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Disinfection and Bacterial Contamination of Dental Unit Waterlines in Nanjing's Healthcare Institutions

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ABSTRACT: This study aims to analyze the current status of dental unit waterline (DUWL) disinfection and bacterial contamination in stomatology departments in Nanjing's healthcare institutions. Targeted stomatology departments, a specialized investigation was conducted focusing on DUWL disinfection methods, disinfection frequency, water quality monitoring, and bacterial contamination, systematically analyzing current disinfection management deficiencies and potential risks of bacterial contamination. The investigation revealed significant variations in the implementation effectiveness of DUWL disinfection measures among stomatology departments in Nanjing's dental institutions. Some institutions exhibited deficiencies such as singular disinfection methods, insufficient frequency, and weak water quality monitoring. The bacterial contamination levels exceeded relevant standards, posing an impact on treatment safety. This study suggests to optimize disinfection procedures and strengthen monitoring mechanisms in accordance with industry standards to reduce contamination levels and ensure the safety of dental treatment water.

KEY WORDS: Dental unit waterlines; Disinfection; Current status; Contamination; Safety

Dental water directly contacts patients' oral mucosa and wounds in dental treatment, making water quality safety a core factor of nosocomial infection prevention and control. The dental unit waterline (DUWL), as the sole delivery channel for dental water, are prone to bacterial growth and biofilm formation if disinfection is not standardized, posing potential contamination risks and imperiling patient health and treatment quality. Currently, Nanjing experiences high demand for dental medical services, with high frequency of dental chair use, increasing pressure on the disinfection management and pollution control of waterline systems. This study focuses on the current status of DUWL disinfection and bacterial contamination in Nanjing healthcare institutions' stomatology departments, collated data, analyzed shortcomings, and provided a basis for optimizing procedures and reducing risks.

Dental treatments involve invasive procedures. The treatment water delivered by DUWL directly contacts patients' oral mucosa and wounds, making its water quality safety a critical link in nosocomial infection prevention and control. In recent years, the demand for dental medical services in Nanjing has continued to grow, with a significant increase in the daily average use frequency of dental chair. Under long-term high-load operation, if maintenance procedures are non-standard and disinfection measures are inadequate, waterline systems are prone to growing bacteria and forming biofilm inside the pipes, leading to water quality contamination risks. To systematically understand the operational status of DUWL in stomatology departments across different levels of healthcare institutions in Nanjing, identify weaknesses in disinfection management links and water quality safety hazards, and provide scientific data support for formulating targeted improvement measures, this specialized investigation covered 58 stomatology departments from tertiary, sec-

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ondary, and primary healthcare institutions in Nanjing. Data were collected through questionnaires combined with on-site verification. The overall situation of DUWL disinfection management and water quality safety in the region was systematically analyzed and comprehensively presented.

1 Materials and Methods

1.1 Special Investigation Implementation

A specialized investigation was conducted focusing on dental unit waterlines (DUWLs) in the stomatology departments of healthcare institutions in Nanjing. The survey covered 58 departments from tertiary, secondary, and primary healthcare institutions. Data were collected through questionnaires combined with on-site verification to gather information regarding DUWL disinfection methods, disinfection frequency, water quality monitoring, and bacterial contamination status. A total of 63 water samples related to DUWLs were collected from these institutions, including water from dental handpieces, three-way syringes, ultrasonic scalers, and mouth rinse units. The detection and qualification of these samples were based on the criteria specified in the *Hygienic standard for disinfection in hospitals* (GB 15982—2012) and the *Regulation of disinfection technique in healthcare settings* (WS/T 367—2012), which define qualified water as having a bacterial colony count ⩽100 CFU/mL and no detection of pathogenic bacteria such as Pseudomonas aeruginosa and Staphylococcus aureus. The specific time period of the investigation and the individuals responsible for on-site sampling and testing are not detailed in the available text.

1.2 Basic Operational Conditions of Stomatology Department

Stomatology departments in all 58 healthcare institutions involved in this investigation possess basic operational conditions meeting daily treatment needs. Basic indicators were statistically analyzed from the investigation data, as shown in Table 1.

1.3 Basic Configuration of Dental Chairs and Waterline Systems

All 58 institutions are equipped with dental chairs, showing diverse characteristics in years of use: chairs aged 5 years and above account for 59.9% (35 units), 1~5 years account for 34.5% (20 units), and 1 year or less account for 5.6% (3 units). Water supply modes are divided into three categories: municipal centralized water supply (24 institutions, 41.38%), municipal centralized water supply + independent water tank supply (24 institutions, 41.38%), and independent water tank supply (10 institutions, 17.24%). Basic waterline maintenance mechanisms are in place: 89.66% (52 institutions) flush waterlines before and after treatment, 62.07% (36 institutions) use filtration treatment, and 20.69% (12 institutions) implement continuous disinfection, laying a foundation for the stable operation of the waterline systems.

Table 1 Basic Daily Treatment Conditions of Stomatology Departments in 58 Healthcare Institutions

Basic Condition	Classification and Proportion	Quantity
Department establishment duration	⩽5 years	18(31. 0%)
	6~15 years	27(46. 6%)
	⩾16 years	13(22. 4%)
Dental chair quantity	1~5 units (Small treatment unit)	21(36. 2%)
	6~15 units (Medium treatment unit)	29(50. 0%)
	⩾16 units (Large treatment unit)	8(13. 8%)
Staff-to-patient ratio	1∶0. 5~1. 0 (Basic ratio)	35(60. 3%)
	1∶1. 1~1. 5 (Optimized ratio)	20(34. 5%)
	⩾1∶1. 6 (Sufficient ratio)	3(5. 2%)
Average daily patient volume	⩽30 person-times	16(27. 6%)
	31~80 person-times	32(55. 2%)
	⩾81 person-times	10 (17. 2%)

1.4 Analysis of Existing Deficiencies and Bacterial Contamination Risks

Based on the information gathered from the on-site investigation, this study mainly analyzes the following: (1) Deficiencies in implementation of disinfection methods, disinfectant selection, and disinfection frequency; (2) Deviations and non-compliance in water quality sampling and monitoring; (3) Current status of bacterial contamination. Categorical variables are presented as frequencies and percentages (%). We also analyzed the underlying causes of non-compliance based on the test results of the operation practices of the institutions.

2 Results

2.1 Deficiencies in Implementation of Disinfection Methods, Disinfectant Selection, and Disinfection Frequency

There is a significant gap between the DUWL disinfection practices in the 58 institutions and the requirements of the standard *Technical regulation for cleaning and disinfection of dental unit waterlines* (T/WSJD 40—2023), evidenced by three factors. (1) Inefficient disinfection methods: 72.41% of institutions rely on passive maintenance such as flushing and filtration; only 20.69% (12 institutions) carry out the standard-recommended continuous disinfection; and 6.90% (4 institutions) take no disinfection measures, making it difficult to achieve stable and compliant results. (2) Dispersed and non-optimal disinfectant selection: 55.56% (32 institutions) use corrosive chlorine-containing disinfectants; 28.57% (17 institutions) use hydrogen peroxide; 10.71% (6 institutions) use irritating sodium hypochlorite; the usage rate of the standard-recommended low-irritation, pipeline-friendly disinfectants is 3.45% (2 institutions) only, increasing operational difficulty and pipeline aging risks. (3) Insufficient disinfection frequency and chaotic management: only 44.83% (26 institutions) meet the requirement of daily disinfection; frequencies are too low for 27.59% (16 institutions) with weekly disinfection and 10.34% (6 institutions) with monthly disinfection; 17.24% (10 institutions) have no defined frequency and no ledgers, creating conditions for microbial growth and significantly increasing the risk of waterline contamination.

2.2 Deviations and Non-compliance in Water Quality Sampling and Monitoring

According to industry standards such as *Technical regulation for cleaning and disinfection of dental unit waterlines* (T/WSJD40—2023), water sampling and monitoring for dental treatment water shall meet core requirements of standardized methods, timely submission, and adequate frequency[1]. The 58 institutions in this investigation showed significant implementation deviations. (1) Deviation in sampling methods: Only 50% (29 institutions) use the industry-recommended membrane filtration method; the rest apply ordinary sampling methods, which do not meet standardized testing requirements, leading to distorted results. (2) Inadequate implementation of submission systems: 10.34% (6 institutions) have not established a regular submission mechanism, preventing timely understanding of water quality dynamics. (3) Non-compliance with sampling frequency: 3.85% (2 institutions) sample every six months, far below the standard; 19.23% (11 institutions) sample monthly, which is a relatively low proportion; although 76.92% (45 institutions) sample quarterly, the overall interval is unreasonable, making it difficult to promptly detect water abnormalities. These deficiencies lead to some contamination persisting undetected, indirectly increasing the risk of treatment-related infections.

2.3 Current Status of Bacterial Contamination

Based on the *Hygienic standard for disinfection in hospitals* (GB 15982—2012) and the *Regulation of disinfection technique in healthcare settings* (WS/T 367—2012), This investigation defined the following criteria as the basis for qualification determination of water related to DUWL: Bacterial colony count ⩽100 CFU/mL, and no detection of pathogenic bacteria such as *Pseudomonas aeruginosa* and *Staphylococcus aureus*. A total of 63 water samples related to DUWL (including dental handpiece water, three-way syringe water, ultrasonic scaler water, and mouth rinse water) were collected from the 58 healthcare institutions. Test results showed

bacterial contamination in some water samples, as shown in Table 2.

According to the test results of the operation practices of the institutions, the causes for non-compliance are manifested as follows: (1) The three institutions with unqualified dental handpiece water did not implement continuous disinfection, conducting pre- and post-treatment flushing only, and the concentration of the chlorine-containing disinfectant used was below the standard 500 mg/L, unable to effectively remove biofilms inside the pipes, leading to *Pseudomonas aeruginosa* growth which easily forms biofilms in damp pipes and tolerates low-concentration disinfectants. (2) The institution with unqualified three-way syringe water had a disinfection frequency of once per week, which is too long an interval, and did not apply the membrane filtration method for sampling, failing to detect contamination in time. *Staphylococcus aureus* proliferated in the pipes after being sucked back via oral secretions during treatment (negative pressure when dental instruments stop working easily causes back-flow contamination). (3) The institution with unqualified ultrasonic scaler water used a dental chair over 8 years old; the aging waterline pipes had developed micro-cracks, creating gaps during cleaning, leading to bacterial residue and proliferation. (4) The institution with unqualified mouth rinse water used an independent water tank supply but did not clean and disinfect the tank monthly as required; prolonged static storage of water caused mild bacterial proliferation[2]. The aforementioned contaminated water directly contacts patients' oral mucosa or wounds. Especially, aerosols generated during the use of dental handpieces and three-way syringes may expand the transmission range of pathogenic bacteria, significantly increasing the risk of cross-infection. This intuitively reflects execution flaws in targeted disinfection, equipment maintenance, and risk prevention and control in some institutions.

3 Discussion

3.1 Optimization Strategies for Disinfection Deficiencies

3.1.1 Refining Disinfection Operation Procedures Based on Standards

Addressing deficiencies in the original procedures, such as low coverage of continuous disinfection (only 20.69%), non-standard disinfectant concentration and operation, lack of unified standards for disinfection frequency, and failure to meet pre- and post-treatment flushing requirements, targeted improvement procedures are formulated in consideration of the standard *Regulation for disinfection and sterilization technique of dental instruments* (WS 506—2016), the standard *Regulation of disinfection technique in healthcare settings* (WS/T 367—2012), and related research, details as follows. (1) Mandate the implementation of continuous disinfection mode, specifying that the chlorine-containing disinfectant is used at a concentration of 500~1 000 mg/L with an action duration of no less than 20 minutes; hydrogen peroxide diluted at 1∶100 is injected into the pipeline and left for 15 minutes, then rinsed 3 times with purified water in prevent of incomplete disinfection or pipeline corrosion caused by improper concentration in the original procedures. (2) Dynamically set disinfection frequency based on daily average patient volume: more than 180 patients daily

Table 2 Bacterial Contamination in Water Used for Dental Unit Waterlines from 58 Healthcare Institutions

Water Type	Number of Samples Tested	Number of Qualified Samples	Qualification Rate (%)	Unqualified Colony Count Range (CFU/mL)	Pathogen Detection
Dental handpiece water	15	12	80. 00	150~200	2 samples detected Pseudomonas aeruginosa
Three-way syringe water	19	17	89. 47	120~140	1 sample detected Staphylococcus aureus
Ultrasonic scaler water	13	12	92. 31	110	None
Mouth rinse water	16	15	93. 75	105	None
Total	63	56	88. 89	—	—

requiring 3 times/day; 80~180 patients daily requiring 2 times/day; and less than 80 patients requiring every 2 days/2 times, which addresses chaotic frequency (only 44.83% disinfected daily) in the original procedures. (3) Standardize the pre- and post-treatment waterline flushing (no less than 40 seconds) to reduce microbial attachment from residual water.

3.1.2 Improving Water Quality Monitoring System Referring to Standards

Based on standards such as *Regulation of disinfection technique in healthcare settings* (WS/T 367—2012), it is explicitly required that the monitoring frequency for dental treatment water should be at least once per month. Research by WANG Guiqin[1] *et al.* establishes a standardized sampling system on the membrane filtration method, making it a mandatory sampling method covering critical instruments such as dental handpieces and three-way syringe nozzles, aiming to increase the usage rate of the membrane filtration method from 50% to 100%. Addressing the current non-compliance with sampling frequency, all institutions are required to conduct membrane filtration method sampling once per month (collecting 100 mL water sample each time). Institutions that currently sample quarterly (76.92%) or semi-annually (3.85%) shall rectify within a time limit to ensure compliance with the qualified frequency requirement of "once per month". Simultaneously, the operational procedures of the 5 institutions (19.23%) are already standardized to sample monthly. The sampling operation procedure is detailed: Sampling tools are sterilized by high-pressure steam at 121 ℃ for 30 minutes, sampling time is selected during non-peak hours before or after treatment, and samples are delivered for testing within 2 hours to avoid external contamination and loss of sample viability. A graded response mechanism is established: If colony count exceeds 100 CFU/mL, immediately suspend using the dental chair and re-test within 24 hours; for 50~100 CFU/mL, intensify disinfection within 12 hours; for below 50 CFU/mL, follow routine monitoring, thus constructing a "sampling-detection-handling" closed loop. After implementation, the timely detection rate of water abnormalities is expected to increase to 95%, and the regular submission rate is expected to reach 100%.

3.1.3 Strengthening Management Mechanisms Based on Equipment Characteristics

Research by WANG Jue[3] *et al.* points out that the risk of waterline pipe aging increases significantly for dental chairs used over 5 years, and contamination incidence for chairs over 8 years old increases by 40% compared to new equipment. According to the *Regulation of disinfection technique in healthcare settings* (WS/T 367—2012) that "Dental treatment equipment should have regular maintenance and testing, and aging equipment should be timely updated", special dossiers for dental chair usage years and maintenance are established: Incorporate dental chairs used over 5 years (accounting for 59.9%) into critical inspection; conduct waterline pipe integrity testing twice a year; check for aging and leakage, and replace parts promptly; and gradually promote the renewal of dental chairs used over 8 years, prioritizing new equipment with built-in disinfection functions to reduce maintenance difficulty[4]. Regarding management measures for different water supply modes, requirements are proposed based on the *Standards for drinking water quality* (GB 5749—2022) and the research conclusion by Wang Jue *et al.* in 2022 on waterline pollution prevention and control: Institutions using the "municipal centralized water supply + independent water tank supply" mode should clean and disinfect the water tank monthly (using dedicated cleaning agents) in preventing from bacterial growth in the water storage[3]; institutions using only municipal centralized water supply should install secondary filtration devices with a filtration precision ≥5 μm at the waterline inlet (replace filter material every 3 months) to intercept external impurities and microorganisms; and establish equipment maintenance ledgers and records, detailing maintenance time, content, and part models for traceability management. After the implementation, the incidence of DUWL failures is expected to decrease by 25%, and pollution issues related to old dental chairs are expected to decrease by 30%.

3.2 Expected Effectiveness and Practical Value of Implementing Optimized Strategies

3.2.1 Expected Improvement in Water Safety

After the implementation of optimized strategies, standardized disinfection procedures can reduce conditions for bacterial growth in waterlines. Combined with a sound monitoring system, water quality changes can be detected promptly, preventing unqualified water from entering the treatment process. Based on data from similar regions (e.g., the water quality compliance rate after standardized management by WANG Xinrong[2]), it is expected that the bacterial qualification rate of dental treatment water from DUWL in stomatology departments in Nanjing's healthcare institutions can increase from the current 80%~93.75% to over 95%, with out-of-specification colony counts almost eliminated. This ensures the safety of patients' treatment water from the source and significantly reduces the risk of nosocomial infections induced by water quality deficiencies.

3.2.2 Role in Safeguarding Treatment Order

Standardized equipment maintenance and disinfection procedures reduce the incidence of DUWL failures, extend equipment service life, and reduce dental chair suspension due to malfunctions or unqualified water quality. Clear disinfection and monitoring standards provide clear operational guidelines for medical staff, avoiding work confusion caused by inconsistent operations. Stable waterline operation and safe water quality enhances patient trust, alleviating their concerns about water safety. These factors jointly ensure the orderly progress of treatment in the stomatology department, improving service quality and patient satisfaction[5].

3.2.3 Practical Significance for Industry Standard Promotion

The optimization practice in Nanjing forms replicable and promotable management experience, providing reference for DUWL management in stomatology departments in other regions. The combined mode of "disinfection-monitoring-equipment management" explored during the optimization process supports to formulate dental healthcare industry standards (e.g., supplementing operational details of the national standard WS/T 367—2012), promoting the industry's transition from decentralized, experience-based management to standardized management. Targeted references for similar institutions are provided based on summarized adaptation plans for institutions of different scales, assisting in the improvement of DUWL management nationwide and promoting the development of infection prevention and control in dental healthcare.

4 Conclusion

This study conducted a investigation focusing on the current status of DUWL disinfection and bacterial contamination in stomatology departments in Nanjing's healthcare institutions, clarified the investigation background, operational and equipment configuration, analyzed deficiencies in disinfection and monitoring, determined the contamination levels, proposed optimization strategies in consideration of national standards such as WS/T 367—2012 and related literature, and elaborated on expected effectiveness. Subsequently, management standard can be implemented based on the investigation experience and strategies can be regularly reviewed and dynamically adjusted to meet treatment needs. Therefore, a comprehensive water safety assurance system can be constructed, laying the foundation for improving the quality of dental treatment.

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