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A laboratory evaluation of the decontamination properties of microfibre cloths

G. Moore [1], C. Griffith*

School of Applied Sciences, University of Wales Institute, Cardiff, UK

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Summary Standards of cleanliness in health care continue to attract attention. Effective cleaning requires the input of energy, and microfibre cloths may help in the physical removal of soil. The ability of these cloths to remove organic soil (measured by ATP) and bacteria was compared with paper towel and a conventional cloth in controlled wet and dry conditions. When used wet on a dry surface, the cleaning ability of six different microfibre cloths was variable, and in most cases, not significantly better than paper towel or a conventional cloth. One type of microfibre cloth did perform significantly better than the others and paper towel in reducing both organic soil and microbial load. When used dry on a dry surface, there was no significant difference between the cloths, and none of the cloths reduced microbial and organic bioburden effectively. The ability of the cloths to recontaminate the surface was also tested, and some of the microfibre cloths transferred significantly less organic debris and micro-organisms back to the surface than other cloths. Different makes of microfibre cloths have different characteristics, and the name 'microfibre' should not imply superior cleaning efficacy.

Introduction

Standards of cleanliness in healthcare institutions worldwide continue to attract attention.[1–6] Effective cleaning is important for aesthetic and economic reasons, and may help to reduce infections.[1,2,4] In the UK, this has resulted in a number of national initiatives to improve cleaning.[7–9]

* Corresponding author. Address: School of Applied Sciences, University of Wales Institute, Cardiff, Llandaff Campus, Western Avenue, Cardiff CF5 2YB, UK. Tel./fax: +44 2920 416306.
E-mail address: cgriffith@uwic.ac.uk
[1] Present address: School of Health Sciences, Jordonstown Campus, Shore Road, Newtonabbey, Co. Antrim BT37 0QB, UK.

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Cleaning requires the input of energy, including heat, mechanical and chemical energy, and time.[10] Maximizing the efficacy of the energy expended should help to improve cleaning and it is claimed that microfibre cloths help.[11,12]

Microfibres are produced when larger polyester and polyamide fibres are split during production.[13] However, unlike conventional cloths, they have thousands of randomly arranged sharp-edged microfibre strands, and this may improve cleaning efficacy.[13,14] Previous studies have reported on their ability to remove dust and high-fat soils from surfaces compared with conventional cloths, without the need for detergents.[12,13,15]

Cleaning cloths should not recontaminate cleaned surfaces. The food industry recognizes that cleaning cloths can act as both a source of, and vehicle for, spreading pathogens.[16–20] Similarly, contaminated cleaning equipment has been implicated in outbreaks of infection in hospitals.[21–23] It has also been suggested that higher surface microbial counts after cleaning in hospitals may be due to contaminated cloths.

A report by the Association of Domestic Management suggested the introduction of cleaning systems based on microfibre technology to reduce and improve standards.[11] This was based on trials using visual assessment of cleaning efficacy and staff user satisfaction. One study using microbiological testing indicated that 'both systems (microfibre and non-microfibre) were able to impact favourably on the environmental bacterial load but neither method completely and consistently removed the microbiological population'.[11] Traditional cleaning regimens may be inadequate with poor compliance, and a feature of these 'in-use' hospital trials was that staff received specialized training in the use of the microfibre products prior to the trials, which could have influenced behaviour.[1] Remedial refresher training, on its own, may have led to increased cleaning efficacy.

There is limited information regarding the comparative performance of microfibre cloths under controlled conditions. Both 'in-use' and laboratory trials have advantages and both are necessary for decision making. Laboratory studies allow controlled comparisons with consistency in cleaning protocol and application, surface type, cleanliness and condition, inoculum level, residue type and drying times.

The aims of the present study were to compare the cleaning efficacy, indicated by organic soil removal and reduction in microbial load, and the recontamination potential of a range of different microfibre cloths with those of a conventional cloth and paper towel.

Materials and methods

Inoculum

A standard menstruum of tryptone soya broth (TSB, Oxoid, Basingstoke, UK) and 5% horse serum (Oxoid) was used to represent proteinaceous organic debris.[24,25] A marker organism was used to assess the ability to reduce microbial contamination.

Bacterial cultures were prepared by transferring a single colony of *Staphylococcus aureus* (an untyped environmental isolate) aseptically into a 250-mL conical flask containing 100 mL of sterile Nutrient Broth No. 2 (Oxoid). Stationary phase cultures were obtained by incubating the bacteria at 37 °C in an orbital shaking incubator (100 revolutions/min; Model 4518, Forma Scientific Inc., Ohio, USA) for 18 h. After incubation, a 15-mL volume of the overnight culture was centrifuged at 3000 *g* for 30 min. The supernatant was removed and discarded, and the resulting pellet was resuspended in 15 mL of quarter-strength Ringer's solution (Oxoid). The bacterial suspension, approximately 10^9 colony-forming units (CFU)/mL, was mixed and diluted 10 fold using the TSB/horse serum mix.

Preparation and inoculation of test surface

Prior to inoculation, a stainless steel table marked with 10 cm × 10 cm squares was sanitized using an in-house validated cleaning protocol.[26] Once the surface was completely dry, 0.1 mL of the test inoculum was spread on to each of the squares.

Cloths and wiping technique

All the tested cloths (six different re-usable microfibre cloths, a general-purpose non-woven synthetic cloth, and paper towel) were commercially available. Each cloth was cut into 4 × 4-inch swatches. These were used to wipe a single test square (10 replicates) immediately after its inoculation, whilst the surface was still wet, or after it had been allowed to airdry for 45 min (no visible liquid remaining on the surface).

The cloths were used dry or damp following rinsing in hand-hot potable water. One individual performed all wiping procedures, involving five clockwise rotations, five anti-clockwise rotations, and four strokes around the perimeter of the test square.

The weight of each sample before and after its immersion in water was recorded to compare the

absorption properties of the different cloths. Moisture regain was calculated using Equation 1.[15]

$$\text{Moisture regain} = \left(\frac{\text{weight of cloth after immersion}}{\text{weight of cloth before immersion}}\right) \times 100 \quad (1)$$

Adenosine Tri-phosphate (ATP) bioluminescence was used to measure the ability of the cloths to remove microscopic organic matter, whilst aerobic colony counts (ACC) were used to assess the level of residual microbial contamination that remained on the surface after wiping.[26] Controls were inoculated surfaces that had not been wiped.

Non-microbiological sampling of the stainless steel surface

Immediately after wiping, the Clean-Trace Rapid Cleanliness Test (UXL 100, Biotrace Ltd, Bridgend, UK) was used to sample five of the 10 replicate test surfaces. The surfaces were swabbed, the device was activated using the manufacturer's instructions, and readings were taken in relative light units (RLUs) in a Biotrace Uni-Lite NG luminometer.

Microbiological sampling of the stainless steel surface

Immediately after wiping, sterile cotton swabs (TS6-A; Technical Service Consultants Limited, Heywood, Lancashire, UK), premoistened with sterile quarter-strength Ringer's solution, were used to sample five of the 10 replicate test surfaces using a standardized protocol.[26] Each swab was passed, in a zig-zag pattern (20 strokes), over the surface then repeated at an angle of 90° to the first swabbing. The swab was rotated constantly, ensuring that the entire swab bud came into contact with the test surface. The swab was then transferred to 10 mL of quarter-strength Ringer's solution and vortexed for 20 s before 1 mL of an appropriate dilution was pipetted into a Petri dish. Approximately 15 mL of plate count agar (Oxoid) was added, the contents were mixed well and the plates were incubated at 30 °C for 48 h.

Transfer of contaminants from wet cloths to dry stainless steel surfaces

Ten replicate cloth swatches were immersed in the test inoculum for approximately 10 s and squeezed, with a consistent pressure, to remove any excess liquid. Each cloth sample was then used to wipe clean dry stainless steel test areas using the wiping technique described above, and the cloth samples were subsequently tested for their microbial count and ATP load.

Statistical analysis

Cleaning efficacy is expressed as the reduction in detectable surface contamination achieved after wiping [(level of ATP in RLUs, or number of micro-organisms detected on controlled, unwiped surfaces) − (level of ATP or number of micro-organisms detected after wiping)]. Data analysis was performed using Microsoft Excel 2000. Statistical significance was at a level of $P < 0.05$ and determined by use of *t*-tests or analysis of variance combined with Tukey's multiple comparison test.

Results

Absorbency

The paper towel absorbed significantly more moisture than any of the other cloths. With the exception of Microfibre Cloth 1 (MF 1), which had a significantly lower moisture regain than either MF 4 or the general-purpose cloth, no other differences were significant ($P > 0.05$).

Cleaning efficacy

It is recommended that microfibre cloths should be wet for general-purpose cleaning and dry for dusting.[11] Hospital surfaces, other than toilet/sink areas, are nearly always dry at the time of cleaning.[1] When used dry on a dry surface, none of the cloths were significantly better than the others in reducing the level of ATP or the microbial count, and none of the cloths removed the microbial or organic bioburden effectively. Figure 1 illustrates the ability of each cloth when wet to remove the mixed bioburden from a dry surface. Although there was variability in the results obtained, the log reductions in ACCs were significantly greater than for RLUs.

Table I summarizes the statistically significant differences in cloth performance. The cleaning ability (removal of organic residue) of all the microfibre cloths was dissimilar. Compared with all other cloths, when wet, MF 1 removed significantly more soil than MF 2 and the paper towel (Figure 1). MF 1 and MF 6 were superior to MF 2 for the removal of micro-organisms. However, in absolute terms, none of the cloths achieved a 2 log (99%) reduction in RLUs, and only two cloths (MF 1 and MF

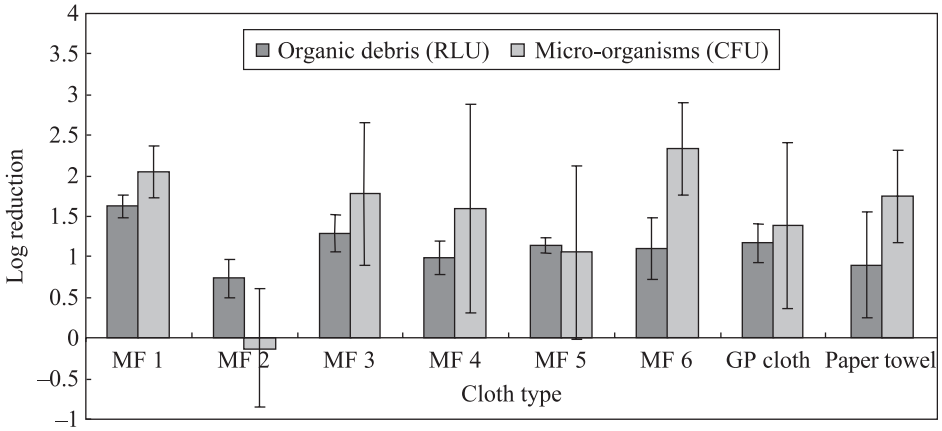

Figure 1 Reduction [mean ($N = 5$) $\pm$ 2 standard errors] in the level of organic debris and associated micro-organisms when a dry surface was wiped using a wet cloth. MF, microfibre cloth; GP, general purpose; RLU, relative light units; CFU, colony-forming units.

6) achieved a 2 log reduction or greater in the number of micro-organisms.

Transfer of contaminants

Figure 2 illustrates the amount of organic soil and associated micro-organisms that were transferred from inoculated cloths to a surface during wiping, and provides an indication of the potential for each cloth to act as a vehicle for cross-contamination. The log increase in the number of micro-organisms was significantly higher than the increase in RLUs for each cloth.

The general-purpose cloth transferred significantly more organic debris than MF 3, MF 4 or MF 1. The latter two cloths also transferred significantly less organic debris than the other types of microfibre cloth, and significantly fewer micro-organisms than MF 2, MF 6 and the general-purpose cloth. Nonetheless, even using MF 1, the best of the microfibre cloths, this equated to a microbial transfer greater than 30 CFU/cm^2, although this could be underestimated due to sampling limitations.[26,27]

Table I Summary of significant differences

In ATP — reduction in total organic bioburden
Wet cloth and dry surface:
Microfibre Cloth 1 removed significantly more organic debris than Microfibre Cloth 2 and paper towel
Dry cloth and dry surface:
No significant difference between any of the microfibre cloths and/or general-purpose cloth and paper towel
Reduction in surface aerobic colony count
Wet cloth and dry surface:
Microfibre Cloths 1 and 6 removed significantly more micro-organisms than Microfibre Cloth 2
Dry cloth and dry surface:
No significant difference between any of the microfibre cloths and/or general-purpose cloth and paper towel

Discussion

Previous studies have suggested that microfibre cloths provide a visually superior surface appearance when removing dust and grease from dry surfaces.[13] Microfibre cloths have good electrostatic properties for the removal of dust. Grease is composed of polar and non-polar compounds, in which the non-polar part predominates, and these weakly charged residues tend to be attached to surfaces less firmly. When surfaces come into contact with body fluids, they are rapidly coated with proteins, leading to the formation of a surface conditioning film that can facilitate the attachment of micro-organisms.[28] Charged organic soils are known to be more difficult to remove, and visual assessment of surface cleanliness has been shown to be a poor measure of invisible soiling.[1] Visually clean surfaces can still harbour large numbers of micro-organisms and organic residues.[1,28]

The presence of organic residues can protect pathogens from dehydration.[29,30] Although anecdotal evidence suggests that microfibre cloths are effective for the removal of grease, no previous studies have reported on the efficacy of microfibre cloths to reduce invisible soil in controlled conditions.[11] During the current study, their superiority in removing soil was shown to be more limited.

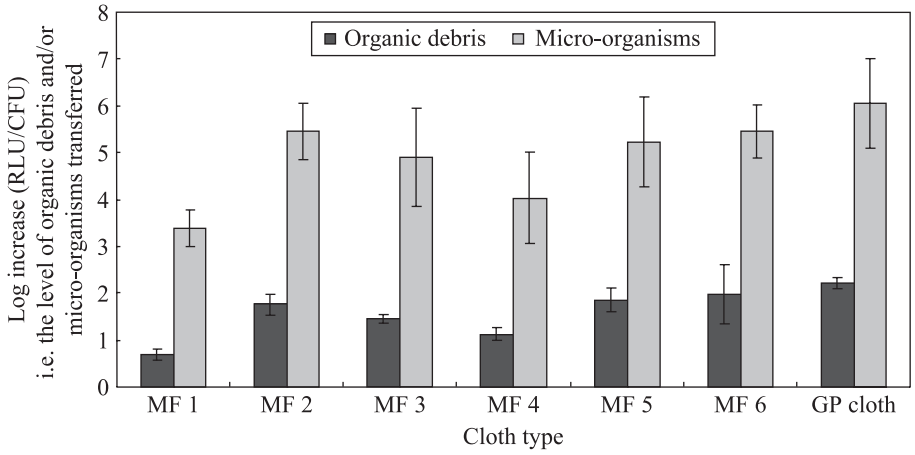

Figure 2 Increase [mean ($N = 5$) $\pm$ 2 standard errors] in the level of organic debris and associated micro-organisms when a clean dry surface was wiped using a contaminated damp cloth. MF, microfibre cloth; GP, general purpose; RLU, relative light units; CFU, colony-forming units.

When used to remove dried organic debris and micro-organisms, dry cloths, regardless of type, were ineffective. The texture of MF 1, which performed the best overall when wet, resembled that of a terry cloth; thus, in addition to the mechanical energy generated by the microfibres themselves, the longer, looped fibre arrangement could be more effective in trapping and removing organic matter.[31]

MF 2, in comparison with the other microfibre cloths, had a lower polyester content. This can affect efficacy and the cloth surface was smoother.[11] Fewer soil-adsorbing fibres coupled with lower mechanical energy due to a more compressed fibre arrangement may have reduced the efficacy of MF 2 when wet.

Large variations in results were obtained and this not only masked statistical differences but also highlighted problems with the consistency of cloth cleaning. When wet, all cloths were capable of reducing the microbial population by 1 log value (90%). However, it should be appreciated that hospital surfaces can be highly contaminated, with ACC $>$ 200 CFU/cm^2 and staphylococcal counts $>$25 CFU/cm^2.[1]

The transfer experiment in this study indicated that the cloths had the potential to recontaminate surfaces with organic soil and micro-organisms. It has been suggested that microfibre fabrics possess certain 'self-cleaning' properties, and that contaminating particles adhering to water droplets are removed as the water droplets simply roll off the fabric due to the high hydrophobicity of the fibres.[32] Thus, this 'lotus effect' may have some advantages but could prove detrimental due to surface recontamination during cleaning if cloths are not changed frequently. The number of bacteria transferred to a surface via fabric with a high polyester component has been shown to be consistently higher than that released from an all-cotton material.[33]

The three-dimensional structure of a cloth is important and previous studies have demonstrated that microbial transfer rates are higher from dishcloths than sponges.[19] Cloth has a relatively smooth structure with a large contact area and carries a risk of transferring organic debris and/or micro-organisms to any subsequently wiped surface.[20] Practices relating to the changing and cleaning of cloths are crucial, however, and there is evidence that hospital cloths are not changed as frequently as necessary.

If cloths are stored damp after use, entrapped bacteria can become even more strongly attached to the fibres, and the presence of organic matter within the cloth matrix can protect and encourage their growth.[34]

In comparison with the microfibre cloths, the smooth, more open surface of the general-purpose cloth is likely to result in a shorter drying time, exposing any bacterial contaminants to increased desiccation stress. In order to ensure cloth hygiene and to minimize the risk of cross-contamination, the exclusive use of disposable or paper towels has been actively encouraged.[16,17,35,36]

Cleaners are more likely to clean diligently if they like the materials they are provided with, and there is some evidence that microfibre cloths are preferred by cleaners. For optimal performance, microfibre cloths should be used damp. However, this study found that microfibre cloths can differ in terms of their cleaning efficacy, so the name

'microfibre' should not necessarily imply superior cleaning efficacy in relation to conventional cloths.

Depending on the brand, microfibre cloths may carry less recontamination potential than conventional cloths. However, the structural properties that may minimize microbial transfer may also provide a protective environment that facilitates microbial growth during storage.

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