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GDC 'Highly Recommended' CPD topic
Disinfection and Decontamination

Evaluation of Quaternary Ammonium Compound Disinfectants against Mycobacteria in Dental Practices

Abstract: This paper discusses the use in dental practices of quaternary ammonium compounds (QAC) and alcohol-based disinfectants in relation to bactericidal efficacy against mycobacteria. QAC disinfectants are commonly used in dental practices, although there are concerns about their efficacy against tuberculosis-causing bacteria. The paper discusses a recent study where two QAC products (ready-to-use and saturated wipe liquor presentations) were tested, using a recognized suspension test, at the manufacturer's recommended concentration, under simulated 'clean' and 'dirty' conditions. The test data indicated that, after a 10-minute contact time, suitable kill of the test organism was not obtained. These findings raise questions about the suitability of QAC disinfectants for dental practices.
CPD/Clinical Relevance: Tuberculosis, a disease caused by *Mycobacterium tuberculosis*, is increasingly becoming a communicable disease of concern. It is important that dental practices ensure that a suitable level of decontamination takes place between patients. QAC disinfectants may not be suitable for this purpose and alternative biocides, like alcohol, may need to be considered.
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Within dental practices there is a concern about the transfer of pathogens between patients.[1] A pathogenic organism where the level of alert has recently increased is with the causative agent of tuberculosis: *Mycobacterium tuberculosis*.[2] Reports suggest that cases in the UK have increased in the past 15 years; moreover, incidents in the UK are above the Western European average: 14 per 100,000 people for the UK and 12 per 100,000 throughout Western Europe.[3-4] This prevalence is complicated by a global increase in multi-drug resistant types of the bacterium.[5]

Tuberculosis infection occurs through inhalation of the bacterium, which then travels to the alveoli of the lungs. Most people who carry the bacterium do not show any symptoms (latent tuberculosis); however, the condition can become serious for people with weak immune systems.[6] Here symptoms include fever, fatigue and, in some cases, the coughing up of blood. Although the disease remains rare, dentists need to be aware of the possible occurrence of oral lesions of tuberculosis and consider them in the differential diagnosis of suspicious oral ulcers. Patients who have pulmonary or laryngeal tuberculosis pose a risk of infection, especially if they are coughing due to the generation of aerosols;[7] furthermore, dental equipment coming into contact with the mouth is potentially contaminated and this contamination can be transferred where items come into contact with work surfaces (Figure 1).

There are also risks of cross-infection from asymptomatic patients. Because symptoms are not apparent, appropriate infection control strategies, including surface disinfection, glove changes and hand sanitization should be in place in-between patients.[8,9] Cleaning and disinfection are integral elements of good hygiene practice within the dental environment. In particular, surfaces must be rendered clean and decontaminated between patients in order to minimize the risk of patient-to-patient and patient-to-staff infection. Disinfection, as a regular between-patient activity, is recommended by the UK – Health Technical Memorandum 01-05[10] and by the UK Dental Council (GDC). The purpose of applying a disinfectant agent to a surface is to reduce the population of potentially pathogenic micro-organisms, including *Mycobacterium tuberculosis*. This is not, however, straightforward given that mycobacteria

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are known to be relatively resistant to many disinfectants.

Disinfectants for dental practices

A disinfectant, as defined by European norms, is a chemical agent designed to reduce a known population of micro-organisms by a pre-set logarithmic value within a short period of time, during which the disinfectant agent must remain in contact with the surface (contact time).[11] An ideal disinfectant will have a high inactivating capacity for a wide range of viruses, such as HIV and hepatitis, as well as being effective against a broad spectrum of pathogenic bacteria, including mycobacteria.[12] In addition, disinfectants must be safe for staff to use; and be suitable for frequent application, in terms of not aggressively damaging surfaces.

Within dental surgeries, disinfectants are typically supplied as pre-saturated wipes or as ready-to-use solutions, for use on hard, non-porous surfaces. Pre-saturated wipes are often preferred owing to their convenience[13] and their use also negates the need for staff to remember the quantity of the disinfectant to deploy onto a surface. Wipes are provided in tubs and are normally saturated with chemical solutions, which act as the disinfectant. Highly absorbent wipes are ideally designed to allow a rapid clean down of surfaces and equipment. With disinfectants in ready-to-use formats (such as trigger sprays), the disinfectant is applied to a surface and then wiped off with a single-use, disposable dry wipe. With both techniques, the important factor is a consistent and controlled application of the disinfectant[14] (Figure 2).

There are two formulations of disinfectants common to dental practices: alcohol-based and non-alcohol based; the latter group are most commonly types of quaternary ammonium compounds.[8] Quaternary ammonium compounds are amphoteric surfactants, composed of positively charged polyatomic ions. A common example is benzalkonium chloride. This class of disinfectant has a broad-spectrum antimicrobial activity. The antimicrobial action involves perturbation of cytoplasm and the lipid bilayers that form the bacterial cell membrane. On entering the bacterial cell, the chemical forms mixed-micelle aggregates with hydrophobic membrane components; these function to solubilize membranes and cause cell lysis.[9] Alcohol-based disinfectants are typically either ethyl alcohol or isopropyl alcohol diluted in water (a concentration range of 60–90% is the most effective). Alcohol disinfectants kill the microbial cell by either denaturation of protein or by deactivating enzymes like dehydrogenases.[15]

These two types of disinfectants theoretically differ in terms of spectrum of activity. Quaternary ammonium compounds, despite being recommended in some dental practice guidances,[10] are generally regarded as ineffective against the tuberculosis causing bacterium, especially in the presence of protein residues.[16] Mycobacteria are difficult to kill because the bacterial cell has a tough, waxy outer hydrophobic cell wall that helps to prevent disinfectant entry. Here a substance called arabinogalactan is predominant; this is a biopolymer consisting of arabinose and galactose monosaccharides (esterified to mycolic acids) which seems to limit the concentration of active disinfectant that can reach the target site.

Alcohol-based disinfectants have theoretical bactericidal properties against mycobacteria, with 70% alcohol solutions being the most effective.[17] Aside from endospore forming bacteria, alcohols possess the widest disinfectant kill ranges of the commercially available disinfectants.[18] Alcohols are effective against enveloped and non-enveloped viruses, whereas quaternary ammonium compounds are not generally effective against 'non-enveloped' viruses, including poliovirus, rhinoviruses and hepatitis A.[19]

Examining the performance of QACs against mycobacteria

Due to theoretical concerns about the efficacy of QAC with regard to *Mycobacterium tuberculosis*, a study was performed by the author to examine the efficacy of quaternary ammonium compounds against mycobacteria. For this, *Mycobacterium terrae* (ATCC 35741) was used as a replacement for *Mycobacterium tuberculosis* (for safety reasons, *M terrae* has a similar susceptibility profile to disinfectant agents)[20] (Figure 3).

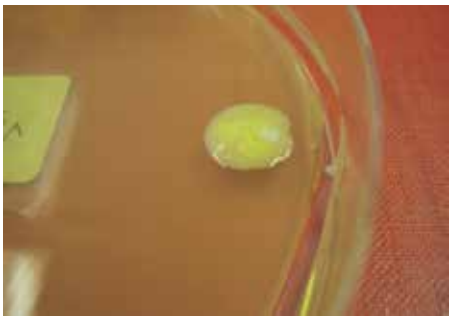

Figure 1. Bacterial colony on a test agar plate.

Figure 2. Wiping a surface with a saturated disinfectant wipe.

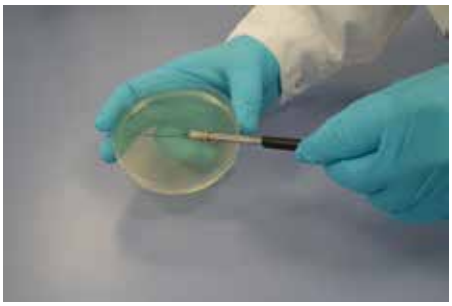

Figure 3. Streaking out an agar plate to assess bacterial levels.

Figure 4. Microbiologist examining bacteria under a microscope.

For the evaluation, the quantitative European suspension test was selected (EN 1276).[21] The suspension test has an advantage over other disinfectant test methods, like surface carrier tests, because the bacteria are uniformly exposed

to the disinfectant.

A suspension test measures the efficacy of a disinfectant against selected micro-organisms after a predetermined contact time. Contact time is an important measure when assessing disinfectant efficacy. It is the time taken for the disinfectant to contact the bacterial cell and to traverse the cell wall so that the active ingredient can begin bactericidal activity. Three contact times were considered: 5, 10 and 60 minutes. In reality, only 5 minutes or less would be suitable for a busy dental practice. The microbial challenge was high – at around one million cells – which enabled the extent of microbial kill to be measured (Figure 4).

With the test, after challenging a disinfectant solution with a microbial population the mixture is plated after the required contact time, and the surviving micro-organisms enumerated. A degree of robustness is introduced by the simulation of 'soiling'. This is by the addition of bovine serum albumin (at 0.03%, representing 'clean' conditions and at 0.3% representing 'dirty' conditions, which was as recommended by the standard) and is designed to reflect the conditions within dental practices where protein residues (such as blood or pus) may be found on surfaces.

Because both pre-saturated wipes and ready-to-use preparations of disinfectants are used in dental practices, both forms were included in the study (ready-made concentrations and the liquor extract from wipes). Products from two different manufacturers were examined. Product 1 had an active ingredient containing benzyl-C12-C18-alkyldimethyl, chloride; and product 2 contained didecyldimethyl ammonium chloride.

This study showed the liquid results were superior to the liquor results (extracted from wipes). With the liquid results (from the ready-to-use solutions), for both products, a satisfactory level of microbial kill (a greater than 5-log reduction) was achieved following a 10-minute contact time under clean conditions. However, under dirty conditions (more representative of practical conditions) the requirements of the standard could only be met with extended contact times. This indicates that the presence of soil (protein, blood etc) presents a barrier to the disinfectant in addition to the mycobacterium hydrophobic, waxy, mycolic acid-rich cell membrane.

With the liquor results (extract from pre-saturated wipes), lower microbial kill was observed. This may have been a feature of the formulation or linked to the method of extraction (here an insufficient amount of the active ingredient could be extracted as might be the case when saturated wipes are used on a surface). These results suggest that using a pre-prepared solution of disinfectant and spraying onto a surface may be more effective than using a pre-saturated wipe, although further experimental data would need to be run to support this.

Overall the study results confirmed literature findings that quaternary ammonium compounds are less effective against mycobacteria than alcohols.[22] In the UK, the use of this disinfectant group forms part of the HTM 01-05 recommendations,[10] which is surprising given that the ability of quaternary ammonium compounds to disaggregate bound protein does not improve the chemical effectiveness once the disinfectant makes contact with the bacterial cell.[23]

A theoretical concern sometimes presented with alcohol-based disinfectants is their ability to penetrate some types of protein.[24] However, the protein penetration of alcohols can be improved with multiple wiping.[25] Two wipes are sufficient to remove protein aggregates and to allow the alcohol to be absorbed by the bacteria cell membrane.[26]

Summary

The optimum selection of a disinfectant is important for the prevention of cross infection within a dental practice,[27] particularly to minimize the risk from communicable infectious diseases like tuberculosis. The disinfection of surfaces between patients forms part of such good hygiene standards. The discussion presented in this paper about the efficacy of quaternary ammonium compound disinfectants raises some concerns.

Given the efficacy of alcohols against mycobacteria, these types of disinfectants may present a more suitable agent for use within dental practices. This issue is worthy of consideration for, if the elimination of *Mycobacterium tuberculosis* is a concern, then quaternary ammonium compounds in the dental practice may not be the disinfectant type of choice and this should trigger a review of current practice guidance.

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