Concise Review

Dental Unit Waterlines: Disinfection and Management

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ABSTRACT

Dental unit waterlines (DUWLs) are the conduits within the dental chair through which water derived from the municipal or other peripheral supply systems flows through the dental chair to reach the dental patient. The quality of the water so delivered must have a low pathogenic microbial burden so as to be safe for the patient and the dental personnel. Regulatory bodies have therefore set minimum standards for the quality of water that exits from DUWLs as part of routine infection control. Adopting a comprehensive approach that combines physical, chemical, and automated methodologies is recommended to effectively decontaminate DUWLs. This review discusses the complexities of DUWL decontamination in terms of (1) Best Practice Guidelines in dental healthcare settings to mitigate DUWL contamination, (2) origins of DUWL contamination and biofilm formation and the associated infectious risks, (3) contemporary approaches for minimizing DUWL contamination, and (4) constraints in combating biofilms in DUWLs. Compliance with regional and national regulations on DUWL decontamination is a legal obligation for all dental practitioners and fundamental to protecting public health.

Introduction

The proper functionality of the dental chair and its components is essential for the safe and successful delivery of dental care. In general, a standard dental unit is connected to several external services, such as water, compressed air, and suction. The water can be from a connection to the municipal supply or from a bottled water system. From these, water flows through dental unit waterlines (DUWLs) to reach dental handpieces, the air/water syringe, and the ultrasonic scaler. All of these require a potable and hygienic water source for cooling and rinsing dental surfaces during clinical procedures and to mitigate the harmful, tissue-damaging thermal effects of high-speed instrumentation. Furthermore, DUWLs also provide water for the cup fill for patients to rinse with, and the water to cleanse the spittoon.[1]

In general, the water supply that feeds into DUWL can be of several types, including a direct connection to the local municipal water supply, or an integrated, refillable, water reservoir bottle/s. This bottle can then be filled with water of various types, such as sterile distilled water, or reverse osmosis water, or tap water to which various chemicals have been added. Within the dental chair, the waterlines transport the water from the external source to a multichannel control box in the unit, and from there to the various water lines that feed handpieces, the air/water syringe, the ultrasonic scaler, the cup fill, and the spittoon rinse.

Under ideal circumstances, the water delivered to the operational surfaces of the patient's oral cavity would be sterile. It would then be subsequently removed in its entirety by the suction system. However, the reality is that a major proportion of the water delivered into the mouth is either swallowed by the patient during procedures or escapes from the

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mouth as splashes of fluid or as aerosols. The latter comprise airborne particles less than 5 μm in diameter that are generated by the triple syringe or powered dental instruments (handpieces and ultrasonic scalers) as part of their normal operation. Clearly, dental personnel working near the dental unit inhale such airborne material, which sometimes may reach distances over three meters from the patient's mouth.[2] It is also noteworthy that the irrigant water spray contaminates any exposed intraoral surgical sites during operational procedures. Hence, it is essential to ensure the hygienic quality of water that exits from DUWLs.

Although it is desirable to have a sterile water feed-in supply for dental units, this is unachievable due to the presence of water contaminants. These can originate from two major sources. First, the municipal potable water supply usually contains a low number of saprophytic organisms, depending on the local jurisdiction. For instance, tap water in the United Kingdom may contain 100 to 500 colony-forming units (CFU) per mL of saprophytic nonpathogens. These extraneous bacteria then contaminate the DUWLs. Second, contamination of DUWL can occur from when antiretraction valves are nonfunctional or absent, because of the 'suck-back' phenomenon that occurs during the opening and closing of the water control valves. In this case, fluids from the mouth may be drawn back into the water lines.

Unfortunately, the natural hydro-dynamic properties of DUWLs promote microbial growth. DUWLs usually have a very small diameter but a high surface area, and this, accompanied by the intermittent, slow flow rate, may result in stagnation. This problem is worsened when the whole column of water in the water line does not move for prolonged periods, such as overnight or on weekends. Under these low shear flow circumstances, microbial contaminants adhere to the luminal surface of the water lines and develop into microcolonies and eventually into robust biofilms that may be difficult to eradicate. Studies have shown that even when the water entering the DUWL at the outset contains very few organisms (such as less than 100 CFU/mL), water exiting the handpiece may contain up to 100,000 to 1,000,000 CFU/mL. This reflects organisms that are shed off the surface of the bacterial biofilms that have formed within the DUWLs.

Although most microbes isolated from DUWLs are innocuous, waterborne environmental saprophytic bacteria, on some occasions pathogens have been isolated (eg, *Shigella* species, *Escherichia coli, Salmonella* species), and their potential to cause infections has received much attention.[3] In addition, some fungi and viruses are infrequently isolated, but to a lesser extent than bacteria.

The main risk to dental staff and patients from DUWL contamination arises from opportunistic respiratory pathogens such as *Legionella* spp., nontuberculous *Mycobacteria*, and *Pseudomonads*. These organisms can be amplified in the biofilm to reach infective concentrations, with the potential for inhalation-associated respiratory infections in vulnerable individuals, These pathogens may also directly contaminate surgical wounds or exposed operative sites, leading to possible wound/surgical site infection. Indeed, reports from different regions imply that such sources contribute to morbidity and sometimes even mortality of dental patients.[4] Usually, these infections occur in compromised patients with debilitated immune and defence systems, and rarely, if ever, in healthy individuals.

Given this scenario, various regional medical/dental authorities have promulgated legislation and guidelines for the quality of the water exiting DUWLs, including stating the permitted upper limit of bacteria and the requisite policies and procedures for mitigating DUWL contamination and suppressing biofilm growth.

In this review, we provide a comprehensive account of the DUWL with regards to:

- Best Practice Guidelines in dental healthcare settings to mitigate DUWL contamination;
- Origins of DUWL contamination and biofilm formation, and the associated infectious risks; contemporary approaches for minimizing DUWL contamination; and
- Constraints in combating biofilm deposits in DUWLs.

Guidelines for the best practice in dental healthcare settings

Guidelines for the permitted bacterial content of water from dental water units differ from one jurisdiction to another. The guidelines from the CDC in the USA recommend water delivered to patients from DUWL during nonsurgical dental procedures should meet drinking water standards, that is, ≤500 CFU/mL of aerobic, mesophilic heterotrophic water bacteria. On the other hand, The American Dental Association prescribes a more stringent ≤200 CFU/mL threshold for the heterotrophic bacterial load in water from DUWL.[5] The same limit of ≤200 CFU/mL is used in Australia. The UK recommendations for dental unit water quality set even lower at 100 CFU/mL of aerobic heterotrophs at 22°C.

There are no specific DUWL guidelines in the European Union. However, in certain member countries, the standards that apply for drinking water are often employed as a benchmark. For instance, the European Union standard for potable water establishes a limit for an aerobic colony count of <100 CFU/mL following 72 hours of incubation at 22°C, or 20 CFU/mL after 24 hours incubation at 37°C.[6]

Origins of DUWL contamination and biofilm formation and infectious risks

The problems of microbial contamination of output water and biofilm development within DUWLs can be attributed to multiple factors.[7] As already mentioned, these include the narrow bore of waterlines, prolonged periods of water stagnation, and malfunctioning antiretraction valves. Other contributing factors include water heaters that may encourage microbial growth, fluctuations in the quality of feed water entering the dental unit, the use of different water types as feed water, and other contributory factors[8] as shown below (Figure 1).

Mains water supply and secondary storage units

The water output quality from DUWLs primarily depends on the feed water quality of the primary supply unit, which can

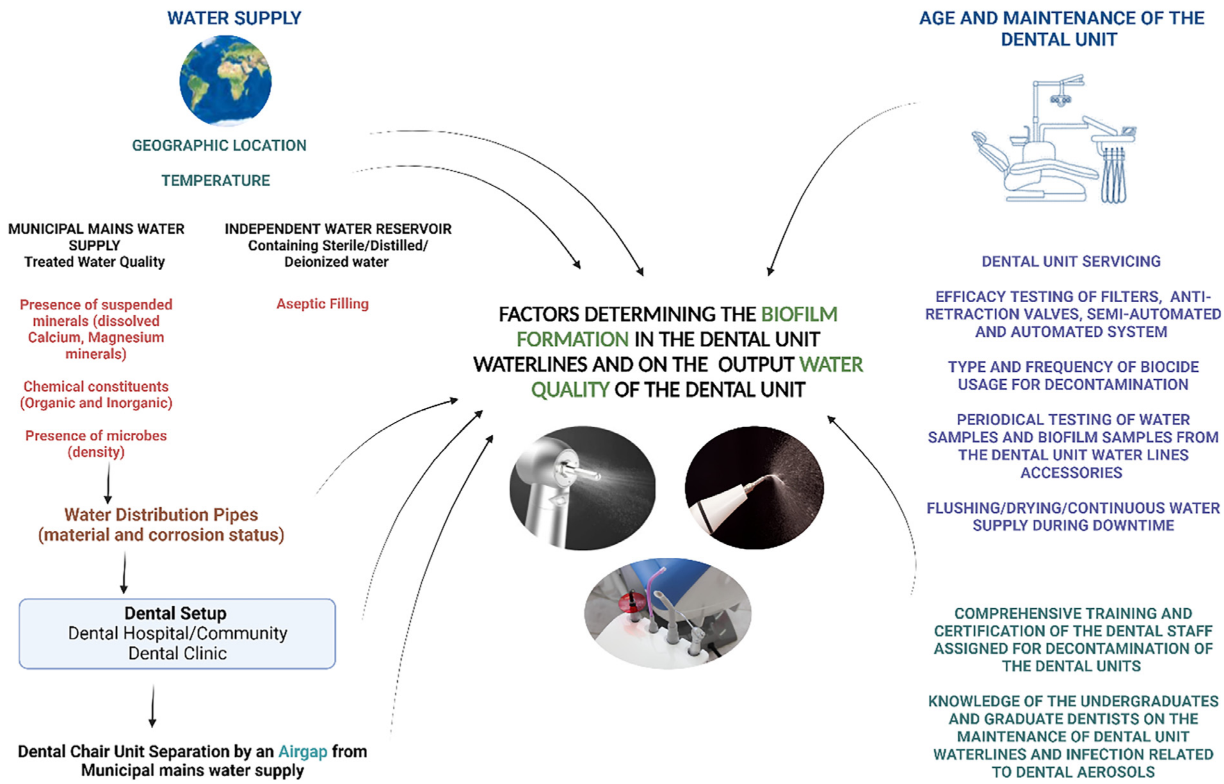

Fig. 1 – Factors contributing to biofilm formation in dental unit water lines, and measures to mitigate these.

be the main municipal water supply, external storage tanks, or isolated bottled reservoirs.[1] In large institutions such as dental hospitals and teaching establishments, water is often sourced from the mains municipal supply, and stored in secondary reservoirs such as large tanks from where water is then supplied to DUWLs.

Therefore, the state and upkeep of the water distribution systems and storage tanks within a facility impact feed water quality. Relevant factors include the physicochemical properties of water, such as dissolved and suspended inorganic and organic compounds in water, microbiological characteristics of the feedwater, and ambient environmental factors in the storage tanks[6,9] (Figure 1). Poor quality water heightens the risk of biofilm development in DUWLs, as environmental aerobic heterotrophs can utilize organic material as a source of nutrition, and develop into a large biomass that is difficult to eradicate, even with disinfectants.[8,9]

DUWLs and tubing

DUWLs are an ideal reservoir for biofilm formation. As mentioned, the narrow tubing diameter, various junction valves and connectors, a high surface-to-volume ratio, and biofilm-friendly materials such as polyvinyl chloride and polyurethane create a favourable breeding ground for microorganisms.[10] Additionally, during operational hours, water flow is intermittent, leading to periods of stagnation. These periods of inactivity allow microorganisms to thrive undisturbed, forming a robust, matrix-encapsulated biofilm that can be resilient to antimicrobials.[8,10]

The microbial contaminants

Apart from the mains water supply, the microbial contaminants in DUWLs can also originate from contamination of bottled water supplies and from the backflow of patients' saliva. Despite the integration of antiretraction valves in dental couplings and dental handpieces that are designed to prevent backflow, issues such as clogging and irregular operation of these can occur, leading to further biofilm development, as additional contaminants enter the system.[11]

Since Blake et al[12] first reported evidence of microbial contamination in dental output water in 1963, researchers have discovered a diverse array of microorganisms in DUWLs. These include oral flora, unicellular algae, bacteria, protozoa, and fungi such as *Candida* spp.,[8] A range of pathogens have also been successfully isolated from DUWL exit water samples, including potential respiratory pathogens such as *Legionella pneumophila*, nontuberculous *Mycobacterium* spp., and *Pseudomonas aeruginosa*, as well as water-inhabiting protozoal organisms such as *Giardia* species and amoebae.[8,13,14] These organisms have an avidity for surface adherence and biofilm development, and the *Mycobacteria*, in particular, may resist common disinfectants.[13]

Infection risks associated with dental unit water lines

Several reports indicate that dentists and their staff, because of their proximity to dental equipment, can inhale airborne droplets of contaminated water from DUWLs.[13] This represents a prolonged, chronic occupational source of exposure to waterborne bacterial aerosols emanating from dental instruments connected to DUWLs.[15-17] Occupational exposure of dental staff was shown in an elegant study by Fotos et al who evaluated the levels of serum antibodies to specific contaminants in dental personnel with over 2 years of clinical experience. Their findings clearly showed that 23% of personnel in the USA had significant quantities of IgG antibodies to *L. pneumophila,* and 19% had IgM antibodies. This was greatly elevated over the community baseline rate of 8% for IgG antibodies for people who were not working in dental clinics.[18] The presence of such antibodies in healthy individuals is not a matter of major concern. However, what is disconcerting is the infection risks associated with highly contaminated DUWL for dental patients with compromised immune systems, such as those with chronic debilitating diseases such as leukemic patients on cytotoxic chemotherapy and immunosuppressed organ transplant recipients.[17,19] In one documented case, an 82-year-old Italian woman succumbed to pneumonia caused by exposure to *L. pneumophila* serogroup 1. Molecular typing substantiated the intimate clonal relationship between the causative strain of pneumonia and the contaminant isolated from the specific DUWL in the dental clinic where she had been treated.[20]

Previous anecdotal reports have also indicated transmission of organisms such as *Pseudomonas* and *Klebsiella* species and associated morbidity in dental patients.[21] A recent meta-analysis of the available data on this subject indicates that *P. aeruginosa* and *L. pneumophila* are the main pathogens isolated from DUWLs, with overall prevalence estimates of 12.0% and 8.0%, respectively.[22] Other opportunistic saprophytes isolated include *Acinetobacter, Methylophilus, Escherichia, Shigella, Streptococcus, and Flavobacterium* species, as well as many nonculturable organisms.

Finally, in this context, it should be noted that the presence of the same organism in a patient sample and the DUWL does not necessarily indicate that the organism originated from the latter source. It is essential that genetic typing is performed to show that the causative organism and the isolate from the DUWL are both of the same genotype. Many anecdotal reports in the literature have claimed disease acquisition by dental patients from DUWLs, but as many of these lack molecular typing to show a cause-and-effect relationship, such reports of illness associated with dental treatment should be treated with caution.

Current approaches for minimizing DUWL contamination

As DUWL contamination is now a well-recognized health hazard, several mechanisms are now available to mitigate bacterial growth in waterlines, and these fall into the following categories.

1. Engineering controls
2. Procedural controls
3. Chemical controls

Engineering controls

Dental units with a separate reservoir and use of pretreated water

The US Centers for Disease Control and Prevention advises that manufacturers equip dental units with an independent reservoir of approximately 1 L. This can then be used to supply sterile, deionized, or distilled water to the dental unit.[23]

In-line-point of use of microbial filters

An alternative engineering technique to enhance water quality is to employ point-of-use microbial filters positioned just before the couplings where instruments are attached. This method can be highly effective; however, it necessitates frequent replacement as these filters tend to rapidly become clogged, thereby contributing to increased maintenance costs.[24,25] Additionally, microbial filters affixed to the water supply line of dental units exert no influence on pre-existing biofilms within the DUWLs.[24]

Various filters for feed in water coming into the dental chair are available, such as simple mesh filters, and activated carbon filters. Feed water can also be drawn from reverse osmosis systems or deionizer systems.[26] Various filters can be integrated directly within the dental unit to lower the risk of contaminants in feed water entering the dental chair's internal piping system.[26] For instance, filters with a pore size of $\leq 0.2\ \mu m$ can trap microorganisms.[27]

Antiretraction valves

Antiretraction valves are built into many high-speed handpieces or their couplings. These are designed to avoid the suck-back of organic material due to a centrifugal suction effect when the handpiece is turned off.[28] When functioning properly, such valves can prevent backflow and subsequent bacterial growth inside the handpiece.[28] However, their effectiveness depends on how well the valves and the handpiece are maintained.[6]

Antistagnation devices

Antistagnation mechanisms maintain continuous water circulation, especially during inactive, nonoperational periods such as weekends and after working hours.[13]

Automated systems for DUWL disinfection

Automated systems offer several advantages over traditional manual disinfection methods, providing continuous disinfection, and ensuring that the water in the DUWLs remains relatively free of microorganisms throughout the day.[25,29] They deliver consistent levels of disinfection, reducing the risk of human error or inconsistency. Additionally, they minimize the need for direct handling of disinfectants, reducing the risk of exposure for dental staff.[29]

Some systems incorporate automated monitoring features, providing real-time data on disinfection levels and water quality. They are generally easy to install and operate, require minimal maintenance from dental staff, and are user-friendly requiring minimal maintenance.[25] However, they still necessitate cost-effectiveness evaluations and continuous monitoring, which are crucial for proper functioning, entailing additional costs and labor.[25,30] Staff need to refill reservoirs that dose the disinfectant into the waterlines.

Contemporary dental units are progressively equipped with automated or semiautomated DUWL cleaning systems, exemplified by technologies such as the Poseidon-S disinfectant system and the Planmeca Waterline Cleaning System.[31] The disadvantages of these automated systems are that they have reduced efficacy against certain types, such as biofilms or spore-forming bacteria.[13] Additionally, the possibility of system malfunction presents a risk of water line contamination and subsequent infection hazards.

A notable issue is the potential overdependence on these technological solutions, which might diminish the focus on manual disinfection practices. These manual practices are essential during periods of system downtime or maintenance.[32]

Moreover, the effectiveness of these systems can be compromised by improper installation or maintenance, often resulting from human error, leading to potential contamination. Consequently, dental staff may necessitate additional training to operate and maintain these systems proficiently.[32,33] Furthermore, dental practices must ensure that their automated disinfection systems comply with local and national regulations, introducing an extra layer of complexity in their adoption and ongoing use. This compliance is crucial to guarantee the safety and effectiveness of the disinfection protocols in dental settings.[32]

Modification of the chemical compositions of tubing and cleaning system

The emerging body of research focuses on creating innovative DUWL tubing, utilizing antimicrobial agents like N-halamine, polytetrafluorethylene, and polyvinylidene fluoride.[34]

Procedural controls

Manual flushing and drying

According to the guidelines from the US CDC and a range of other regulatory bodies, devices connected to waterlines and used intraorally, including handpieces, ultrasonic scalers, and air/water syringes, require a preuse flushing protocol: a minimum of 2 minutes at the start of the day and 20 to 30 seconds before each patient's treatment.[5]

Drying the water lines at the end of each day of operation is generally recommended. This can be done by flushing the lines with compressed air or using a drying agent following the manufacturer's instructions for drying the specific water line system.[35]

While the flushing process does achieve a reduction in microbial density within the output water, it fails to eliminate biofilm.[31] Consequently, this approach should be combined with other methods of microbial control, such as chemicals and electrochemical activation, etc., discussed below to ensure the water quality emitted from DUWLs.[31]

Chemical controls

Several biocides and disinfectants have been used over the last few decades to combat waterline biofilms. These are discussed below.

Several disinfectants in various dilutions have been used for DUWL decontamination. Any such agents for use in dental settings must fit the purpose. They should ideally be (1) cost-effective and (2) possess minimal, if any, adverse effects on the oral tissues of patients, (3) have a low detrimental impact (eg, corrosion, clogging) on the dental unit itself, and finally, (4) minimize environmental pollution.

DUWL biocide formulations commonly integrate multiple antimicrobial agents with a chelating agent like citric acid or EDTA.[31] Literature indicates that products incorporating peroxide compounds, bisbiguanides, and chlorine-based compounds are effective biocides for DUWL decontamination.[31] The application protocols differ, with some necessitating an initial high concentration followed by a sustained application of a reduced concentration, whereas others demand periodic application of the chemical at a higher concentration. This is sometimes referred to as shock treatment.

Of the array of available disinfectants, those with peroxide and chlorine-based compounds have demonstrated superior effectiveness relative to others.[31] Nevertheless, these agents are associated with several undesirable effects, including the potential for dental equipment corrosion, obstruction of DUWL, alteration of the colour of water and equipment surfaces, and minor irritation of oral tissues of patients.[36,37] Moreover, prolonged application of a particular DUWL biocide may result in a preferential overgrowth of certain microorganisms due to a phenomenon known as microbial habituation.[37] As an example, O'Donnell et al[25] observed an enhanced growth of catalase-positive bacteria such as Staphylococci consequent to the extended use of biocides based on hydrogen peroxide.

The frequency of DUWL decontamination also plays a pivotal role in determining the efficacy of various treatment methods. Chemical-based approaches can use either periodic or continuous dosing, with the latter generally being more effective. Continuous treatments prevent biofilm regrowth, but may expose staff and patients to chemicals for extended periods.[32] Intermittent treatments, on the other hand, face issues with microbial recolonization and biofilm regrowth between treatments.[32] Combining periodic low-dose treatments with occasional high-concentration biocidal 'shock treatments' seems most effective.

Recent literature suggests electrochemically activated solutions, plasma sterilization, and iodine cartridges offer satisfactory bactericidal effects with minimal toxicity.[38]

Finally, the likelihood of human error should not be overlooked when applying regular treatment protocols.[13] An example of this is staff handling treatment chemicals with bare ungloved hands. This can cause shed skin bacteria to enter the water system of the dental chair.

Constraints in combating biofilms in DUWLs

Clearly, the engineering and chemical controls discussed above are critical for maintaining a clean water supply for DUWLs. However, these alone are inadequate, and it is crucial to consider the feed water source and quality before implementing any treatment strategies. As mentioned earlier, dental units can utilize water directly from municipal sources or a supplementary storage tank containing mains, distilled, or sterile water.[39] Poor quality water contributes significantly to the likelihood of biofilm formation inside the tubing of dental chair units (DCUs).[40]

The composition of municipal water and its chemical and microbial content are subject to variations based on geographical location, and the extent and effectiveness of water treatment processes implemented by local authorities.[41] Also, the water hardness due to the concentration of dissolved minerals, mainly magnesium and calcium, leads to the accumulation of mineral deposits within the DUWLs and associated control valves. These mineral accumulations augment the internal surface area of the DUWLs, thereby facilitating an increased biofilm formation.[24]

As seen above, many factors contribute to the water quality of DUWLs. Each must be carefully considered when installing a new dental chair, depending on the area's local and regional regulations.

Some recommendations for best practices and regulatory guidelines for DUWL standards

Regional health regulatory bodies and standardized administrative controls:

1. Health and safety legislation:
   Implementing standardized regulatory controls is essential for DCUs, considering they are reusable medical devices, which includes the necessity for premarket clearance (Figure 2).
2. Dental students and dentists' knowledge of DUWL management protocols: Educating dental students and dentists about the types and sources of microorganisms found in dental units and highlighting the potential health dangers associated with the contamination of dental units, including infections and cross-contamination, is important. Enticing the dentists to participate in workshops, seminars, and conferences on infection control regarding DUWL and keeping up with the latest research and developments will contribute to greater awareness of DUWL contamination risks. Both dental students and dentists must have access to the most recent guidelines and advice regarding the decontamination of DUWL. Additionally, it is important for dental professionals to keep track of emerging technology and its potential for use in dental practice scenarios. Encouraging dental students and dentists to report concerns or observations regarding the potential risks or contamination of DUWL can help minimize DUWL-related risks to dental professionals and patients alike. As an example of this, periodic testing of bacteria levels in exit water from DUWL can highlight problems in individual dental chairs.
3. Training of staff involved in DUWLs decontamination: It is advisable to employ simulators or actual dental equipment to enhance the efficacy of training in dental practices for those dental staff involved in DUWL decontamination. This approach fosters a realistic and practical learning environment. It is critical to emphasize the importance of maintaining contemporaneous record keeping, and the need to maintain such records to meet regulatory standards. Therefore, thorough training and certification for dental staff in documenting all DUWL decontamination procedures is crucial. Furthermore, providing standardized templates or electronic systems for easy and standardized documentation can help streamline this process at a unified regional level.
4. Standardized operating procedures for dental hospitals and clinics: Formulating Standard Operating Procedures (SOPs) at a regional level that encompass every facet of DUWL decontamination is strongly recommended. These SOPs should detail the protocols for daily disinfection, periodic disinfection, troubleshooting, monitoring, and recordkeeping. Ensuring that these SOPs are easily accessible to all personnel engaged in DUWL decontamination is vital for maintaining consistency and efficacy in practices. Moreover, it is imperative that regional governing bodies should periodically review and revise these SOPs to align with evolving best practices and regulatory requirements. This continuous process of updating will ensure that the decontamination procedures used remain effective and compliant with current standards.
5. Periodic monitoring microbiological levels in DCU output water for patient safety: Implementing a systematic schedule for monitoring the microbiological quality of DCU output water is highly advisable. While a range of point-of-care test system exist that use bacterial culture or ATP approaches to monitor the quality of DUWL exit water, a laboratory that is certified by the regional regulatory body if preferred for conducting this monitoring, to ensure the accuracy and reliability of results. Maintaining a periodic monitoring log of microbiological levels in water samples and waterline biofilm is crucial for tracking water quality over time. When microbiological levels surpass established acceptable thresholds, prompt corrective actions can then be initiated to mitigate potential health risks and maintain compliance with health and safety standards. This proactive approach is fundamental to ensuring the safety and efficacy of dental practices.
6. Periodic monitoring biocide residues in DCU output water and patient safety: Implementing a structured schedule for assessing biocide residues in DCU output water is also recommended. This again should use an authorized laboratory to guarantee the accuracy of the monitoring process. Furthermore, it is essential to document the results in a periodic monitoring log systematically. This log will serve as a vital tool for tracking the levels of biocide residues over time. Should these residues exceed the predefined acceptable limits, prompt corrective measures can be initiated to uphold water quality integrity and ensure compliance with health and safety regulations.

Fig. 2 – Recommendations for globally standardized strategies for best DUWL maintenance practices in dentistry.

7. Periodic log of adherence to the recommended service life of the DCU by the manufacturer: Maintaining a detailed log of the service dates for each DCU is strongly advised. This log should be regularly reviewed and compared against the manufacturer's recommended service life for each unit. Based on this comparison, servicing appointments can be arranged to ensure each DCU is serviced within the manufacturer's suggested timeframe. Adhering to the manufacturer's recommendations will help maintain the operational efficacy and longevity of the dental chair, thereby ensuring consistent quality of dental care. This proactive approach is crucial for the optimal functioning and maintenance of dental practice infrastructure.
8. Periodic log of adherence to the recommended maintenance of the DCU and its accessories: It is highly recommended to systematically record the maintenance dates for each DCU and its accompanying accessories in a maintenance log and regularly compare these logged dates with the maintenance schedules suggested by the manufacturers. Such a comparison is crucial for identifying any deviations from the recommended timeline. Based on this comparison, the dental clinic can then perform the necessary maintenance activities on their fleet of dental chairs and their accessories as required. This practice ensures adherence to manufacturer guidelines and promotes the longevity and optimal functioning of the dental equipment, which is essential for delivering high-quality dental care.

Conclusion

In conclusion, decontaminating DUWLs is vital to ensure the safety of both patients and dentists. Dynamic and consistent water quality evaluation is essential to mitigate biofilms and microbial proliferation in DUWLs that contribute to waterborne infections in dental environments. Adopting a comprehensive approach that combines physical, chemical, and automated methodologies is recommended to effectively decontaminate DUWL biofilms, according to the standard legislative compliance requirements. Finally, a thorough knowledge of the subject described above by all dental personnel, including students, dentists, and dental staff, is imperative for upholding high standards of dental practice. Additionally, compliance with regional and national regulations about DUWL decontamination is a legal obligation and fundamental to protecting public health. Such adherence maintains the confidence and safety of those receiving dental care.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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