Medicine®

OPEN

A program to improve the quality of dental unit water in a medical center

Su-Ping Chang, RN[a], Hui-Li Jiang, RN[a], Yun-Cheng Wang, RN[a], Hui-Chen Chao, MT[b], Jen-Jyh Lee, MD[a], Hui-Chun Chung, RN[c], Lih-Shinn Wang, MD[a], Dah-Ching Ding, MD, PhD[d,e,*]

Abstract

The water quality of dental unit waterlines (DUWLs) is associated with patient safety. No program for DUWL water quality improvement has been formulated since the time they were established 20 years ago. This study provides an improvement program for the quality of dental unit water. The improvement program was implemented step by step: discharge of DUWLs for 5 minutes in the morning before clinical service to flush out the water left in the pipeline overnight; weekly disinfection of the handpiece connector with 75% alcohol and replacement of the old connector when the water quality of the same dental chair unit (DCU) was continuously found to be unqualified; monthly disinfection of the water supply system and pipeline; and establishment of DCU maintenance work standards and staff education and training. From 2016 to 2018, the water quality of 18 DCUs was tested by microorganism culture. The colonies >200 colony forming unit were categorized as unqualified. This program was divided into a pre-test phase, Phase 1, a maintenance phase, and Phase 2. A Chi-square test was used to calculate the difference of unqualified water quality numbers between each phase of the improvement program. In the pre-test phase, the water quality rate (high quality number/high-quality number + low-quality number) was 58.3%. In Phase 1, the quality rate before and after the intervention was 64.8% (35/54) and 92.2% (83/90) (P < .001), respectively. After Phase 1, the quality rate reached 100%. However, the quality rate dropped to 75% during the maintenance phase. Then, we proceeded into Phase 2 of the improvement program by further monthly disinfection to DUWLs. In Phase 2, the quality rate was 62/73 (84.9%) and improved to 142/144 (98.6%) after the intervention (P < .001). The quality rate reached 100% once again and was maintained at 100% thereafter. In conclusion, the 4 steps of the improvement program improved the water quality of the DUWL, which is important for patient safety.

Abbreviations: ADA = American Dental Association, CDC = Centers for Disease Control and Prevention, CFU = colony-forming unit, DCU = dental chair unit, DUWLs = dental unit waterlines, RO water = reverse osmosis water.

Keywords: dental chair, dental unit waterlines, disinfection, improvement, water quality

[a] Department of Infection Prevention and Control, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, and Tzu Chi University, Hualien, Taiwan, [b] Department of Laboratory Examination, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, and Tzu Chi University, Hualien, Taiwan, [c] Department of Nursing, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, and Tzu Chi University, Hualien, Taiwan, [d] Department of Obstetrics and Gynecology, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, and Tzu Chi University, Hualien, Taiwan, [e] Institute of Medical Sciences, Tzu Chi University, Hualien, Taiwan.

* Correspondence: Dah-Ching Ding, Department of Obstetrics and Gynecology, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Foundation, No. 707, Chung-Yang Rd., Sec. 3, Hualien 970, Taiwan (e-mail: dah1003@yahoo.com.tw).

1. Introduction

The dental unit waterline (DUWL) supplies all instruments attached to the dental chair unit (DCU) such as tri-purpose spray guns, high- and low-speed handpieces, and ultrasonic cleaning machines. These intricate waterlines are susceptible to microbial biofilm contamination.[1] The US Centers for Disease Control and Prevention mentioned the microorganisms present in DUWLs may be undermining dental care by introducing infection directly into the patient's mouth during surgery.[2]

As DUWLs are complex and narrow, water remaining in the pipeline for a long time, a low flow rate, valve failure, or an unclean water supply system may all contribute to the promotion of bacterial growth and biofilm formation.[1] The formation of over 40 microorganisms, such as oral Streptococci, *Pseudomonas* spp., Enterobacteria, *Candida albicans*, *Legionella pneumophila*, and nontuberculous mycobacteria, have been confirmed in DUWLs. There is no epidemiological evidence that the presence of these microbes in the pipeline causes is a public health hazard but the presence of these microorganisms in environmental water is potentially pathogenic for immunocompromised patients.[3–7]

In June 2016, the Taiwan Department of Health and Welfare announced the guidelines for dental infection control.[8] No program for DUWL water quality improvement has been formulated since the time they were established 20 years ago. Therefore, the aim of this study was to develop a program to improve the quality of water used in dental care.

2. Methods

2.1. Ethical issues

This study did not require approval from the research ethics committee because no human subject was involved.

2.2. Setting

There were 18 DCUs in the dental department. The water from the water plant was rich in calcium carbonate, which might damage dental instruments following long-term use. To avoid this, the hospital used an reverse osmosis water (RO water) storage tank and supplied water through pipes to the DCUs. However, our hospital had not been following any program for promoting water quality in DUWLs since their establishment 20 years ago. Water quality may influence patients' decision to seek dental care. Therefore, we set up a program to survey and improve the water quality of DCUs.

2.3. Water quality improvement program

The improvement program was implemented step by step: discharging the DUWLs for 5 minutes in the morning before clinical service to flush out the water left in the pipeline overnight; weekly disinfection of the handpiece connector with 75% alcohol and replacing of the old connector when the DCU water quality was continuously unqualified; monthly disinfection of the water supply system and pipeline; and establishing DCU maintenance work standards and staff education and training.

The main factors that led us to determining the specific interventions above were as follows: originally, the dental care staff only discharged DUWLs for 1 minute before the daily service; however, the DUWLs extended far from the RO water tank and therefore, there was risk of contamination. Hence, we suggested that they discharge water for 5 minutes; we found 2 connectors too old to clean; therefore, we suggested replacing them; the water supply system requires regular disinfection; we therefore suggested a monthly disinfection; and new work standards need to be established and staff education and training is required for familiarization with the standards.

2.4. Surveillance on water quality improvement program

From 2016 to 2018, the water quality of 18 DCUs was tested. The pre-test was performed before intervention twice, at 2 different points of time. If low water quality was detected, we would proceed to phase 1 of the improvement program, including the above mentioned strategies. After reaching the high-quality standards, the monitored program would go into maintenance phase. If water quality was low-quality during this phase, the improvement program would proceed to phase 2, with the addition of new improvement strategies. It was expected that water quality would reach high-quality standards after the phase 2 improvement program was implemented.

2.5. Monthly DUWLs disinfection method

The monthly DUWLs disinfection method followed was as below.

After filling water tank with approximately 500 l of RO water, 500 ml of 6% sodium hypochlorite was added.[9] The final disinfectant concentration was >50 parts per million. The mixture was discharged through the dental unit cup filler and the handpiece connectors of 18 DCUs together for 2 to 3 hours. Then, the pipeline was flushed with fresh RO water for 2 to 3 hours. Finally, the pipeline was tested with diethyl benzene for residual chloride in RO water (normal limit of chloride <0.1 parts per million) [10]. The disinfection procedure was conducted between 8 AM and 2 PM on Sunday.

The infection control staff collected water samples from the dental clinic every month. The culture results of the water samples were presented in the infection control meeting, where doctors, lab staff, infection specialists, and nurses discussed the results and considered the next improvement strategy.

Dental care personnel training was provided by the infection control staff. The new standards were established and the equipment disinfection method was taught after implementing the strategies.

2.6. Samples collection in the clinic

Water was sampled from all 18 DCUs, including 2 sampling sites, the hi-speed handpiece connector and the dental unit cup filler.

2.7. Sample collection

Water samples were taken before clinical service began in the morning. The standard sampling procedures for DUWLs were as follows: dry hand sanitizer was used to clean the hands; latex gloves were worn; sterile cotton swabs were used to disinfect the handpiece connector and inner wall of the cup filler. The clean range can be as extensive as possible; and after disinfection, the water flow was released for a few seconds. We then collected 5 to 10 ml of RO water in a sterile sample container for microorganism culture. No neutralizer was added, as our residual chloride content in RO water was very low.

2.8. Microbial culture and identification

The water samples were sent to the laboratory immediately after collection. We used a dropper to suck 1 ml into the Tryptic Soy Agar (Becton Dickinson, BD Difco Tryptic Soy Agar) and placed the agar in the 35°C CO_2 incubator for 48 hours to grow the microorganisms. The number of colony forming units (CFU) per ml was counted.[11] If colonies were >200 CFU/ml, we performed microbial identification using the BD Phoenix 100 automated identification and susceptibility testing system.[12]

Since RO water from the Hemodialysis Unit was used as dental water, the microbiological requirements of water from a DUWL were equal to previous AAMI Microbiological Standards for Dialysis Water [heterotrophic plate count levels <200 CFU/ml]. If colonies were >200 CFU/ml, it was regarded as a low-quality water.

2.9. Statistical analysis

Chi-square tests were used to examine the quality rate of the pre-test results as well as the following phases' tests. The quality rate was calculated as: (high-quality number/high-quality number + low-quality number). All statistical analyses were performed using SAS 9.4 software (SAS Institute Inc., Cary, NC). $P < .05$ was considered statistically significant.

Table 1

Surveillance outcomes of dental department water quality at the dental department of Tzu Chi Hospital from December 2016 to February 2018.

Phase	Pre-test 1	Pre-test 2	Phase 1		Maintenance phase		Phase 2			
Date of surveillance	12/19/2016	2/21/2017	3/16/2017	4/14/2017	6/2/2017	7/11/2017	9/28/2017	12/4/2017	1/9/2018	2/2/2018	2/27/2018
Date of DUWLs disinfection			3/11/2017				9/24/2017	11/26/2017	12/31/2017	1/28/2018	2/25/2018
No. of samples	36	18	18	36	36	37	36	36	36	36	36
No. of high-quality samples	21	14	14	33	36	35	27	34	36	36	36
Quality rate (%)	58.3	77.8	77.8	91.7	100	94.6	75.0	94.4	100.0	100.0	100.0

3. Results

3.1. Before implementation of the improvement program

In December 2016, the surveillance quality rate in pre-test 1 was only 58.3% (Table 1). In February 2017, the inspection of pre-test 2 was performed again following the extension of the water release time to at least 3 minute, resulting in a quality rate of 77.8% (Table 1). Because these 2 consecutive inspections had a poor-quality rate, we proceeded with the phase 1 implementation of the improvement program.

3.2. After implementation of the improvement program

The improvement program was implemented from March, 2017 (phase 1) to February, 2018 (phase 2). It was divided into phase 1, the maintenance phase, and phase 2.

3.2.1. Phase 1 (March-June, 2017). As shown in Table 1, on March 11, 2017, the first round of DUWLs disinfection began. On March 17, the water quality rate was 77.8%. In an effort to improve the quality rate, we used 75% alcohol to disinfect the handpiece connector. On April 14, the quality rate was 91.7%. Because the water quality of the same DCU was continuously low-quality, the old handpiece connector was replaced. In addition, we increased the water discharge volume and extended the discharge time of the pipeline. These interventions resulted in a quality rate of 100% on June 2.

3.2.2. Maintenance phase (July-October, 2017). After the implementation of the relevant measures in phase 1, the quality rate on July 11 showed a reduction from 100% to 94.6% (Table 1). Thereafter, the second round of DUWLs disinfection was performed on September 24, and the quality rate after the disinfection of pipelines was only 75% on September 28. The DUWLs disinfection interval was speculated to be too long to prevent recurrent microbial growth. The phase 2 improvement program was initiated.

3.2.3. Phase 2 (November, 2017-February, 2018). From November 26, 2017, the monthly DUWLs disinfection was performed consecutively for 4 months. The quality rates for each month were 94.4%, 100%, 100%, and 100%, respectively (Table 1). Thereafter, the DUWLs disinfection was performed on a monthly basis, and the quality rate remained at 100% in August 2018 (data not shown).

3.3. Bacteria strains identified

The water from the DCULs contained strains of *Sphingomonas paucimobilis*, *Ralstonia pickettii*, *Alcaligenes faecalis*, *Coryne-bacterium* spp., *Pseudomonas* spp., *Brevundimonas vesicularis*, *Delftia acidovorans*, *Comamonas testosteroni*, *Ochrobactrum anthropi*, and coagulase-negative staphylococci.

3.4. The extent of the contamination found

Two DCUs contaminated with bacteria were found. Because the high-speed handpiece connector of the 2 DCUs was old and dirty, the 2 old handpiece connectors were replaced. After that, the positive bacteria cultures randomly appeared among the DCUs.

3.5. Statistics on water quality improvement

Table 2 shows the comparison of water quality before and after intervention. In phase 1, the low-quality number vs high-quality number before the intervention was 19 vs 35 (quality rate was 35/54, i.e., 64.8%); and after the intervention was 7/83 (quality rate was 83/90, i.e., 92.2%). The Chi-square test showed a statistically significant P value ($<.001$). In phase 2, the low-quality number vs high-quality number in the maintenance period was 11 vs 62 (quality rate was 62/73, i.e., 84.9%), improving to 2 vs 142 (quality rate was 142/144, i.e., 98.6%) after the intervention (P value $<.001$).

Table 2

The comparison of water quality before and after intervention of the improvement program at the Dental Department of Hualien Tzu Chi Hospital.

	Phase 1			Phase 2		
	Before	After	P value[*]	Before	After	P value[*]
Low-quality number	19	7	<.001	11	2	<.001
High-quality number	35	83		62	142	
Quality rate (%)	64.8	92.2		84.9	98.6	

Quality rate = high-quality number/(high-quality number + low-quality number).
[*] Chi-square test. P values <.001 were considered statistically significant.

The intervention and its effect on water quality in the phases of the improvement program.

	Pre-test	Phase 1	Maintenance phase	Phase 2
Interventions began Date	2016/12/19	2017/3/16	2017/7/11	2017/12/4
DUWLs disinfection	Nil	Once	Nil	Monthly
Change handpiece connector	Nil	Change 2 handpiece connectors	Nil	Nil
Clean handpiece connector	Nil	Weekly	Weekly	Weekly
Drainage water	Nil	Daily	Daily	Daily
Education	Nil	Done	Done	Done
Surveillance	Monthly	Monthly		Monthly
Quality rate	58.3% to 77.8%	77.8% to 100%	94.5% to 75%	94.4% to 100%

3.6. The intervention methods used in each phase

Table 3 shows the intervention and its effect on quality rate in the phases of the improvement program. The interventions of the improvement program included DUWLs disinfection, changing of the handpiece connector, cleaning of the handpiece connector, draining water, education, and surveillance. Results demonstrated that the intervention increased the quality rate.

4. Discussion

On surveillance, the quality rate was only 58.3% prior to the intervention (Table 1). After phase 1 of the improvement program, the quality rate reached 100%. However, the quality rate dropped to 75% after 3 months (Tables 1 and 3). Then, phase 2 of the improvement program was initiated by implementing monthly DUWLs disinfection. The quality rate reached 100% again and the water quality was maintained thereafter.

Several factors can influence the water quality of DUWLs,[13] such as usage of effective DUWL treatment agents, improved water quality supply to DCU, improved the design of DCU, and developed automated DUWL treatment procedures.[13] The reasons for only 58.3% of samples being high-quality in the pre-test stage may be: Taiwan's dental water quality monitoring standards have not been clearly defined; a biofilm might exist in the pipeline, resulting from insufficient discharge time and water output, thereby incompletely purging the waterway; the machine was old, so that the pipeline could not be renewed; further, the handpiece connectors were not cleaned and had visible dirt; and the relevant standard operating procedures had not been established. Therefore, the improvement program was planned accordingly.

A surveillance protocol (every 6 months) and standard cleaning procedure for DUWL had been established in a previous study.[14] They concluded that the local protocols are adequate but dental students could not follow the standard protocol to improve the water quality. A survey also showed only 2.6% of dental offices in Eastern Frances had a microbial surveillance program.[15] They concluded that it is necessary to provide better training to dental staff regarding measures to improve DUWL water quality. Using 5 disinfectants for 4 weeks could effectively reduce the microbial colony count of DUWLs and the DUWL contamination rates.[16] This conforms to our study outcome, wherein the surveillance and improvement programs effectively improved the water quality of DUWLs.

The other reason for water contamination might be RO water. Because RO water has no residual chlorine, it cannot inhibit or eliminate bacterial growth. Once the bacteria have adhered to the inner wall of the RO water delivery line, it is easy to form a biofilm.[17] Previous studies have mentioned that regular disinfection and maintenance of dental tubing can effectively reduce the potential risk of microbial infection of DUWLs.[18] The cause of bacterial contamination of DUWLs may be the biofilm contamination of the RO water delivery pipeline. For the RO water delivery pipeline, it was recommended to choose a polyvinylidene fluoride material that did not allow easy breeding of bacteria and was chemically resistant, since it would be used for a long time without accidental contamination.[17] Because our hospital was unable to completely replace the pipes with a polyvinylidene fluoride-material, the above program was implemented along with the monthly disinfection of pipelines and reservoirs. These procedures resulted in the quality rate reaching 100%. However, there was no verification checklist in place. In the future, the audit protocol should be included in the operating standards.

In 1995, the American Dental Association (ADA) set the target of $<200\,CFU/ml$ for water quality in DUWLs. This was revised to $<500\,CFU/ml$ as per Centers for Disease Control and Prevention recommendations in 2004, while Taiwan regulations stipulate a maximum limit of $100\,CFU/ml$ as the drinking water standard.[19–21] Arvand and Hack (2013) recommend that water quality monitoring standards should be formulated according to the recommendations of the hospital or the government. The ADA recommends DUWLs maintenance and water quality to be maintained according to the manufacturer's recommendations.[4] In our study, the ADA standard to examine the water quality of DUWLs ($<200\,CFU/ml$) was adopted.

Many different types of bacteria could be found in the culture of DUWL water. One study showed Pseudomonas was found in the DUWL pipeline that may be harmful to cystic fibrosis patients.[22] Another report showed *Legionella* and *Mycobacterium* spp. were found in DUWL that may be harmful to immunocompromised dental patients.[23] One recent report also revealed several kinds of gram (+) and gram (−) bacilli were found in DUWL.[11] In the study, the most detected gram (−) bacilli were Burkholderiaceae, Pseudomonadaceae, Ralstoniaceae, and Sphingomonadaceae. The most prominent bacteria were *R pickettii*. The most gram (+) bacilli found were *Brevibacterium* and *Actinomyces* spp.[11] The bacteria strains found in our study were consistent with the above studies.

In this study, we used 6% sodium hypochlorite to disinfect the DUWL. However, the impact of chlorination on equipment function was not evaluated due to dental units used for more than 20 years. No company was held responsible for the regular maintenance of the equipment. In the future, using ClO_2 to

disinfect the DUWL will be considered to prevent possible damage of the equipment.[24]

Although this study did not require the approval of the research ethics committee due to no human subject involvement, the results of this study will affect patient safety. During dental treatment, the patient's and doctor's wellbeing is a major concern. Infectious diseases, incidents, and radiation tend to be exposed during the treatment.[25] Therefore, control of infection is important for dental care.[26] Maintaining dental water quality is one of the methods for infection control. Therefore, the implementation of a dental water quality improvement program will have an implication on patients' safety, such as avoiding water borne infection.

5. Conclusion

After the implementation of the improvement program by water drainage before service and cleaning the handpiece connector regularly and the monthly disinfection of the RO water pipe, the water quality rate reached 100%. It is expected that other hospitals can set their in-house standard according to their regional water characteristics, utilizing the improvement measures provided in this study, to formulate standard procedures for monitoring and operation to improve dental water quality and maintain patient health and safety.

Acknowledgments

We thank Dr. Jon-Son Kuo for English editing.

Author contributions

SPC, HLJ, YCW, LSW, and DCD designed the study; SPC, HLJ, YCW, and HCC performed study; SPC, HLJ, YCW, and DCD analyzed the data; JJL, HCC, LSW, and DCD supervised the project; all authors wrote and gave approval of the manuscript.

Data curation: Su-Ping Chang, Hui-Li Jiang, Yun-Cheng Wang, Hui-Chen Chao.

Formal analysis: Su-Ping Chang, Hui-Li Jiang, Yun-Cheng Wang, Hui-Chen Chao.

Investigation: Su-Ping Chang.

Methodology: Su-Ping Chang.

Supervision: Jen-Jyh Lee, Hui-Chun Chung, Lih-Shinn Wang, Dah-Ching Ding.

Validation: Jen-Jyh Lee, Hui-Chun Chung, Lih-Shinn Wang, Dah-Ching Ding.

Visualization: Lih-Shinn Wang, Dah-Ching Ding.

Writing – original draft: Su-Ping Chang, Dah-Ching Ding.

Writing – review & editing: Dah-Ching Ding.

References

[1] Ji XY, Fei CN, Zhang Y, Zhang W, Liu J, Dong J. Evaluation of bacterial contamination of dental unit waterlines and use of a newly designed measurement device to assess retraction of a dental chair unit. Int Dent J 2016;66:208–14.

[2] Kohn WG, Harte JA, Malvitz DM, et al. Guidelines for infection control in dental health care settings–2003. J Am Dent Assoc 2004;135:33–47.

[3] Hsueh PR, Teng LJ, Pan HJ, et al. Outbreak of Pseudomonas fluorescens bacteremia among oncology patients. J Clin Microbiol 1998;36:2914–7.

[4] American Dental Association. Oral Health Topics: Dental Unit Waterlines. American Dental Association. 2018.

[5] Hatzenbuehler LA, Tobin-D'Angelo M, Drenzek C, et al. Pediatric dental clinic-associated outbreak of Mycobacterium abscessus infection. J Pediatric Infect Dis Soc 2017;6:e116–122.

[6] Ricci ML, Fontana S, Pinci F, et al. Pneumonia associated with a dental unit waterline. Lancet 2012;379:684.

[7] Schönning C, Jernberg C, Klingenberg D, et al. Legionellosis acquired through a dental unit: a case study. J Hosp Infect 2017;96:89–92.

[8] Centers for Disease Control. Guidelines for infection control in dentistry. Centers for Disease Control. June 15 2016.

[9] Kalantari MH, Malekzadeh A, Emami A. The effect of disinfection with sodium hypochlorite 0.5% on dimensional stability of condensation silicone impression materials of speedex and irasil. J Dent 2014;15:98–103.

[10] Cai X, Han JC, Li R, et al. Effect of several factors on pseudo-kinetics in chlorine disinfection of phage MS2. Desalin Water Treat 2016;57:4974–81.

[11] Szymańska J, Sitkowska J. Bacterial contamination of dental unit waterlines. Environ Monit Assess 2013;185:3603–11.

[12] Coulliette AD, Arduino MJ. Hemodialysis and water quality. Semin Dial 2013;26:427–38.

[13] Coleman DC, O'Donnell MJ, Shore AC, Russell RJ. Biofilm problems in dental unit water systems and its practical control. J Appl Microbiol 2009;106:1424–37.

[14] Volgenant CMC, Persoon IF. Microbial water quality management of dental unit water lines at a dental school. J Hosp Infect 2019;103:e115–117.

[15] Baudet A, Lizon J, Martrette JM, Camelot F, Florentin A, Clément C. Dental unit waterlines: a survey of practices in Eastern France. Int J Environ Res Public Health 2019;16:4242.

[16] Pawar A, Garg S, Mehta S, Dang R. Breaking the chain of infection: dental unit water quality control. J Clin Diagn Res 2016;10:80–4.

[17] Molk DM, Karr-May CL, Trang ED, Sanders GE. Sanitization of an automatic reverse-osmosis watering system: removal of a clinically significant biofilm. J Am Assoc Lab Anim Sci 2013;52:197–205.

[18] Lin SM, Svoboda KKH, Giletto A, Seibert J, Puttaiah R. Effects of hydrogen peroxide on dental unit biofilms and treatment water contamination. Eur J Dent 2011;5:47–59.

[19] Environmental Protection Administration. Drinking water quality standards. Environmental Protection Administration. January 10 2017.

[20] Bowen CG, Greenwood W, Guevara P, Washington MA. Effectiveness of a dental water waterline treatment protocol with A-Dec ICX and citrisil disinfectants. Mil Med 2015;180:1098–104.

[21] Lizon J, Florentin A, Martrette JM, Rivier A, Clement C, Rabaud C. Microbial control of dental unit water: feedback on different disinfection methods experience. Am J Infect Control 2016;44:247–9.

[22] Pankhurst CL, Philpott-Howard J. The environmental risk factors associated with medical and dental equipment in the transmission of Burkholderia (Pseudomonas) cepacia in cystic fibrosis patients. J Hosp Infect 1996;32:249–55.

[23] Pankhurst CL, Johnson NW, Woods RG. Microbial contamination of dental unit waterlines: the scientific argument. Int Dent J 1998;48:359–68.

[24] Dallolio L, Scuderi A, Rini MS, et al. Effect of different disinfection protocols on microbial and biofilm contamination of dental unit waterlines in community dental practices. Int J Environ Res Public Health 2014;11:2064–76.

[25] Leggat PA, Kedjarune U, Smith DR. Occupational health problems in modern dentistry: a review. Ind Health 2007;45:611–21.

[26] Aziz AAAA, Hasnan SN, Jamil SA, Mohamad AH, Abdullah S, Alias A. Study of microbial contamination in dental unit water line: a clinical implication. IOSR J Dent Med Sci 2017;16:63–6.