


BMJ Open Quality **Managing dental unit waterlines: a quality improvement programme**

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ABSTRACT

The presence of bacterial biofilms within dental unit waterlines (DUWLs) can cause secondary bacterial infections in immunocompromised patients. As a result, the management of biofilms within waterlines has always concerned medical and dental professionals. In February 2020, an internal audit identified the high bacterial counts within the DUWLs at the Aga Khan University Hospital, Karachi and this paper discusses a pragmatic approach to improving the water quality of DUWLs.

A three-person committee was developed and the area for improvement was identified as the contaminated DUWLs. Distilled water samples from two dental units were first assessed as baseline in July 2020. The process changes were then implemented which included daily flushing of the dental unit waterlines and 'shock treatment' using A-dec ICX capsules. Subsequently, the units were tested after intervention on 24 August 2020 and water from all 16 dental units assessed on 20 November 2020 and again on 22 April 2021.

The samples from all the dental units assessed showed marked reduction in bacterial counts and compliance with the Centers for Disease Control guidelines after intervention. All the dental units showed minimal bacterial counts; however, a slightly low pH was noted in the final round of water testing.

DUWLs are heavily contaminated with microbes and pose potential risk both to the patient as well as the DHCPs. This study suggests that chemical disinfection using A-dec ICX tablets and flushing as an effective method of reducing the bacterial load in DUWLs.

PROBLEM

Almost all dental procedures revolve around the dental unit, which requires an uninterrupted water supply to function effectively.¹ The water is delivered from a reserved source through a complex arrangement of narrow bore tubes called dental unit waterlines (DUWLs). These tubes have a narrow diameter, high surface area and undergo periods of water stagnation when the unit is not used, which may facilitate the growth of microorganisms and lead to the formation of a biofilm.² Biofilms are microbial communities that adhere to solid surfaces wherever there is sufficient moisture.² In DUWL, these biofilms reside within the lumen of the tubes and contain a plethora of microorganisms including *Pseudomonas* spp, *Mycobacterium* spp and *Legionella pneumophila*.³ It is noteworthy

WHAT IS ALREADY KNOWN ON THIS TOPIC?

- ⇒ The risk of bacterial infections as a result of contaminated dental unit waterlines (DUWLs) is well documented in the literature.
- ⇒ Although the disinfection of DUWLs has been described previously, there is a lack of clarity regarding the process of disinfection and maintenance of DUWLs.

WHAT THIS STUDY ADDS?

- ⇒ This study provides a template for the baseline measurement, disinfection and maintenance of water quality in DUWLs from the perspective of dental practitioners and quality improvement teams.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY?

- ⇒ The use of Plan-Do-Study-Act cycles provide a comprehensive guide for the management of contaminated DUWLs, which can help dental practitioners provide safe patient care.
- ⇒ Moreover, the detailed description regarding the process of team work and staff training to achieve these results can help quality improvement and hospital management teams in developing policies for the maintenance of DUWLs.
- ⇒ This study also opens area for further research regarding the cost-effectiveness of the type of water used within DUWLs.

that during the use of a dental unit, part of the biofilm may be transferred to the patient, or be expelled into the air through a hand piece, increasing risk of infections for both patients and dental practitioners.² Additionally, the use of rotary instruments creates back pressure which allows a retrograde flow of fluids from the oral cavity into the DUWL, which may be expelled onto the next patient.^{2,3}

The issue of DUWL quality was first highlighted by G.C Blake in 1963.⁴ This was followed by the Center of Disease Control (CDC) in 1993 and the American Dental Association (ADA) in 1996.⁵ As a result, since 2003 the CDC has recommended that all dental units produce water that meets drinking water standards (bacterial count less than 500 mL/L CFU) for non-surgical procedures.⁶ The CDC suggests systems to maintain



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the water quality, which includes the use of anti-retraction valves to prevent backflow of oral fluids into the DUWL, along with flushing the waterlines at the start of the day and in between patients is advised by the CDC.⁶ Moreover, chemical disinfection of DUWL has also proven to be a sustainable method to reduce bacterial counts.⁶ However, the gold standard for the maintenance and surveillance of water quality in a dental clinic setting is yet to be determined.⁷

MEASUREMENT

To understand the quality of water supplied in our hospital, the Aga Khan University Hospital (AKUH), an internal audit collected baseline samples of potable water (tap water) from three different locations within the hospital, on 7 July 2020. It was found that of the three samples assessed, high bacterial counts were evident only in the sample taken from the dental clinic building, which did not comply with the JCI standards.

The Dental Clinics at AKUH comprise of 16 dental operatories, and offer outpatient multispecialty dental services, including restorative dentistry, endodontics, paediatric dentistry, orthodontics, oral surgery and periodontology. Being a tertiary care hospital, our dental patient population also includes patients who are immunocompromised, undergoing chemotherapy and/or with complex comorbidities. Therefore, the high bacterial counts raised concerns regarding dental care safety, and a quality improvement (QI) programme was initiated. A three-person quality improvement committee (QIC) was established, comprising of the service line chief, business manager and quality representative, to address the following objectives:

1. To measure baseline quality of the water reservoir and DUWL.
2. To perform chemical treatment on DUWL in concordance to manufacturer's guidelines and maintain the water quality through Plan-Do-Study-Act (PDSA) cycles.
3. To ensure a sustainable method of improving dental care safety by improving compliance to JCI standards 10.3, ME 5.

DESIGN

During an internal review, the results of these baseline measurements were discussed among the QIC and shared with the dental assistant supervisor (DAS). The aforementioned objectives were discussed and concerns were raised over the inconsistency of potable water, which was linked with high bacterial counts during the monsoon season. Alternatively, it was suggested that distilled water be purchased from a vendor to be used in the DUWLs since this water is already tested by the vendor. The team also discussed the comparative cost of each water source, along with the cost of water testing. The CDC requires water testing to be carried out four times each year for potable water, which is reduced to twice a year if distilled

water is used. However, despite the reduced water testing for distilled water a cost-benefit analysis revealed the total cost of using distilled water would be 0.72 million per year, compared with 0.54 for potable water, due to the added expense of purchasing distilled water.

Despite the added cost of using distilled water, the QIC decided that only distilled water should be used within the DUWLs, since this water is already tested by the vendor. Moreover, potable water shows high variability according to seasonal changes, making continuous assessment challenging. Therefore, the distilled water was to be assessed from its main source as supplied by the vendor, and when dispensed through dental unit 2. The DAS was assigned to overlook the water testing and disinfection process within this room and collaborate with the QIC accordingly.

APPROVAL

This quality improvement project was approved by the chief medical officer (CMO) responsible for quality improvement programmes at AKUH.

STRATEGY

For this QI programme, a PDSA cycle approach was selected to develop a disinfection and maintenance protocol for the DUWLs. We aimed to reduce the bacterial counts of the DUWL and assess their maintenance using consecutive PDSA cycles, which are summarised in table 1.

Our first objective was to measure the baseline quality of the water reservoir and DUWL, which was addressed in the first PDSA cycle. Samples of distilled water were collected after distilled water was dispensed from the units in the dental clinics by a trained ERC (Environmental Research Centre) representative, in a sterile airtight container and delivered to the ERC (Department of Earth and Environmental Sciences) at Bahria University, within 24 hours. The water quality was assessed according to 12 parameters, as shown in table 2. The first sample contained distilled water taken from the tri-syringe of the dental unit, with distilled water, after allowing water to run for the first 60 s. High bacterial counts were noted in this sample, and therefore, another sample was taken directly from the source of distilled water. Table 2 compares the two samples and highlights that the distilled water only shows high bacterial counts when dispensed through the dental unit. Thereafter, *the area for improvement was identified as the contaminated DUWLs.*

Our second objective was to perform chemical treatment on DUWL in concordance to manufacturer's guidelines and maintain the water quality through PDSA cycles. Each dental unit has a two 2-litre self-contained water bottle and the manufacturers recommend placing one tablet per 2-litre bottle for optimum concentration. This has been described in the second PDSA cycle, where dental unit 2 was disinfected using an ICX effervescent tablets (A-dec ICX). Additionally, 'flushing' of water from the unit was carried out for 2 min every morning and

Table 1 PDSA (Plan-Do-Study-Act) cycles summarising the process of disinfection and maintenance of DUWL

| Cycle No. | Plan | Do | Study | Act |
|-----------|--|--|---|---|
| 1 | To assess distilled water from its main source and the DUWL | <ul style="list-style-type: none"> ▶ Distilled water was tested after being dispensed through the dental unit (room 2) ▶ The distilled water supply was then tested directly from the main source | <ul style="list-style-type: none"> ▶ The distilled water source showed bacterial counts within the acceptable range ▶ The same water showed high bacterial counts once dispensed through the DUWL (table 2) | The source of contamination was identified as the contaminated DUWLs and not the source of distilled water |
| 2 | To assess the effectiveness of the suggested disinfection protocol | <ul style="list-style-type: none"> ▶ ICX disinfection tablet was used in DUWL of room 2 every 15 days ▶ Water from the dental unit was flushed for 2 min each morning and 30s between patients | <ul style="list-style-type: none"> ▶ Bacterial counts reduced within 1 month of the disinfection protocol (table 3) | The suggested disinfection protocol was effective for one dental unit |
| 3 | To assess generalisability | <ul style="list-style-type: none"> ▶ The DAS briefed all the dental assistants on the disinfection protocol | <ul style="list-style-type: none"> ▶ The remaining DUWLs showed reduced bacterial counts and compliance with the JCI standards (table 3) | The same disinfection protocol was effective on all the dental units |
| 4 | To assess the sustainability and compliance of this protocol | <ul style="list-style-type: none"> ▶ Water was sampled 6 monthly, from each dental unit ▶ A logbook accounting for daily flushing and shock treatment every 15 days was assigned to each assistant | <ul style="list-style-type: none"> ▶ At 6 months, the reduced bacterial counts were maintained (table 3) ▶ All of the dental assistants complied to the suggested disinfection protocol | The suggested protocol was deemed sustainable. However, the cost-effectiveness of this protocol was identified as an area for further improvement |

DAS, dental assistant supervisor; DUWL, dental unit waterline; QIC, quality improvement committee.

for 30s in between patients. Table 3 compares the water samples that were taken before and after the aforementioned treatment, on dental unit 2. It is noteworthy that

Table 2 Water testing of dental unit water (dental room 2) using distilled water and distilled water supplied by vendor

| Parameters | SSDWQ | Dental room 2 (DW) 21 July 2020 | Main source (DW) 24 August 2020 |
|---|--------------|---------------------------------|---------------------------------|
| Total coliform (cfu ¹) | 0 cfu/100 mL | >5000 | <1 |
| Faecal coliform (cfu ¹) | 0 cfu/100 mL | >1700 | <1 |
| <i>Escherichia coli</i> (cfu ¹) | 0 cfu/100 mL | >500 | <1 |
| Colour (TCU ²) | ≤15.0 | <0.1 | <0.1 |
| Taste | N/O | N/O | N/O |
| Odour | N/O | N/O | N/O |
| Turbidity (NTU ³) | <5.0 | 8.93 | 0.75 |
| TH as CaCO ₃ (mg/L) | <500.0 | 102.0 | <0.8 |
| Three times a day (mg/L) | <1000.0 | 319.5 | 0.8 |
| pH value (SU) | 6.5–8.5 | 6.67 | 7.35 |

DW, distilled water; PSS:N/O, non-objectionable; SSDWQ, Sindh Standard Drinking Water Quality; TDS, total dissolved solids; TH, total hardness.

no bacteria was detected and compliance with the CDC standards was evident in all parameters.

Furthermore, the third PDSA cycle planned to assess the generalisability of this disinfection protocol on the remaining dental units. The DAS then communicated this protocol to dental assistants assigned to each dental unit in a briefing session. It is noteworthy that use of the said tablet does not require any special training. The team members decided to instil these changes as a continuous process, following a daily schedule of flushing and use of A-dec ICX tablet every 15 days, according to the manufacturer's instructions. All the dental units were then sampled on 20 November 2020 and low bacterial counts were evident (table 3)

Third, we intended to ensure a sustainable method of improving dental care safety by improving compliance to the aforementioned disinfection protocol. Therefore, in the fourth PDSA cycle, each dental assistant was given a logbook for their respective dental unit to ensure that this schedule was being followed by all the staff members involved. The log book contained relevant information regarding the date and time of disinfection protocol of each unit along with the name of dental assistant carrying out the process. The clinic supervisor was assigned to

Table 3 Samples taken from the DUWL before treatment in room 2 on 21 July 2020 and after treatment on 24 August 2020 and 22 August 2021

| Dental room | Date | TC (cfu/100mL) | FC (cfu/100mL) | E-Coli (cfu/100mL) | pH value (SU) | TSS (mg/L) |
|-------------|------------------|----------------|----------------|--------------------|---------------|------------|
| Room 1 | 20 November 2020 | <1 | <1 | <1 | 7.23 | 3.60 |
| | 22 April 2021 | <1 | <1 | <1 | 5.63 | <0.45 |
| Room 2* | 21 July 2020 | >5000 | >1700 | >500 | 7.35 | <1.0 |
| | 24 August 2020 | <1 | <1 | <1 | 7.34 | <1.0 |
| | 22 April 2021 | <1 | <1 | <1 | 5.58 | <0.45 |
| Room 3 | 20 November 2020 | 30 | <1 | <1 | 7.05 | <1.0 |
| | 22 April 2021 | <1 | <1 | <1 | 5.80 | <0.45 |
| Room 4 | 20 November 2020 | 20 | <1 | <1 | 7.11 | 16.0 |
| | 22 April 2021 | <1 | <1 | <1 | 5.71 | <0.45 |
| Room 5 | 20 November 2020 | 60 | <1 | <1 | 7.15 | 19.0 |
| | 22 April 2021 | <1 | <1 | <1 | 5.64 | <0.45 |
| Room 6 | 20 November 2020 | <1 | <1 | <1 | 7.25 | 1.5 |
| | 22 April 2021 | <1 | <1 | <1 | 5.91 | <0.45 |
| Room 7 | 20 November 2020 | <1 | <1 | <1 | 7.29 | <1.0 |
| | 22 April 2021 | <1 | <1 | <1 | 5.76 | <0.45 |
| Room 8 | 20 November 2020 | <1 | <1 | <1 | 7.14 | 21.0 |
| | 22 April 2021 | <1 | <1 | <1 | 5.58 | <0.45 |
| Room 9 | 20 November 2020 | 15 | <1 | <1 | 7.08 | 10.4 |
| | 22 April 2021 | <1 | <1 | <1 | 6.02 | <0.45 |
| Room 10 | 20 November 2020 | <1 | <1 | <1 | 7.21 | 10.6 |
| | 22 April 2021 | <1 | <1 | <1 | 5.73 | <0.45 |
| Room 11 | 20 November 2020 | 10 | <1 | <1 | 7.11 | 7.05 |
| | 22 April 2021 | <1 | <1 | <1 | 5.68 | <0.45 |
| Room 12 | 20 November 2020 | <1 | <1 | <1 | 6.92 | 5.7 |
| | 22 April 2021 | <1 | <1 | <1 | 5.58 | <0.45 |
| Room 13 | 20 November 2020 | 10 | <1 | <1 | 6.96 | 6.7 |
| | 22 April 2021 | <1 | <1 | <1 | 5.58 | <0.45 |
| Room 14 | 20 November 2020 | 10 | <1 | <1 | 7.12 | 9.6 |
| | 22 April 2021 | <1 | <1 | <1 | 6.05 | <0.45 |
| Room 15 | 20 November 2020 | <1 | <1 | <1 | 7.15 | 1.8 |
| | 22 April 2021 | <1 | <1 | <1 | 5.80 | <0.45 |

Continued

Table 3 Continued

| Dental room | Date | TC (cfu/100mL) | FC (cfu/100mL) | E-Coli (cfu/100mL) | pH value (SU) | TSS (mg/L) |
|--------------|------------------|----------------|----------------|--------------------|---------------|------------|
| Room 16 | 20 November 2020 | <1 | <1 | <1 | 6.91 | <1.0 |
| | 22 April 2021 | <1 | <1 | <1 | 5.65 | <0.45 |
| Limits SSDWQ | | 0 | 0 | 0 | 6.5–8.5 | NoGL |

FC, faecal coliform; SSDWQ, Sindh Standard Drinking Water Quality; TC, total coliform.

maintain compliance by checking if the disinfection protocol had indeed been carried out, every 15 days and reported that all dental assistants were able to comply with the suggested protocol. Water testing of all the dental units was then carried out on 20 November 2020 and repeated on 22 April 2021, which showed reduced bacterial counts (table 3).

Moreover, to assess the sustainability of the disinfection protocol, the Facility and Material Safety department allowed water testing of all the dental units every 6 months (as recommended by the CDC for distilled water). These steps will guarantee sustainability and compliance to JCI standards of DUWL maintenance. However, in the fourth PDSA cycle, further improvement regarding the cost-effectiveness of disinfecting and maintaining the DUWLs was noted.

RESULTS

The reports of the samples have been summarised in table 3, which compares the samples taken on various occasions. On 21 July 2020, a sample from dental room 2 shows high bacterial counts, which are negligible after the disinfection of the DUWL, as seen on the sample taken on 24 August 2020. The remaining dental rooms were tested on 20 November 2020 (after disinfection) and again on 22 April 2021, after the disinfection protocol was maintained. It is noteworthy that despite disinfection, the samples taken in seven rooms show elevated bacterial counts (shown as red) on 20 November 2020. However, after maintaining the disinfection protocol for another 5 months, the bacterial counts on 22 April are negligible in all the rooms, which complies with CDC standards. Moreover, although most of the parameters assessed were within the recommended range, the pH for all the dental units was comparatively lower than the recommended range of 6.5–8.5, implying an acidic nature of the water.

DISCUSSION

The importance of maintaining DUWL is already well documented in the literature; however, this discussion becomes even more relevant in light of the recent pandemic.⁸ During the lockdown, disciplines such as dentistry came to a standstill with little or no usage of dental water systems. The stagnant water can harbour waterborne pathogens, such as *Legionella*, which puts

immunocompromised patients at risk of developing secondary bacterial infection.^{6–8} However, recent evidence indicates that patients with COVID-19 are also at risk of developing infections in the months following their recovery, which further heightens the importance.⁹ Despite these implications, there is little practical advice for dentists regarding protocols to monitor or maintain DUWLs, especially when buildings are reoccupied after a hiatus.²

The role of PDSA cycles as an effective tool for quality improvement programmes is well documented in the literature; however, as per our knowledge, this tool has not been used to assess or maintain DUWLs previously.¹⁰ This methodology aims to provide a helpful process for continuous improvement through a cyclic approach. Although this concept is simple, its implementation is not, since it requires repetition of the steps, in the correct order with specific changes made in the methodology, making it more cumbersome than intended.¹⁰

Various methods have been proposed for the management of DUWLs, including purging or flushing the DUWLs, use of anti-retraction devices and chemical disinfection.² In this study, we used a combination of chemical disinfection (A-dec ICX) with flushing to disinfect and maintain the DUWLs.¹¹ Considering that A-dec ICX tablets remain in the dental unit for 15 days, a 'shock treatment' was done on the dental units every week and a 'continuous treatment' which is performed daily was deemed unnecessary.¹¹ As a result, a dramatic decrease in the bacterial counts was noted and compliance with the recommended guidelines was achieved in the first round of water testing after intervention. A similar protocol was used by Meiller *et al*, who also noted similar results after shock treatment.¹¹ Furthermore, these results were maintained in the second testing cycle, done after 4 months. A pH lower than the recommended range (6.5–8.5) was noted in these results, which may be attributed to leaving the distilled water bottles open. However, when freshly opened water bottles were assessed independently, the pH was also low, which requires further investigation. Although this did not compromise the taste or odour of the tested water, a lower pH value may affect the cuprosolvency of brass fittings within the dental unit, which identifies an area for further improvement.¹²

It is also noteworthy that potable water is not sterile, even when complying with drinking water standards and



that the complex tubing of the dental unit can lead to bacterial proliferation, even when distilled water is used. Although the CDC recommends testing distilled water twice and potable water four times a year, a cost-benefit analysis revealed that the annual cost of using potable water is 0.54 million PKR, compared with the 0.72 million PKR for distilled water, in our setting. Although potable water appears to be more cost-effective, it showed inconsistent results, which were effected by weather, particularly the monsoon season where higher bacterial counts were noted.¹³ Moreover, the water samples collected in this study were tested in a laboratory; however, alternatives such as the Petrifilm test, heterotrophic plate count sampler and Aquasafe water tests allow in-office testing and have also been recommended for monitoring bacterial counts.¹⁴ Although these in-office tests lack sensitivity, they are very specific and should be looked into for a more cost-effective method for water testing.^{14 15} This paper aims to provide a template as a practical guide for dentists to maintain DUWL.

LIMITATIONS

This was a single centred study, with 16 dental operatorys, which may not make it generalisable to other centres. Additionally, considering the complex architecture of the dental unit, certain components such as the anti-retraction valves were not assessed, as samples were drawn from the tri-syringe of the dental units. Moreover, due to the financial limitations, only one dental unit was assessed for the baseline testing, which may be due to a fault in that particular unit and ideally should not have been generalised to all the dental units. Lastly, there was no template of the time of sample collection to account for the number or type of procedures done on each dental unit, which may influence our results.

CONCLUSION

Within the limitations of the current study, it can be concluded that the DUWLs are heavily contaminated with microbes and pose potential risk both to the patient as well as the DHCPs. This study suggests chemical disinfection using ICX (A-dec ICX) tablets and flushing as an effective method of reducing the bacterial load in DUWL. The transparency of the process described in this paper can provide a guide for practitioners and administrators on how to improve, maintain and monitor the water quality in a dental setting.

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