 1998. editors. Standard methods for the examination of water and wastewater. 20th edn. Washington: American Public Health Association, American Water Works Association and the Water Environment Federation.

Davies KJ., Herbert AM., Westmoreland, Bagg J. 1994. Seroepidemiological study of respiratory virus infections among dental surgeons. *Br Dent J.,*176:262e265

Harrel SK., Molinari J. 2004. Aerosols and splatter in dentistry: a brief review of the literature and infection control implications. *J Am Dent Assoc*.,135:429e437.

Health and Safety Commission. Legionnaires' disease. The control of legionella bacteria in water systems. Approved code of practice and guidance. 3rd edn. London: HMSO; 2000.

Kettering JD., Stephens JA., Munoz-Viveros Carlos A., Naylor P. 2002. Reducing bacterial count in dental unit waterlines: tap water vs. distilled water. *J Contemp Dent Pract.,* 3:1-9.

Khosravi AD., Hashemi Shahraki A., Hashemzadeh M., Sheini Mehrabzadeh R., Teimoori A. 2016. Prevalence of non-tuberculous mycobacteria in hospital waters of major cities of Khuzestan Province, Iran. Frontiers in cellular and infection microbiology. Apr 13;6:42.

Kohn WG., Collins AS., Cleveland JL., Harte JA., Eklund KJ., Malvitz DM. 2003. Centers for disease control and prevention (CDC), guidelines for infection control in dental health-care settingsd. *Morb Mortal Wkly Rep Recom Rep.,* 52: 1-61.

Leggat PA., Kedjarune U. 2001. Bacterial aerosols in the dental clinic: a review. *Int Dent J.,* 51:39e44. 4. Siegel SC, von Fraunhofer JA. The effect of handpiece spray patterns on cutting efficiency. J Am Dent Assoc 2002;133: 184e188.

Montecalvo MA., Forester G., Tsang AY., du Moulin G., Wormser GP. 1994. Colonisation of potable water with Mycobacterium avium complex in homes of HIV infected patients. Lancet. 343:1639

O'Donnell MJ., MacCarthy D., Coleman DC. 2006. Microbiology and cross-infection control. In: Ireland R, editor. Clinical textbook of dental hygiene and therapy. Oxford: *Blackwell Munksgaard*., 18:1-207.

O'Donnell MJ., Shore AC., Coleman DC. 2006. A novel automated waterline cleaning system that facilitates effective and consistent control of microbial biofilm contamination of dental chair unit waterlines: a one-year study. *J Dent.,* 34:648-661.

O'Donnell MJ., Shore AC., Russell RJ., Coleman DC. 2007. Optimisation of the long-term efficacy of dental chair waterline disinfection by the identification and rectification of factors associated with waterline disinfection failure. *J Dent.,* 35:438-451

Pankhurst CL., Coulter WA. 2007. Do contaminated dental unit waterlines pose a risk of infection? *J Dent.,* 35:712-720.

Pankhurst CL., Philpott-Howard JN., Hewitt JH., Case well MW., 1990. The efficacy of chlorination and filtration in the control and eradication of Legionella from dental chair water systems. *J Hosp Infect.,* 16:9-18.

Pankhurst CL., Scully C., Samaranayake L. 2017. Dental unit water lines and their disinfection and management: a review. *Dental update*. 2;44(4):284-92.

Pankhurst CL., Scully C., Samaranayake L., 2017. Dental unit water lines and their disinfection and management: a review. Dental update. 2;44(4):284-92.

Rangel-Frausto MS., Rhomberg P., Hollis RJ. et al., 1999. Persistence of Legionella pneumophila in a hospital water system: a 13-year survey. *Infect Control Hosp Epidemiol*., 20: 793-797

Rusin PA., Rose JB., Haas CN., Gerba CP. 1997. Risk assessment of opportunistic Bacterial pathogens in drinking water. *Rev Environ ContamToxicol.,* 152:57-83

Schulze-Robbecke R., Feldman C., Fischeder R. 1995. Dental units: an environmental study of sources of potentially pathogenic mycobacteria. *Tuber Lung Dis*., 76:318-323

Smith AJ., McHugh S., Aitken I. 2002. Evaluation of the efficacy of Alpron disinfectant for dental unit water lines. *Br Dent J.,* 23;193(10):593-6

Strauss WL., Plouffe JF., File Jr TM., et al., 1996. Risk factors for domestic acquisition of Legionnaires disease. *Arch Intern Med.,* 156:1685-1692.

Tall BD., Williams HN., George KS., Gray RT., Walch M. 1995. Bacterial succession within a biofilm in water supply lines of dental air-water syringes. *Can J Microbiol*., 41:647-65.

Walker JT, Bradshaw DJ, Bennett AM, Fulford MR, Martin MV, Marsh PD. 2000. Microbial biofilm formation and contamination of dental-unit water systems in general dental practice. *Applied and Environmental Microbiology*. Aug 1;66(8):3363-7.

Walker JT. Marsh PD. Microbial biofilm formation in DUWS and their control using disinfectants. J Dent 2007;35:721–730.

Walker JT., Bradshaw DJ., Fulford MR., Marsh PD. 2003. Microbiological evaluation of a range of disinfectant products to control mixed-species biofilm contamination in a laboratory model of a dental unit water system. *Applied and environmental microbiology*. Jun 1;69(6):3327-32.

Watanabe A., Tamaki N., Matsuyama M., Kokequchi S. 2016. Molecular analysis for bacterial contamination in dental unit water lines. *New Microbiol*. 1;39(2):143-5.

Williams JF., Molinari JA., Andrews N. 1996. Microbial contamination of dental unit waterlines: origins and characteristics. Compendium of continuing education in dentistry (Jamesburg, NJ: 1995). Jun;17(6):538-40.

Yoon HY., Lee SY. 2015. Bacterial contamination of dental unit water systems in a student clinical simulation laboratory of college of dentistry. *Journal of dental hygiene science.,* 15(2):232-7.

Yoon HY., Lee SY. 2015. Bacterial contamination of dental unit water systems in a student clinical simulation laboratory of college of dentistry. *Journal of dental hygiene science.* 15(2):232-7.

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