

Economic comparison of conventional maintenance and electrochemical oxidation to warrant water safety in dental unit water lines

Kostenvergleich von konventioneller Wartung und elektrochemischer Oxidation zur Gewährleistung der Trinkwasserqualität in Dentaleinheiten

Abstract

Background: In preparation for implementation of a central water processing system at a dental department, we analyzed the costs of conventional decentralized disinfection of dental units against a central water treatment concept based on electrochemical disinfection.

Methods: The cost evaluation included only the costs of annually required antimicrobial consumables and additional water usage of a decentralized conventional maintenance system for dental water lines build in the respective dental units and the central electrochemical water disinfection system, BLUE SAFETY™ Technologies.

Results: In total, analysis of costs of 6 dental departments revealed additional annual costs for hygienic preventive measures of € 4,448.37. For the BLUE SAFETY™ Technology, the additional annual total agent consumption costs were € 2.18, accounting for approximately 0.05% of the annual total agent consumption costs of the conventional maintenance system. For both water processing concepts, the additional costs for energy could not be calculated, since the required data was not obtainable from the manufacturers.

Discussion: For both concepts, the investment and maintenance costs were not calculated due to lack of manufacturer's data. Therefore, the results indicate the difference of costs for the required consumables only. Aside of the significantly lower annual costs for required consumables and disinfectants; a second advantage for the BLUE SAFETY™ Technology is its constant and automatic operation, which does not require additional staff resources. This not only safety human resources, but add additionally to cost saving.

Conclusion: Since the antimicrobial disinfection capacity of the BLUE SAFETY™ was demonstrated previously and is well known, this technology, which is comparable or even superior in its non-corrosive effect, may be regarded as method of choice for continuous disinfection and prevention of biofilm formation in dental units' water lines.

Keywords: electrochemical water disinfection, BLUE SAFETY™ Technology, ECA, hydrogen peroxide based maintenance, dental unit, cost evaluation

Zusammenfassung

Hintergrund: Die Kostenanalyse von konventioneller dezentraler Wartung von Dentaleinheiten dient der Vorbereitung der Einführung eines Verfahrens zur zentralen Trinkwasseraufbereitung auf der Basis der elektrochemischen Aktivierung.

Methoden: Für die konventionelle Wartung von Dentaleinheiten wurden der Verbrauch der eingesetzten Dekontaminationspräparate einschließlich des dafür erforderlichen Wasserverbrauchs analysiert und dafür die Kosten berechnet. Analog wurde der Verbrauch an Betriebsmitteln

Sebastian Fischer¹

Georg Meyer²

Axel Kramer¹

1 Institute of Hygiene and Environmental Medicine
Greifswald, University Medicine, Greifswald, Germany

2 Center of Dentistry, Oral Medicine and Maxillofacial Surgery, University Medicine, Greifswald, Germany

für die zentrale Wasserdekontamination mittels BLUE SAFETY™ Technologie berechnet.

Ergebnisse: In der Summe von sechs Abteilungen ergaben sich als jährliche hygienische Gesamtmittelverbrauchskosten von € 4.448,37. Für die BLUE SAFETY™ Technologie ergaben sich als jährliche Gesamtmittelverbrauchskosten 2,18 €. Das entspricht rund 0,05% der Kosten der konventionellen Wartung. Bei beiden Verfahren konnte der Verbrauch an elektrischer Energie nicht berücksichtigt werden.

Diskussion: Beim Vergleich beider Verfahren wurden die Investitions- und Wartungskosten für beide Verfahren auf Grund fehlender Herstellerangaben nicht berücksichtigt. Unabhängig davon kommt neben den geringen Gesamtmittelverbrauchskosten als weiterer Vorteil der BLUE SAFETY™ Technologie die Entlastung des Personals hinzu.

Schlussfolgerung: Da die Dekontaminationsleistung der BLUE SAFETY™ Technologie auf Grund der Datenlage als gesichert angesehen werden kann, ist dem Verfahren unter der Voraussetzung einer vergleichbaren oder geringeren Korrosivität im Vergleich zur Wasserstoffperoxid-basierte Dekontamination der Vorzug zu geben.

Schlüsselwörter: elektrochemische Wasserdekontamination, BLUE SAFETY™ Technologie, ECA, Wasserstoffperoxid-basierte konventionelle Wartung, Dentaleinheiten, Kostenanalyse

Introduction

In preparation for implementation of a central water processing system at a dental department, we analyzed the costs of conventional decentralized disinfection of dental units through daily continuous decontamination, purging and regular intensive decontamination against a central water treatment concept based on electrochemical disinfection. This was studied at six departments running dental clinics in Germany with a total of 44 dental units and approximately 35,000 patient contacts per year.

The necessity for preventive microbiological maintenance of dental units' water line is given because of the ambient water temperature in the water lines [1], the synthetic material of water lines supporting biofilm formation together with curves and kicking leading to stagnation [2], [3], [4], because of dead spaces [5], and because of water stagnation during non-operational times [6], [7]. The combination of the above conditions is an ideal prerequisite for biofilm formation in case of bacterial contamination of the indwelling water, which is always the case.

Biofilms, harboring non-pathogenic and pathogenic micro-organisms, are a source for continuous contamination of the cooling water in dental units [3], [8], [9], [10], [11]. Aside of the total bacterial count, which also includes non-pathogenic microorganisms, also facultative and obligate pathogenic bacteria such as *Pseudomonas aeruginosa* [12], [13], [14], *Legionella pneumophila* [15], [16], [17], mycobacteria and amoeba [13], [18] may be present in contaminated cooling water. If a microbial contamination with high colony counts of pathogenic bacteria is present, patients may be exposed to the risk of infection, particularly because of aerosol generation during treatment.

Because of this, the cooling water in modern dental units is continuously processed with hydrogen peroxide during patient treatment. This, however, will not eliminate already existing biofilms, but may only be feasible to prevent initial biofilm formation, if continuously applied [19], [20], [21]. Therefore, continuous purging and intensive purging is required and recommended by the manufacturers of dental units [21].

Alternatively, instead of a decentralized, in the dental unit based purging system, a centralized decontamination concept may be applied, whereby the indwelling water is continuously treated before entering the dental unit's water line. Which of the both methods, however, is more cost effective, was not systematically investigated so far.

Methods

For calculation of the costs of the conventional decentralized water treatment concept, the intervals of the treatment and the volume of water usage during the decontaminating process were determined. Water costs are based on the price of 1 m³ water, during the time of the investigation at € 1.96/m³ of water. The unit price of decontamination chemicals was € 23.34 respectively € 13.34 per 1,000 mL of disinfectant. The added concentration of hydrogen peroxide during the routine operation and the costs of the individual water usage for a dental unit could not be calculated because of technical restrictions.

The concentration of hydrogen peroxide was monitored continuously during patient treatment. For this, 1 mL of a sample was added to 100 mL using deionized water and mixed. 1 mL thereof was mixed with water and acidified by adding 40% sulfuric acid. The hydrogen peroxide concentration was measured by titration against potas-

Table 1: Processing scheme of two dental units at six dental departments

Department	Purge		Interval (d) of intensive purge	
	Morning	Morning and evening	Sirona-unit*	Kavo-unit**
1		x	14	
2	x		28	
3		x	7	
4		x	7	7
5		x	35	7
6	x		14	7

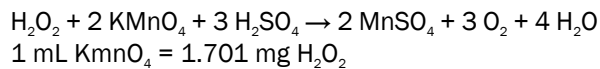
* The manufacturer recommends an interval of 28 days

** The manufacturer recommends an interval of 7 days

Table 2: Calculated costs for automatic hydrogen peroxide dosage during routine operation, stratified by purge and intensive purge as well as dental units

Measure		Costs (€) for decontamination products	Costs (€) for water consumption
Dosage during normal operation		Not measurable	Not measurable
Purge:	Sirona	852.23	12.44
	Kavo	----	----
Intensive purge:	Sirona	2,175.10	0.63
	Kavo	1,380.40	27.58

sium permanganate until the color changed to pink over 30 seconds. The hydrogen peroxide concentration was calculated using following formula:



For calculation of the costs of the BLUE SAFETY™ Technology concept, the costs of the required resources for generating hypochlorous acid, fundamentally NaCl and water were calculated. The system delivers a maximum of 10 liter hypochlorous acid per hour at a pH of 7.0.

Results

The 44 investigated dental units consisted of two different models from different manufacturers each. Hence, the water line processing programs varied among the models, but also between the 6 encompassed dental departments (Table 1).

For disinfection, two hydrogen peroxide based products of two different manufactures were used. For Sirona units, a product with 1.41% hydrogen peroxide (recommended dilution of hydrogen peroxide: 0.0141%), and for Kavo-units with 6% hydrogen peroxide (recommended dilution of hydrogen peroxide: 0.02%) was used.

For maintenance, the Sirona-unit has a *purge* rinsing function. The concentration of the decontamination product corresponds to a dosage of 1:100 hydrogen peroxide during the normal operation of the unit. The program can be set variably between 60 to 120 seconds. This program is also available as *auto-purge* which con-

sists of two single rinse procedures. The typical flow rates range between 150 mL/min and for motor, turbine and ultrasound 60 mL/min, each. During intensive purge 250 mL of decontamination solution are rinsed without any further dilution. Additionally, one rinse is run before and after intensive purge with a total water volume of 500 mL. The concentration of the decontaminating agent during the rinsing operations corresponding to the normal operation

For the Kavo-unit 12 litres of water and 60 mL of the 6% decontamination product were used for intensive purge. The concentration of the decontamination product ranges at 0.25% during intensive purge (1.5 litres decontamination product/water mixture). The Kavo-unit does not possess a comparable purge function like the Sirona-unit. In total annual costs of € 4,448.37 were determined for the 6 investigated departments for routine maintenance of the dental units' water lines (Table 2).

During the decontamination phase, the hydrogen peroxide concentration ranged above the 1:100 dilution recommended by the manufacturer for 8 Sirona-units at 36.5% ±23% above the target concentration. For 4 Kavo-units, the target concentration for hydrogen peroxide at 0.02% as recommended by the manufacturer was not reached. In total, the mean hydrogen peroxide dosage for constant dosage ranged at 2.5% ±16.5% above the target concentration.

The BLUE SAFETY™ technology device generates hypochlorous acid through membrane electrolysis of a 0.2%–0.3% NaCl solution. According to the manufacturer, the anolyte at a concentration of 200 mg/L contains ~158 mg/L hypochlorous acid, ~2 mg/L hypo chlorite ions, <1 mg/L ozone, <2.5 mg/L chlorine dioxide,

<1.5 mg/L chlorous acid, and <3 mg/L chlorine acid at a pH of 7.0 and a half life time of up to 48 hours.

The redox potential of the anolyte solution is +914 mV (± 1 mV). The anolyte solution is stored in a storage tank and a concentration of 0.6 mg/L hypochlorous acid is injected directly into the water-works network centrally. Therefore, issues with manufacturer's warranty of dental units do not arise, since the active compound is injected into the water work of the indwelling water before it enters the dental unit itself. Based on the calculated annual water consumption of approximately 1,012 m³ water (Table 2), which is added additionally 0.6 mg/L of allowed free chlorine, the system must generate 3,036 liters of a 200 mg/L concentrated anolyte solution. This results in a consumption of 9.1 kg of NaCl per year. A 25 kg bag of NaCl costs approximately € 6. Calculated on an annual consumption, this results in costs for the salt of € 2.18. Since the water consumption of 4 m³ will incur anyway, the water costs are not to be included further into this calculation.

Discussion

The cost of the consumables for the BLUE SAFETY™ Technology accounts for 0.05% of the costs for the decentralized, in-built disinfection procedure. This, however, is only based on the required consumables and disinfection products during maintenance, since for both methods the additional costs of electricity could not be calculated because of missing information not provided by the manufacturers. Also, the costs for investment could not be calculated, since the disinfection program in the dental units are part of the device, making it difficult to assess the sole price of this feature without the price for the dental unit alone. Because the BLUE SAFETY™ Technology was newly developed at the time of this study, the manufacturer was not able to provide commercial prices for purchasing the technology, installation, and validation. However, because the BLUE SAFETY™ Technology fundamentally uses salt as medium to generate antimicrobially active hypochlorous acid as chief active agent, it can be concluded that the one-time only investment costs of possibly € 10,000 to 15,000 will quickly amortize during routine usage. If the avoided costs for sanitizing heavily contaminated water lines, loss of income due to closure of a unit during sanitation etc. are added, then the breakeven will occur even faster. Finally, because of no requirement for purchasing, storage, manual preparation and maintenance of decontamination products, an additional saving of staff time, and hence money, may be assumed. After installation of the BLUE SAFETY™ Technology, a continuous dosage of hydrogen peroxide is dispensable and can be omitted as cost factor.

A comparable procedure to the BLUE SAFETY™ Technology is the electrochemical generation of Ecasol™. The efficacy of this was demonstrated during a 2-years clinical study [22]. The authors concluded that no higher concentrations than 1–2 mg/L free chlorine were required. The

necessary constant water conditions were achieved by a cascade of lavishly processing steps, starting with particle filtration, water softening, an active charcoal module, and KDF (kinetic degradation fluxion) – 80 medium, and finally a KDF-55 filter. By means of gas chromatographic mass spectrometry the processed water was regularly checked for unwanted side products such as chloroform, bromodichloromethane, dibromochloromethane, bromoform, trichloroethane, tetrachloroethane, and 1,2-dichloroethane. For all, the levels ranged below <0.01 mg/L, the level of 1,2-dichloroethane was below 0.001 mg/L. At these concentrations, no corrosive occurrences were observed at the investigated dental units or their water lines. However, a comparison of the corrosivity related to the hydrogen peroxide-based decontamination has not been made so far.

Although the concentrations of hydrogen peroxide partly surpassed the manufacturer's recommendations, the mean concentration of 0.021% \pm 0.007% was not exceeded. Because of the high D-value particularly of *Candida spp.* even at planktonic state, such a hydrogen peroxide concentration may not be able to inhibit biofilm formation, particularly in segments with stagnation or dead spaces, if used only during patient treatment [23]. This is further supported, if the unit's routine preventive maintenance using purge and intensive purge is not regularly performed [21].

Notes

Competing interests

The authors declare that they have no competing interests.

References

1. Ciszewski HJ. Die Wasserversorgung zahnärztlicher Handstücke, eine Gefahrenquelle für Zahnarzt und Patient. Dt Zahnärztl Z. 1982;37(5):398-99.
2. Mayo JA, Oertling KM, Andrieu SC. Bacterial biofilm: a source of contamination in dental air-water syringes. Clin Prev Dent. 1990 Jun-Jul;12(2):13-20.
3. Shearer BG. Biofilm and the dental office. J Am Dent Assoc. 1996 Feb;127(2):181-9.
4. Mills SE. The dental unit waterline controversy: defusing the myths, defining the solutions. J Am Dent Assoc. 2000 Oct;131(10):1427-41.
5. Souza-Gugelmin MC, Lima CD, Lima SN, Mian H, Ito IY. Microbial contamination in dental unit waterlines. Braz Dent J. 2003;14(1):55-7. DOI: 10.1590/S0103-64402003000100010
6. Hesselgren SG, Nedlich U. Bakterienwachstum in zahnärztlichen Geräten [Bacterial growth on dental equipment]. Quintessenz. 1981 Mar;32(3):531-6.
7. Forde A, O'Reilly P, Fitzgerald G, O'Mullane D, Burke FM, O'Sullivan M. Microbial contamination of dental unit water systems. J Ir Dent Assoc. 2005 Autumn;51(3):115-8.

8. Prucha J, Tilkes F. Wasserversorgung der zahnärztlichen Behandlungseinheiten. In: Beck EG, Schmidt P, eds. Hygiene in Krankenhaus und Praxis. Berlin: Springer; 1986. p. 155-7. DOI: 10.1007/978-3-642-70813-8_18
9. Singh T, Coogan MM. Isolation of pathogenic Legionella species and legionella-laden amoebae in dental unit waterlines. J Hosp Infect. 2005 Nov;61(3):257-62. DOI: 10.1016/j.jhin.2005.05.001
10. Al-Hiyasat AS, Ma'ayeh SY, Hindiyyeh MY, Khader YS. The presence of Pseudomonas aeruginosa in the dental unit waterline systems of teaching clinics. Int J Dent Hyg. 2007 Feb;5(1):36-44. DOI: 10.1111/j.1601-5037.2007.00221.x
11. Dahlén G, Alenäs-Jarl E, Hjort G. Water quality in water lines of dental units in the public dental health service in Göteborg, Sweden. Swed Dent J. 2009;33(4):161-72.
12. Furuhashi M, Miyamae T. Prevention of bacterial contamination of water in dental units. J Hosp Infect. 1985 Mar;6(1):81-8. DOI: 10.1016/S0195-6701(85)80022-0
13. Barbeau J, Buhler T. Biofilms augment the number of free-living amoebae in dental unit waterlines. Res Microbiol. 2001 Oct;152(8):753-60. DOI: 10.1016/S0923-2508(01)01256-6
14. Borneff M. Legionellen-Vorkommen in Dentaleinheiten und Konsequenzen für die Praxishygiene [The occurrence of legionella in dental units and the consequences for practice hygiene]. Zentralbl Bakteriol Mikrobiol Hyg B. 1989 Apr;187(4-6):295-311.
15. Fotos PG, Westfall HN, Snyder IS, Miller RW, Mutchler BM. Prevalence of legionella-specific IgG and IgM antibody in a dental clinic population. J Dent Res. 1985;64(12): 382-85. DOI: 10.1177/00220345850640121101
16. Reinthaler FF, Mascher F, Stünzner D. Serological examinations for antibodies against Legionella species in dental personnel. J Dent Res. 1988 Jun;67(6):942-3. DOI: 10.1177/00220345880670061001
17. Atlas RM, Williams JF, Huntington MK. Legionella contamination of dental-unit waters. Appl Environ Microbiol. 1995 Apr;61(4):1208-13.
18. Michel R, Borneff M. Über die Bedeutung von Amöben und anderen Protozoen in wasserführenden Systemen von Dentaleinheiten [The significance of amoebae and other protozoa in water conduit systems in dental units]. Zentralbl Bakteriol Mikrobiol Hyg B. 1989 Apr;187(4-6):312-23.
19. Lewis K. Riddle of biofilm resistance. Antimicrob Agents Chemother. 2001 Apr;45(4):999-1007. DOI: 10.1128/AAC.45.4.999-1007.2001
20. Zanetti F, De Luca G, Tarlazzi P, Stampi S. Decontamination of dental unit water systems with hydrogen peroxide. Lett Appl Microbiol. 2003;37(3):201-6. DOI: 10.1046/j.1472-765X.2003.01378.x
21. Bachfeld D. Analyse des Hygienestatus im Zentrum für Zahn-, Mund- und Kieferheilkunde der Universität Greifswald ergänzt durch eine experimentelle Studie zur Wirkung von Guanidinthiocyanat auf Nickel-Titan-Instrumente [Diss]. Greifswald: Med Fak Univ Greifswald; 2009.
22. Coleman DC, O'Donnell MJ, Shore AC, Swan J, Russell RJ. The role of manufacturers in reducing biofilms in dental chair waterlines. J Dent. 2007 Sep;35(9):701-11. DOI: 10.1016/j.jdent.2007.05.003
23. Kramer A, Reichwagen S, Heldt P, Widulle H, Nürnberg W. Wasserstoffperoxid. In: Kramer A, Assadian O, eds. Wallhäußers Praxis der Sterilisation, Desinfektion, Antiseptik und Konservierung. Stuttgart: Thieme; 2008. p. 719-25.

Corresponding author:

Prof. Dr. Axel Kramer

Institute of Hygiene and Environmental Medicine
 Greifswald, University Medicine, Walther-Rathenau-Str.
 49a, D- 17489 Greifswald, Germany, Phone:
 +49-3834-515542 Fax: +49-3834-515541
 kramer@uni-greifswald.de

Please cite as

Fischer S, Meyer G, Kramer A. Economic comparison of conventional maintenance and electrochemical oxidation to warrant water safety in dental unit water lines. GMS Krankenhaushyg Interdisziplin. 2012;7(1):Doc08.
 DOI: 10.3205/dgkh000192, URN: urn:nbn:de:0183-dgkh0001925

This article is freely available from

<http://www.egms.de/en/journals/dgkh/2012-7/dgkh000192.shtml>

Published: 2012-04-04**Copyright**

©2012 Fischer et al. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by-nc-nd/3.0/deed.en>). You are free: to Share – to copy, distribute and transmit the work, provided the original author and source are credited.