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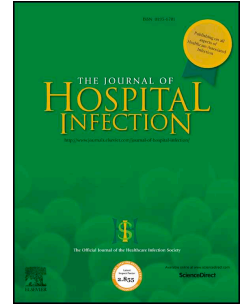
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The potential of alcohol release doorplates to reduce surface contamination during hand contact

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Abstract

BACKGROUND:

Optimal hand hygiene may be compromised by contact with contaminated environmental surfaces.

AIM:

To investigate the in-vitro efficacy of a novel, alcohol-release doorplate to reduce surface contamination during hand contact.

METHODS:

Prototype, horizontally-held, Surfaceskins, alcohol gel-impregnated and control (aluminium) doorplates were challenged (n=72 per microorganism) with *Staphylococcus aureus, Eschericia coli*, *Enterococcus faecalis* or *Clostridium difficile* contaminated fingers. *S. aureus* and *E. faecalis* were used for challenges (90 per microorganism) of vertical (modified design) doorplates, on days 0,3,4,6 and 7. Surface contamination was measured pre- and immediately post-challenges using agar contact plates.

FINDINGS:

Horizontal test, but not control, doorplates demonstrated bacterial killing of *S. aureus*, *E. faecalis* and *E. coli*, but not *C. difficile;* hence, only testing of *S. aureus* and *E. faecalis* was continued. Vertical Surfaceskins, but not control, doorplates demonstrated rapid killing of *S. aureus* over 7 days. There were significant reductions (>90% up to day 6; P$\leq$0.01) of surface bacterial colony counts compared with controls immediately post-challenge. There were also significant reductions in Surfaceskins doorplate enterococcal colony counts compared with controls on every day of testing (p$\leq$0.004). There was no evidence that bacterial recovery was greater from the tops of Surfaceskins doorplates (i.e. due to pooling of contents).

CONCLUSION:

Surfaceskins doorplates were efficient at reducing surface contamination by *S. aureus*, *E. faecalis* and *E. coli*. Reducing microbial contamination of frequently touched door surfaces,

and so bacterial transfer via hands, could feasibly reduce the risk of healthcare associated and other infections.

Introduction

Hands and particularly fingertips are strongly implicated in the cross transmission of microbial pathogens[1]. The introduction of multiple methods for achieving and maintaining clean hands aims to reduce the prevalence of pathogens persisting within the environment, and so break the cycle of infection. Alcohol based hand rubs (liquid, gel or foam) are widely used for routine hand disinfection in healthcare settings when hands are not visibly soiled. Alcohol gels are effective at reducing healthcare associated infection (HCAI) within healthcare environments, and are particularly effective at removing pathogens from the hands of healthcare workers (HCWs) and visitors before entering a ward environment [2-4].

The bacteria on hands can be divided into two categories: resident and transient. Resident flora include coagulase-negative staphylococci, Propionibacteria and micrococci that reside under the superficial cells of the stratum corneum and on the surface of the skin[5]. Transient potential pathogens such as *Staphylococcus aureus*, enterococci and Gram-negative enterobacteria colonise the superficial skin layers. These bacteria, which do not usually proliferate on skin but can survive but may sporadically multiply, are more amenable to removal by routine hand hygiene than resident flora[6]. Transient organisms tend to be acquired by HCWs, particularly during direct contact with patients or contaminated environmental surfaces.[7]

We have evaluated *in vitro* during simulated use the effectiveness of a new device, Surfaceskins doorplate, that aims to maintain the cleanliness of hands after opening doors via push plates i.e. it is designed to prevent contamination of (clean) hands upon touching a contaminated door surface. The alcohol gel releasing doorplate, developed by Surfaceskins (University of Leeds, UK), is designed to replicate a standard door plate in size and function and is mounted onto a door in the normal position. The Surfaceskins doorplate is composed of a disposable alcohol gel filled pad with a porous membrane on the top. This fits into a permanent plastic holder mounted onto the door. When pressure is applied by a hand onto the surface of the doorplate, a small amount of alcohol gel is released through small pores on the device surface, which is deposited onto the hand.

Materials and Methods

Determination of the number of bacteria on the fingertips of healthcare workers

In order to simulate the process of touching a doorplate with fingers (contaminated with bacteria), we first needed to determine the approximate number of bacteria present on the skin of the three (index, middle and ring) fingers that primarily touch a doorplate. To do this, we randomly recruited and sampled a wide range of healthcare workers from within the hospital to screen for hand bacteria. Staff were asked (with no prior warning) to dab their index, middle and ring fingers onto a Tryptone Soy Agar (TSA) plate (E&O Laboratories, Bonybridge, UK). They were also asked if they had washed or decontaminated their hands in the last 30 minutes. Following testing, all TSA plates were incubated and colonies counted after 24 hours. We also assessed the total surface area of skin (of the three fingers) that came into contact with the doorplate during the process. Ten people were asked to dip their fingers into endorsing ink, and then to touch graph paper to give a representation (in cm^2) of the surface area of a 'three finger touch.'

Preparation of bacterial strains for doorplate challenge experiments

A single strain each of four common healthcare associated pathogens were used (*S. aureus* ATCC29213*, Eschericia coli* NCTC10418 , *Enterococcus faecalis* NCTC2421 and *C. difficile* P24 strain ribotype (CE)001. These were cultured overnight in TSA broth (Schlaedlers broth for *C. difficile* to provide a predominantly spore inoculum), and a suspension of bacterial cells (10^5 CFU/ml) in a petri dish was used for inoculating gloved fingers (Latex Free, nitrile examination gloves, Healthline, Milton Keynes, UK) and used for each challenge experiment. This was to simulate bacterial contamination on three fingers, and was measured via replicate plate counts (by a process of dipping fingers into the suspension, dabbing on a paper towel and colony counts on TSA (data not shown)).

Experimental set up for challenge experiments

Surfaceskins door plates (n=3) were removed from packaging and placed into the plastic holders and secured horizontally on the bench. Control doorplates (n=3) used were standard aluminium doorplates that had been thoroughly cleaned using disinfectant wipes (P.D.I Sani -Cloth Flintshire, UK), were also secured horizontally. For the vertical tests, the Surface Skin doorplates (n=3) in the holders were secured onto a vertically mounted hand

pressure detector, providing a force reading (in kgf) and control doorplates (n=3) as above were secured horizontally (for ease of testing, and given the absence of a gel layer)). Onto each doorplate (Surfaceskins and controls) three separate circular areas (each 6 cm diameter) were allocated for testing; i.e. a top, middle and lower area. A plastic template, with three cut-out circles (top, middle and low) was secured over the top of each doorplate (Surfaceskins and control doorplates) to define the areas for testing and so to determine if bacterial kill was achieved/maintained in all areas.

Testing process for doorplate challenge experiments

Doorplates were tested firstly in the horizontal plane, and then (using a modified different Surfaceskins doorplate design that comprised different key components and configuration) in the vertical plane. For the horizontal doorplate challenges, four bacteria (*S. aureus*, *E. faecalis*, *E. coli* and *C. difficile*) were used and testing was carried out on days 0, 2 and 7. In total, 72 challenges (pre- and post-samples) were performed for each microorganism (36 on Surfaceskins doorplates and 36 on control doorplates). For the vertical doorplate challenges, two bacteria were used (*S. aureus* and *E. faecalis*), and testing was carried out on days 0, 3, 4, 6 and 7. Challenges were carried out in triplicate (3 doorplates were used) and three different areas on each doorplate were sampled, to give 9 challenges per organism per testing day. In total, 90 challenges (pre- and post) were performed per microorganism (45 on surface skin doorplates and 45 on control doorplates).

For each challenge experiment, the process involved the following steps. Firstly a pre-inoculation sample of the doorplate was taken by pressing a contact agar plate (Count-Tact Agar plate; Biomerieux, France) onto the defined area (top, middle or low) of the doorplate to be tested. Then gloved fingers were dipped into the suspension of bacterial cells in the petri dish. Fingers were briefly dabbed onto paper towel to remove excess fluid, and then were pressed against one of the defined areas of the door plate, to reach a pressure of 5 kgf. After no longer than 30 seconds, a second contact plate was used to take a post-inoculation sample of the same area of the doorplate. The same process was used for sampling the control doorplates. Following sampling, doorplates remained in place until the next test and throughout the duration of the 7 day testing period. All contact plates were incubated either aerobically or anaerobically (37°C for 48 hours). Following incubation, all

colonies were counted; for each challenge experiment, the number of colonies counted on the pre-inoculation sample was subtracted from the post-inoculation sample count to calculate a number of colonies transferred from fingertips. SPSS statistics version 16 (IBM) was used for data analysis.

Results

Presence of bacteria on the hands of healthcare workers

In total, 93 healthcare workers (32% male), including laboratory, administrative, medical and nursing staff, were recruited anonymously and tested for the number of bacteria on their hands. The mean contact area of the skin that would come into contact with the surface of the doorplate was 7.9 cm^2. The mean number of bacteria on the fingertips was 161 CFU, with 34% of the subjects recruited having washed or decontaminated their hands in the previous 30 minutes before testing. There were significantly fewer bacteria on the hands of those who had versus had not washed/decontaminated their hands in the last 30 minutes (mean 131 CFU versus 176 CFU, p=0.038). There was no significant difference in counts according to whether alcohol gel or soap and water had been used (117 CFU versus 144 CFU, p=0.55). Also, there was no significant difference between the bacterial counts recovered from the fingertips of females versus males (142.2 CFU versus 202.7 CFU, p=0.406).

Surfaceskins and control doorplates mounted horizontally and challenged with *E. coli*, *S. aureus*, *E. faecalis* and *C. difficile*

For the first challenge day (Day 0) all control doorplates showed bacterial recovery of >50 CFU bacteria for each test bacterium, while the Surfaceskins doorplates demonstrated a rapid kill of *S. aureus*, *E. coli* and *S. faecalis* (Figures 1a-c). Results were similar for the second challenge day. From the control doorplates bacterial recovery was greater than 150 CFU in all cases, the surface skin doorplates demonstrated a rapid kill of *S.aureus* and *E. coli* but not *E. faecalis (*low levels of *E. faecalis* (mean 26 CFU, p=0.128) were recovered. At the final challenge (Day 7) it was possible to demonstrate recovery from all control doorplates (>100 CFU). All three test organisms were recovered from the Surfaceskins doorplates; the greatest recovery was of *E. coli* (243 CFU, p= 0.810), followed by *E. faecalis* (202 CFU, p= 0.045) and *S. aureus* (90 CFU, p= 0.936).

Figure 1d shows the control and Surfaceskins doorplate bacterial challenge with *C. difficile*. At the first challenge day (Day 0) there was very similar recovery for the control doorplate and the surface skin doorplate (100 CFU versus 96 CFU p= 0.810). As the Surfaceskins

doorplates were shown to be ineffective at reducing *C. difficile* spore counts, no further testing was carried out with this bacterium.

Surfaceskins and control doorplates mounted vertically and challenged with *S. aureus* and *E. faecalis*

Surfaceskins doorplates demonstrated a rapid kill of *S. aureus*, with no viable *S. aureus* recovered on days 0 or 3 (Figure 2a&b). On day 4, small numbers of *S. aureus* were recovered from the Surfaceskins versus control doorplates (6 CFU versus 122 CFU, p=0.0041). On days 6 and 7, *S. aureus* recovery was significantly reduced (p=0.015 and p=0.0004, respectively) compared with the control doorplate. For *E. faecalis* similar results were obtained. There were significant reductions in Surfaceskins doorplate enterococcal colony counts compared with controls on every day of testing (p$\leq$0.004).

Comparison of bacterial recovery from the different regions tested on the Surfaceskins and control doorplates

There was no evidence that bacterial recovery (of either *S. aureus* or *E. faecalis*) was greater from the tops of Surfaceskins doorplates as the experiments proceeded i.e. no evidence that alcohol gel delivery decreased from the upper parts of the test doorplates because of movement of the gel contents under gravity. For example, the proportion of total *S. aureus* and *E. faecalis* recovered from the upper regions of Surfaceskins plates on day 7 was 48% and 38%, respectively. These proportions were similar to those seen with control doorplates.

Persistence of bacteria on the doorplate surface over 7 days

The pre-inoculation samples (Figures 3a&b) demonstrated the amount of bacteria surviving on doorplates throughout the duration of testing. For the *S. aureus* control doorplate, bacteria persisted on the doorplate from day 3 until day 7 (range 7-91 CFU). For the Surfaceskins doorplates very few *S. aureus* persisted from day 0 to day 6 (1 CFU); this number increased to 33 CFU on day 7. Similar results were seen for *E. faecalis* on the control doorplates, with a gradual increase in bacterial recovery during the testing period (up to 200 CFU by day 6). Very few *E. faecalis* (maximum 4 CFU) persisted on the Surfaceskins doorplates across days 0-7.

Discussion

Our study is the first to investigate the effectiveness of a novel alcohol gel releasing doorplate to help maintain hand cleanliness with respect to common healthcare associated pathogens. We showed that Surfaceskins doorplates were effective at rapidly reducing the number of bacteria on the test doorplates compared with a standard doorplate over the seven day testing period. As expected, the clear exception was for *C. difficile*, because the alcohol gel used in these prototype doorplates did not have activity against the spores of this bacterium. Unless a sporicidal agent could be incorporated into the doorplate, then this will be not effective for *C. difficile.* Alternative hand decontamination products could be explored to increase the effectiveness of surface skin door plates against *C. difficile*, although practicable product options are not clear at this point.

The benefits of alcohol gel use are widely established in healthcare practice. For example, Stone *et al* demonstrated a significant inverse correlation between the total volume of alcohol gel used and the incidence of MRSA blood stream infection across hospitals in England and Wales [8]. Studies have demonstrated that use of alcohol-based hand gels is more effective and better tolerated than non-antiseptic soap. Soap use can be associated with a risk of spreading contamination, and sub-optimal tolerance can influence the number and quality of hand hygiene procedures [9;10]. It is important to stress here that the Surfaceskins doorplate is not designed to decontaminate hands per se, but rather to prevent their contamination and so maintain hand cleanliness.

We have shown that persistence of bacteria on the Surfaceskins doorplates was very low up until day 6 for *S. aureus*, and throughout the 7 days for *E. faecalis*. This implies that the Surfaceskins doorplates are effective at controlling bacteria on this frequently touched part of a door surface and so recontamination of the next users' fingertips would not be likely to occur. We note reports of contaminated hands transferring bacteria onto taps or alcohol gel dispensers, with persistence of microbes and so a potential source of cross-transmission to other users. Forrester *et al* [11] found that coagulase-negative staphylococci, *diptheroids* and *Bacillus* spp., but not *C. difficile*, persisted on alcohol gel dispensers.

We measured the mean number of bacteria (166 CFU) on the fingertips in a cohort of healthcare workers using a contact touch plate. This was consistent with Pittet *et al* [12] who reported that fingertip contamination ranged from 0-300 CFU when sampled by similar methods. Price *et al* [13] found that although the count of transient and resident flora varied considerably among individuals, it was often constant for any individual. Pathogenic organisms deposited on the skin may become part of the normal cutaneous flora, or may only survive for a short time. Normal skin microflora also influence the survival of contaminants and there is a reciprocal action between the micro-organisms on the skin and their habitat [14].

There are a number of limitations to the present study. We aimed to standardise the pressure applied to the doorplate in each challenge experiment and therefore standardise the amount of alcohol released. However, this may have varied between tests and so may explain some variability in our results. There is no consensus as to the appropriate amount of alcohol gel which should be applied to hands. Guidelines acknowledge that the ideal volumes of product that should be applied to hands is unknown but state, for example, that hands dry before 10-15 seconds an insufficient amount was used,[15] but the minimum effective amounts of these products are unknown[16]. We did not monitor the drying time for the alcohol gel emitted by Surfaceskins doorplates. We note, however, that this product is not intended to be a substitute for the use of alcohol hand dispensers, but rather to supplement these. We did not actually measure fingertip contamination associated with use of the doorplates, but instead inferred that markedly lower recovery of bacteria from hands after contact with potentially contaminated door surfaces would be expected to occur.

There was a modest trend to reduced immediate killing and increased persistence of bacteria on the Surfaceskins doorplates towards the end of the 7 day testing period (Figures 2 and 3). Notably, however, bacterial survival was still markedly reduced compared with control doorplates. The doorplate is designed to be in place for a period of 7 days (or approximately 1000 uses), then disposed of and replaced. There was no clear evidence that bacterial killing was reduced at the tops of Surfaceskins doorplates, that is secondary to the movement of gel under gravity. We tested the doorplates in a laboratory environment, where they were subjected to controlled use in relatively stable environmental conditions.

In situ testing would be useful to confirm the efficacy of the doorplates under more varied challenges. Ultimately hand decontamination is related not only to its antimicrobial effectiveness, but also acceptability by users.[17] To ensure compliance the doorplates may have to be labelled as such, as some users may be put off using them if they are uncertain of their use and also may query the identity of the liquid released onto the hands. It is possible to add instructions for use and or pictures to the surface of these devices and so help to educate as to their aim/value. Cleary, if contact with a door handle is required to open a door then this remains a point of potential hand contamination; work is at an advanced stage to develop an alcohol gel emitting Surfaceskins tubular device that can be fitted to door handles. An alcohol gel emitting product is commercially available, but this is instead of rather than an addition to conventional door handles (http://www.purehold.co.uk/the-hygiene-handle/).

Surfaceskins doorplates are easy to install and require minimal maintenance, with replacement on a weekly basis. Discussion with cleaning staff shows that methods are in place for cleaning doors, and so doorplate replacements could be incorporated into standard cleaning practice. Our findings suggest that Surfaceskins doorplates may have applications within healthcare environments and other settings where frequent contact with doors could undermine hand hygiene (e.g. washrooms, restaurants). Reducing the contamination by and transfer of bacteria via hands could feasibly reduce the burden of healthcare associated and other infections.

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Potential Conflicts of Interest

MHW has received consulting fees from Abbott Laboratories, Actelion, Astellas, Astra-Zeneca, Bayer, Biomèrieux, Cerexa, Cubist, Durata, The European Tissue Symposium, The Medicines Company, MedImmune, Merck, Motif Biosciences, Nabriva, Optimer, Paratek, Pfizer, Qiagen, Roche, Sanofi-Pasteur, Seres, Summit, and Synthetic Biologics; lecture fees from Abbott, Alere, Allergan, Astellas, Astra-Zeneca, Merck, Pfizer & Roche; grant support from Abbott, Actelion, Astellas, Biomèrieux, Cubist, Da Volterra, MicroPharm, Morphochem AG, Sanofi-Pasteur, Seres, Summit, Surfaceskins and The European Tissue Symposium, Merck.

Figure 1a-d. Bacteria recovered from control and horizontal Surfaceskins doorplates challenged with (a) *S. aureus (*day 7 *p=0.936),* **(b)** *E. coli (*day *7 p=0.810),* **(c)** *E. faecalis* **(day 2** *p=0.128* **and day 7** *p=0.045*) **and (d)** *C. difficile* **over 7 days (no further testing was carried out for** *C. difficile* **on days 2 and 7).**
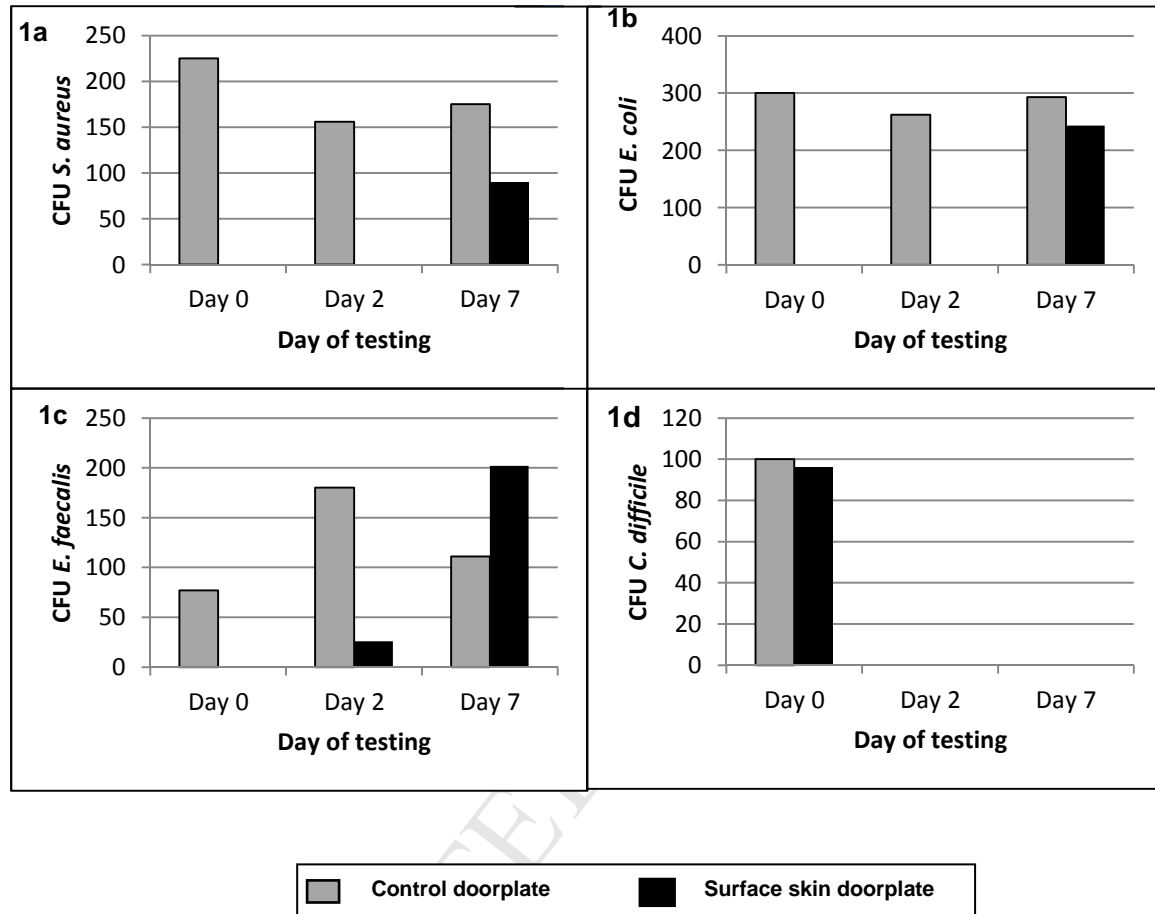

Figure 2a&b. Bacteria recovered from control and vertical Surfaceskins doorplates challenged over 7 days with (a) *S. aureus* (day 4 *p=0.0041,* day 6 *p=0.015* and day 7 *p=0.0004*) and (b) *E. faecalis* (all days *P≤0.004*).
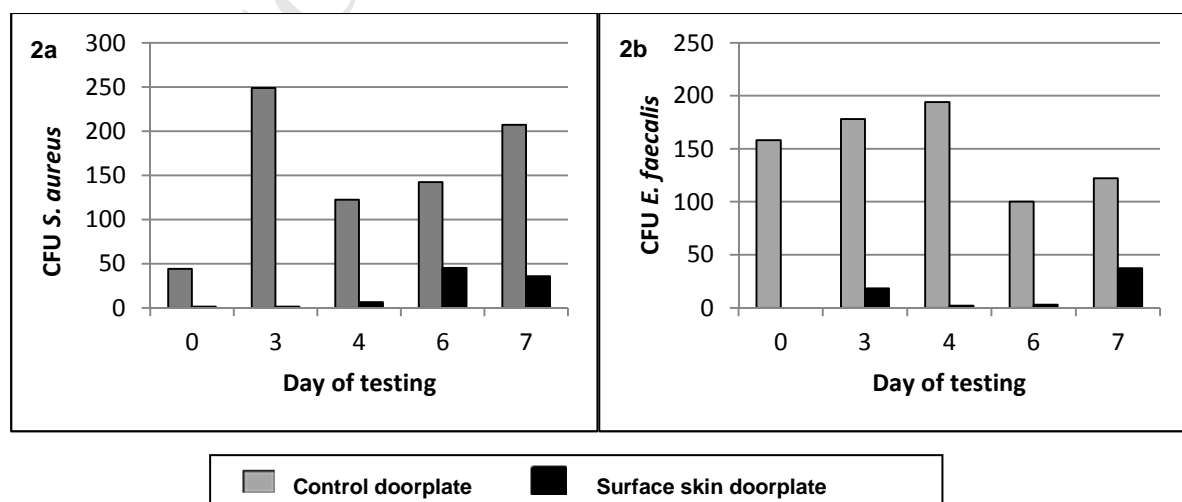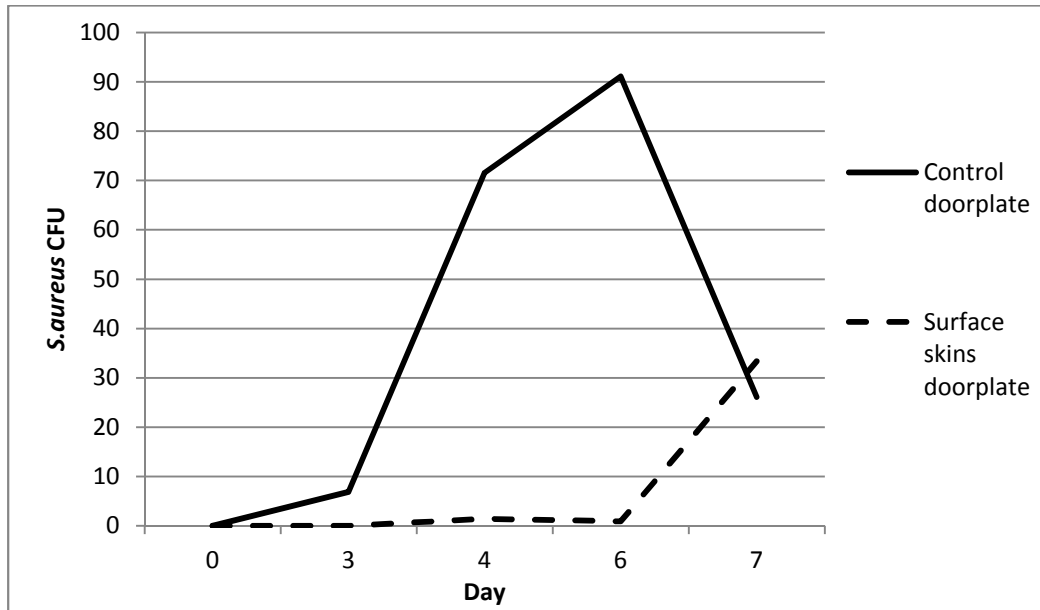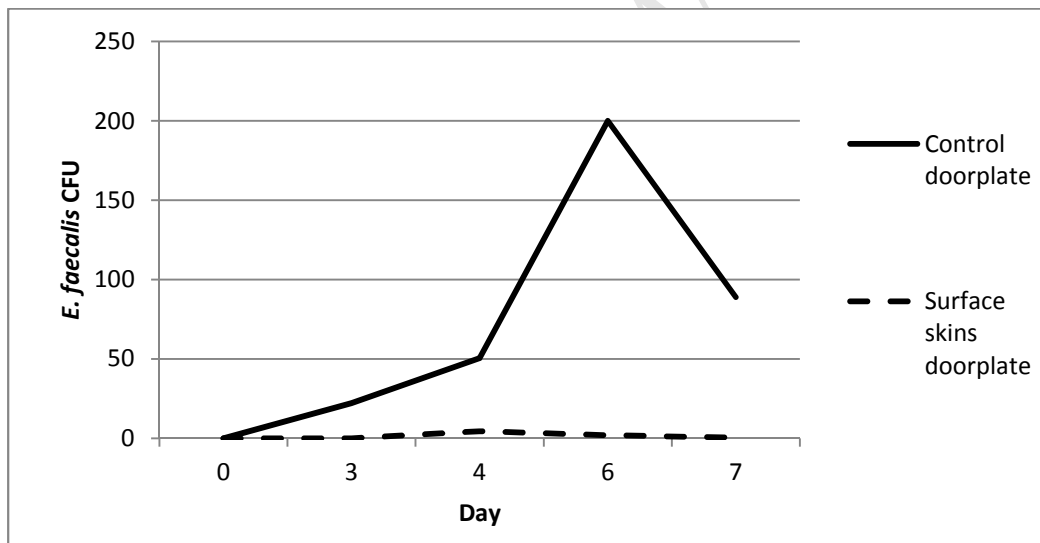
Figure 3. Persistence of *S. aureus* (a) and *E. faecalis* (b) on control and Surfaceskins doorplates over 7 days.

3a.

3b.

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