



Surgical hand disinfection with a propanol-based hand rub: equivalence of shorter application times

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Summary The aim of this study was to determine the efficacy of a propanol-based hand rub at application times shorter than 3 min. The bacterial pre-value was obtained from the finger tips (prEN 12791). Subjects treated their hands with the reference procedure (*n*-propanol, 60%) for 3 min or the product (crossover design). Sterillium™ was applied for 3, 2, 1.5 and 1 min. Four other preparations were tested for 1 min. Post-values (immediate effect) were taken from one hand, and the other hand was gloved for 3 h. After the gloves were removed, the second post-value was taken (sustained effect). Sterillium was more effective than the reference procedure at 3, 2 and 1.5 min (immediate and sustained effect). The immediate effect after 1 min was significantly lower [mean log₁₀ reduction factor (RF): 1.91 ± 0.90 vs. 2.52 ± 0.95; *P* = 0.001], whereas the sustained effect was not (mean RF: 1.81 ± 1.06 vs. 2.05 ± 1.14; *P* = 0.204). All other preparations failed the efficacy requirement at 1 min for both the immediate and sustained effect. Using 2 × 3 mL Sterillium for a total of 1.5 min for surgical hand disinfection was at least as effective as the 3-min reference disinfection.

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Introduction

Surgical hand disinfection has become an infection control standard worldwide,¹ although its impact on the incidence of surgical-site infections has

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rarely been studied. Higher rates of surgical-site infection after use of plain soap and water, compared with an antiseptic handwash preparation, have been reported in a vascular surgery department.² A similar outbreak was described from a cardiac surgery department with eight cases of surgical-site infection caused by *Candida tropicalis* which were traced to a theatre nurse who used plain soap and water for the pre-operative treatment of hands.³ Repetitive change of surgical gloves after perforation has been described to lead to prosthetic valve endocarditis caused by *Candida parapsilosis*.⁴ Finally, a doctor with hand dermatitis who changed gloves above the surgical field during operations was found to be a source in seven cases of surgical-site infection caused by *Staphylococcus epidermidis*.⁵ The last two examples underline the importance of the sustained effect of a surgical hand disinfectant, especially when hands are regloved without a preceding surgical hand disinfection.

The aim of surgical hand disinfection is the reduction of resident and transient micro-organisms on the surgeon's hands.⁶ With average perforation rates of surgical gloves of 18%, the immediate and sustained efficacy of hand disinfectants has become an important quality marker of the pre-operative treatment of hands.⁷ Alcohol-based hand rubs are often preferred to antimicrobial soaps based on chlorhexidine or PVP iodine because they have a broader spectrum of activity,⁸⁻¹¹ act faster¹¹⁻¹³ and have a better skin tolerance.^{11,14-17} The clinical impact on the incidence of surgical-site infections, however, is not clear.¹⁴

The history of surgical hand disinfection underwent a few changes in the last century.¹⁸ In 1894, three steps were suggested: (1) wash hands with hot water, soap and a brush for 5 min; (2) apply 90% ethanol for 3-5 min with a brush; and (3) rinse the hands with an 'aseptic liquid'.¹⁹ In 1939, a similar procedure was suggested. Initially, a 7-min hand-wash with soap, water and a brush was performed, and hands were dried with a towel. The second step was the application of 70% ethanol for 3 min.²⁰ Since then, the duration of the washing phase has become less and less. The application time of the alcohol-based hand rub, however, has remained more or less at 3 min.^{13,21,22} Shorter application times have not been studied to date.

In Europe, the efficacy of surgical hand disinfectants is usually tested in two parts: in vitro tests to determine the spectrum of antimicrobial activity²³ and in vivo tests against a reference treatment (*n*-propanol 60% for 3 min).²⁴ Significant differences between various commonly used preparations used for 3 min have recently been shown

in vivo. A propranol-based hand rub (Sterillium™) was the only formulation found to be significantly more effective compared with the reference disinfection; other preparations, such as Betadine, failed to meet the efficacy requirements in vivo.²¹ The importance of the duration of exposure to a hand-hygiene agent as a key variable has been emphasized recently.²⁵ Based on this finding, the in vivo efficacy of Sterillium for surgical hand disinfection at shorter application times of 2, 1.5 and 1 min, compared with 1-min use of other common preparations for surgical hand disinfection, was studied.

Materials and methods

Products

The following products were used in the study: Sterillium (hand rub; BODE Chemie GmbH & Co. Melanchthonstr. 27, 22525 Hamburg, Germany), contains 2-propanol (45%), 1-propanol (30%) and mecetronium etilsulphate (0.2%); Desderman N™ (hand rub; Schülke & Mayr GmbH, Robert-Koch-Str. 2, 22851 Norderstedt, Germany), contains ethanol (78.2%) and 2-biphenylol (0.1%); Spitacid™ (hand rub; Ecolab GmbH, Reisholzer Werftstrasse 38-42, 40589 Düsseldorf, Germany), contains ethanol (46%), iso-propanol (27%) and benzylalcohol (1%); Hibistat™ (hand rub; Regent Medical, 3585 Engineering Drive, Norcross, GA 30092, USA), contains iso-propanol (70%) and chlorhexidine (0.5%); and Hibiscrub™ (hand wash; SSL International, Canute Court, Toft Road, Knutsford WA16 ONL, UK), contains chlorhexidine (4%).

Test principle and pre-requisites

The in vivo bactericidal efficacy of the products was assessed according to prEN 12791 in 18-20 healthy volunteers per experiment in a crossover design.²⁴ At some application times, two experiments were carried out in order to increase the sample size. No skin breaks, such as cuts or abrasions, and no other skin disorders were present. Nails were short and clean. Volunteers did not use any substances with antibacterial activity or antibacterial soaps for one week prior to testing.

Wash phase

To remove transient bacterial flora and any foreign

particles, volunteers' hands were washed with a non-medicated soap (sapo kalinus). Five millilitres of the soft soap were poured into the subjects' cupped dry hands and rubbed vigorously on to the skin up to the wrists for 1 min in accordance with the standard procedure to ensure total coverage of the hands. Hands were then rinsed with running tap water and dried with a sterile paper towel.

Determination of the pre-values

The distal phalanges of the right and left hand were rubbed separately, including thumbs, for 1 min on to two Petri dishes (diameter 9 cm) containing 10 mL of tryptic soy broth (TSB). From the sampling fluid obtained from each hand, a 0.1-mL aliquot, as well as 0.1 mL of 1:10 and 1:100 dilutions, were seeded in TSB. Sampling fluids were spread over tryptic soy agar (TSA) dishes with a sterile glass spatula. No more than 30 min elapsed between sampling and seeding. Dishes were incubated for a total of 48 h at 36 ± 1 °C and the colony forming units (cfu) were counted.

Disinfection phase

Each of the 18-20 volunteers was treated with both a reference product (*n*-propanol, 60% v/v) and a study product. A rest period of at least one week elapsed between each product application in order to allow the reconstitution of normal skin flora.

Products were applied as shown in Table I. After treatment with a surgical handwash preparation, hands were rinsed with running tap water for 15 s and then dried with a sterile paper towel.

Determination of post-values

After the disinfection step, the volunteer rubbed the distal phalanges of one hand (selected at

random) for 1 min on to a Petri dish containing 10 mL of TSB supplemented with neutralizers (immediate effect). The following neutralizers were used: 3% Tween 80, 3% saponin, 0.1% histidine and 0.1% cysteine. They have been shown previously to be effective.²⁶ The other hand was gloved for 3 h for assessment of the sustained effect. After removing the glove, sampling was done in the same way as for the immediate effect. From the sampling fluid, both 1- and 0.1-mL volumes were seeded in Petri dishes with solidified TSA. A 1:10 dilution of the sampling fluid in TSB was prepared and a 0.1-mL aliquot was seeded as above. Dishes were incubated at 36 ± 1 °C for a total of 48 h.

For each dilution, the mean number of cfus was calculated. The mean number was then multiplied by the dilution factor in order to obtain the number of cfu/mL of sampling liquid.

All pre- and post-values were expressed as \log_{10} values. For calculation purposes, values of 0 ($\log 0 = -\infty$) were reset to 1 ($\log 1 = 0$). If values in the range that could be entered into calculations were obtained from more than one dilution, their mean was used as the final logarithm value. For each volunteer, the logarithmic reduction factor (RF) was obtained as the difference between the \log_{10} pre-value and the \log_{10} post-values.

The mean RF of the reference treatment was compared with the corresponding mean for each product for a paired analysis of the immediate and sustained effects.

For a product or application time to be considered effective for surgical disinfection, the mean RF of both the immediate and sustained effects had to be not significantly lower than the corresponding mean RF of the 3-min reference treatment.²⁴ Statistical analysis of means was performed using the Wilcoxon matched-pairs signed-rank test (SPSS). The mean RF at more than two application times was compared with the ANOVA model (SPSS).

Table I Mode of application of different products at various application times for surgical hand disinfection

Product	Application time (min)	Mode of application
Reference alcohol	3	As many portions of 3 mL as necessary to keep hands moist for the total application time
Sterillium	3	
	2	
	1.5	3 mL for 45 s, another 3 mL for 45 s
	1	3 mL for 30 s, another 3 mL for 30 s
Desderman N	1	
Spitacid	1	
Hibistat	1	
Hibiscrub	1	5 mL for 60 s

Table II Immediate effect of Sterillium for surgical hand disinfection at different application times (1, 1.5, 2 and 3 min) compared with the reference surgical hand disinfection (3 min), presented as the mean reduction of the resident skin flora

Volunteers (N)	Reference disinfection		Sterillium		P value
	Application time (min)	Mean RF (SD)	Application time (min)	Mean RF (SD)	
20	3	2.52 (0.56)	3	2.92 (0.57)	0.029
19	3	2.01 (0.86)	2	2.81 (1.13)	0.016
37	3	1.92 (0.99)	1.5	2.58 (0.96)	0.003
40	3	2.52 (0.95)	1	1.91 (0.90)	0.001

RF, reduction factor; SD, standard deviation.

Table III Sustained effect (after 3 h under a surgical glove) of Sterillium for surgical hand disinfection at different application times (1, 1.5, 2 and 3 min) compared with the reference surgical hand disinfection (3 min), presented as the mean reduction of the resident skin flora

Volunteers (N)	Reference disinfection		Sterillium		P value
	Application time (min)	Mean RF (SD)	Application time (min)	Mean RF (SD)	
20	3	2.44 (0.47)	3	2.58 (0.45)	0.365
19	3	1.63 (0.98)	2	2.19 (1.28)	0.147
37	3	1.31 (1.16)	1.5	1.90 (1.03)	0.012
40	3	2.05 (1.14)	1	1.81 (1.06)	0.204

RF, reduction factor; SD standard deviation.

Results

Immediate effect (0-h values)

The mean RF with Sterillium was between 2.92 ± 0.57 (3 min) and 1.91 ± 0.90 (1 min) with a significant difference between the four application times ($P < 0.001$, ANOVA). A direct comparison between the 3-min reference treatment and Sterillium revealed a significantly higher mean RF for Sterillium at 3 min ($P = 0.029$; Wilcoxon matched-pairs signed-rank test),²⁷ 2 min ($P = 0.016$) and 1.5 min ($P = 0.003$; Table II). A 1-min application of Sterillium, however, was significantly less effective than the 3-min reference disinfection ($P = 0.001$). No significant difference was found between mean RFs of Sterillium at application times of 3, 2 and 1.5 min ($P = 0.365$, ANOVA).

Sustained effect (3-h values)

The mean RF with Sterillium was between 2.58 ± 0.45 (3 min) and 1.81 ± 1.06 (1 min) with a significant difference between the four application times ($P = 0.038$, ANOVA). A direct comparison between the 3-min reference disinfection and Sterillium revealed a higher mean RF for Sterillium at 3 min ($P = 0.365$, Wilcoxon matched-pairs signed-rank test), 2 min ($P = 0.147$) and 1.5 min ($P = 0.012$; Table III). At 1 min, Sterillium was less effective than the 3-min reference disinfection, but the difference was not significant ($P = 0.204$). No significant difference was found between mean RFs of Sterillium at application times of 3, 2 and 1.5 min ($P = 0.055$, ANOVA).

Comparison with other hand disinfectants

Four other surgical hand disinfectants were also tested at 1 min: Desderman N, Hibiscrub, Hibistat and Spitacid. All surgical hand preparations were

significantly less effective for the immediate effect, and most preparations were also significantly less effective for the sustained effect compared with the 3-min reference disinfection (Tables IV and V). Only Sterillium was not significantly less effective after 1 min for the sustained effect (Table IV). Differences of mean RF were smallest with Sterillium (0.61, immediate effect; 0.24, sustained effect) and highest with Hibiscrub (1.74, immediate effect; 1.83, sustained effect). The differences of the other three preparations were variable.

Discussion

This study showed that a 1.5-min application time with 2×3 mL of a propanol-based hand rub is at least as effective as the 3-min reference hand disinfection. The use of 2×3 mL Sterillium over 1 min failed in the immediate effect but still met the efficacy requirement of the sustained effect compared with the 3-min reference disinfection. All other alcohol-based hand rubs and the chlorhexidine-based hand scrub failed to reveal sufficient efficacy after 1 min for both the immediate and the sustained effect. This finding is of clinical relevance, especially in emergency surgery, because surgical hand disinfection should be as short as possible without diminishing the required efficacy.

Alcohols have been described to have superior efficacy on the resident skin flora compared with other agents such as chlorhexidine or povidone iodine.⁸ Most studies have been carried out with application times of 3 or 5 min.²⁸ In the present study, a 1-min surgical scrub with Hibiscrub revealed the lowest mean RF of the resident hand flora for both the immediate and the sustained effect. Significant differences were also observed among the four different alcohol-based hand rubs. For the immediate effect, the difference in the

Table IV Immediate effect of various products for surgical hand disinfection after a 1-min application time, presented as the mean reduction of the resident skin flora

Preparation	Type of procedure	Volunteers (N)	Mean RF of preparation (1 min)	Mean RF of reference disinfection (3 min)	Difference between treatments	P value
Sterillium	Hand rub	40	1.91 ± 0.90	2.52 ± 0.95	0.61	0.001
Hibistat	Hand rub	20	1.79 ± 1.20	2.54 ± 1.12	0.75	0.03
Spitacid	Hand rub	20	1.43 ± 0.60	2.54 ± 1.12	1.11	0.001
Desderman N	Hand rub	20	1.53 ± 0.82	2.93 ± 1.01	1.40	<0.001
Hibiscrub	Hand wash	20	0.80 ± 0.58	2.54 ± 1.12	1.74	<0.001

RF, reduction factor.

Table V Sustained effect (after 3 h under a surgical glove) of various products for surgical hand disinfection after a 1-min application time, presented as the mean reduction of the resident skin flora

Preparation	Type of procedure	Volunteers (N)	Mean RF of preparation (1 min)	Mean RF of reference disinfection (3 min)	Difference between treatments	P value
Sterillium	Hand rub	40	1.81 ± 1.06	2.05 ± 1.14	0.24	0.204
Desderman N	Hand rub	20	1.50 ± 1.07	2.38 ± 1.21	0.88	0.004
Hibistat	Hand rub	20	1.65 ± 1.05	2.59 ± 0.72	0.94	0.001
Spitacid	Hand rub	20	1.18 ± 1.14	2.59 ± 0.72	1.41	<0.001
Hibiscrub	Hand wash	20	0.76 ± 0.69	2.59 ± 0.72	1.83	<0.001

RF, reduction factor.

mean RF between the 3-min reference disinfection and the 1-min hand rub was 0.61 with Sterillium but 1.40 with Desderman N. For the sustained effect, the difference in the mean RF between the 3-min reference disinfection and the 1-min hand rub was 0.24 with Sterillium but 1.41 with Spitacid. These data illustrate that considerable differences can be found among alcohol-based hand rubs with a similar total alcohol content. In hygienic hand disinfection, the differences between different alcohol-based liquid rubs compared with the reference disinfection are almost negligible.²⁹ It is clear that it makes a bigger difference if the resident hand flora is investigated.

An interesting observation is that the application time itself has a considerable influence on the overall result. Using 2 × 3 mL Sterillium for a total of 1 min was not as efficacious as the 3-min reference treatment. Using the same amount of Sterillium for a total of 1.5 min exceeded the efficacy of the 3-min reference treatment. The additional 30 s of rubbing the preparation into the hands is clearly very important to reach the required efficacy. Longer application times (i.e. 2 or 3 min) did not result in an additional effect on the resident skin flora compared with 1.5 min. To date, the kinetics of alcohol-based hand rubs on the resident hand flora have not been studied in this way. However, it seems that a maximum effect can be achieved with a specific dose and application time which may be variable for each preparation.

The comparison of a product with a reference treatment has been established for many years. For surgical hand disinfection, a 3-min treatment with *n*-propranol (60%, v/v) is required according to prEN 12791.²⁴ The 3-min treatment has similar efficacy as a 5-min application,²⁸ and was, therefore, chosen as the reference treatment. A log₁₀ reduction factor of 2.0-2.9 has been described regarding the immediate effect. The sustained effect after 3 h under the surgical glove is lower,

with a mean log₁₀ reduction factor of 1.0-1.8 log steps.²⁸ The reference disinfection in our study revealed a reduction in the same range. A reduction of 1.92-2.93 was found for the immediate effect, and a lower reduction (1.31-2.59) was obtained for the sustained effect. These reference data illustrate the good reproducibility of the surgical reference disinfection.²² The principle of a reference treatment has also been established in efficacy testing for hygienic hand disinfection.^{30,31}

Overall, a 1.5-min application time using 2 × 3 mL Sterillium for 45 s can be regarded sufficient antimicrobial efficacy for surgical hand disinfection according to prEN 12791. A 1-min application time, however, will not yield sufficient efficacy, irrespective of the type of preparation.

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