TRANSFER OF BACTERIA BETWEEN BIOMATERIALS SURFACES IN THE OPERATING ROOM

an experimental study

Knobben BAS, Van der Mei HC, Van Horn JR, Busscher HJ

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Introduction

The number of biomaterials implants placed worldwide is huge and will only increase during the next few decades. Biomaterials implants are foreign bodies on which a biofilm can grow, provided bacteria are given the opportunity to adhere and multiply. Once a biofilm has formed, the bacteria within a biofilm are highly resistant to antibiotic treatment. In most cases, a prosthesis has to be removed temporarily until the infection has cleared fully from the surrounding tissue. This makes infection one of the worst complications, as most evident in orthopaedic implant surgery. Since many decades *Staphylococcus aureus* has been identified as a virulent micro-organism causing periprosthetic infection.\(^1\)\(^2\) The coagulase-negative *Staphylococcus epidermidis* was long considered non- to low-virulent, but is now considered as the major source of intra-operative contamination and a cause of periprosthetic infection.\(^1\)\(^-\)\(^6\) The obligate anaerobe *Propionibacterium acnes* was present in 62\% of contaminated hip prostheses retrieved after removal due to chronic low-grade infection.\(^2\) i.e. as frequently as *Staphylococcus* spp.

The most common cause of orthopaedic implant infection are bacteria entering the wound during surgery.\(^7\)\(^-\)\(^8\) Intra-operative contamination is common in every operating room.\(^4\)\(^-\)\(^9\)\(^-\)\(^11\) However, despite several technological and behavioural developments, bacteria can not be fully eliminated from an operating room.\(^12\) Bacterial adhesion to and transfer between surfaces is a complicated process and with regard to the success of biomaterials implants, studies on bacterial adhesion and transfer should not be confined to biomaterials surfaces in the human body, but also encompass surfaces in the operating room, where the origin of many biomaterials related infections is found.

Hydrophobicity and roughness of the interacting surfaces are generally considered as important factors in bacterial adhesion, but also environmental conditions like moistness of the surface and the application of friction will affect bacterial transfer between surfaces. In clear contrast to what is currently being studied most in the literature (bacterial adhesion to surfaces) the problem in the clinical situation is much more to prevent transfer of bacteria from one surface to another. Contact lens induced keratitis is the result of bacterial transfer from the lens case to the lens and from the lens to the cornea. Similarly, intra-operative contamination is the result of a series of bacterial transfers from the skin of the patient or theatre personnel via instruments and other materials to the wound area.\(^13\)\(^-\)\(^14\) Davis et al. identified materials that are frequently contaminated during elective orthopaedic surgery. In 14.5\% of the procedures, the
light handles were contaminated, in 17% the theatre gowns and in 28.7% the gloves of the operating team. The used sets of instruments were contaminated in 3.2% to 11.4% of the sampled cases. As a result, as much as 70% of all air-borne bacteria reach the wound via hands of the surgical personnel or by instruments used, while only 30% reach the wound directly via the air.

The purpose of this study is to quantify the transfer of bacteria (the aerobes S. epidermidis and S. aureus and the anaerobe P. acnes) from one operating room material to another, while accounting for surface hydrophobicity and roughness, moistness and application of friction during transfer. As a possible clinical intervention method to prevent transfer, it was investigated whether dipping the gloves in a chlorhexidine splash-basin affected the viability of the transferred bacteria.

Materials and methods

Bacterial strains, culture conditions and harvesting

Three bacterial strains, S. epidermidis 8162, S. aureus 5434 and P. acnes 5198 isolated from patients with septic prosthetic loosening were employed. From these strains, a frozen stock was precultured at 37ºC on blood agar plates for 24 h aerobically (S. aureus and S. epidermidis) and for 48 h anaerobically (P. acnes). For the preparation of experimental cultures, colonies were inoculated into a 10 ml batch culture of Tryptone Soya Broth (TSB, Oxoid, United Kingdom) for 24 h at 37ºC under aerobic (S. aureus and S. epidermidis) and anaerobic (P. acnes) conditions. This preculture was used to inoculate a main culture of 200 ml TSB, which was allowed to grow for 16 h. Bacteria from this main culture were harvested in their stationary phase by centrifugation at 5000 g 5 min at 10ºC. The strains were washed twice with ultrapure water and resuspended in 10 ml ultrapure water. Finally, bacteria were suspended in 0.9% saline to a concentration of 1 x 10⁸ cells ml⁻¹, as determined in a Bürker-Türk counting chamber. All bacteria were used immediately after harvesting.

Operating room materials

Bacterial transfer was studied between frequently contaminated materials, including latex operating gloves (Gammex, Ansell, Belgium), polyester theatre gowns (Gore-Prooftex, Rentex, Germany), polyvinylchloride (PVC) light handles and stainless steel broaches. Operating
gloves and theatre gowns were mounted onto sample stubs to obtain samples suitable for measurements. PVC light handles could also be mounted to allow easy measurements on a flat instrument piece. Gloves, theatre gowns and light handles were cleaned with 70% ethanol prior to measurements. Stainless steel samples were made from plate material, commercially purchased, ground down to grit number 1200, and subsequently polished with a diamond water-based suspension (Metadi 6 and 3 µm diamond suspension and Trident polishing cloth, Buehler, Lake Bluff) for 3 and 1.5 min, respectively. Both procedures were performed on a polishing machine with a 30 N load and with oppositely rotating axes (Phoenix Beta and vector grinder/polisher, Buehler, Lake Bluff). After polishing, the steel was cleaned by 5 min sonication in 2% alkaline cleaning agent followed by thorough rinsing with tap water, sonication in ethanol and rinsing in ultrapure water. After cleaning, the steel was passivated according to ASTM F86-91.

**Measurement of surface hydrophobicity and roughness**

Hydrophobicity of the materials was assessed through the measurement of water contact angles, employing the sessile drop technique and a homemade contour monitor. Water contact angles of 3 µl droplets were determined. For the measurements of bacterial cell surface hydrophobicity, bacteria were suspended in 10 ml ultrapure water. A cellulose acetate membrane filter with a pore diameter of 0.45 µm was put on a fritted glass support, and a bacterial deposit was obtained by filtration of the bacterial suspension under negative pressure. The filters, containing $10^8$ bacteria per square millimetre, were placed on a metal sample disc with double-sided sticky tape and dried for 30-40 min in order to measure plateau water contact angles. Measurements for both materials and bacteria were performed in triplicate.

The roughness of the materials was measured with the aid of a profilometer (Proscan 2000, Scantron Industrial Products Ltd, Taunton, Somerset, UK). The samples were placed in a holder and mounted on the profilometer with the use of double-sided sticky tape. The slide was put below the laser to obtain height images in three dimensions of an area of one square centimetre. The height was measured in this area every 100 µm. The average roughness $R_A$ was obtained from these images and indicates the average distance of the roughness profile to the centre plane of the profile. All measurements were done in triplicate.
Initial adhesion and bacterial transfer

Sterile donor materials (5 glove samples, 3 broach samples, 3 theatre gown samples and 2 light handle samples) with a diameter of 5 cm were exposed to different baths with the same bacterial suspension of $1 \times 10^8$ cells ml$^{-1}$ for 15 min at room temperature (Figure 1A). After removal from the bacterial suspension, sterile filtration paper was used to remove excess suspension and the sample edges were cleaned with an alcohol soaked cotton swab.

For quantification of initial adhesion, one sample of each material was put in 20 ml of sterile 0.9% saline (Figure 1B) and sonicated for 30 s, after which serial dilutions were made (1, 10, 50 and 100 times) and plated on TSB agar. Plates were left to incubate at 37°C for 24 h under aerobic conditions for the staphylococcal strains and for 48 h under anaerobic conditions for P. acnes. Finally, the number of CFUs was determined in order to yield the number of CFUs per unit area present on the donor material before transfer. The other samples were used to do the transfer experiments.

Table I shows the different bacterial transfers that were tested from one material surface to another. In all experiments the contact time was 10 s and the applied pressure 1.0 kg cm$^{-2}$. The experiments were performed both when the inoculum was still moist and after it was allowed to dry after inoculation. In case bacterial transfer from or to gloves was measured,
experiments were also performed with additional friction applied, consisting of 10 half-circle rotations during contact. Subsequently, the samples were handled as described above and in Figure 1.

Table I. Donor and recipient materials used to study the transfer of bacteria. All experiments were performed under a pressure of 1.0 kg cm\(^{-2}\) and a contact time of 10 s. Experiments with gloves were performed both with and without friction. Friction consisted of 10 half-circles of rotation during the 10 s contact time.\(^{15}\)

<table>
<thead>
<tr>
<th>Donor</th>
<th>Recipient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glove moistened with inoculum / allowed to dry after inoculation</td>
<td>Glove</td>
</tr>
<tr>
<td>Broach moistened with inoculum / allowed to dry after inoculation</td>
<td>Broach</td>
</tr>
<tr>
<td>Theatre gown moistened with inoculum / allowed to dry after inoculation</td>
<td>Theatre gown</td>
</tr>
<tr>
<td>Light handle moistened with inoculum / allowed to dry after inoculation</td>
<td>Glove</td>
</tr>
</tbody>
</table>

Intervention methods

In order to determine whether chlorhexidine is an effective antimicrobial agent to prevent transfer of *S. aureus*, *S. epidermidis* and *P. acnes*, gloves after bacterial inoculation were dipped in chlorhexidine-digluconate (4%, 0.4% and 0.04% in water) prior to transfer. The experiments were performed both with the inoculated gloves still moist and after air drying (1 min). After chlorhexidine dipping, gloves were either immediately handled or allowed to dry. Similar procedures were carried out with 0.9% saline as a control.

Statistical analysis

Statistical analyses were performed using SPSS software version 12.0 (SPSS Inc., Chicago, IL). Differences between initial adhesion of *S. epidermidis*, *S. aureus* and *P. acnes* to the materials were determined with the two-sided Students t-test (accepting p<0.05 as the limit for statistical significance). Transfer was calculated as the percentage of CFUs cm\(^{-2}\) on the donating material that had transferred to the receiving material and was the mean of three experiments. Differences in transfer percentages for the three bacterial strains to and from the materials were again calculated using the two-sided Students t test (p<0.05). The same applies for the difference in transfer between moist and dry transfer and between transfer with and without the application of friction.
Finally, a univariate analysis was performed to test the independent variables "bacterial strain", "moistness", "friction", "donating" and "receiving" material for their correlation with bacterial transfer. The p values indicate the significance of the effect of an independent variable on the transfer (p<0.05). The percentage of the total variation in transfer that can be explained by an independent variable was expressed as the percentage of variance.

Results

Initial adhesion

Figure 2 compares the initial adhesion of the different bacterial strains to the various donor materials. Initial adhesion of *S. aureus* and *P. acnes* to the different donor materials is similar, but adhesion of *S. epidermidis* to gloves, theatre gowns and light handles is significantly (p<0.05) higher than for the two other strains. However, initial adhesion of *S. epidermidis* to the stainless steel broach is significantly (p<0.05) lower than of *S. aureus* and *P. acnes*.

The theatre gown attracts most bacteria, regardless of the strain involved, with almost similar numbers of *S. aureus* and *P. acnes* adhering to the broach. However, the broach attracted the lowest number of *S. epidermidis* of all materials involved. Adhesion of the strains to light handles was only slightly less than to theatre gowns.

![Figure 2. Initial adhesion of *S. epidermidis*, *S. aureus* and *P. acnes* to glove, broach, theatre gown and light handle. Mean values are shown in colony-forming units per square centimetre (CFU cm⁻²). Error bars represent standard deviations over triplicate runs with separately cultured bacteria.](image-url)
Transfer

Table II summarizes the bacterial transfer between different surfaces for transfer from a moist donor in the absence of friction. The mean transfer percentage of the tested transfers from moistened donors is 38% (SD=20.5) and ranges from 17 to 71%. The average transfer is generally lower from theatre gown and light handles than from gloves and broaches. Transfer from the broach was lowest for *S. aureus*, which is also the reason why the average transfer for *S. aureus* is lower than for the two other strains.

Transfer percentages for *S. epidermidis* are highest from glove to broach and from broach to theatre gown (both 67%) and lowest from light handle to glove (17%) and from theatre gown to glove (24%). Transfer percentages from the glove are significantly (p<0.05) higher to the broach than to the glove and to the light handle. In general, transfer percentages from the broach are significantly (p<0.05) higher than those from the theatre gown. When looking at the transfer percentages to the glove it can be seen that these are significantly (p<0.05) higher from the broach than from the theatre gown and from the light handle.

Table II. Mean transfer percentages for *S. epidermidis*, *S. aureus* and *P. acnes* in case of moist transfer without friction from one operating room material to another. Data are results of triplicate runs with separately cultured bacteria (± indicates standard deviation).

<table>
<thead>
<tr>
<th>S. epidermidis</th>
<th>S. aureus</th>
<th>P. acnes</th>
<th>Average over strains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glove</td>
<td>Glove</td>
<td>33 ± 8</td>
<td>26 ± 5</td>
</tr>
<tr>
<td>Broach</td>
<td>67 ± 16</td>
<td>71 ± 14</td>
<td>33 ± 8</td>
</tr>
<tr>
<td>Theatre gown</td>
<td>45 ± 6</td>
<td>40 ± 9</td>
<td>39 ± 11</td>
</tr>
<tr>
<td>Light handle</td>
<td>29 ± 5</td>
<td>28 ± 10</td>
<td>61 ± 3</td>
</tr>
<tr>
<td>Average over materials</td>
<td></td>
<td>44</td>
<td>41</td>
</tr>
<tr>
<td>Broach</td>
<td>Glove</td>
<td>47 ± 8</td>
<td>24 ± 8</td>
</tr>
<tr>
<td>Theatre gown</td>
<td>67 ± 11</td>
<td>29 ± 8</td>
<td>57 ± 7</td>
</tr>
<tr>
<td>Average over materials</td>
<td></td>
<td>57</td>
<td>27</td>
</tr>
<tr>
<td>Theatre gown</td>
<td>Glove</td>
<td>24 ± 6</td>
<td>28 ± 5</td>
</tr>
<tr>
<td>Broach</td>
<td>32 ± 3</td>
<td>23 ± 6</td>
<td>19 ± 6</td>
</tr>
<tr>
<td>Average over materials</td>
<td></td>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>Light handle</td>
<td>Glove</td>
<td>17 ± 7</td>
<td>17 ± 4</td>
</tr>
<tr>
<td>Average over all transfer</td>
<td></td>
<td>40</td>
<td>32</td>
</tr>
</tbody>
</table>

Transfer of *S. aureus* is comparable to the transfer of *S. epidermidis*, except for its transfer from the metallic broach. Transfer of *S. aureus* from broach to glove (24%) and theatre
gown (29%) is significantly (p<0.05) lower than observed for *S. epidermidis* (47% and 67%, respectively) and *P. acnes* (56% and 57%, respectively).

The transfer of *P. acnes* proceeds along different lines than of the staphylococcal strains. Transfer of *P. acnes* from glove to light handle (61%) and from light handle to glove (48%) are significantly (p<0.05) higher than that of *S. epidermidis* (29% and 17%, respectively) and *S. aureus* (28% and 17%, respectively).

**Influence of moistness and application of friction on bacterial transfer**

Figure 3 shows that when the donor surface is allowed to dry prior to transfer, transfer percentages decrease significantly for all nine transfer pathways and all three bacterial strains when compared to moist surfaces without friction. On average over all nine pathways, the transfer of *S. epidermidis* decreased 2.7-fold, of *S. aureus* 1.5-fold and the transfer of *P. acnes* 1.7-fold.

The application of friction increases bacterial transfer from one material to another (see also Figure 3). The mean transfer percentage of *S. epidermidis* increased 1.6-fold, of *S. aureus* 1.8-fold and of *P. acnes* 1.5-fold compared to moist without friction.

Table III shows that all studied variables (“bacterial strain”, “moistness”, “application of friction” and “donating” and “receiving” material) have a significant influence on bacterial transfer, with the percentage of variance explained by moistness and application of friction being largest (41.0% and 36.5%, respectively).

**Table III. Univariate analysis of variance of the transfer model used in this study. P-values show the significance of each factor. Percentages of variance indicate the strength of the influence of each factor on the transfer percentage.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Significance (p)</th>
<th>Percentage of variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacterial strain</td>
<td>&lt; 0.001</td>
<td>2.0</td>
</tr>
<tr>
<td>Moistness</td>
<td>&lt; 0.001</td>
<td>41.0</td>
</tr>
<tr>
<td>Friction</td>
<td>&lt; 0.001</td>
<td>36.5</td>
</tr>
<tr>
<td>Donating surface</td>
<td>&lt; 0.001</td>
<td>3.7</td>
</tr>
<tr>
<td>Receiving surface</td>
<td>&lt; 0.001</td>
<td>2.7</td>
</tr>
</tbody>
</table>
Figure 3. Transfer percentages for *S. epidermidis*, *S. aureus* and *P. acnes* from one operating room material to another. Mean transfer percentages are shown for moist transfer without friction (Moist), dry transfer without friction (Dry) and moist transfer with application of friction (Friction). Transfer from broach to theatre gown and vice versa were not performed. Error bars indicate standard deviations over triplicate runs with separately cultured bacteria. G = Glove; B = Broach; Tg = Theatre gown; Lh = Light handle.

Influence of hydrophobicity and roughness of bacterial strains and operating room materials on bacterial transfer

Table IV shows the mean water contact angles and the mean roughness of the surfaces of the operating room materials and the mean water contact angles of the bacterial strains. The stainless steel of the broach constituted the most hydrophilic surface and the polyester theatre gown was the most hydrophobic, likely also as a side-effect of its roughness. The
material is the roughest and the broach material the smoothest. The *S. aureus* and *P. acnes* strains employed are relatively hydrophilic, whereas *S. epidermidis* is a more hydrophobic strain.

<table>
<thead>
<tr>
<th>Material surface</th>
<th>Hydrophobicity (degrees)</th>
<th>Roughness (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glove</td>
<td>99</td>
<td>25</td>
</tr>
<tr>
<td>Broach</td>
<td>62</td>
<td>7.6</td>
</tr>
<tr>
<td>Theatre gown</td>
<td>136</td>
<td>35.4</td>
</tr>
<tr>
<td>Light handle</td>
<td>107</td>
<td>19.9</td>
</tr>
<tr>
<td><em>S. epidermidis</em></td>
<td>57</td>
<td>-</td>
</tr>
<tr>
<td><em>S. aureus</em></td>
<td>27</td>
<td>-</td>
</tr>
<tr>
<td><em>P. acnes</em></td>
<td>25</td>
<td>-</td>
</tr>
</tbody>
</table>

Table IV. Hydrophobicity (determined by water contact angle measurements) and surface roughness (determined by AFM) of the operating room materials (glove, broach, theatre gown and light handle) and bacterial strains (*S. epidermidis*, *S. aureus* and *P. acnes*).

Figure 4 shows the average moist transfer percentages from the donating (A) and to the receiving operating room material surface (B) as a function of the hydrophobicity measured by water contact angles and roughness for *S. epidermidis*, *S. aureus* and *P. acnes* in a single parameter regression model. Transfer of *S. epidermidis* and *P. acnes* decreases with increasing hydrophobicity and roughness of the donating surface (Figure 4A-1 and 4A-2): the more hydrophobic and rough the material surface, the better the bacteria stick to it (i.e. the least transfer to the receiving surface). The only exception is the transfer of *S. epidermidis* from the light handle, which is surprisingly low (17%). *S. aureus* acts somewhat differently, mainly by sticking to the hydrophilic and smooth metallic broach surface on transfer.

When considering the hydrophobicity and roughness of the receiving material surface, transfer of the two staphylococcal strains is best to both the smooth and hydrophilic broach and to the rough and hydrophobic theatre gown, the latter especially for *S. epidermidis*. Transfer of *P. acnes* to a surface is worst when this surface is hydrophilic and smooth, transfer to the light handle is highest.
Figure 4. Average moist transfer percentages from the donating (A) and to the receiving operating room material surface (B) as a function of the hydrophobicity (A-1 and B-1) and roughness (A-2 and B-2) for S. epidermidis (■), S. aureus (▲) and P. acnes (◊).

**Intervention**

Table V shows that dipping the glove material in a 4% or 0.4% chlorhexidine solution kills all bacteria present, regardless of whether surfaces were dried prior to transfer or still moist. Dipping in 0.04% chlorhexidine was only effective under dried conditions, and under moist transfer conditions results were similar as for a 0.9% saline control.
Table V. Number of CFUs cm$^{-2}$ still present on the sample after dipping in a saline (0.9%) or chlorhexidine solution (0.04, 0.4 and 4%). Experiments were performed when the inoculum was still moist and when the inoculum had been allowed to dry before dipping. After dipping half of the samples were allowed to dry before counting CFUs, the others were counted immediately.

<table>
<thead>
<tr>
<th></th>
<th>Inoculum still moist</th>
<th></th>
<th>Inoculum allowed to dry</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SE</td>
<td>SA</td>
<td>PA</td>
<td>Dipping fluid still moist</td>
</tr>
<tr>
<td>0.9% saline</td>
<td>365</td>
<td>285</td>
<td>303</td>
<td>521</td>
</tr>
<tr>
<td>0.04% chlorhexidine</td>
<td>316</td>
<td>213</td>
<td>227</td>
<td>0</td>
</tr>
<tr>
<td>0.4% chlorhexidine</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4% chlorhexidine</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

SE = *S. epidermidis*, SA = *S. aureus*, PA = *P. acnes*

**Discussion**

Transfer between glove, broach, theatre gown and light handle surfaces as well as initial adhesion onto these material surfaces was evaluated in this study for *S. epidermidis*, *S. aureus* and *P. acnes*. This is the first study to quantify this transfer of bacteria between different material surfaces used in the operating room. Most other studies focussing on bacterial adhesion or transfer are performed in the food sector or are contact lens related.\(^{16-21}\) Several studies have focussed already on the initial adhesion of *S. epidermidis* and *S. aureus* to different material surfaces, but initial adhesion of *P. acnes* to comparable material surfaces was studied here for the first time.

Regarding initial adhesion, it is generally accepted that hydrophobic bacteria adhere to a greater extent than hydrophilic bacteria, especially to hydrophobic surfaces.\(^{22}\) In this study, initial adhesion of the most hydrophobic bacterial strain used (*S. epidermidis*), is higher on all materials than the initial adhesion of *S. aureus* and *P. acnes*, except for the more hydrophilic metallic broach. This is in accordance with the generally accepted thought that bacteria with hydrophobic properties prefer to adhere to hydrophobic material surfaces; the ones with hydrophilic characteristics prefer hydrophilic surfaces.\(^{17,23-24}\) Ramage et al., studying biofilm formation of *P. acnes*, *S. epidermidis* and *S. aureus* on PMMA (polymethylmethacrylate) bone cement and titanium alloys found that initial adhesion (within 30 min) to the titanium alloys was significantly higher for *S. epidermidis* than for *P. acnes* and *S. aureus*.\(^{25}\) Faille et al. found that the more hydrophobic a material surface, the more likely bacteria will adhere to it.\(^{17}\) With the exception of the hydrophilic *S. aureus* and *P. acnes* adhering best to the hydrophilic broach, similar conclusions can be drawn from our study.
Transfer was demonstrated to some extent with all bacterial strains and every tested material. The transfer that attracts the most attention is the transfer of the hydrophilic *S. aureus* from glove to broach and from broach to both glove and theatre gown. It appears that *S. aureus* transfers to the hydrophilic and smooth stainless steel very easily, and it sticks to it rather strongly, leading to low transfer percentages to other materials. This is again in accordance with the knowledge that hydrophilic strains adhere well to hydrophilic surfaces.\(^{26}\)

All three bacteria adhere best to the theatre gown. Probably this has to do with the severe roughness of this material. A rough surface has a greater surface area and the depressions in the roughened surface provide more favourable sites for colonization.\(^{27-29}\)

Transfer from the rough and hydrophobic theatre gown was low for all three bacterial strains. Because of the high roughness, a small contact area exists between the donating theatre gown surface and the other receiving surface, creating low transfer percentages. On the other hand, transfer to the theatre gown was quite high for all tested strains. Perhaps the hydrophobic nature of this material and some minor friction applied during the transfer experiments can account for this. In the discussion of the use of cotton or polyester theatre gowns this is quite interesting. A bacterial transfer study performed by Sattar et al. showed that a polyester-cotton blend releases bacteria much easier than cotton alone.\(^{19}\) Comparison of fabrics indicate that disposable, polypropylene, spun bond laminate materials offer best protection.\(^{30}\) In conclusion, it can be said that cotton gowns are more convenient to wear, but too permeable for bacteria (especially when wet); polyester-cotton drapes on the other hand are more inconvenient to wear, less permeable to bacteria, but apparently release attached bacteria more easily than cotton drapes.

*P. acnes* is increasingly being considered a potential pathogen to cause periprosthetic infection. Ramage et al. showed its possibility to grow a biofilm on orthopaedic implants and bone cement.\(^{25}\) Our study shows that *P. acnes* transfers between all tested operating room material surfaces and that it transfers best away from the broach (56-57%) and between glove and light handle (61 and 48%). Combining these last findings with those of Davis et al., describing that 14.5% of the light handles are contaminated, it is obvious that the light handle issue still remains a problem.\(^{4}\) Several studies have pointed out that light handles are often contaminated with bacteria, but few of them have given solutions. The proposed ‘compromise’ by Davis et al. is to manipulate the light handle with a sterile cloth, which is then discarded. Our proposed regime of dipping the gloves in a chlorhexidine splash-basin may further decrease bacterial adhesion and transfer into the wound.
Bacteria that are living in a biofilm are far more resistant to antibiotic treatment than planktonic bacteria, which makes the treatment of periprosthetic infection very difficult. During the transfer of bacteria in the operating room, the sessile bacteria are still in a monolayer and can easily be treated with chlorhexidine. Chlorhexidine has already been demonstrated to be effective against bacteria in such a state.\textsuperscript{31-35} Intervention with this agent in the operating room by dipping the surgical gloves in a chlorhexidine splash-basin every ten minutes would be an easily applicable method to decrease bacterial transfer into the wound and hence lower the risk of postoperative infection.

This study examines the bacterial transfer between different material surfaces used in the operating room. Transfer (moist and without friction) was demonstrated to some extent with all three bacterial strains and with every tested material, ranging from 17 to 71\%, and was influenced by the type of strain, moistness of the inoculum, the application of friction and the characteristics of both the donating and the receiving surface. Dipping the glove material in 4\% or 0.4\% chlorhexidine solutions killed all bacteria present, regardless of whether surfaces were dried or moist and thus prevented transfer.
References
