STUDY CONDUCTED FOR SOREDEX

Efficiency of SOREDEX DIGORA® Optime UV disinfection system

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Objectives: The aim of this study was to evaluate the efficiency of ultraviolet (UV-C) disinfection of harmful microbes on the surfaces of the imaging plate carrier of the SOREDEX DIGORA® Optime intraoral imaging plate system.
Methods: A literature research was done to evaluate the sensitivity of the pathogenic microbes to ultraviolet light at UV-C (< 280 nm) wavelengths emitted by the UV-disinfection system inside the DIGORA® Optime imaging plate reader. The technical characteristics of the UV-C system were provided by SOREDEX.
Results: The calculated germicidal efficiency of UV-C radiation, equivalent to UV light emitted by the UV light source within the DIGORA® Optime imaging plate reader, is at least 99.9 % for the pathogenic microbes of primary interest.
Conclusions: UV radiation used in the DIGORA® Optime UV- disinfection system is 99.9% effective in reducing the number of harmful pathogens of primary interest. The elimination of pathogenic microbes efficiently reduces the theoretical risk of cross-contamination via the imaging plate reader and imaging plates. Together with other Opticlean™ features the SOREDEX DIGORA® Optime offers a comprehensive means of ensuring uniquely high level of hygiene for practical workflow in clinical dentistry.

Introduction

Ultraviolet-C light (UV-C, λ < 280 nm) is known to be effective in the disinfection of suspensions and surfaces of the area irradiated with an appropriate radiation dose[11]. UV-C irradiation eliminates the infectivity by disrupting the genomic DNA/RNA, thus rendering the cells and viruses unable to grow and reproduce. This review summarizes the experimental studies investigating the kinetics of the UV-C inactivation of known pathogens, with particular emphasis on clinical dentistry.

Microbes of primary interest, (*Corynebacterium diphteriae*, *Mycobacterium tuberculosis*, Hepatitis viruses A, B, and C, Herpes simplex virus 1, and Human immunodeficiency virus) are a significant hygiene concern in dental practices. Specific safety measures must be carried out when patients with known infections are being treated. Importantly, precautionary actions are also needed as patients may be unaware or unwilling to inform about any infection they may have. These actions include the disinfection of all visible surfaces in the dental office. The internal parts of the imaging plate readers often remain unattended due to access difficulties. The unique SOREDEX DIGORA® Optime UV disinfection system has been developed to minimize cross-contamination even in the event of inadequate hygiene precautions during the handling of the imaging

plates. . The Table 1 lists the UV-C inactivation data for pathogens of concern in clinical dentistry, and shows that the irradiation doses used in the DIGORA® Optime, efficiently eliminate the pathogens of primary as well as secondary interest.

SOREDEX Opticlean™ concept

The Opticlean™ concept focuses on ensuring a uniquely high level of hygiene in the use of the DIGORA® Optime imaging plate system in all environments. The Opticover™ imaging plate protective covers and the Optibag™ imaging plate hygiene bags provide an effortless end-to-end hygiene workflow in dental offices. The Opticlean™ concept also includes touchless operation of the imaging plate reader to reduce the risk of cross contamination via the outer parts of the system as well as a UV-C system that irradiates the internal parts of the reader which are in contact with the imaging plate (the imaging plate carrier).

The frequency of the UV-C treatment can be easily set by the user according to the risk level. Each treatment consists of a 250s UV-C exposure period on the plate carrier surfaces in contact with the imaging plate. The UV-C lamp with a peak wave length of 253.7 nm and output power of 160 mW is positioned 31 mm away from the imaging plate carrier to provide the most efficient level of irradiation. The measured dose at the imaging plate carrier is at least 450 $\mu W/cm^2$ (*i.e.*, 112 mJ/cm^2).

Results and discussion

This study is based on information that SOREDEX has disclosed about its UV-C disinfection system and on published scientific results. Table 1 summarizes the UV-C inactivation kinetics of the selected pathogens with references to the original research. Under the disclosed conditions and based on the published and well established research, the UV-C radiation dose used by the Opticlean™ system of the DIGORA® Optime is able to eliminate at least 99.9% the following pathogens

- human immunodeficiency virus (HIV)
- Hepatitis viruses A, B, and C
- *Mycobacterium tuberculosis*
- *Corynebacterium diphtheriae*
- Herpes simplex virus-1 (HSV-1)

All other microbes of secondary interest in clinical dentistry, listed in the Table 1 are inactivated by at least 99%.

The Opticlean™ concept of the DIGORA® Optime imaging plate system provides a comprehensive set of solutions to address the concerns of cross contamination in the use of imaging plates and provides a uniquely high level of hygiene for practical workflow in clinical dentistry.

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Table 1. Summary of the germicidal UV-C doses.

Microbe	Pathology, comments	UV dose ($mJcm^{-2}$) needed for MIC(log)[A]				Notes	References
		1 (90%)	2 (99%)	3 (99.9%)	4 99.99%)		
Bacteria							
Bacillus anthracis	Anthrax	4.52				complete inactivation at 8.7 $mJcm^{-2}$[B]	2, 19
Bacillus subtilis	A commonly used reference/model organism in, e.g. germicide studies. Not considered as a human pathogen.	56	111	167	222		11, 23
Campylobacter jejuni	Campylobacteriosis: inflammatory diarrhea, perodontis or dysentery syndrome associated with fever, and severe cramps and pain. *C. jejuni* infection may cause a latent autoimmune neuropathy. Infections normally due to contaminated food or drink.	3	7	10	14		11, 23
Clostridium perfringes	Diarrhea. Clostridial myonecrosis, a.k.a. gas gangrene, is a very serious medical emergency.	45	95	145			11, 23
Clostridium tetani	Tetanus.	4.9					2
Corynebacterium diphteriae	Diphteria.	3.4				complete inactivation at 6.5 $mJcm^{-2}$[B]	2, 19
Enterococcus faecalis	Can cause endocarditis, bladder, prostate, and epididymal infections; rarely nervous system infections.	9	16	23	30		11, 23
		5 (100 %)				complete inactivation at 5 $mJcm^{-2}$[B]	15
Escherichia coli	Virulent strains can cause gastrointestinal or urinary tract infections.	5	9	14	18		11, 23
Legionella pneumophila	Legionnaire's disease and milder Pontiac fever; eg. pneumonia. may be dangerous especialy to elderly. Infections most commonly via aerosols.	8	15	23	30		11, 23
Mycobacterium tuberculosis	Tuberculosis.		10	20[J]			3, 9
		7	14[J]	21[J]			6
Pseudomonas aeruginosa	Normally not a pathogen in healthy humans. An opprtunistic pathogen in immunocompromised or in patients with respiratory illnesses.	6				complete inactivation at 10.5 $mJcm^{-2}$[B]	19, 24
Salmonella enteridis	Fever, cramps, diarrhea. Infections throug contaminated food. The cause of "egg-associated salmonellosis".	4				complete inactivation at 7.6 $mJcm^{-2}$[B]	2, 19
Salmonella typhi	Enteric (typhoid) fever; a sustained systemic fever with headache and nausea. Other symptoms include constipation or diarrhea, enlargement of the spleen, possibly meningitis, and/or general malaise. Infections throug contaminated food.	6	12	17	51		11, 23
Salmonella typhimurium	Enteric (typhoid) fever ("mouse typhoid fever). Infections throug contaminated food.	8				complete inactivation at 15.2 $mJcm^{-2}$[B]	2, 19
Shigella dysenteriae	The causative agent of the most severe shigellosis: severe dysentery - fever, diarrhea, vomiting, and cramps, along with ulceration, rectal bleeding, and drastic dehydration. Infections through contaminated food or drink.	3	5	8	11		11, 23
Shigella sonnei	Shigellosis - see S. dysenteriae.	6	13	19	26		11, 23
Staphylococcus aureus	A common habitant on skin and in the nose. may cause illnesses ranging from mild skin infections (e.g., pimples) to life-threatening pneumonia, meningitis, osteomyelitis, endocaridtis, toxic-shock syndrome, &c. Amongst the commonest cause of nosocomila ("hospital") infections.				18	> 9 log	26
Streptococcus faecalis	Enterococcus faecalis (see above).						

Streptococcus mutans	The main contributor to tooth decay					complete inactivation at <11 mJcm^{-2}[C]	7
Vibrio cholerae	Cholera: exhaustive diarrhea, dehydration, hypotension, shock. Very contagious; infections normally through food or drink contaminated by another patient.	2	4	7	9		11, 23
Yersinia enterocolitica	The most common cause of yersinosis: enteritis and diarrhea. Infections through contaminated food or (less commonly) drinks.	3	7	10	13		11, 23
Viruses:							
Adenoviruses	Respiratory infections, pharyngitis, gastroenteritis, eye infections, especially in children.	75	111			complete inactivation at 225 mJcm^{-2}[B]	13, 23
Coxsackie virus B5	Coxsackie B virus is the causative agent of pleurodynia (Bornholm disease) with fever, headache, sore throat, gastointestinal distress, and chest and muscle pain. May progress to myo- or pericarditis and possible permanent heart damage or death. may also cause meningitis. Possibly asssociated wit type I diabetes.	8	17	25	34		11, 23
Hepatitis A virus	Acute hepatitis (a.k.a. infectious hepatitis). Infections through contaminated food or water.	6	11	17	22		11, 23
Hepatitis B virus	Acute or chronic hepatitis (hepatitis B), may lead to liver cirrhosis; hepatocellular carcinoma. Infections through blood or body fluids.	≤4.1[H]	≤8.2[J]	≤12.3[J]	≤16.4[J]		16, 17
Hepatitis C virus	Acute hepatitis, may lead to liver cirrhosis. Infections normally through blood or mucosal contact.	≤8.4[H]	≤16.8[J]	≤25.2[J]	≤33.6[J]		16, 17
Herpes simplex virus 1	Oral (orofacial) and genital herpes are the commonest ilnesses caused by the herpesviruses, characerized with painful inlammation. HSV1 causes also infections elsewhere in the skin, in the eyes, and in the neuronal system.		<30[D]	60[J]			20
		<16[E]	<48[E]	<96[J]			21
Human immunodeficiency virus	Acquired immunodeficiency syndrome					complete inactivation at 66 mJcm^{-2}[G]	8, 10
		28	56[I]	84[J]			14, 27
Influenza A virus	Influenza.	1.8	≤8.2	≤16.4[J]			1, 4, 12, 17
Poliovirus type 1	Poliomyelitis; different types of neuronal symptoms, most often infections in motor neurons associated with muscle weakness paralysis.	7	15	22	30		11, 23
Rotavirus SA-11	Mild to severe gastroenteritis. The most common cause (along with adenoviruses) of severe diarrhea in infants and young children.	10	20	29	39		11, 23
Unicellular eukaryotes[G]							
Giardia lamblia (G. duodenalis)	Giardiasis can be associated with a wide range of clinical symptoms. Acute gastrointestinal giardiasis causes severe diarrhea, abdominal cramps and vomiting, and fever. majority of the patients develop recurrent or resistant symptoms. Additional symptoms may include, e.g., lomg-term malaise and fatique. Infections through contaminated food or drink.	2	5	11			11, 23
				1		> 3 log	22
			3				18

Notes:

[A]MIC (log): microbial inactivation credit[11-23]. 1 log means 90 % inactivation, 2 log 99 %, 3 log 99.9 %, and 4 log 99.99 % inactivation at the given dose (fluence).

[B]No detectable infectivity after 8.7 mJcm^{-2} for B. anthracis[19], 6.5 mJcm^{-2} for C. diphteriae[19] , 5 mJcm^{-2} for E. faecalis (ref 15), 10.5 mJcm^{-2} for P. aeruginosa[19,24] , 7.6 mJcm^{-2} for S. enteridis, nor after 225 mJcm^{-2} for adenovirus 41[13] .

[C]For S. mutans, the absolute UV fluence value is not available; the inactivating UV dose (1 and 3 log MIC) has been shown to be smaller than for P. aeruginosa, B. thermophilus, and C. albicans[7]. For P. aeruginosa, the dose 11 $mJcm^{-2}$ has been reported[24] .
[D]Estimated from the Fig 1[20].
[E]16-48 $mJcm^{-2}$ corresponded to 20-412-fold reduction in infectivity, i.e., 5 % - 0.24 % inf. left, i.e., >> 1 log - >> 2 log MIC.
[F]Complete inactivation of HIV was reported after 5 min exposure to 0.220 $mWcm^{-2}$, shorter treatments were not reported. Inactivating dosage 30 $mJcm^{-2}$ has been reported on the web page http://lightbulbs101.com/germicidal-lights.html (no reference to the original data).
[G]Formerly inappropriately called "protozoa".
[H] Predicted dose[17] based on Lytle & Sagripanti [16].
[I] Predicted dose based on ref 14.
[J] Values calculated according to the "Chick's law" of inactivation ($N/N_0 = e^{-kIt}$; eg. ref 25), based on the assumption of "quasi" first order inactivation kinetics (ie., linear correspondence of the log-inactivation to the UV dose). The first order kinetics is a general assumption in the literature; several studies support this assumption at relevant virus/bacterial concentrations [5,10,25] .