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Assessing the efficacy of different microfibre cloths at removing surface micro-organisms associated with healthcare-associated infections☆

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SUMMARY

This study investigated the ability of 10 different microfibre cloths to remove microbial contamination from three surfaces commonly found in hospital settings (stainless steel, furniture laminate and ceramic tile), under controlled laboratory conditions. Tests were conducted using organisms known to cause healthcare-associated infections, i.e. meticillin-resistant *Staphylococcus aureus* (MRSA), *Clostridium difficile* (in spore form) and *Escherichia coli*. For all the cloths tested, there was significant statistical evidence to suggest a difference in cleaning performance between them on first and single use ($P < 0.001$). However, the overall performance of the nine re-useable cloths did not differ in practice with differences in $\log_{10}$ reductions of <1. The performance of the disposable microfibre cloth was notably worse. The performance of all cloths decreased with repeated use on a succession of contaminated surfaces. After repeated washing, re-usable cloth performance improved at 75 washes, and reduced after 150 washes, although, in most instances, performance after 150 washes was better than at first wash. For all cloths, price was not an indication of performance. Based on these laboratory findings, it is concluded that use of the microfibre cloths investigated is an effective way to reduce the levels of MRSA, *E. coli* and *C. difficile* (in spore form) on a range of surfaces found in the clinical environment and could therefore be of benefit to these environments.

Introduction

Many hospitals now use microfibre cloths as part of their cleaning regime. The cloths use small volumes of water, do not require the addition of detergents or biocides, and remove particles by a combination of capillary action and static attraction.[1]

The cleaning performance of microfibre cloths has been investigated previously by a number of researchers.[2,3] Moore and Griffith concluded that 'different makes of microfibre cloth have different characteristics, and the name 'microfibre' should not imply superior cleaning efficacy'.[3]

A number of different microfibre cloths are available for use in the clinical environment, varying in price and the number of times they can be washed and re-used (up to 500 times). This study aimed to assess the cleaning performance (in terms of microbial removal) of 10 microfibre cloths, including four currently available through the National Health Service (NHS) Supply Chain, under controlled laboratory conditions. The study investigated the automated cleaning of three different surfaces commonly found in hospital settings contaminated with organisms associated with healthcare-associated infections.

Methods

Prior to use, all re-useable microfibre cloths were washed once using an Electrolux W455H, Compass Control washing machine (Electrolux, Luton, UK). Cloths were washed according to Health

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Service Guidelines (95)18 for washing of soiled laundry, i.e. 71 °C for 3 min, using a washing detergent recommended for use with microfibre cloths (Horizon light; Johnson Diversey, Northampton, UK) and then air-dried.[4]

One hour prior to testing, cloths were placed in separate plastic bags and dampened with volumes (as per manufacturer's instructions) of sterile distilled water.

All test surfaces (316 grade stainless steel with 2B milled finish: Durbin Metal Industries, Bristol, UK; white ceramic glazed tiles: Topps Tiles, Stratford upon Avon, UK; white, Formica fundamental, shell finish furniture laminate: C L S Fabrication Ltd, Leamington Spa, UK; all 15 cm by 60 cm) were new and were washed (hot soapy water), rinsed and either disinfected (laminate, 90% alcohol; Fisher Scientific, Loughborough, UK) or autoclaved (stainless steel and ceramic tile) prior to use.

Repeated testing was undertaken to determine if any one cloth was practically more effective, as expressed by its ability to effect a $\log_{10}$ reduction ≥ 1 in bacterial numbers, greater than any other cloth.

All inoculated surface cleaning trials were conducted using a custom-made automated cleaning rig (Vikan Ltd, Skive, Denmark).

Pre-trial

A number of different variables were assessed during the pre-trial, using suspensions of *E. coli* (NCIMB 10083) inoculated on to stainless steel, to determine the methods used for the subsequent experiments, as detailed below.

(a) *The appropriate automated cleaning rig operations*

A microfibre cloth was attached to the robotic arm of the rig and then lowered on to the soiled surface until a slight surface deflection was observed. The distance by which the cloth was lowered to achieve this deflection was noted for each surface type and subsequently used for that surface type to ensure consistent pressure application for all samples. The robotic arm then moved the cloth twice, forwards and backwards, at a speed of 34 cm/s, over the soiled surface. The speed, pressure, number and direction of wiping were estimated to be typical of the cleaning actions performed by hospital staff. The use of the automated cleaning rig ensured that all cleaning operations were standardised.

(b) *An appropriate number of replicate samples to do*

Sample size = 3, determined by one-way analysis of variance Power and Sample Size tool in Minitab as being able to provide a 98% chance that if a $\log_{10}$ difference of ≥ 1 existed between the cloths, it would be observed.

(c) *The most appropriate soil type, condition (wet or dry), microbial loading and inoculum volume to use*

Soil type – Browne's (Steris Limited, Basingstoke, UK; Code: 2304, used by the NHS as an indicator soil to validate equipment cleaning). To provide a visible easy-to-spread inoculum, Browne's soil was made up using twice the recommended reconstitution volume. Inoculum volume = 2 mL, providing the optimum surface coverage and challenge to cleaning. Inoculum condition = wet, based on two-sample *t*-test analysis of data obtained using Browne's soil. Although the evidence of difference between removal of wet (soil applied to surface, left for 1 min and then cleaned off) and dried-on (soil applied to surface, left to dry for 1 h at 20 °C ± 1 °C, and then cleaned off) soils from stainless steel was statistically significant ($P < 0.05$), it was not substantial (0.5 $\log_{10}$). Consequently, a wet soil was used to eliminate the need for drying time. Inoculum level = minimum 10^5/mL (see explanation under (d)).

(d) *A method to determine cleaning efficacy*

After a surface had been cleaned with a microfibre cloth the entire area of the surface was swabbed with a sterile sponge (Envirosponge, Sterilab Services, Harrogate, UK), moistened with 10 mL of sterile diluent [Maximum Recovery Diluent (MRD), LAB 103; LABM, Bury, UK]. Each sponge was placed back into the sterile bag from which it came, a further 90 mL of MRD was added and the organisms recovered from the sponge by the commonly used stomaching method (using a Colworth 400 machine; A.J. Seward Ltd, London, UK) for 30 s each, to ensure consistency. The stomached diluent suspension was then serially, decimally diluted using MRD, and 1 mL volumes pour plated using Nutrient Agar (NA, CM131; Oxoid, Basingstoke, UK, in 90 mm sterile Petri dishes). Inoculated NA plates were incubated at 37 ± 1 °C for about 48 h, colony-forming units (cfu) then counted and $\log_{10}$ reductions, in the number of organisms originally inoculated on to the surface, were determined.

A reduction of approximately 2 to 3 $\log_{10}$ in the number of organisms remaining on the surface resulted following surface cleaning with a mid-priced, mid-quality (based on the number of times the cloth could be re-used) microfibre cloth. Consequently, due to the limit of the detection of the analysis method being used (10^2/mL), a minimum starting inoculum of 10^5/mL was used for the subsequent experiments.

Single cloth use

On each testing day, a spore suspension (10^5/mL) of *C. difficile* (NCIMB 10666; stock solution prepared using a method based on that described in Anellis et al.[5]) and 10^8/mL suspensions of *E. coli* (NCIMB 8879) and MRSA (NCTC 13143), both prepared by re-suspension of colonies, grown on NA slopes, in MRD, were prepared. Stock solution spore numbers were determined by plating. Aliquots of the stock spore solution were then diluted to provide the required level for each experiment, and serial dilutions of these plated to determine the actual inoculum level. Bacterial cell numbers were determined using a spectrophotometer (Libre S4; Biochrom, Cambridge, UK). These solutions were also diluted as required for each experiment and plated to determine actual levels. Test surfaces and cloths were prepared as previously described. Browne's soil solutions were prepared using 20 mL of the *C. difficile* spore suspension and 10 mL each of the *E. coli* and MRSA 10^8/mL suspensions. Test surfaces (stainless steel, furniture laminate and ceramic tile), were inoculated, left for 1 min and then cleaned using the automated cleaning rig fitted with a microfibre cloth. For each type of cloth, each of three inoculated surfaces, per surface type, were cleaned with a different cloth. Following cleaning by the cloth, each surface was swabbed and the sponges were stomached and diluted as previously described. For *E. coli*, 1 mL of these dilutions was pour-plated, and overpoured, with Violet Red Bile agar (VRBA, LabM:Lab31); for MRSA, 0.1 mL spread-plated on Baird Parker agar (BP, Oxoid: CM0275); and for *C. difficile*, 1 mL pour-plated with Tryptone Sulphite Cycloserine agar + egg and supplements (TSC, Oxoid: CM0587 + egg, CSR 0047 and CSR 0058). Inoculated VRBA plates were incubated at 37 ± 1 °C for about 24 h, BP plates at 37 ± 1 °C for about 48 h, and TSC plates at 30 ± 1 °C for 5 days, anaerobically. The number of cfu were then counted and $\log_{10}$ reductions determined as previously described.

Repeat cloth use

A spore culture of *C. difficile* (10^5/mL) was prepared as previously described, and used to make up the Browne's solution. Nine cleaned and disinfected furniture laminate surfaces were inoculated. Surface 1 was cleaned using the automated cleaning rig fitted with

a once-washed and air-dried microfibre cloth and then swabbed. Using the same cloth, a further four inoculated surfaces were cleaned and surface 5 was swabbed. A further four inoculated surfaces were then cleaned and surface 9 was swabbed. All sponges were analysed as previously described.

Cloth performance after washing

Cloths that had been washed and air-dried once were fitted to the automated cleaning rig and used to clean individual pieces of furniture laminate inoculated with 10^5/mL *C. difficile*/Browne's suspension. After cleaning each surface was swabbed. Each cloth was then washed a further 74 times (total 75 times, including the original wash prior to first use) as previously described, air-dried after the 75th wash, and then used to clean a further inoculated laminate surface, which was then swabbed. The cloths were then washed to a total of 150 times, air-dried after the 150th wash and used again to clean an inoculated laminate surface. The resultant cleaned surfaces were swabbed and all sponges analysed as previously described. Note: all cloths were tested at one, 75 and 150 washes except the Johnson Diversey's Taski Micro Light cloth (one and 50 washes) and the Taski Micro Easy cloth (one and 100 washes). This was in line with manufacturers' claims that these cloths can be washed to 50 and 100 washes respectively. The disposable cloth was not included in this experiment.

Statistical analysis

For each experiment, an analysis of variance (ANOVA) of $\log_{10}$ reductions by relevant explanatory variables (selected from Surface, Organism, Cloth type, Use number, and Wash number) was conducted using Minitab (V15; Minitab, Inc., State College, PA, USA).

Results

For overall mean $\log_{10}$ reductions, achieved on single use of a cloth, for all test organisms, by surface and cloth type, ANOVA suggested that there was significant evidence of a difference between cloth ($P < 0.001$) and micro-organism type ($P < 0.001$). The evidence of a difference for surface material was marginally below the critical 95% confidence level ($P = 0.072$), but there was significant evidence of all two-way and three-way interactions of surface material with the other factors ($P < 0.001$), so overall there was conclusive evidence of the effect of surface material.

Overall mean differences in the performance of individual, reuseable cloths showed a $\log_{10}$ reduction of <1. However, the overall mean disposable cloth $\log_{10}$ reduction (1.41) differed by >1 when compared to that achieved by the Contico Standard cloth (2.75), the Vileda Quick Star cloth (2.57), and the Ecolab Polifix Microlin cloth (2.56). Differences in $\log_{10}$ reductions >1, for removal of all test micro-organisms, were observed for some individual cloths and surfaces, e.g. Contico Standard cloth achieved a $\log_{10}$ reduction >1 compared to that achieved by the Johnson Diversey Taski Micro Light cloth, the Vikan Ergoclean cloth, the Vermop SoftTronic 1 cloth, and the Contico disposable cloth, when used on ceramic tile. The mean numbers of bacteria ($\log_{10}$ reductions, cfu) removed from all surface types by each microfibre cloth are shown in Figure 1. MRSA was consistently more difficult to remove than *C. difficile* and *E. coli*, though the ease of removal of these two organisms was dependent on cloth type used.

The results for the mean number of *C. difficile* ($\log_{10}$ reduction, cfu) removed from furniture laminate on repeated use of a single cloth are shown in Figure 2. For all data, ANOVA suggested that there was significant evidence of a difference between cloths ($P < 0.001$) and the number of repeat wipes ($P < 0.001$), with mean $\log_{10}$ reductions declining with increasing wipe number (for one, five and nine wipes). The JD Taski Micro Easy and Micro Light cloths were consistently the worst at one, five and nine wipes. The Contico Standard cloth, the Vermop SoftTronic 1 cloth and the JD Jonmaster cloth were consistently the best. However, no one cloth performed consistently better across the one, five and nine wipes than all the others. Within each one, five or nine wipe number, the best cloths effected a $\log_{10}$ reduction >1 when compared to the worst cloths, in terms of microbial removal.

The results for the mean number of *C. difficile* ($\log_{10}$ reduction, cfu) removed from furniture laminate on repeat washing of single cloths are shown in Figure 3. For all data, ANOVA suggested that there was significant evidence of a difference between cloth ($P < 0.001$) and number of washes ($P < 0.001$). Microbial removal was greater for the majority of cloths after 75 washes (and 50 washes for JD Taski Micro Light, and 100 washes for JD Micro Easy) than after a single wash, with a slight decline in 75 wash performance by most

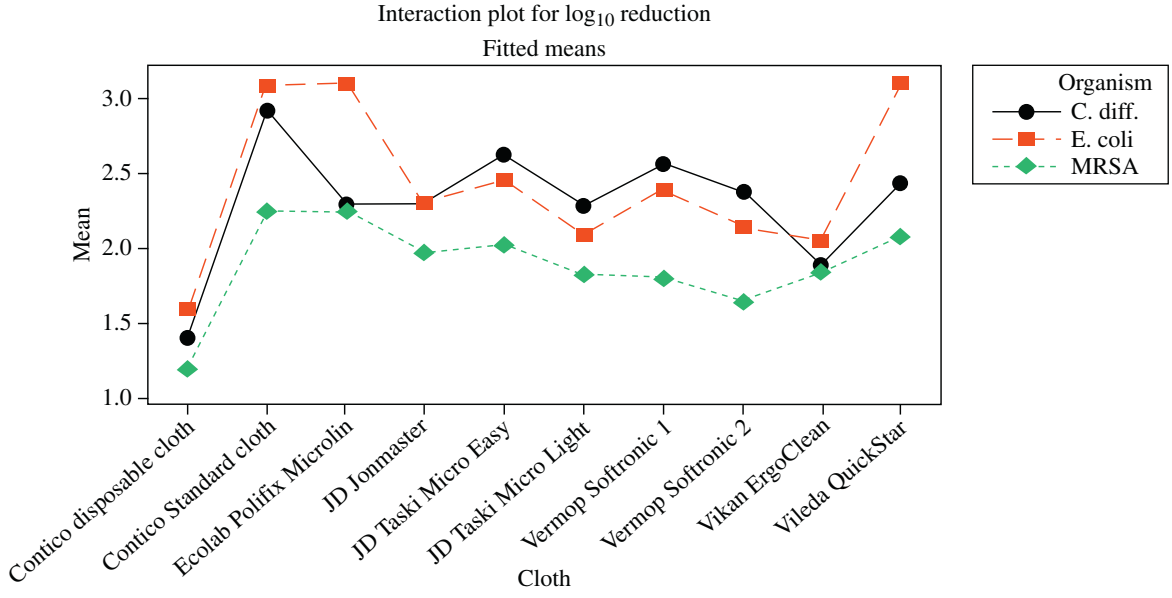

Figure 1. Mean number of bacteria ($\log_{10}$ reduction, cfu) removed from all surface types by each microfibre cloth.

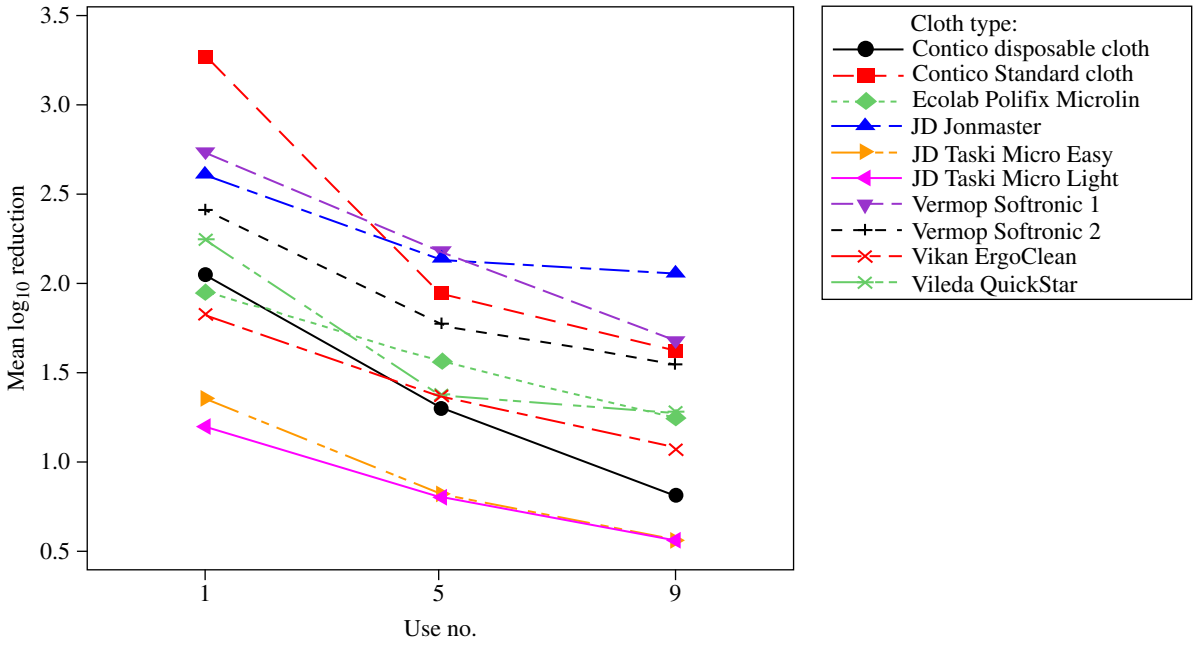

Figure 2. Mean number of *Clostridium difficile* (log_{10} reduction, cfu) removed from furniture laminate on repeated use of a single cloth.

cloths after 150 washes. After 75 and 150 washes, the performance of the Vermop SoftTronic 1 and 2 together with Contico Standard cloth was notably lower than JD Jonmaster, Ecolab Polifix Microlin and Vileda Quick Star. For 75 and 150 washes (but not for one wash) the Vermop SoftTronic 1 and 2 and the Contico Standard cloths effected a log_{10} reduction >1, better than the JD Jonmaster, Ecolab Polifix Microlin and Vileda Quick Star cloths in terms of microbial removal.

Discussion

Overall results for the single use cloth trial indicated a mean log_{10} reduction of 2.21 in the number of micro-organisms on the surfaces following cleaning with the microfibre cloths. Another recent study found similar results with log_{10} reductions of between 2.1 and 3.6 achieved with ceramic tiles, inoculated with 10^6 cfu *E. coli* or *Staphylococcus aureus*, cleaned with a damp microfibre cloth (Polyclean International, Ahaus, Germany).[6] Overall, there was no evidence that any one of the re-useable cloths outperformed the others in practice to a log_{10} reduction of ≥1. However, the performance of the disposable microfibre cloth was notably different. The results also indicated that, for each cloth type, there was significant evidence of a difference in cleanability with regard to cloth, surface and organism type, i.e. all three factors investigated influence how much contamination is left on the

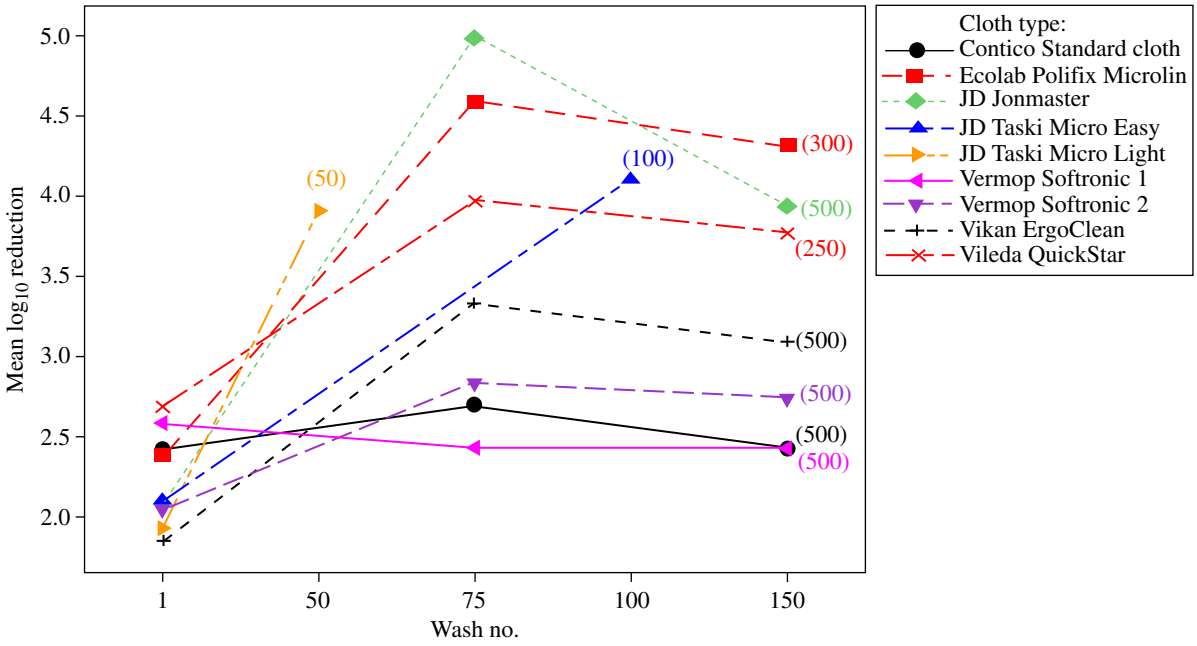

Figure 3. Mean number of *Clostridium difficile* (log_{10} reduction, cfu) removed from furniture laminate on repeat washing of single cloths. Numbers in parentheses are the maximum number of times the cloth can be washed, as stated by the manufacturer.

surface. Consequently, the individual performance of each cloth will depend on the circumstances under which it is used, e.g. expected surface or contaminating organism. Although the inoculum level used was high (minimum 10^5/mL), to allow comparison of removal by different cloths, it is likely that many surfaces in hospitals will present a much lower microbial challenge. Additionally, although the pre-trials indicated that the difference between removal of wet and dried-on soils from stainless steel was not substantial, the removal of dry inoculum from different surfaces may present a greater challenge.

It was unsurprising that repeated use of a cloth to clean a succession of contaminated surfaces lowered its performance. Some manufacturers are very prescriptive about the way their cloths should be used. This can include that the cloth be re-folded to expose a clean area of the cloth for use on each successive surface. As instructions for use were not available for all the cloths tested, the same area of each cloth was used on the succession of surfaces cleaned. Consequently, the results are only a reflection of this. It is recommended that manufacturers' instructions on the preparation, use and washing of the cloths should always be followed in order to maximise cloth performance.

Following repeat washing, the performance of the nine re-useable cloths improved initially, but in general then slightly declined after 150 washes. However, performance at this stage was still better than at first wash. It was not known why this phenomenon occurred, but some cloth manufacturers speculate that fibre breakdown during repeated use, to form even smaller fibres, may improve cloth performance. The cloths used for this trial were only air-dried three times. It is suggested that a wash and tumble-dry laundry process could also affect microfibre structure and therefore impact on cloth performance to a greater degree than washing alone. It is unlikely that the detergent used (Horizon light, Johnson Diversey) affected the cloth performance as it is recommended for use with Microfibre cloths, as was the design of the washing machine (Electrolux W455H, bottom draining), which minimised the risk of contaminant retention, including detergent residues, by the cloths during laundering.

Diab-Elschahawi et al. also investigated the decontamination efficacy of new and reprocessed microfibre cloths. Their study found that cloths washed 20 times left 7.9×10^3 cfu *S. aureus* on the cleaned surface, compared with 1.3×10^3 cfu when new cloths and cloths washed 10 times were used, i.e. the cloths were more effective at removing *S. aureus* when new than when washed 20 times.[6] Conversely, when used to remove *E. coli*, remaining counts were 2.5×10^2 cfu after being cleaned with a cloth washed 20 times, compared with 7.9×10^2 and 1.3×10^3 cfu after using a cloth washed 10 times and when new, respectively. These observations do not reflect the large increase in cleaning efficacy observed by the study presented here. However, this may be due to the fact that the cleaning efficacy of the microfibre cloths in the Diab-Elschahawi et al. study was assessed when new, and after 10 and 20 washes, compared to after one, 50, 75, 100 and 150 washes for this study. It may be that cloth efficacy does not improve greatly until the cloths have undergone a certain number of washes.

Whereas reductions of >1 $\log_{10}$ were seen in the individual performance of cloth types in the repeat use and repeat washing studies, these studies only used *C. difficile* and laminate. It is not possible, therefore, to rank these cloths for general use against all micro-organisms and surfaces. The results for the single-use trials, in which no overall difference in re-useable cloth performance was established, is probably more reflective of cloth performance.

Although no single re-useable cloth outperformed another in practice during these laboratory-based trials, the individual price of the cloths investigated ranged from pence to pounds (current prices may be obtained from the individual cloth manufacturers). The findings of this study would therefore indicate that, for the cloths investigated, price is not an indication of performance and consequently this has implications with regard to the purchase of microfibre cloths by any user.

Additionally, the fact that the performance of the re-useable cloths investigated improved with repeated washing would imply that, as long as decontamination of the cloths can be assured, re-use of washable microfibre cloths is desirable. The overall cost of the re-useable cloth selected should take into account the number of times it can be washed and re-used.

In conclusion, this study compared the difference in cleaning performance of 10 different microfibre cloths, under controlled laboratory conditions, and found that, overall on first use and regardless of cost, cleaning was effective with no practical difference between them in terms of microbial contamination removal from surfaces commonly found in clinical environments. It also found that microfibre cloth cleaning performance improved with repeated washing. These findings are of significant value to users of microfibre cloths.

Only by conducting the study under controlled laboratory conditions, where the only variable was the cloth, was the accurate determination of any difference in cloth performance possible. It is recognised that in real-life situations microfibre cloths may be used and/or abused in a variety of ways including variation in the pressure applied to the surface while cleaning and the addition of a range of cleaning chemicals. This may result in improved cleaning, as compared to that demonstrated by this study, or, conversely, problems with cross-contamination.[7] Further studies to investigate the real use of microfibre cloths by staff in clinical environments, may be beneficial in confirming these laboratory findings. Effort should also be focused on ensuring that microfibre cloths are used correctly in real-life situations, through provision and application of manufacturers' instructions for use (where available) and staff training.

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None declared.

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