SHORT COMMUNICATION

Antimicrobial efficiency of ethanol and 2-propanol alcohols used on contaminated storage phosphor plates and impact on durability of the plate

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Objectives: To assess (1) antimicrobial efficiency of wiping intraoral phosphor plates with alcohol tissues based on ethanol or 2-propanol alcohols after contamination with *Candida albicans* and *Streptococcus oralis*, (2) a concept for autodisinfection with ultraviolet light of the transport ramp in a scanner for phosphor plates and (3) the impact of wiping with alcohol tissues on durability of the plate.

Methods: Suspensions of *C. albicans* and *S. oralis* were prepared in concentrations of 10⁹ and 10⁵ organisms per ml, and Digora (Digora[®] Optime Imaging Plate, size 2; Soredex, PalaDEX Group Brenntag Nordic A/S, Hellerup, Denmark) and Vista (VistaScan[®] Imaging Plate PLUS, size 2; Dürr Dental AG, Bietigheim-Bissingen, Germany) plates were contaminated. The plates were wiped with ethanol or 2-propanol disinfectant tissues and imprints obtained on agar. Number of microbial colonies after culturing was recorded. The scanner ramp was contaminated with *C. albicans* or *S. oralis*, respectively, the ultraviolet light (UV light) disinfection in the scanner was activated and the number of colonies after culturing was recorded. Plates from each system were sequentially wiped (5–60 times) with ethanol and 2-propanol, exposed and scanned. 48 images from each system were scored blind: 1 = no artefact, 2 = small artefacts and 3 = severe artefacts.

Results: Ethanol eliminated *C. albicans* and *S. oralis* in high and low concentrations from both types of plates, whereas 2-propanol did not eliminate all micro-organisms at high concentrations. The UV light eliminated all micro-organisms from the ramp. Ethanol degraded the plates to a larger extent than did 2-propanol. Images from Vista plates showed severe artefacts after wiping with ethanol; those from Digora plates did not.

Conclusions: Ethanol eliminated all micro-organisms but degraded phosphor plates, whereas 2-propanol did not eliminate all micro-organisms and still degraded plates from Vista but not from Digora.

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Introduction

In opposition to the conventional film, an intraoral digital radiographic receptor, e.g. the storage phosphor plate, is

intended to be used for multiple patient exposures.^{1,2} Although the storage phosphor plate is packed in a sealed plastic bag before use, the reusable nature of this receptor represents a risk for cross-contamination between patients.^{3,4} The phosphor layer in storage phosphor plates may be sensitive to rubbing with disinfectants, such as alcohols, although coated to increase resistance

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to both scratching and wiping.⁵ Just like the film, the phosphor plate is processed after exposure, and the scanner for processing the plate may also be contaminated if micro-organisms have contaminated the plate prior to scanning.

Ethanol in a mixture with chlorhexidin and glycerol is a common means of disinfecting instruments and units between patients in the dental clinic; however, manufacturers of storage phosphor plates have claimed that the plate does not tolerate wiping with ethanol.⁵ One manufacturer has, on the other hand, suggested the use of a milder alcohol, 2-propanol, to be used for cleaning the plate between exposures,⁶ but the effectiveness of this disinfecting method has not been studied, and neither has the life span of a plate when subjected to wiping with alcohol tissues.

Streptococcus oralis is a primary colonizer of teeth, and *Candida albicans* is the most predominant fungus in the oral cavity.⁷ Fungi are less sensitive to disinfectants than bacteria. These two micro-organisms may therefore be used to simulate a clinical situation with contamination of phosphor plates and the scanner ramp.

The aims of this experimental study were to assess (1) the antimicrobial efficiency of manual wiping intraoral phosphor plates with alcohol tissues based on ethanol or 2-propanol alcohols after contaminating the plates with *C. albicans* and *S. oralis*, (2) a concept for autodisinfection with ultraviolet light (UV light) of the transport ramp in a scanner for a phosphor plate system and (3) the impact of wiping with alcohol tissues on durability of the plate.

Experiments and results

Suspensions of micro-organisms

C. albicans (own isolate) and *S. oralis* (SK335) (donated by M Kilian, University of Aarhus, Denmark) were cultivated on Saboraud agar (selective medium for fungi) and blood agar (non-selective medium), respectively, and incubated for 24 h in air enriched with 10% carbon dioxide at 37 °C. Suspensions of micro-organisms corresponding to a concentration equalling that in saliva (≈10⁹ organisms per ml) and half of the saliva concentration (10⁵ organisms per ml) were prepared, and the number was verified by plating dilutions in

triplicate on Saboraud agar for *C. albicans* and Mitis-Salivarius agar for *S. oralis*.

Pre test to Experiment 1

An initial test was performed to assess the influence of evaporating disinfectant on survival of subsequently added micro-organisms. A Digora plate and a Vista plate (full names and companies in Table 1) were manually disinfected for 10 s with either 2-propanol or ethanol disinfectant tissue, respectively, and the phosphor plates were left to evaporate for 1 min. After evaporation, the phosphor plates were contaminated with *C. albicans*, and a direct imprint on Saboraud agar was made (Figure 1) and cultivated. The test was repeated with evaporation times of 5 min, 10 min and 30 min. The entire test was also performed with *S. oralis* and subsequent imprint on blood agar. The results showed that 1 min for evaporation of 2-propanol did not result in sufficient evaporation of the disinfectant measured by the transfer of subsequently added micro-organisms to agar plates. Consequently, for all experiments, the phosphor plates were left to evaporate for at least 5 min between experiments.

Experiment 1—antimicrobial efficiency of wiping storage phosphor plates with alcohols

Four new phosphor plates (two Digora, two Vista) were contaminated with *C. albicans* 10⁹ organisms per ml. The surface was air-dried for 5 min, after which it was manually wiped for 10 s with a 2-propanol disinfectant tissue. The plates air-dried again for 5 min, and a direct imprint of the plate was obtained on Saboraud agar. This was repeated with ethanol disinfectant tissues on four new phosphor plates (two Digora, two Vista). The whole experiment was repeated on a different day. Thereafter, the experiment was performed with 10⁵ organisms per ml of *C. albicans*, again repeated on consecutive days. The entire experiment was also performed with *S. oralis* (Figure 2). Ethanol eliminated cultivable *C. albicans* and *S. oralis* at both high and low concentrations, whereas 2-propanol failed to eliminate all micro-organisms at high concentrations (Tables 2 and 3).

Pre tests to Experiment 2

Purity of Digora Optime Plus scanner ramp: The Digora® Optime Plus (Table 1) scanner’s autodisinfection by UV light (duration 4 min 15 s) was activated

Table 1 Storage phosphor plates, scanners and alcohols used in the study

Name of storage phosphor plate	Name of scanner	Antimicrobial scanner disinfection	Name of company	Address of company	Trade name of alcohol tissue	Content of alcohol tissue
VistaScan® Imaging Plate PLUS, size 2	VistaScan Mini Plus	—	Dürr Dental AG	Bietigheim-Bissingen, Germany	VistaScan image plate cleaning wipe	4 g 2-propanol/tissue
Digora® Optime Imaging Plate, size 2	Digora Optime Plus	Opticlean™ UV light	Soredex PaloDEx Group	Tuusula, Finland	—	—
			Brenntag Nordic A/S	Hellerup, Denmark	Idu-Scrub®	Ethanol 82% chlorhexidin 0.5% glycerol 2%

UV, ultraviolet.

Figure 1 Imprint of the plate contaminated with *Candida albicans* directly on Sabouraud agar demonstrating transferability of organisms from plate to agar

and the three surfaces of the ramp of the scanner were sampled with a sterile cotton stick. Four sampling and inoculation methods were tested: (1) sampling with a dry cotton stick and direct streaking onto an agar plate; (2) sampling with a dry cotton stick that was cut into a test tube with 2 ml of 0.85% NaCl solution and glass beads, mixed for 2 min, after which 100 μ l was disseminated on an agar plate; (3) sampling with a wet cotton stick and direct streaking onto an agar plate and (4) sampling with a wet cotton stick that was cut into a test tube with 2 ml of 0.85% NaCl solution and glass beads, mixed for 2 min, after which 100 μ l was disseminated on an agar plate. No micro-organism could be cultured from the scanner ramp using any of the sampling and inoculation methods; thus the ramp was considered free of organisms at the start of Experiment 2.

Transfer of micro-organisms from Digora Optime Plus scanner ramp to agar: The ramp was contaminated with *C. albicans* at 10^9 organisms per ml, sampled and inoculated by each of the four methods described above and plated in duplicate on Sabouraud agar. The test was

Figure 2 Colonies of *Streptococcus oralis* on Mitis-Salivarius agar cultured after imprint of plate contaminated with a $\approx 10^9$ organisms per ml concentration and disinfected with 2-propanol

repeated with *S. oralis* on Mitis-Salivarius agar. Sample and inoculation method (4) retrieved the highest number of micro-organisms; therefore, this method was used when assessing the efficacy of the UV light disinfection procedure in the scanner in Experiment 2 (Figure 3).

Experiment 2—effect of the UV light disinfection procedure in the Digora Optime Plus scanner on culturing of micro-organisms

The scanner's autodisinfection was activated three times. The scanner ramp was contaminated using suspensions of *C. albicans* and *S. oralis* at high concentration (10^9 organisms per ml). After contamination, the scanner ramp air-dried for 5 min, and the autodisinfection (4 min 15 s UV light) was activated. The three sides of the ramp were sampled and inoculated. The experiment was repeated on a different day. Then the experiment was performed with 10^5 organisms per ml of either *C. albicans* or *S. oralis*, again repeated on consecutive days. Contamination of the ramp with either *C. albicans* or *S. oralis* and sampling after running the disinfection program showed that the disinfection

Table 2 Survival of *Candida albicans* on Digora and Vista plates after wiping with ethanol or 2-propanol

Concentration	Plate	2-propanol ^a	Ethanol ^a
$\approx 10^9$ organisms per ml	Digora	2/5	0/0
	Vista	4/2	0/0
$\approx 10^5$ organisms per ml	Digora	0/0	0/0
	Vista	0/0	0/0

^aNumber of colonies on agar plate; mean of duplicate measurements of repeated experiments.

The Digora® Optime Imaging Plate (size 2) is manufactured by Soredex PalaDEx Group Brenntag Nordic A/S (Hellerup, Denmark), and the VistaScan® Imaging Plate PLUS (size 2) by Dürr Dental AG (Bietigheim-Bissingen, Germany).

Table 3 Survival of *S. oralis* on Digora and Vista plates after wiping with ethanol or 2-propanol

Concentration	Plate	2-propanol ^a	Ethanol ^a
≈10 ⁹ organisms per ml	Digora	2.5/5	0/0
	Vista	2.5/5	0/0
≈10 ⁵ organisms per ml	Digora	0/0	0/0
	Vista	0/0	0/0

^aNumber of colonies on the agar plate; mean of duplicate measurements of repeated experiments.

The Digora[®] Optime Imaging Plate (size 2) is manufactured by Soredex PalaDEx Group Brenntag Nordic A/S (Hellerup, Denmark), and the VistaScan[®] Imaging Plate PLUS (size 2) by Dürr Dental AG (Bietigheim-Bissingen, Germany).

program was capable of eradicating the micro-organisms irrespective of concentration.

Experiment 3—impact of wiping with alcohol tissue on durability of plates

This experiment included four new Digora and four new Vista plates. The eight plates were exposed, including an aluminium step wedge phantom with nine steps, and scanned in their respective system scanner (Table 1) before the experiment. These test images showed that there were no scratches or other defects in the plates before the study. Two from each plate system were thereafter wiped with the ethanol-based tissues and the other two with the 2-propanol tissues. Each plate was wiped for 10 s in a series where the number of wipes gradually increased: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55 and 60 times, each time for 10 s. Two observers wiped with a gentle pressure (one observer was a tall man and the other was a smaller woman). Both

observers wiped two plates from each system, one for each of the two alcohols. There was always 1 min between a new 10-s wipe. After each series, the plates were again exposed with the aluminium step wedge phantom and scanned in their respective system scanner, resulting in a total of 48 images from the Digora Optime system (24 wiped with ethanol and 24 with 2-propanol) and 48 from the VistaScan[®] Mini Plus system (Table 1) (24 wiped with ethanol and 24 with 2-propanol).

Thereafter, the 96 images were scored in random order by two independent observers (Obs1 and Obs2) blinded to the number of wipes and the image plate system. The score categories were: 1 = no artefacts in the image, 2 = small artefacts < ½ cm in width at the borders of the image and 3 = severe artefacts > ½ cm in width into the image (Figure 4). Recordings were made on a quality monitor [Eizo FlexScan MX190 (19 inch, colour, 1280 × 1024, 32 bit, digital)] in a room with subdued lighting. To assess observer reproducibility, a second scoring session was accomplished 2 days after the first one.

Artefacts were seen in the form of blotches around the borders of the image (Figure 4). Table 4 illustrates number of images classified with artefacts by the two observers in their first and second scoring sessions after wiping with ethanol and 2-propanol, respectively. Ethanol degraded Vista plates even after 5 wipes, while only small defects were seen in Digora plates after 60 wipes. 2-propanol degraded Vista plates to a minor extent after 40 wipes, while Digora plates were not affected. Note in Figure 4 that the “D” for Dürr in Vista plates was soon wiped out.

Kappa values for intraobserver agreement were 0.75 (Obs1) and 0.90 (Obs2) for Digora images and 0.81 (Obs1) and 0.87 (Obs2) for Vista images. Interobserver agreement ranged between 0.63 and 0.73 (Table 4).

Discussion

Use of digital storage phosphor plates for intraoral radiography implies the risk for cross-contamination between patients since the plates cannot be autoclaved.⁸ The phosphor plate has been stated also not to tolerate wiping with disinfectant tissues, and therefore, it has been recommended to use a barrier or double barrier, which should then be disinfected before the plate is removed from the barrier and placed in the scanner.^{3,9,10} Some studies have shown that a large number of plastic barriers leaked after use in the oral cavity,^{3,8,11} while another found that barrier envelopes was an effective means of reducing contamination.⁴ A recent study has suggested that, in addition to the use of a barrier, weekly gas sterilization of the plates could be a solution.¹²

Various manufacturers have suggested different solutions to solve some of the hygienic problems that may exist when using storage phosphor plate systems. Recently, one manufacturer has recommended that a mild alcohol, 2-propanol, is used for cleaning the plate

Figure 3 Colonies of *Candida albicans* on Saboraud agar after contamination of the scanner ramp with ≈10⁹ organisms per ml concentration and sampling with a wet cotton stick demonstrating transferability of micro-organisms from ramp to agar

Figure 4 Digora (Digora[®] Optime Imaging Plate, size 2; Soredex, PalaDEx Group Brenntag Nordic A/S, Hellerup, Denmark) and Vista (VistaScan[®] Imaging Plate PLUS, size 2; Dürr Dental AG, Bietigheim-Bissingen, Germany) plate images after the plate was wiped with ethanol or 2-propanol 5, 20, 30, 40, 50 and 60 times each for 10 s

between patients. Another manufacturer has developed a scanner with the possibility for autodisinfection of the ramp that guides the plate during scanning, using UV-light. It has not been studied previously whether these precautions can aid in solving the potential problems of cross-contamination, and whether wiping the plate with alcohol tissue will eventually damage the plate.

The pre tests in our study showed that it was possible to contaminate the plates and transfer bacteria and fungi to agar media. The effect of evaporation of disinfectant was secured before the experiment, and all plates were left to evaporate for at least 5 min between experiments. A pre test further showed that the scanner ramp was free of bacteria before the study, and the best method for sampling of micro-organisms from the ramp was using a wet cotton stick. To improve hygiene in relation to storage phosphor plate systems, the Digora Optime Plus scanner is touch-free, *i.e.* the scanner opens and the plate can be inserted without touching the plate or the scanner. In addition, the UV light function (Opticlean[™]; Table 1) has been developed to inactivate bacteria that none the less may be transported to the scanner ramp via a contaminated plate. The function is user-determined and takes approximately 4 min. The VistaScan Mini Plus scanner does not provide this function. Our results showed that the UV light disinfection of the ramp was effective since no micro-organism could be cultured after UV light radiation. It may therefore be tempting to suggest that the UV light disinfection program should be mandatory between patients, even though this will prolong the waiting time before a plate exposed in a new patient can be scanned.

The disinfectant tissue Idu-Scrub[®] (Table 1) contains ethanol in 82% concentration, chlorhexidin and glycerol, and is widely used to disinfect units, instruments and other materials in the clinic which cannot be sterilized by autoclave. The manufacturer Dürr Dental has launched a disinfectant tissue (VistaScan image plate cleaning wipe) that contains the alcohol 2-propanol. Wiping with this tissue is supposed to be gentler to the phosphor layer than ethanol. According to the manufacturer, this alcohol has bactericidal, fungicidal and virucidal effects. The ethanol-based tissue was, in our study, able to eliminate all cultivable bacteria and fungi in a concentration equalling that in saliva ($\approx 10^9$ organisms per ml). In contrast, 2-propanol in a concentration of 4 g per tissue left viable micro-organisms. At half of the saliva concentration ($\approx 10^5$ organisms per ml), all

Table 4 Number of images with score 1 (no artefacts), 2 (small artefacts) and 3 (severe artefacts) after wiping with ethanol and 2-propanol scored by Observer 1 (Obs1) and Observer 2 (Obs2) in two sessions

Score	Ethanol			2-propanol		
	1	2	3	1	2	3
Digora Obs1 (first)	13	11	0	24	0	0
Digora Obs1 (second)	15	9	0	24	0	0
Digora Obs2 (first)	10	14	0	24	0	0
Digora Obs2 (second)	8	16	0	24	0	0
Vista Obs1 (first)	0	5	19	16	8	0
Vista Obs1 (second)	0	6	18	15	9	0
Vista Obs2 (first)	0	0	24	12	12	0
Vista Obs2 (second)	0	0	24	12	12	0

The Digora[®] Optime Imaging Plate (size 2) is manufactured by Soredex PalaDEx Group Brenntag Nordic A/S (Hellerup, Denmark), and the VistaScan[®] Imaging Plate PLUS (size 2) by Dürr Dental AG (Bietigheim-Bissingen, Germany).

micro-organisms were eliminated. Throughout the study, the time for wiping with an alcohol tissue was 10 s, which is believed to reflect a maximum of what can be expected in the clinical situation. Other wiping times may give different results but were not tested in this study. From a hygienic point of view, the use of ethanol disinfectant tissues to clean the plate between patients should thus be advised.

On the other hand, wiping with ethanol in our study resulted in a degradation of the image since the borders of the plates, particularly from Vista, were to some extent damaged by the alcohol. The VistaScan system recommends the use of the 2-propanol tissue for disinfecting the plate between patients, but even this alcohol resulted in damage to the plates after several wipes had been performed. This was not the case for the Digora plate in which no damage was seen after using 2-propanol. In our experiment, the plates were wiped with a gentle pressure repeatedly up to 60 times, each for 10 s with a drying time of 1 min between the wipes. This may not totally mimic the clinical situation, in which the plate may usually be left for a longer time period before it is reused. Whether a longer drying period between wipes would change the results was not studied. Our results should therefore be interpreted as a “worst-case” situation.

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In conclusion, a disinfectant tissue containing ethanol 82%, chlorhexidin-gluconate 0.5% and glycerol 2% (Idu-Scrub) was able to eliminate micro-organisms, *C. albicans* and *S. oralis* in concentrations $\approx 10^5$ and $\approx 10^9$ (saliva concentration) micro-organisms per ml. A milder alcohol, 2-propanol (4 g per tissue), did not eliminate micro-organisms in the higher concentration. UV light built into a plate scanner was able to eliminate both types of micro-organisms in both concentrations after activated for about 4 min. Ethanol degraded the plates to a larger extent than did 2-propanol, but even 2-propanol to some extent degraded Vista plates, but not Digora plates. Images from Vista plates were classified with severe artefacts after wiping with ethanol, which was not the case for Digora plate images. It is recommended that a scanner's UV light is used between patients in the clinic and that the plates as a minimum are wiped with 2-propanol.

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