J Antimicrob Chemother 2010; **65**: 1712–1719
doi:10.1093/jac/dkq212 Advance Access publication 15 June 2010

Journal of Antimicrobial Chemotherapy

Standardized comparison of antiseptic efficacy of triclosan, PVP–iodine, octenidine dihydrochloride, polyhexanide and chlorhexidine digluconate

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Received 1 February 2010; returned 11 March 2010; revised 10 May 2010; accepted 11 May 2010

Background: This study presents a comparative investigation of the antimicrobial efficacy of the antiseptics PVP–iodine, triclosan, chlorhexidine, octenidine and polyhexanide used for pre-surgical antisepsis and antiseptic treatment of skin, wounds and mucous membranes based on internationally accepted standards.

Methods: MICs and MBCs were determined in accordance with DIN 58940-7 and 58940-8 using *Staphylococcus aureus* (including methicillin-resistant *Staphylococcus aureus*), *Enterococcus faecalis* (including vancomycin-resistant *Enterococcus*), *Streptococcus pneumoniae*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Clostridium perfringens*, *Haemophilus influenzae* and *Candida albicans*. The microbicidal efficacy was determined in accordance with DIN EN 1040 and 1275 using *S. aureus*, *P. aeruginosa* and *C. albicans*.

Results: For chlorhexidine, octenidine and polyhexanide, MIC_{48} and MBC_{24} ranged from 16 to 32 mg/L. Maximum values for triclosan ranged from 256 to 512 mg/L, with an efficacy gap against *P. aeruginosa*, while the maximum values of PVP–iodine were 1024 mg/L, with a gap against *S. pneumoniae*. Comparing the minimal effective concentrations, octenidine was most effective. After 1 min, only octenidine and PVP–iodine fulfil the requirements for antiseptics.

Conclusions: Tests under standardized and harmonized conditions help to choose the most efficacious agent. When a prolonged contact time is feasible, ranking of agents would be polyhexanide = octenidine > chlorhexidine > triclosan > PVP–iodine. This is consistent with the recommendations for antisepsis of acute wounds. Polyhexanide seems to be preferable for chronic wounds due to its higher tolerability. If an immediate effect is required, ranking would be octenidine = PVP–iodine ≫ polyhexanide > chlorhexidine > triclosan.

Keywords: wounds, antisepsis, disinfection, skin, mucous membranes, EN 1040, EN 1275, DIN 58940, MIC, MBC, microbistatic, microbicidal

Introduction

Antiseptic agents such as triclosan [5-chlorine-2-(2,4-dichlorphenoxy)-phenol], PVP–iodine [poly(vinylpyrrolidone)–iodine complex], octenidine dihydrochloride (octenidine), polyhexanide (polyhexamethylene biguanide) and chlorhexidine digluconate (chlorhexidine) are widely used for the prevention and therapy of bacterial infections, especially for antisepsis of mucous membranes and wounds.[1–10] Numerous studies have been published concerning the antimicrobial properties of these agents.[11–24] However, there are no systematic investigations comparing these antiseptics against each other using standardized and harmonized test procedures. Furthermore, many of these studies have been performed using commercial products, such as disinfectants and hand scrubs, which contain the active ingredients in different concentrations, making it difficult to compare the antiseptic properties of the active substance itself and to decide which is the antiseptic of choice for specific indications.

In order to provide reliable and reproducible information on the MIC/minimal microbicidal concentration (MBC) (microdilution test; DIN 58940) as well as the microbicidal efficacy (quantitative suspension tests; EN 1040, EN 1275) of triclosan, PVP–iodine, octenidine, polyhexanide and chlorhexidine, a comparative study under standardized conditions based on the DIN EN standards[25–28] was performed.

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Materials and methods

Test preparations and neutralization

Octenidine (Schülke & Mayr GmbH, Norderstedt, Germany), polyhexanide (Fagron GmbH & Co. KG, Hamburg, Germany), PVP–iodine and chlorhexidine digluconate (Sigma-Aldrich Biochemie GmbH, Hamburg, Germany) were diluted in water of standardized hardness (WSH; according to DIN EN 1040[25]) to the final test concentrations. Triclosan (Fluka/Sigma-Aldrich Biochemie GmbH, Buchs, Switzerland) was only poorly soluble in water, so a stock solution of 50% triclosan in 80% dimethylsulphoxide (DMSO) was prepared and diluted in several steps to yield a final concentration of 1% triclosan in 40% DMSO/WSH. All further dilutions were prepared with 40% DMSO/WSH. The suitability as solvent of 40% DMSO/WSH regarding inefficacy was demonstrated using the quantitative suspension test as well as in the microdilution test. After a contact time of 24 h, no microbicidal or microbistatic effect was observed against *Staphylococcus aureus*, *Pseudomonas aeruginosa* or *Candida albicans*.

As neutralizing agents, the following solutions were used in accordance with DIN EN 1040 and 1275:[25,26] 3.0% polysorbate 80 + 3.0% saponin + 0.1% L-histidine + 0.1% cysteine for neutralizing octenidine, chlorhexidine and polyhexanide; 3.0% polysorbate 80 + 0.3% lecithin + 0.3% L-histidine + 0.5% sodium thiosulphate for neutralizing PVP–iodine; and 8.0% polysorbate 80 + 2.0% SDS + 0.8% lecithin + 1.0% sodium thiosulphate + 6.0% saponin (double-concentrated) for neutralizing triclosan.

To determine the MICs and the MBCs as the first step of the investigation, all substances were prepared in concentrations in the range 1024–0.00390625 mg/L. The concentration ranges used in the quantitative suspension tests are summarized in Table 1.

Test organisms and nutrient solutions

In the microdilution method, the test organisms *S. aureus* (ATCC 6538), *P. aeruginosa* (ATCC 15442), *C. albicans* (ATCC 10231), *Enterococcus faecalis* (ATCC 29212), *Streptococcus pneumoniae* (ATCC 49619), *Escherichia coli* (ATCC 35218), *Clostridium perfringens* (ATCC 13124), *Haemophilus influenzae* (ATCC 49247), a methicillin-resistant *S. aureus* (MRSA; North German epidemic strain, clinical isolate, Institute for Hygiene and Environmental Medicine, University Greifswald) and a vancomycin-resistant *Enterococcus* (VRE; clinical isolate, Institute for Hygiene and Environmental Medicine, University Greifswald) were used. Except for *H. influenzae* and *C. perfringens*, bacteria were cultivated on blood agar and Mueller–Hinton broth (MHB). *H. influenzae* was grown in MHB, supplemented with 2% lysed horse blood, 5 mg/L NAD and 5 mg/mL yeast extract. *C. perfringens* was cultivated in heart–brain–glucose bouillon or the respective solid medium. *C. albicans* was cultivated on Sabouraud agar and in 'high-resolution' (HR) medium.

In the quantitative suspension tests, the test organisms *S. aureus* (ATCC 6538), *P. aeruginosa* (ATCC 15442) and *C. albicans* (ATCC 10231) were used. The bacteria were cultivated on casein peptone soybean agar (CSA). *C. albicans* was cultivated on malt extract agar (MEA).

Microdilution test

To determine MICs and MBCs, DIN 58940-7[27] and 58940-8[28] and the corresponding supplementary sheets were strictly followed. Briefly, the test organisms were cultivated on agar at 36°C for 18 h; thereafter, one colony was transferred into 1 mL of Mueller–Hinton bouillon and diluted to reach 10^5 cfu/mL. Tests were performed using 96-well microtitre plates. Each well was filled with 100 μL of defined antiseptic dilution and 100 μL of test organism suspension.

After 24 h, the turbidity was evaluated as the indicator for bacterial growth. For determination of the MBC, samples in the range around the threshold for turbidity after 24 h were transferred onto blood agar as described in the standard[28] and evaluated for growth after 24 h.

Table 1. Concentration ranges of the test preparations used in the quantitative suspension tests according to DIN EN 1040 and 1275[25,26]

Antiseptic agent	PVP–iodine	Chlorhexidine	Octenidine	Polyhexanide	Triclosan
Concentration range (mg/L)	500–31.25	4000–5	250–1	5000–1	50000–10

Table 2. Results of MIC and MBC determination according to DIN 58940-7 and 58940-8[27,28]

	MIC and MBC (mg/L)														
	octenidine			PVP–iodine			polyhexanide			chlorhexidine			triclosan		
Test organism	MIC_{24}	MIC_{48}	MBC_{24}	MIC_{24}	MIC_{48}	MBC_{24}	MIC_{24}	MIC_{48}	MBC_{24}	MIC_{24}	MIC_{48}	MBC_{24}	MIC_{24}	MIC_{48}	MBC_{24}
S. aureus	2	2	2	512	8	8	0.5	1	1	8	8	8	0.125	0.125	1
E. faecalis	4	4	1	≥1024	1024	1024	2	16	16	16	16	16	16	16	16
S. pneumoniae	8	32	32	>1024	>1024	>1024	1	2	2	4	4	4	8	8	8
E. coli	2	2	8	1024	1024	1024	0.5	1	1	8	16	16	2	4	4
P. aeruginosa	2	8	8	1024	1024	1024	2	2	2	32	32	32	>512	>512	>512
C. perfringens	1	1	1	1024	1024	1024	2	2	2	32	32	32	256	256	512
H. influenzae	1	1	1	512	512	512	2	2	1	8	8	8	32	0.125	0.125
C. albicans	1	1	1	256	256	1024	1	1	4	4	ND	8	8	32	128
MRSA	1	1	2	256	256	1024	0.5	0.5	1	2	2	2	64	64	64
VRE	4	4	4	1024	1024	1024	4	8	32	16	32	32	128	128	128
Maximum value	8	32	32	>1024	>1024	>1024	4	16	32	32	32	32	>512	>512	>512

ND, not determined.

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Quantitative suspension test

Bactericidal and fungicidal efficacy was determined without organic load, strictly following DIN EN 1040[25] and DIN EN 1275.[26] Briefly, 1 mL of the test organism suspension and 1 mL of WSH were mixed and incubated for 2 min. Afterwards, 8 mL of the respective test substance was added. The resulting solutions were incubated for 1, 5, 10, 60, 360 or 1440 min. At the end of the contact time, 1 mL of the test solution was transferred to 8 mL of the respective neutralizing solution and 1 mL of WSH and neutralized for 5 min. Thereafter, 1 mL of the neutralized test solution was spread onto two nutrient agar plates. After incubation for 24 h (bacteria) or 48 h (yeast), the colonies were counted and the number of recoverable colonies (N_a) in the test solution was calculated. The reduction factor (RF) was determined as the difference between the log number of cells in the test solution at the beginning of the contact time (N_0) and the log of N_a.

In addition to DIN EN, water controls using 8 mL of WSH instead of test preparation were performed simultaneously in the first test run to

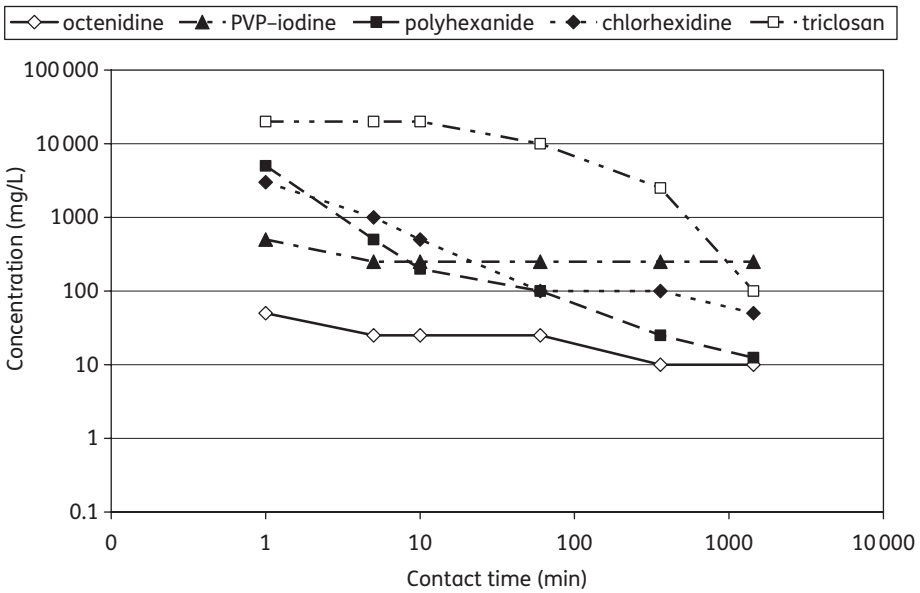

Figure 1. Concentration–time curves for the concentrations of the antiseptic agents to achieve the minimum required reduction of the most resistant test organism at each contact time. Data points represent the concentrations achieving a log reduction of ≥4.8 or ≥3.8 for the test bacteria (*P. aeruginosa* and *S. aureus*) and *C. albicans*, respectively, in at least three experiments.

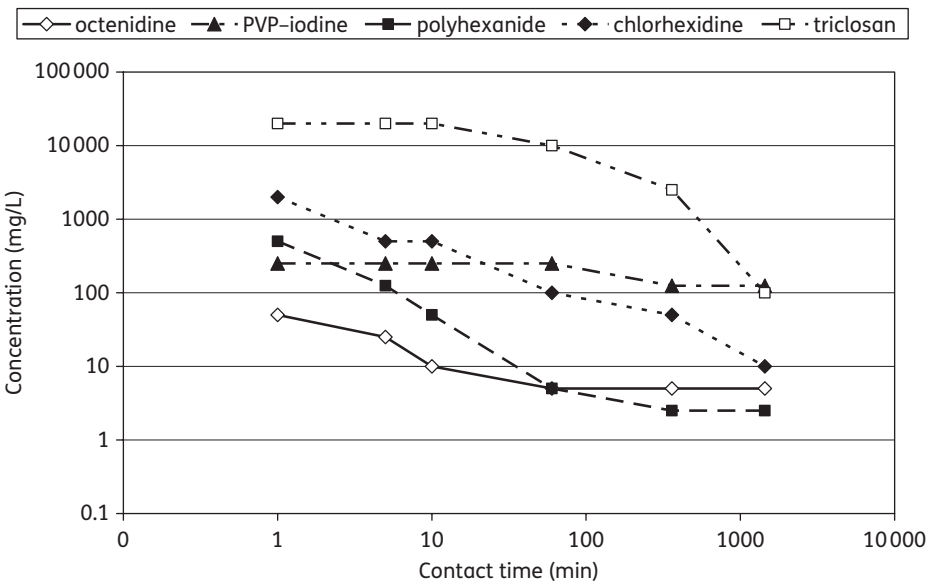

Figure 2. Concentration–time curves for the antiseptic agents to achieve an RF of ≥4.8 with *P. aeruginosa*. Data points represent the concentrations achieving a log reduction of ≥4.8 for *P. aeruginosa* in at least three experiments.

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exclude any bactericidal effects of WSH. In the water controls, no essential difference was observed compared with the N_0 values.

Results

MICs and MBCs

The maximum value of the antiseptic agent describes the concentration required for inhibition or killing of the individually most resistant test organism. For chlorhexidine, octenidine and polyhexanide, comparable concentrations of 16–32 mg/L were determined for the MIC_{48} and MBC_{24}. The MIC_{24} of chlorhexidine (32 mg/L) was at the same level, while those of octenidine (8 mg/L) and polyhexanide (4 mg/L) were lower. For triclosan, the maximum values ranged from 256 to 512 mg/L with a distinct efficacy gap against *P. aeruginosa*, while the maximum values of PVP–iodine were 1024 mg/L with an efficacy gap against *S. pneumoniae* (Table 2).

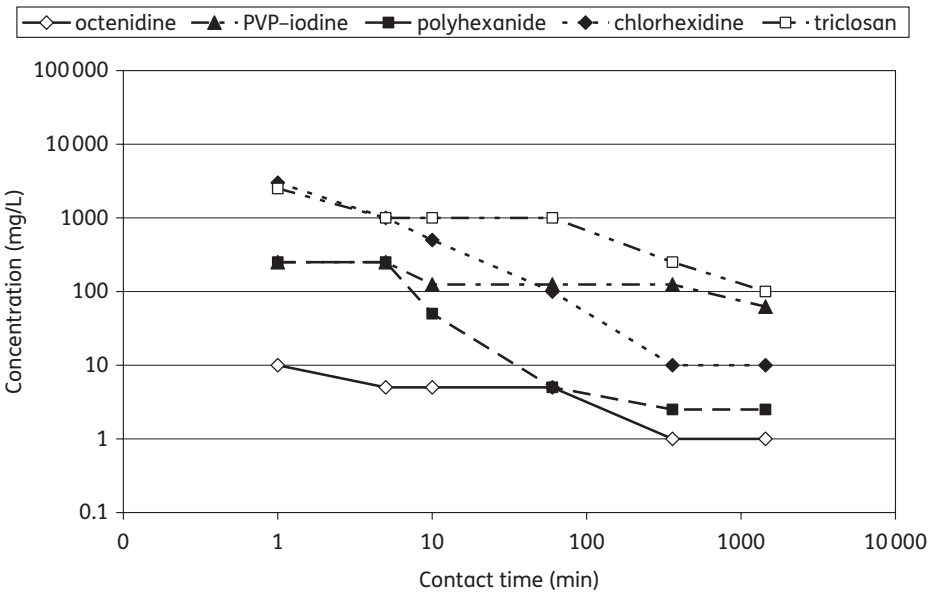

Figure 3. Concentration–time curves for the antiseptic agents to achieve an RF of ≥4.8 with *S. aureus*. Data points represent the concentrations achieving a log reduction of ≥4.8 for *S. aureus* in at least three experiments.

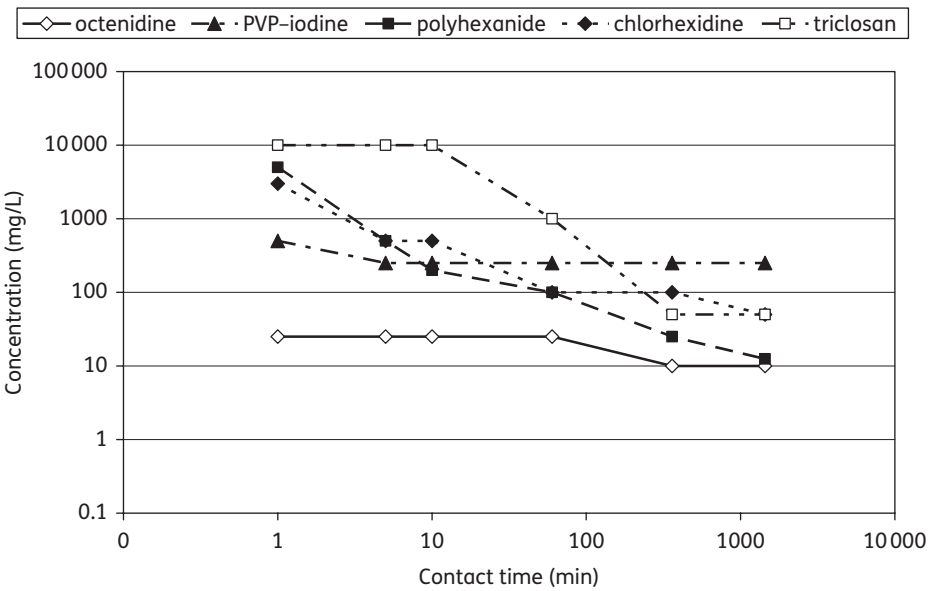

Figure 4. Concentration–time curves for the antiseptic agents to achieve an RF of ≥3.8 with *C. albicans*. Data points represent the concentrations achieving a log reduction of ≥3.8 for *C. albicans* in at least three experiments.

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Table 3. Results according to DIN EN 1040[25] and 1275:[26] concentrations that resulted in an average log reduction of ≥3.8 (*C. albicans*) or ≥4.8 (*S. aureus* and *P. aeruginosa*) with the individual contact times; the highest concentration necessary is underlined for the respective test organism and then summarized in bold for each contact time

		Concentration (mg/L) to achieve a log reduction of ≥3.8 or ≥4.8 (mean reduction in ≥3 experiments/SD)				
Test organism	Contact time	octenidine	PVP–iodine	polyhexanide	chlorhexidine	triclosan
C. albicans	1 min	25 (4.03 log/SD=0.48)	500 (4.16 log/SD=0.20)	5000 (4.07 log/SD=0.22)	5000 (3.82 log/SD=0.25)	10000 (4.03 log/SD=0.45)
P. aeruginosa		50 (4.96 log/SD=0.42)	250 (5.17 log/SD=0.24)	500 (5.29 log/SD=0.12)	5000 (4.94 log/SD=0.37)	20000 (5.20 log/SD=0.16)
S. aureus		10 (5.38 log/SD=0.12)	250 (5.06 log/SD=0.23)	250 (5.27 log/SD=0.07)	2000 (5.30 log/SD=0.15)	2500 (5.19 log/SD=0.10)
Max. required concentration in mg/L for this contact time		**50**	**500**	**5000**	**5000**	**20000**
C. albicans	5 min	25 (3.89 log/SD=0.25)	250 (4.21 log/SD=0.21)	500 (4.13 log/SD=0.21)	500 (4.07 log/SD=0.29)	10000 (4.42 log/SD=0.09)
P. aeruginosa		25 (5.23 log/SD=0.11)	250 (5.18 log/SD=0.05)	125 (5.32 log/SD=0.12)	500 (5.09 log/SD=0.20)	20000 (5.20 log/SD=0.16)
S. aureus		5 (5.15 log/SD=0.35)	250 (5.37 log/SD=0.07)	250 (5.23 log/SD=0.06)	1000 (5.11 log/SD=0.19)	1000 (5.24 log/SD=0.04)
Max. required concentration in mg/L for this contact time		**25**	**250**	**500**	**1000**	**20000**
C. albicans	10 min	25 (4.30 log/SD=0.25)	250 (4.26 log/SD=0.12)	200 (4.16 log/SD=0.13)	500 (4.29 log/SD=0.14)	10000 (4.42 log/SD=0.09)
P. aeruginosa		10 (5.21 log/SD=0.21)	250 (5.18 log/SD=0.05)	50 (5.34 log/SD=0.03)	500 (5.29 log/SD=0.16)	20000 (5.28 log/SD=0.13)
S. aureus		5 (5.32 log/SD=0.08)	125 (5.07 log/SD=0.29)	50 (5.27 log/SD=0.07)	500 (5.06 log/SD=0.23)	1000 (5.22 log/SD=0.11)
Max. required concentration in mg/L for this contact time		**25**	**250**	**200**	**500**	**20000**
C. albicans	60 min	25 (4.30 log/SD=0.25)	250 (4.39 log/SD=0.09)	100 (4.20 log/SD=0.02)	100 (4.10 log/SD=0.09)	1000 (4.16 log/SD=0.61)
P. aeruginosa		5 (5.82 log/SD=0.25)	250 (5.18 log/SD=0.05)	5 (5.28 log/SD=0.12)	100 (5.29 log/SD=0.16)	10000 (5.16 log/SD=0.02)
S. aureus		5 (5.82 log/SD=0.25)	125 (5.13 log/SD=0.13)	5 (5.23 log/SD=0.06)	100 (4.87 log/SD=0.07)	1000 (5.07 log/SD=0.45)
Max. required concentration in mg/L for this contact time		**25**	**250**	**100**	**100**	**10000**
C. albicans	360 min	10 (4.82 log/SD=0.25)	250 (4.31 log/SD=0.19)	25 (4.03 log/SD=0.40)	100 (4.16 log/SD=0.13)	50 (4.19 log/SD=0.13)
P. aeruginosa		5 (5.23 log/SD=0.11)	125 (5.23 log/SD=0.13)	2.5 (5.14 log/SD=0.24)	50 (5.19 log/SD=0.02)	2500 (5.11 log/SD=0.30)
S. aureus		1 (5.832 log/SD=0.08)	125 (5.23 log/SD=0.10)	2.5 (5.14 log/SD=0.11)	10 (5.17 log/SD=0.12)	250 (5.03 log/SD=0.25)
Max. required concentration in mg/L for this contact time		**10**	**250**	**25**	**100**	**2500**
C. albicans	1440 min	10 (4.32 log/SD=0.03)	250 (4.08 log/SD=0.15)	12.5 (4.26 log/SD=0.08)	50 (4.25 log/SD=0.17)	50 (4.36 log/SD=0.39)
P. aeruginosa		5 (5.23 log/SD=0.11)	125 (4.79 log/SD=0.16)	2.5 (5.27 log/SD=0.22)	10 (5.03 log/SD=0.55)	100 (5.11 log/SD=0.06)
S. aureus		1 (5.32 log/SD=0.11)	62.5 (4.96 log/SD=0.52)	2.5 (5.08 log/SD=0.15)	10 (5.13 log/SD=0.23)	100 (4.94 log/SD=0.31)
Max. required concentration in mg/L for this contact time		**10**	**250**	**12.5**	**50**	**100**

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Bactericidal and fungicidal efficacy

In DIN EN, the concentration of an antiseptic agent is considered adequately bactericidal or fungicidal if a reduction in the quantitative suspension test of at least 5 (bactericidal) or 4 (fungicidal) log steps is achieved.[25,26] In this study, bactericidal or fungicidal efficacy was accepted for a tested concentration if three independent tests resulted in a mean reduction of ≥4.8 or ≥3.8 log steps, respectively. In addition to those fixed lower limits, the upper limits are set to 5.55 log or 4.55 log for EN 1040 or EN 1275, respectively—according to those EN standards, greater numbers are not to be stated explicitly. The variation of the data used for claiming sufficient efficacy for a given biocide concentration is therefore confined to a range of 4.8–5.55 log (EN 1040) or 3.8–4.55 log (EN 1275), for all data points and given concentrations.

Comparing the minimal concentrations for the reduction of the individually most resistant test organism, octenidine was the most effective substance at all contact times (Figure 1). Compared with polyhexanide, chlorhexidine and triclosan, the minimal concentrations for PVP–iodine and octenidine were almost constant over the entire time range of 1–1440 min (PVP–iodine, 500–250 mg/L; and octenidine, 50–10 mg/L) (Figures 1–4). For PVP–iodine, the minimal concentrations were ∼10 times higher than those of octenidine (Table 3). The microbicidal efficacy of polyhexanide, chlorhexidine and triclosan showed a clear time dependency, with an up to 400-fold difference in the effective concentration between the shortest and the longest contact time (Table 3). Furthermore, at a contact time of 1 min, the effective concentrations of polyhexanide (5000 mg/L) and chlorhexidine (2000 mg/L) were ∼40–100 times higher than those of octenidine. With a contact time of 10 min, both agents achieved the efficacy of PVP–iodine (Figure 1). Polyhexanide even achieved the efficacy of octenidine at contact times >60 min. Triclosan was the agent with the highest minimal concentration for achieving adequate antimicrobial efficacy, with a distinct efficacy gap against *P. aeruginosa* as already seen in the MIC and MBC tests (Figure 2 and Table 2). The effective concentrations ranged from 20000 mg/L at 1–10 min contact time and >2500 mg/L at 360 min, to 100 mg/L at a contact time of 1440 min (24 h) (Table 3). However, for *S. aureus* and *C. albicans*, the efficacy of triclosan followed a time dependency more comparable to that of polyhexanide and chlorhexidine, but at higher concentrations (Figures 3 and 4).

Comparison of MIC/MBC values and RFs for bactericidal and fungicidal efficacy

For octenidine, polyhexanide and chlorhexidine, slightly higher concentrations were determined in the quantitative suspension tests compared with the microdilution test, whereas for PVP–iodine and triclosan the MIC and MBC values were slightly higher (Table 4).

Discussion

The antimicrobial properties of the antiseptic agents triclosan, PVP–iodine, chlorhexidine, polyhexanide and octenidine, their MICs and MBCs in the microdilution method, as well as bactericidal and fungicidal effects in the quantitative suspension test, were compared in a systematic approach based on European standards that are internationally accepted.

With regard to MIC and MBC, octenidine and polyhexanide were shown to be the most effective agents with equally low maximum values for all timepoints, followed by chlorhexidine, which only failed to reach their efficacy for the MIC after 24 h. The maximum values for triclosan were ∼10 times higher. Against *P. aeruginosa* an efficacy gap was observed, as no effective concentration could be determined. For PVP–iodine, the maximum values were up to 250 times higher than for polyhexanide and octenidine. An efficacy gap was observed against *S. pneumoniae*.

For *S. aureus*, *P. aeruginosa* and *C. albicans*, MIC/MBC data may be compared with the results from the quantitative suspension test after a contact time of 24 h. Triclosan and PVP–iodine seemed to be 4–5 times less active in the microdilution test. This may be explained by differences in the methodology, as the microdilution test was performed in a nutrient solution, which already represents a high organic challenge. For PVP–iodine, a distinct decrease in its antimicrobial activity in the presence of organic matter (e.g. blood or sputum) is well known,[1,3] and Haraszthy *et al.*[29] reported an increase in the MIC of triclosan when defibrinated blood or horse serum was added. In contrast, no such difference was observed for octenidine or chlorhexidine. Only polyhexanide was found to be more effective in the microdilution test than in the quantitative suspension test. This may be explained by a more effective neutralization of this substance in the quantitative suspension test. For

Table 4. Comparison of concentrations required for MIC, MBC and RFs ≥4.8 log or ≥3.8 log in the quantitative suspension test after 24 h of exposure

	Effective concentrations for MIC, MBC and RF (mg/L)														
	octenidine			PVP–iodine			polyhexanide			chlorhexidine			triclosan		
Test organism	MIC	MBC	RF	MIC	MBC	RF	MIC	MBC	RF	MIC	MBC	RF	MIC	MBC	RF
S. aureus	2	2	1	512	8	62.5	0.5	1	2.5	8	8	10	0.125	1	100
P. aeruginosa	2	8	5	1024	1024	125	2	2	2.5	32	32	10	>512	>512	100
C. albicans	1	1	10	256	1024	250	1	4	12.5	4	8	50	8	128	50
Maximum value	2	8	10	1024	1024	250	2	4	12.5	32	32	50	>512	>512	100

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the microdilution test, the use of a neutralizing agent is not specified, as it was established for testing antibiotics for which neutralization need not be performed.

Nevertheless, even under these circumstances, the MIC and MBC values of triclosan and PVP–iodine correlated well with the results of the quantitative tests, insofar as all were higher than those of the more effective antiseptic agents octenidine, polyhexanide and chlorhexidine.

As antiseptics are often used for the antisepsis of skin and mucous membranes before invasive procedures, their short-term efficacy is of great importance. In the quantitative suspension test at a contact time of 1 min, both octenidine and PVP–iodine fulfil the requirements defined for antiseptics at a concentration that is already quite similar to the concentrations required at the longer contact times; however, the effective concentration of PVP–iodine was ~10 times higher than that of octenidine at that contact time. In contrast, the antimicrobial activity of polyhexanide and chlorhexidine noticeably increased over time. While their effective concentrations after 1 min were ~40–100 times higher than that of octenidine, they achieved the level of PVP–iodine after a contact time of 10 min. After 6 h, polyhexanide even reached the efficacy level of octenidine. Concentration-wise, triclosan was demonstrated to be the least effective agent, especially against *P. aeruginosa*. Only at a contact time of 24 h were concentrations that corresponded to those of PVP–iodine sufficient for the intended reduction of the three test organisms.

Nevertheless, the present tests were performed without defined interfering substances, e.g. protein load, and therefore do not completely represent clinical conditions. As could already be seen for PVP–iodine and triclosan, protein load may have a noticeable influence on the results of such investigations. Currently, further investigations under 'dirty conditions' are being conducted to provide additional insight into the influence of protein load on the antimicrobial efficacy of antiseptic agents.

Conclusions

This investigation of antiseptic efficacy under standardized and harmonized conditions allows the user to choose the most efficacious agent. For indications such as wound antisepsis and treatment of mucosal infections, where a prolonged contact time for antiseptic treatment is feasible, the following ranking for the investigated antiseptic agents regarding their effective microbistatic and microbicidal concentration was set: polyhexanide = octenidine > chlorhexidine > triclosan > PVP–iodine. With regard to the tissue compatibility of octenidine and polyhexanide, this ranking is consistent with the recommendations for antisepsis of acute wounds,[5] whereas for chronic wounds polyhexanide seems to be preferable because of its higher tolerability.[30,31] In contrast, for indications requiring a quick onset of antimicrobial activity, for instance, before invasive procedures, the agents of choice are PVP–iodine and octenidine followed by polyhexanide, chlorhexidine and triclosan. The influence of interfering substances on the biocides' efficacy is currently under standardized investigation as well. However, it has also to be noted that the decision for or against a particular antiseptic product cannot be based solely on concentration-based data only—additional factors, such as residual activity, cytotoxicity and systemic risks, need to be taken into account equally. But as those factors will be concentration dependent as well, the data presented herein will further the more judicious use of antiseptics with regard to concentration–contact time relationship, side effects or the speed of onset of antimicrobial activity at a given concentration.

Funding

This research was conducted with the financial support of Schülke & Mayr GmbH (Norderstedt, Germany).

Transparency declarations

M. B. and J. S. are employees of Schülke & Mayr GmbH (Norderstedt, Germany). The antiseptic compound octenidine is used in some of the company's products. M. B. and J. S. do not own stocks or options in Schülke & Mayr GmbH. Other authors: none to declare.

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