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ORIGINAL ARTICLE

Preoperative sterilization and disinfection of drill guide templates

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Abstract The aim of the in vitro study was to evaluate the decontamination potential of common antiseptic solutions for heat-sensitive implantological drill guide templates. One hundred implantologists were evaluated on the basis of a questionnaire for their measures of disinfection. On the basis of these results, 80% alcohol, Octenidine 0.1%, and Chlorhexidine 0.12% were tested in an in vitro model for their decontamination efficacy for heat-sensitive plastic material infected with *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, *Enterococcus faecalis*, *Enterococcus faecium*, *Staphylococcus aureus*, *Enterobacter cloacae*, *Escherichia coli*, and *Candida albicans*. The microorganisms were selected on the basis of results of environmental testing of dental laboratories. The results of the questionnaire revealed that Chlorhexidine was used by 30%, 80% alcohol by 23%, and Octenidine by 7% of the dentists. Using the in vitro model, with the exception of *S. aureus*, Chlorhexidine was not able to completely eliminate the microorganisms after 15 min of application. In contrast, the treatment with Octenidine revealed no further growth of the tested microorganisms after that time. The 80% alcohol was more efficient. No growth of microorganisms could be detected in any of the tests after 5 min of incubation. On the basis of our results and due to the fact that suitable installations for sterilization were hardly used by the dental practitioners, the disinfection of templates should be preferentially performed with 80% alcohol or Octenidine using an incubation time of 15 min with ultrasonication.

Keywords Drill guide template · Disinfection · Sterilization · Antiseptics · Microbiology · Oral surgery

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Introduction

Medical products contaminated with pathogenic microorganisms can cause severe infections in humans. The standards and the guidelines for the use of medical products are extensively defined in America and Europe [1, 2, 6–9, 14, 16]. The different regulations of all these countries reveal heat sterilization for devices for care of the patients and items that are planned to be in contact with patient's blood or wounds. Center for Disease Control (CDC) and Food and Drug Administration (FDA) for USA, the Medical Devices (MEDDEV) guidelines of the EU, and DAHZ (German Study Group for Hygiene in Dentistry) and the 'Regulations for Medical Devices' divide medical products into different categories (uncritical, I; semicritical, IIa,b; and critical, III) [1, 2, 6–9, 13, 14, 16]. These categories are assigned to different processes for cleaning, disinfection, and sterilization [4, 8, 12, 21, 24]. Medical products of group "critical A" (Germany), II a (EU), or "semicritical" (USA) must pass through a thermal or a chemical cleaning and a disinfection procedure, respectively.

Heat sensitive semicriticals may be disinfected with high-level disinfectants, but according to the FDA, this use is to be discouraged [16]. Among the medical products, the drill guide template has an exceptional position, individually manufactured in a dental laboratory for a single use where it might be in touch with many different microorganisms [2, 7, 8]. During the invasive implant procedure, the drill guide templates have contact with patients' blood or with the wound (Fig. 1). Therefore, according to the regulations mentioned above, the drill guide templates have to be estimated as critical/ semicritical/IIa medical products. According to the published guidelines [6, 24, 31], the sterilization has to be performed with suitable validated procedures so that the success of these procedures can be monitored and the safety and health of patients, users, and other persons guaranteed. Thus, the personal, instrumental, and hygiene environments have to correspond to other elective operations [25]. The management of the hygiene procedures is the responsibility of the dentist. This is also the case when a commercial dental laboratory has performed hygiene procedures [13]. The US guidelines point out that the laboratory has to provide written information regarding the methods used to clean and disinfect the material [1]. Pressure pots and water baths are particularly susceptible to the contamination with microorganisms and should be cleaned and disinfected between patients [16].

In most cases, drill guide templates are made of two compound polymethylmethacrylate or polyethylene copolymer resins, processed in cupping technique. Due to their thermosensitivity, these drill guide templates cannot be sterilized by heat or autoclaving procedures. The present investigation is directed towards the question of the species of microorganisms, which may contaminate the drill guide templates during manufacture in the dental laboratory. In the first part of the study, the procedures of disinfection or sterilization of drill guide templates used by the dentists before surgery were evaluated by a questionnaire. The second part of this study investigated the antimicrobial efficacy of three chemical agents commonly used for disinfection. Chlorhexidine-digluconate (CHX) 0.12% is a cationic compound reported to be able to attach to the oral surface. According to the instructions of the manufacturer, slow-release depots are generated that lead to an increased concentration of Chlorhexidine in the mouth for 24 h. CHX is a solution with outstanding preventive efficacy against gingival and mucosal inflammations and an inhibiting effect on plaque growth [28], efficient against yeasts, fungi, and a broad spectrum of Gram-positive and Gram-negative bacteria. It is an antiseptic mouthwash that has received the 'American Dental Association Council on Scientific Affairs Seal of Acceptance based on clinical studies' [11]. The second disinfectant, an aqueous antiseptic solution, contained Octenidine-dihydrochloride 0.1%, phenoxyethanol, (3-cocamidopropyl)-dimethyl ammonium acetate, sodium-D-gluconate, glycerol 85%, sodium hydroxide, and sodium chloride. Octenidin was proven to be a highly efficient substance with a broad antimicrobial spectrum used for the decontamination of skin and mucosa before medical and dental diagnostic and surgical procedures [26, 30]. This substance is effective against Gram-positive and Gram-negative bacteria as well as against yeasts, dermatophytes, and lipophilic viruses at pH 6.0±0.5 [26, 30, 34]. The third disinfectant contained ethanol 80% (ethanol 80%), denatured with ethyl methyl ketone. Ethanol 80% has a broad antimicrobial spectrum against bacteria and fungi and is a fast acting substance [19, 41]. Additionally, ethanol has best properties against viruses. However, no action against spore forms was noted. The antimicrobial activity of the chemical agents investigated has been described by a number of authors under in vitro conditions [10, 34, 35, 43, 44] and under in vivo conditions [4, 5, 26, 30, 33]. Data concerned with the efficacy of these antiseptics on denture acrylic materials infected with microorganisms selected according to environmental investigations in dental laboratories have not been available up to now. The microorganisms were obtained from the American Type Culture Collection ATCC (Rockville, MD, USA). The present study compared three disinfection agents for their decontamination efficacy and added new data with respect to their practical usefulness.

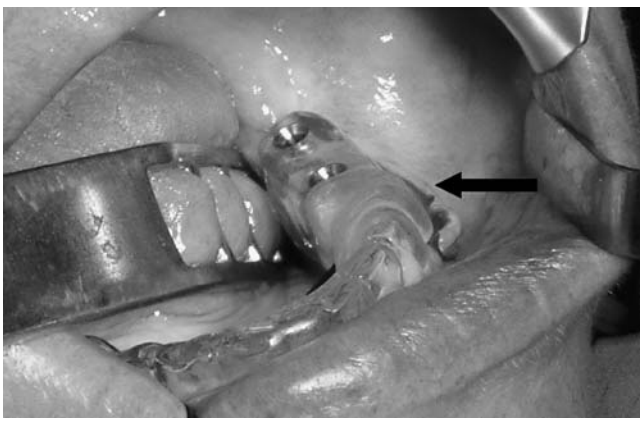

Fig. 1 Drill guide template made of polyethylene copolymer resin, processed in a cupping technique, during implant insertion. The *arrow* indicates the direct contact with the lesion of surgical approach

Materials and methods

Realization of the survey by a questionnaire

Questionnaires (160) were sent to dentists with a focus on implantology, to implantologists, and to maxillofacial

surgeons all over Germany. The participants in this survey were contacted by telephone or had been addressed personally during postgraduate courses or implantological congresses. One question was added for the confirmation of the implantological activity, another question referred to the use of drill guide templates and to the method used for disinfection and sterilization. Additionally, details on the material of the drill guide templates were requested (Fig. 2).

Microbiological investigations of the environment

Five dental laboratories voluntarily took part in microbiological environment surveys with regard to the workspace where thermoplastics were handled. Pressure pots, ultrasonic units, polishing paste pans (pumice), working areas, washbasins, and millings were wiped off the surface area of 5 cm^2 with the Transsystem, DIN 58942 TP-AL, Copan, Italy.

The samples gained were analyzed in the Department for Hospital Hygiene and Infection Control of the university. They were incubated in a standard liquid medium (casein–peptone or soy flour–peptone bouillon) for 72 h. The samples were then analyzed for bacterial and fungal growth by differentiation of the single colony-forming units and by Gram staining [39]. The identification of the microorganisms was performed with commercially available identification systems for Gram-positive bacteria (BD BBL Crystal GP, No 245140, Becton Dickinson, Heidelberg, Germany). In addition, an identification system for Gram-negative rods was used (BD BBL Crystal GP, no. 245000, Becton Dickinson).

Antimicrobial agents and inactivation substances

On the basis of the results of the questionnaire, the chemical disinfecting agents were selected for the in vitro investigation (see below). Chlorhexidine-digluconate 0.12% (Paroex®, Butler, Kriftel, Germany), ethanol 80% (Alkopharm®, Brüggemann, Heilbronn, Germany), and Octenidine-dihydrochloride 0.1% (Octenisept®, Schülke and Mayr, Norderstedt, Germany), representing the agents most often reported, were investigated for their efficacy. Tween 80 (3.0%) + 0.3% saponine + 0.1% histidine + 0.1% cysteine, prepared with phosphate buffer, was used as inactivation substance for both CHX and Octenidine®. Tween 80 (3%) was solely used to inactivate alcohol [41].

Questionnaire

1. **Do you perform dental implant surgery?** Yes □ No □
2. **Do you use drill guide templates?** Yes □ No □
3. **What kind of sterilisation-, disinfection procedures do you use?**
   - a) **Disinfection solution? (If yes, which ones?)**.....
   - b) **Gas sterilisation?** .....
   - c) **Plasma sterilisation?** .....
   - d) **Others:** .....

Fig. 2 Example of a questionnaire distributed to evaluate the methods of disinfection and/or sterilization of drill guide templates

In vitro investigation of the agents

The testing devices (Fig. 3) were specially made for this investigation using a two-compound polymethylmethacrylate resin (Paladur®, Heraeus Kulzer, Hanau, Germany). The sterilization of these testing devices with ethylene oxide was carried out in the central sterilization unit of the university clinics. As control, a sterile testing device without prior contamination and disinfection procedure was added in the test series.

Infecting scheme

The devices were contaminated with a defined number of test microorganisms. The microbes were selected on the

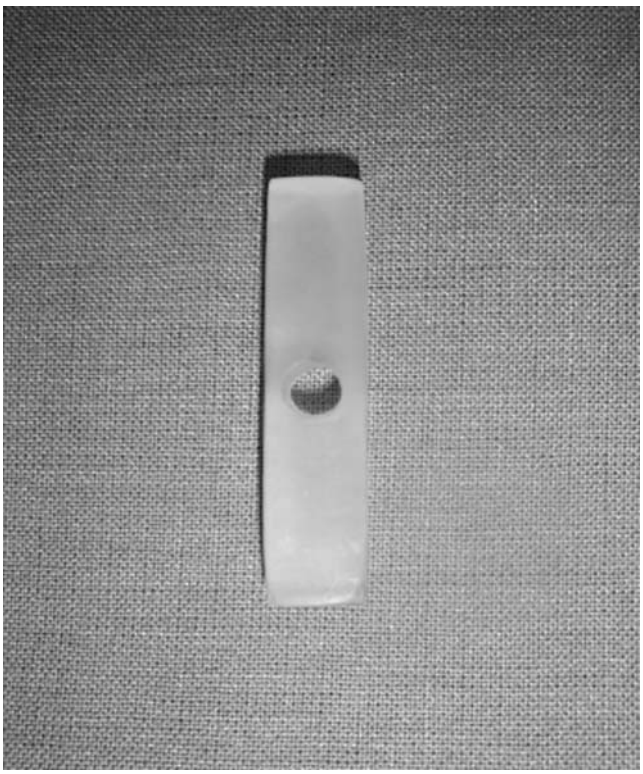

Fig. 3 The testing device made of two-compound polymethylmethacrylate: length 4.0 cm, width 0.8 cm, depth 0.8 cm, and diameter of the borehole 0.3 cm

basis of environmental investigations in dental laboratories. The different microorganisms used for the contamination of the testing devices were obtained from the American Type Culture Collection ATCC (Rockville, MD, USA). These strains were stored in the Department for Hospital Hygiene and Infection Control of the university. The following bacterial strains were used: *Pseudomonas aeruginosa* (ATCC 27853), *Acinetobacter baumanni* (ATCC 19606); *Enterococcus faecalis* (ATCC 29212), *Enterococcus faecium* (ATCC 6057), *Staphylococcus aureus* (ATCC 25923), *Escherichia coli* (ATCC 11229), *Enterobacter cloacae* (ATCC 13047), and *Candida albicans* (ATCC 10231). Five colony-forming units of each microorganism were suspended in 100 ml 0.9% sodium chloride solution and mixed with a vortex mixer (VF 2, Janke and Klunke, Staufen i.Br., Germany). The testing devices were contaminated for 20 min with the different microorganisms.

Disinfecting scheme

The disinfection of the contaminated testing devices was performed with different chemical disinfection solutions on the basis of results of a survey among dental practitioners, implantologists, and maxillofacial surgeons. They were transferred to a solution with disinfection agents for a defined incubation time (1, 5, or 15 min). After a rinsing procedure for 30 s with 0.9% sodium chloride solution, similar to clinical conditions, the rinsed test piece was transferred to a test tube containing the same amounts of liquid culture broth and inactivation substance and was incubated for 30 min. To calculate the efficacy of the different antiseptic solutions, the bacterial concentration of the different samples was determined [39]. The liquid culture broth mentioned above was serially diluted in physiological saline (10^{-1} to 10^{-5}). One hundred microliters of each sample were dispersed onto blood agar plates and incubated for 24 h at 37°C. At the end of this incubation, the agar plates were evaluated for bacterial growth by counting the colony-forming units.

Directly after the disinfection procedure, the efficiency of the antiseptic solutions was proven with different bacterial species. In a further step, the liquid broths that contained the testing devices after the disinfection procedure were incubated additionally for 24 h at 37°C. To estimate the remaining part of viable bacteria, the microorganisms from the broth were directly plated on different agar media. The numbers of colony-forming units in the control testing devices was determined as described above on blood agar plates. The cultivation of *C. albicans* was performed on Sabouraud plates for 48 h. In general, three separate tests were performed to estimate the mean numbers.

Results

Evaluation of the questionnaires and of the microbiological environmental investigations of dental laboratories

Out of the 160 questionnaires that had been distributed among the dental practitioners, 122 were returned for evaluation. Twenty-two dentists did not use drill guide templates for implantological surgery. Therefore, 100 questionnaires could be analyzed. Of this group, 99% disinfected the drill guide templates before use. Thirty percent used CHX solution, 23 % alcohol, and 7% Octenidin for disinfection (Table 1). According to the statements of the respondents, the drill guide templates were handmade of thermoplastic two-compound polymethylmethacrylate resin (Paladur®, Heraeus Kulzer, Hanau, Germany) or polyethylene copolymer resins, processed with a cupping technique (Erkodur®, Erkodent, Pfalzgrafenweiler, Germany).

As a next step, after the evaluation of the questionnaire, five dental laboratories voluntarily took part in an environmental investigation. Microbiological tests were performed with focus on areas of plastic processing. From this study, 56 tests from surfaces of pressure pots, ultrasonic units, polishing paste pans (pumice), working areas, washbasins, and millings were performed. In all dental laboratories, *Staphylococcus epidermidis* was detected on all surfaces analyzed. *S. aureus* was found in the pumice polishing paste pans of two dental laboratories, where *Enterococcus* spp., *Aeromonas caviae*, *Enterobacter cloacae*, and *P. aeruginosa* could also be identified. *Enterococcus* spp. were taken by smear from millings and *Enterobacter cloacae* from washbasins of three laboratories, respectively. *Citrobacter freudii* (2), *Acinetobacter baumannii* (4), and *P. aeruginosa* (3) were detected in ultrasonic units and pressure pots.

Table 1 Results of 100 evaluated questionnaires (compare Fig. 2) concerned with the frequency of use of antiseptic solutions for the decontamination of the drill guide templates prior to implantological surgery

Disinfection substance	Frequency (%)
CHX	30
Alcohol	23
Octenisept®	7
Sterilium®	2
Lysetol FF®	1
Mikrozid®	2
H_2O_2	1
Pursept®	1
Septanin®	1
Various/ indefinable	4
No specification	28

In vitro analysis

Gram positive cocci CHX revealed a bacterial reduction ≥5 $\log_{10}$ grades on *S. aureus* (Fig. 4a) only after 15 min of incubation. In the 24-h controls, no bacterial growth could be detected. In contrast, neither of the *Enterococci* spp. was completely eradicated. One of the 24-h controls showed bacterial growth (Table 2).

Octenidine induced in *S. aureus* after 1 min of incubation a reduction of ≥5 $\log_{10}$ grades. However, in two of three controls, 24 h later, further bacterial growth was detected (Table 2). The incubation of *S. aureus* with Octenidine for ≥5 min revealed no further bacterial growth after 24 h. The same observation was made with *Enterococcus faecalis* (ATCC 29212), while *E. faecium* (ATCC 6057) needed a treatment of 15 min to show no further growth 24 h later.

Alcohol 80% reduced *S. aureus* (ATCC 25923) after 1 min of incubation by ≥5 $\log_{10}$-grades. However, the long-term controls showed no further growth, when an incubation time of ≥5 min was used (Table 2). With *E. faecalis*, the same results were obtained, while for the substantial reduction of *E. faecium* ≥5 $\log_{10}$-grades, an incubation time of ≥5 min was needed.

Gram-negative rods CHX showed a reduction of ≥5 $\log_{10}$-grades with *Escherichia coli* (ATCC 11229) after 15 min of incubation. However, in two out of three long-term controls, bacterial growth was observed (Table 2). Likewise, CHX was not able to reduce the growth of *Enterobacter cloacae* (ATCC 13047) significantly (Fig. 4b). Octenidine needed at least 15 min of interaction to reduce the bacterial growth by ≥5 $\log_{10}$- grades with both bacterial species. No further growth could be detected in the 24-h controls. Alcohol reduced bacterial growth ≥5 $\log_{10}$- grades already after 1 min of application. However, in the case of *E. coli* (ATCC 11229), 5 min of interaction with 80% alcohol was needed to observe no further growth in the long-term controls.

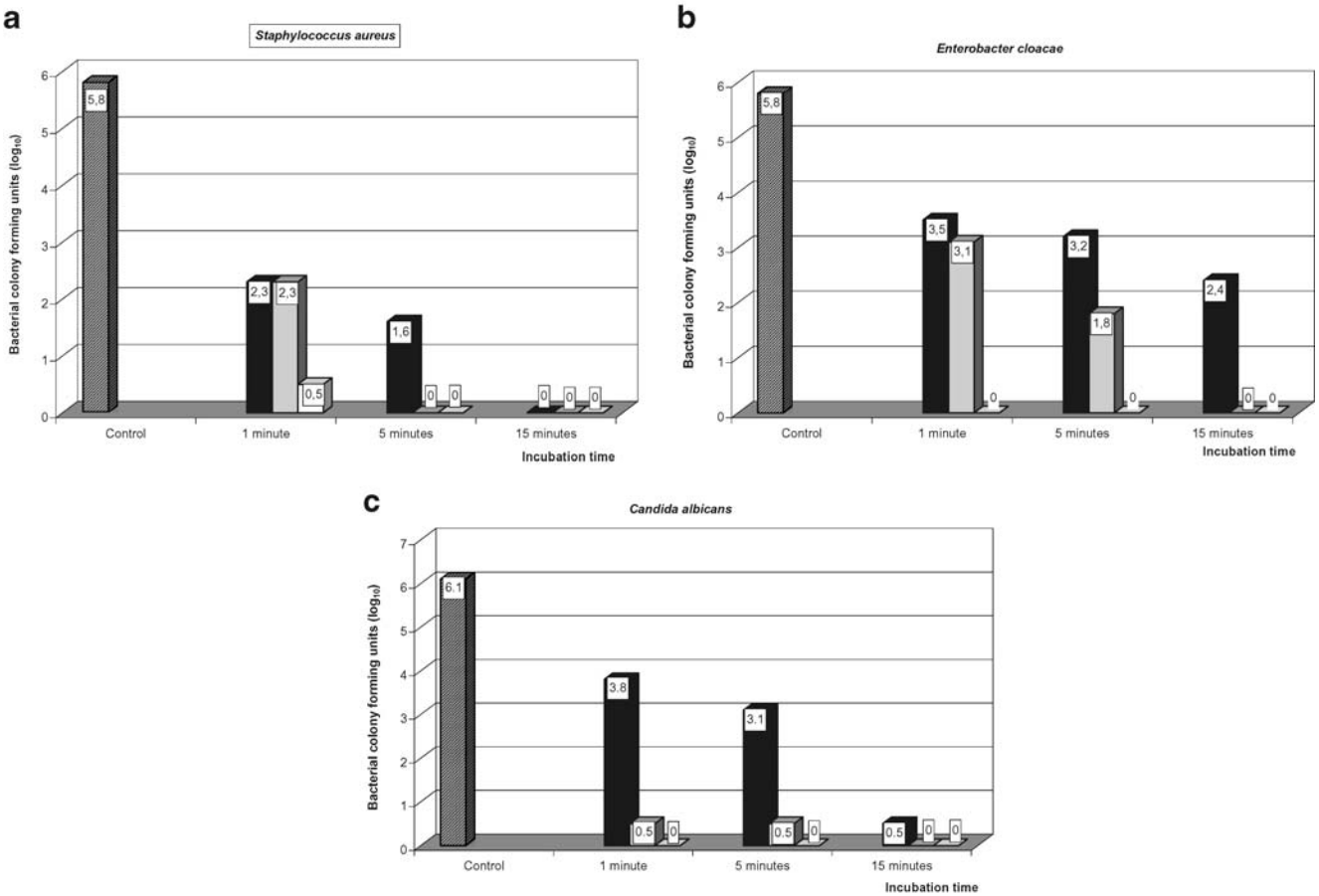

Fig. 4 Efficacy of CHX (on the *left*), Octenidin (in the *middle*), and 80% alcohol (on the *right*) on *Staphylococcus aureus* (**a**), *Enterobacter cloacae* (**b**), and *Candida albicans* (**c**) after 1, 5, and 15 min. The dependence of the effect on the incubation time is depicted exemplarily. For comparison, the number of microorganisms in the control tests is depicted. The further long-term effect of the antiseptic substance tested is shown for all bacteria in Table 2

Table 2 Summary of the results of the disinfection tests

	CHX		Octenisept®		Alcohol	
	∅	24 h later	∅	24 h later	∅	24 h later
Staphylococcus aureus						
K/Pk (log_{10})	5.8		5.8		5.8	
1 min	1.9	+ (2)	1.9	+ (3)	–	+ (2)
5 min	1	+ (2)	–	–	–	–
15 min	–	–	–	–	–	–
Enterococcus faecalis						
K/PK (log_{10})	6		6		6	
1 min	4.3	+ (3)	–	+ (2)	–	+ (1)
5 min	3.1	+ (3)	–	–	–	–
15 min	–	+ (1)	–	–	–	–
Enterococcus faecium						
K/PK (log_{10})	6		6		6	
1 min	4.1	+ (3)	–	+ (2)	1.5	+ (3)
5 min	3.7	+ (3)	–	+ (1)	–	–
15 min	–	+(1)	–	–	–	–
Escherichia coli						
K/PK (log_{10})	6.5		6.5		6.5	
1 min	2.7	+ (3)	1	+ (2)	–	+ (2)
5 min	2.8	+ (2)	–	+ (1)	–	–
15 min	–	+ (2)		–	–	–
Enterobacter cloacae						
K/PK (log_{10})	5.8		5.8		5.8	
1 min	3.5	+ (3)	3.1	+ (3)	–	–
5 min	3.2	+ (3)	1.8	+ (2)	–	–
15 min	2.4	+ (3)	–	–	–	–
Pseudomonas aeruginosa						
K/PK (log_{10})	6		6		6	
1 min	2.8	+(3)	–	+(2)	–	–
5 min	2.7	+(3)	–	–	–	–
15 min	–	+(1)	–	–	–	–
Acinetobacter baumannii						
K/PK (log_{10})	5.9		5.9		5.9	
1 min	–	+(3)	–	+(3)	–	+(3)
5 min	–	+(3)	–	–	–	–
15 min	–	+(3)	–	–	–	–
Candida albicans						
K/PK (log_{10})	6.1		6.1		6.1	
1 min	3.8	+(3)	–	+(2)	–	–
5 min	2.6	+(3)	–	+(1)	–	–
15 min	–	+(2)	–	–	–	–

The antiseptic substances CHX, Octenidin, and 80% alcohol were tested for their efficacy on the Gram-positive bacterial species *Staphylococcus aureus*, *Enterococcus faecalis* + *Enterococcus faecium*, on the Gram-negative bacterial species *Escherichia coli*, *Enterobacter cloacae*, *Pseudomonas aeruginosa*, and *Acinetobacter baumannii* and on *Candida*. The antiseptics were incubated with the microorganisms for 1, 5, and 15 min in triplicates. The mean values (log_{10}-grades) of controls (K/PK) and tests are shown. Additionally, 24-h controls for measurement of bacterial growth qualitatively were added (24 h later).

+ Bacterial growth; – no bacterial growth; (*n*) the number of positive controls is listed.

CHX showed a reduction of ≥5 log_{10}- grades after 15 min of incubation with *P. aeruginosa* (ATCC 27853). However, in one out of three long-term controls, bacterial growth was observed (Table 2). The incubation of *Acinetobacter baumannii* (ATCC 19606) with CHX reduced bacterial growth at all application times tested. However, the long-term controls were not favorable demonstrating bacterial growth in each control (Table 2). Octenidine induced in both species tested, already after 1 min of application, a growth reduction ≥5 log_{10}- grades. However, to gain a

long-term effect, these bacterial species had to be incubated for ≥5 min with this antiseptic substance (Table 2). When 80% alcohol was applied for 1 min, the bacterial growth of both species was reduced for ≥5 $\log_{10}$- grades. However, the long-term controls were only free of bacterial growth, as far as *A. baumannii* was concerned, when they were incubated with alcohol for ≥5 min.

Yeasts CHX reduced the growth of the yeast *Candida albicans* (ATCC 10231) of ≥5 $\log_{10}$- grades when this substance was applied for 15 min. However, this effect was not long-lasting. Two out of three controls obtained 24 h later showed fungal growth. Octenidine reduced the *Candida* growth already after 1 min of application. However, to receive a long-lasting antiseptic effect, an incubation time of 15 min was needed (Table 2). Alcohol revealed a high efficacy already after 1 min of application. No fungal growth was observed in further control tests, 24 h later (Table 2, Fig. 4c).

In summary, these results show that 80% alcohol had a favorable long-lasting effect on the tested bacteria. With the exception of *Enterococcus faecium* (ATCC 6057), 80% alcohol reduced the number of all other bacterial isolates with ≥5 $\log_{10}$- grades after 1 min of application. A long-lasting effect, demonstrating no further bacterial growth in the 24-h controls, was completely achieved when the alcohol was applied at least for 5 min.

Discussion

The intraoperative contamination of open wounds is the most frequent cause of the development of infections. The predominant sources of microorganisms are the operating staff and the patient himself. Microorganisms are transferred into the wound by direct contact or indirect by secondary carriers, such as airborne particles or originally sterile materials [42].

Due to the intensive use of antibiotics, multiresistant microorganisms are becoming an increasingly important problem. This is not only limited to methicillin resistant *S. aureus* (MRSA) but also resistant *Enterococci* spp. and *Pseudomonas* spp. have increased [3]. Therefore, a reduction in bacteria with pathogenic potential is an essential step in the management of infections and one of the main aims of all prophylactic efforts [20].

Drill guide templates consist of thermolabile materials with porous surfaces and are difficult to disinfect. A main aspect of this study was to evaluate the spectrum of bacteria, which came into contact with drill guide templates. Another aspect was concerned with the habits of dentists with implantological focus for the disinfection of the drill guide templates intraoperatively used. The commercially recommended antiseptic solutions (Lysetol AF®, Gigasept AF®, Dentasept®, MD 520®, and Meliseptol®) have been intensively investigated and reviewed. They are not the theme of this study because, according to the results of the questionnaire, they are not often used. The reasons for these results are unknown. However, antiseptic solutions used intraorally seemed to be preferred to the commercially recommended antiseptic solutions of materials due to residues of the antiseptic solutions on the templates.

In an in vitro model, the efficacy of the most frequently used antiseptic solutions against different bacterial species was tested. *P. aeruginosa* is a bacterium, which can be isolated in a damp environment. It is not a member of the physiological oral microflora. It is able to grow in biofilms with high resistance to host immune defense and against antibiotic substances [37]. Especially in immunocompromised hosts, deep systemic infections can occur [17, 23]. The present results with respect to the restricted efficacy of CHX on *P. aeruginosa* are consistent with studies that showed that *P. aeruginosa* persisted in some antiseptic solutions due to its ability to develop alginate [36]. The effects of CHX have been well documented under different prophylactic and therapeutic regimens [12, 15, 29]. As we investigated the decontamination potential against planktonic bacteria on surgical templates and we did not use intraorally grown bacteria, the results of this study are difficult to compare with the data gained from other studies.

Acinetobacter baumannii, *Enterococcus faecium*, *Enterococcus faecalis*, *Enterobacter cloacae*, and *Escherichia coli* do not belong to the normal physiological flora of the mouth; however, they are occasionally present. They are able to cause, for example, wound infections, pneumonia, and septicemia. *S. aureus* and *Escherichia coli* often cause infections in humans [17, 18, 21]. *S. aureus* and *Candida albicans* occasionally colonize the oral mucosa to a small extent. Some reports using in vitro models support the assumption of augmented resistance of *C. albicans* grown in biofilms [10, 27, 32]. Additionally, the interaction between fungi and bacteria in combined biofilms increases the therapeutic resistance [22]. The results of this study contradict those of Shapiro et al. who investigated the efficacy of different mouth rinse solutions in a combined in vitro polyspecies model with *C. albicans* as one part. These authors applied the antiseptic solutions for 1 min with several repetitions on the biofilms. The efficacy of CHX in that model was with or without *Candida* cells in the biofilm equally excellent. The survival rate after the application of CHX in our investigation indicates a reduced sensitivity of the *Candida* cells when grown in the biofilm, which has also been described by other working groups [10, 38]. The results of the present study indicate that an efficient

disinfection of thermosensitive acrylic devices cannot be undertaken with CHX, especially when *C. albicans* is involved.

Against the background of these characteristics, the role of contaminated drill guide templates must be discussed with regard to multiresistant microorganisms. In addition, the question of the sterilization of wound dressing templates often used in immunosuppressed patients must be mentioned.

The results of the survey among dental implantologists and surgeons, focused on implantological problems, indicate that a validated procedure for the disinfection of thermo-sensitive medical products is either not known or not used. It has to be admitted that the survey performed was limited to Germany, and therefore, generalizing statements should be made with restraint. However, it is admissible to elicit tendencies because the survey was performed not only in sub-areas but all over the country.

Due to the situation in dental laboratories where bacteria with affinity to humidity were isolated, a high bacterial exposure during the production of drill guide templates has to be anticipated [40]. With regard to the field of application (intraoperative) at least an effective disinfection, better still a defined procedure for sterilization is an essential requirement for the intraoperative sterility.

The results of the present study reveal that dentists with a focus on implantology, oral surgeons, and maxillofacial surgeons often use Chlorhexidine (30%), 80% alcohol (23%), and Octenidin® (7%) for preoperative disinfection of drill guide templates. In this study, 80% alcohol and Octenidine normally used for disinfection of oral mucosa showed a favorable efficacy. With the frequently used Chlorhexidine, a distinctly lower efficacy was achieved. The current results are in line with the findings of Kramer et al. [26] and Pitten and Kramer [30] who were able to show higher efficacy of Octenidine in comparison with CHX 0.2%. Due to the fact that these in vitro studies were performed under almost clinical conditions, we have to consider similar results in clinical studies.

Conclusions

Drill guide templates must be free of pathogenic microorganisms, as they are used in wound areas. CHX often used for the disinfection of drill guide templates according to the results of the survey among German dentists (30%) is not suited for the elimination of microbes on thermosensitive plastics as could be demonstrated by our in vitro studies.

Following our study results, the disinfection of templates should be preferentially performed with 80% alcohol or Octenidin using an incubation time of 15 min with ultrasonication. Cooperation with dental laboratories, already demanded in the relevant US and EU guidelines, seems not only useful but necessary with respect to the production, storage, transport, and measures for disinfection. Low temperature sterilization, such as gas or plasma sterilization or the usage of temperature-resistant resin for the production of templates, would allow optimal reduction in the number of pathogenic bacteria for the templates used intraoperatively. However, no standard procedures actually exist.

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