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# The cross-contamination potential of mobile telephones

*Author details on a separate document as per manuscript submission guidelines*

## **Abstract**

The use of mobile devices for professional, business, educational, personal and social purposes has accelerated exponentially over the last decade. Staff working in health care organisations, and patients and visitors using healthcare settings, understandably want to use mobile technology. Concerns have been raised about safety in terms of interference with equipment, threats to privacy and dignity, yet less policy attention has been paid to infection risks.

Healthcare professional students were supplied with smartphones as part of a larger educational project. Devices collected from a sub-sample of students working in operating theatre contexts were sampled to estimate the cross contamination potential of the technology. A longitudinal multiple measures design was used. Under laboratory conditions samples were taken from surfaces using swabbing techniques followed by contact plating. The devices were subsequently cleaned with 70% isopropyl alcohol and returned to the students.

All devices demonstrated microbial contamination and over three quarters (86%) polymicrobial contamination. The technique and sites used to sample for microbial contamination influenced the levels of contamination identified. Swabbing alone was less likely to isolate polymicrobial contamination than contact plating, and some microorganisms were isolated only by contact plates and not by swabbing of the same area.

The findings from this study demonstrate further research is urgently needed to inform evidence-based infection control policy on the use of personal equipment such as mobile devices in the healthcare settings where contamination may have adverse effects on patients, staff and visitors..

## **Keywords**

Mobile, cell, phone, telephone, contamination, infection control, infection potential.

## **Introduction**

The Higher Education Funding Council for England (HEFCE) established a number of Centres of Excellence in Teaching and Learning (CETL) to speed dissemination of best practice in learning and teaching. One CETL, the Assessment and Learning in Practice Settings (ALPS) was established in 2005, consisted of five University partners (Bradford, Huddersfield, Leeds, Leeds Metropolitan and York St. John) and involved staff and students undertaking health professional and social work programs. Part of the program of work was the development of e-learning tools for mobile devices (ALPS, 2008), and T-Mobile MDA™ Smartphones were distributed to more than 900 students studying at higher education institutions (HEIs) across Yorkshire. The intention was that the students would use the devices during placements as a communication tool and to collect evidence to contribute to summative assessment of their performance. One of the barriers encountered was some organisations placed restrictions on where, and how, the devices could be used. These restrictions were purportedly founded on a perceived infection risk although the evidence on which these assumptions were based was weak. Those healthcare organisations that allowed students to use the devices recommended washing the devices with detergent-soaked cloths. This compliance standard was in the absence of any evidence of benefit and could have caused irreparable damage to the device.

## **Background**

Interest in the infection potential of telephones can be traced right back to the early 1900s (Aronson, 1977). One of the first investigations conducted in a healthcare environment found pathogens on telephones in an intensive care unit, and consequently claimed this presented an environmental risk (Cozanitis et al, 1978). Two later studies presented opposite views on the contamination risk posed by telephones (White, 1980; Rafferty and Pancoast, 1984).

The first study to test mobile (cell) phones was carried out in one hospital and focused on the identification of multidrug-resistant *Acinetobacter baumannii* contamination of the devices (Borer et al, 2005). Interest in the infection risks associated with telephony, rose significantly from 2006 as mobile phone use became widespread. There was a similar increase in the number of studies

undertaken in clinical settings, despite prohibitions on use due to concerns about interference with hospital equipment (Klein and Djaiani, 2003). This restriction was finally relaxed in the UK in 2009 (DH, 2009).

The accelerating growth in mobile device use permeating professional and personal life, coupled with the apparent lack of evidence to inform local policies regarding safe use of devices in healthcare environments, provided the impetus for this study.

## **Methodology**

Over a nine-month period MDA™ smartphones used by student operating department practitioners (ODP) were sampled. Devices were originally provided to a range of health and social care professional students, including nurses, in the study site (one of the five partner Universities) however only ODP students remained committed to using the devices for social and professional purposes over the study period. These devices enabled the students to access their email, calendar, and the Internet via the 2G networks. As the devices were used in operating department contexts the implications of any significant findings would be transferable to other professions and staff working in similar clinical settings.

Devices used by two different cohorts of students were sampled, one group (nine devices) on six occasions, the other (seven devices) three times, with a period of use between each sampling activity. No other study was found that incorporates repeated longitudinal sampling of mobile devices in its design, despite single sampling having been identified as a study limitation, as the transient or resident status of bacteria cannot be established with once only sampling (Srikanth et al, 2010).

Following receipt of ethical approval from the institutional Research Ethics Panel, devices were collected using aseptic technique, and placed in sterile sample bags, prior to immediate transport to the laboratory. Sampling was carried out using sterile swabs moistened in maximum recovery diluent (MRD), followed by dry swabbing to remove any remaining residue. Surfaces were swabbed using a crosshatch pattern to ensure complete coverage. The use of moistened swabs followed by dry swabbing, has not been previously described.. Following sampling the swab tips were removed

and placed in 5ml of sterile MRD. This process was repeated for the front, back, side edges, screen and keypad of the device, as indicated in Figure 1.



**Figure 1.** Identification of mobile phone areas

Upon completion of swabbing, contact plates of Tryptone soy agar (TSA), were used to 'print' the keypad, front and back of the device, by placing the device in contact with the plate for three seconds. The only other use of contact plates was described by Jeske et al (2007), who used them as the sole method for sampling from both static and mobile phone keypads. This is despite Tunç and Olgun (2006) suggesting contact plates should be used to negate the need to use swabs, on which some bacteria may remain during transfer in the laboratory, resulting in their failure to be plated and cultured.

Each device was then cleaned with a 70% isopropyl alcohol wipe, and placed into a sterile sample bag and then returned to its user, usually within 4 to 5 hours, but always on the same day.

The swab tips in the MRD were spun in a vortex for 30 seconds and then plated onto TSA and incubated for 24 hours at 37°C. Following incubation the numbers of bacteria recovered were recorded and the individual colonies were transferred to individual wells in 96-well plates filled with Tryptone soy broth (TSB) and incubated for a further 24 hours at 37°C. This procedure replicates the isolation and 'purification' processes carried out by Ekraene and Igeleke (2007) and Brady et al (2009). After incubation a 96-well plate replicator was used to plate out the isolated bacteria onto a range of diagnostic culture media including: TSA: Oxacillin resistant staphylococci isolation medium

(ORSIM) (LabM UK); Mannitol salt agar (LabM UK); Slanetz & Bartley medium (LabM UK); Harlequin E.coli/Coliform medium (LabM UK); McConkeys agar (LabM UK); Baird Parker medium (LabM UK); and Brilliance UTI *Clarity* agar (LabM UK). These plates were incubated for 24 hours at 37°C. Growth on these media were subjected to a range of diagnostic tests including Gram staining, latex agglutination and catalase tests in order to arrive at a presumptive identification of the isolated bacteria. After incubation, identification was carried out based upon combinations of outcomes on different media as specified by the manufacturers.

## Results

Devices used by two different cohorts of ODP students were sampled; each student had one device. Nine students in Group 1 were sampled on six occasions, and the seven students in Group 2 were sampled three times. Coagulase-negative *Staphylococcus spp* (CNS *spp.*) was the most common isolate, (Table 1), which is consistent with findings in the literature that tested for these organisms (Nelson et al, 2006; Karabay et al, 2007; Jayalakshmi et al, 2008; Sepehri et al, 2009; Arora et al, 2009; Singh et al, 2010; Srikanth et al, 2010; Brady et al, 2011; Tekerekoğlu et al, 2011).

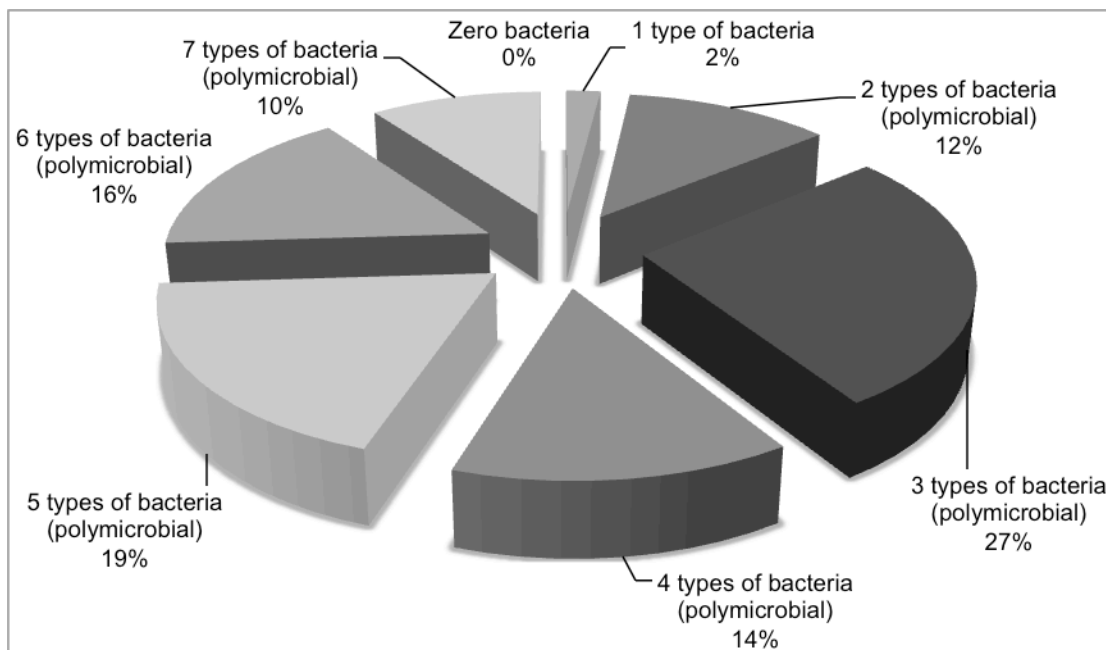
**Table 1.** Total numbers of colony forming units (cfu) isolated at the sampling events, and associated percentages.

Group 1 (a)	March		April		May	
	CNS <i>spp</i>	695	56%	417	49%	149
<i>Micrococcus spp</i>	253	20%	300	35%	83	32%
<i>S. aureus</i> (MRSA)	63 (0)	5% (0%)	17 (4)	2% (0.4%)	2 (16)	0.7% (6%)
<i>Enterococcus spp</i>	32	2%	15	2%	2	0.7%
Coliforms	5	0.4%	38	4%	7	3%
Unknown	179	14%	61	7%	4	1%

Group 1 (b)	October		October		November	
	CNS <i>spp</i>	3492	72%	1711	65%	337
<i>Micrococcus spp</i>	646	13%	678	26%	28	6%
<i>S. aureus</i> (MRSA)	118 (33)	2% (0.6%)	10 (0)	0.3% (0%)	24 (0)	5% (0%)
<i>Enterococcus spp</i>	204	4%	29	11%	0	0%
Coliforms	182	4%	40	2%	72	16%
Unknown	164	3%	150	6%	0	0%

Group 2	September		October		November	
	Count	Percentage	Count	Percentage	Count	Percentage
CNS spp	183	43%	1744	69%	1189	73%
<i>Micrococcus</i> spp	4	0.9%	56	2%	322	20%
<i>S. aureus</i> (MRSA)	31 (19)	7% (4%)	0% (0%)	0% (0%)	7 (0)	0.4% (0%)
<i>Enterococcus</i> spp	60	14%	4	0.1%	0	0%
Coliforms	67	16%	181	7%	107	7%
Unknown	66	15%	544	22%	0	0%

The devices demonstrated polymicrobial (multiple species of microorganism) growth in all cases except one, which was contaminated solely with Coagulase-negative *Staphylococcus* spp. No device was found to be free of growth. The instances of polymicrobial growth are shown in Figure 2. This includes an 'unknown' category, which demonstrated contamination by one or more microorganisms that were not identified by the specific laboratory methods used here. The polymicrobial growths detected show that 12% of devices had just two types of bacteria on them, with 86% of the devices having three or more bacteria on them; with some having as many as seven different types present.



**Figure 2:** Volume of different bacteria types found on devices at the sampling events

Contact plates were applied to three areas of the mobile phones following swabbing and these demonstrated the presence of bacteria not recovered via swabbing of the same areas, see Table 2.

**Table 2.** Separate instances of microorganisms isolated by contact plates of certain areas of the devices, not by the swabs of the same areas

	Front Contact plate not swab	Back Contact plate not swab	Keypad Contact plate not swab
<i>S. aureus</i> (MRSA)	4 (5)	8 (7)	4 (0)
CNS spp	11	9	7
<i>Micrococcus</i> spp	10	14	3
<i>Enterococcus</i> spp	2	1	0
Coliforms	16	13	4
Unknown	10	10	2

On one device, no contamination was found on the front and back when swabbed, but bacteria were isolated using contact plate application in the same areas. Similarly, another mobile phone demonstrated contamination only using the contact plate method on all three areas (front, back and keypad), but not from the swabs of the same areas. There were also instances where the contact plates were the only method to isolate specific bacteria, despite swabbing carried out on the whole of the device.

There were instances where swabbing established the presence of a single type of microorganism, but the plates isolated polymicrobial growth. One example of this was where only Coagulase-negative *Staphylococcus* spp was found from samples taken with swabs of the front and keypad of one device and confirmed by the contact plates taken of the same areas. However, Coliforms were also isolated from this device, but only on the front, back and keypad contact plates.. Another example was where the swabs identified Coagulase-negative *Staphylococcus* spp on the front, back, keypad, edge, and screen, yet the contact plates also isolated MRSA on the front, and both *S. aureus* and Coliforms on the front and back. Coliforms were the microorganisms most regularly isolated by contact plate, but not from swabbing.



## Discussion

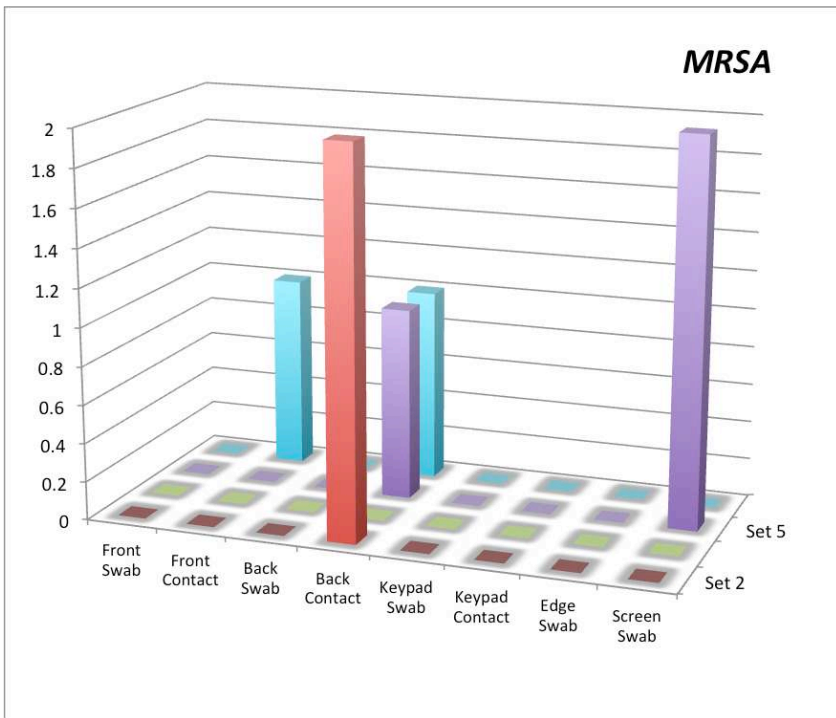
The most commonly found bacterial isolates were coagulase-negative *Staphylococcus*, which are not generally considered to be pathogens, but have been shown to cause infections. For example, *S. epidermidis*, which is a commensal of the skin, has for a long time been regarded as relatively innocuous but has now been generally accepted as a pathogen (Vuong and Otto, 2002); mainly as the most frequent cause of catheter-associated sepsis and implant infections (Presterl, et al, 2007). Likewise, *S. caprae*, another skin commensal, has been implicated in septicaemia, as well as infections of the urinary tract, bones and joints (Shuttleworth et al, 1997); both have also been recorded as methicillin-resistant (Carbon, 2000; Ross et al, 2005). However, other bacteria more widely accepted as pathogenic have also been isolated from mobile phones, including many with a potential for drug resistance: methicillin-sensitive *S. aureus* (MSSA), methicillin-resistant *S. aureus* (MRSA), *Corynebacterium spp.*, *Enterococcus spp.* including vancomycin-resistant enterococci (VRE), *Micrococcus spp.*, *Clostridium perfringens*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Aeromonas spp.*, *Acinetobacter spp.*, and Coliforms (*Klebsiella spp.*, *Enterobacter spp.*, and *Escherichia coli*; strains of which can be pathogenic (Krieger et al, 2011).

This evidence indicates that some pathogens can survive for prolonged periods on plastic surfaces such as mobile devices presenting a potential risk of transmission. Falk et al (2000) and Schabrun and Chipchase (2006) identified that methicillin-resistant *S. aureus*, vancomycin-resistant *Enterococcus*, and some Gram-negative microorganisms survive on inanimate objects such as hospital equipment for many months. Just as Kramer et al (2006) showed that nosocomial bacteria such as *S. aureus*, *Enterococcus spp.*, *Acinetobacter spp.* and *Klebsiella spp.* can survive on inanimate surfaces for extended periods. The weight of evidence predicates that there is high probability that a mobile device, brought into a healthcare environment, will carry live bacteria for a period of time such as a shift and there is risk that these contaminants could be transferred onto hands if the phone is touched. A number of studies have shown that when clean (washed) hands or gloved hands touch contaminated objects, they too become contaminated with these organisms, which carries the potential risk of transmission to other surfaces and people (Rusin et al, 2002; Hayden et al, 2008; Duckro et al, 2005). Sharing phones may directly facilitate the dispersal of

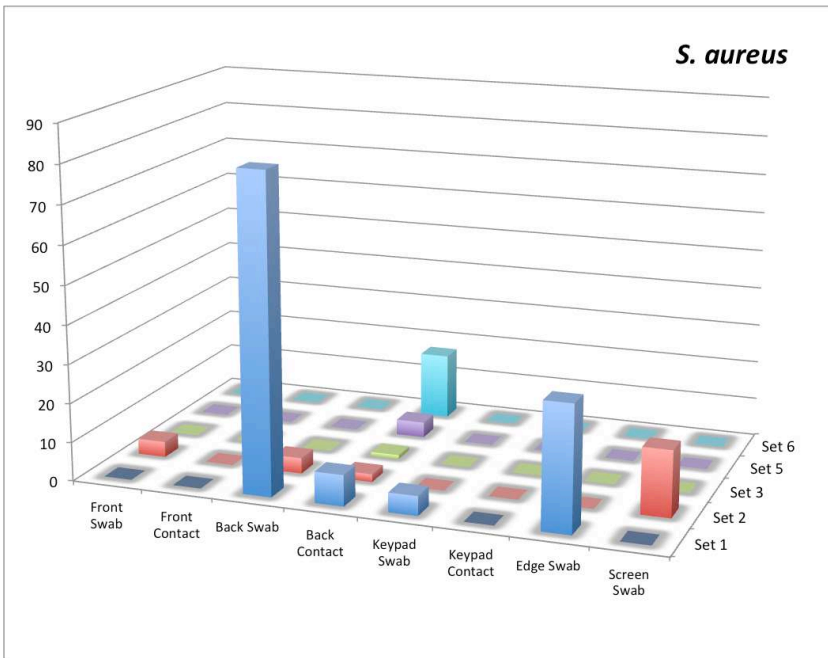
pathogenic bacteria, and perhaps worryingly, could result in dispersal when the mobile phones are taken home (Chawla et al (2009)

The inclusion of contact sampling of the devices after swabbing has identified that isolation of some microorganisms may not be achieved through swabbing alone. There were many instances of bacteria isolated solely by the contact plate method, with *Enterococcus spp* was the only organism not isolated through this approach. No other study, to date, has incorporated both sampling strategies, and hence may have as a consequence failed to isolate bacteria that were present. The effectiveness of the combined sampling strategy appears to explain the significant difference in polymicrobial findings between this study and previous research. In this study, the majority (86%) of devices showed contamination by three or more different bacteria, whereas Srikanth et al (2010) identified that 48% of the mobile phones they tested had two different species of bacteria on them, and just 26% had three or more, whilst Brady et al (2011) found 11.8% and 6.9% respectively, with the majority (64.7%) growing just one species. The efficiency of the sampling strategy used in this study may also account for the finding that no device was free from contamination, unlike other studies where up to 50% (Khivsara et al, 2006) failed to show any growth.

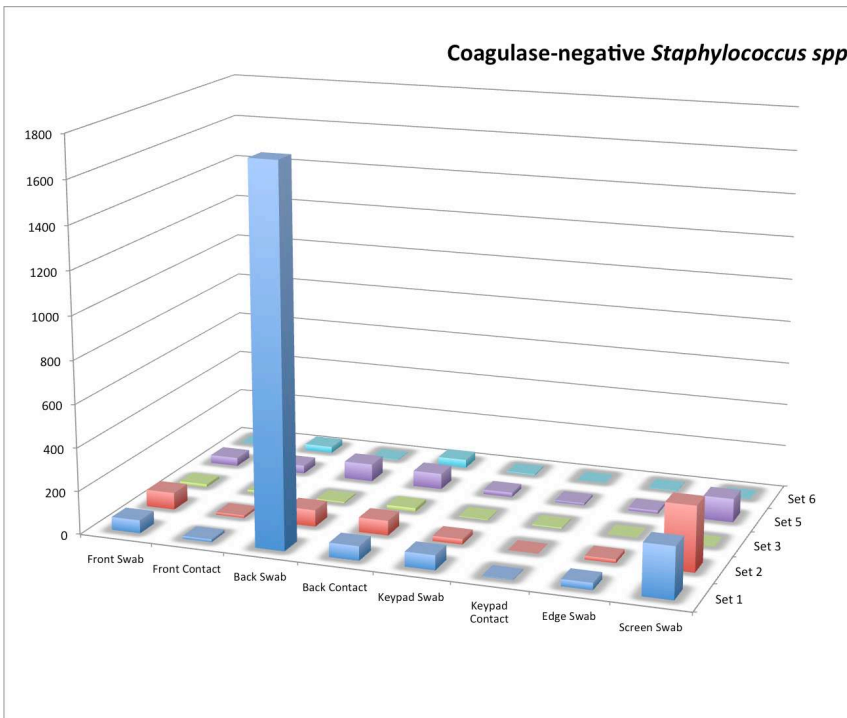
The longitudinal data found a rise in the volume of bacteria on Group 1's devices in the first October sampling point. This sampling was undertaken following a prolonged period between sampling events, during which the students were undertaking clinical placements. It is not possible to establish whether contamination occurred in clinical settings and this contributed to the rise, or if it was due to the extended time lapse between sampling events (five months) and therefore there was greater opportunity to accumulate contaminants. One explanation is that the bacteria are transient in their populating of the devices. This is supported by the results from two devices from Group 1 that were free of MRSA at the first three sampling events, were subsequently contaminated in October (following use in clinical practice), but no evidence of MRSA was found at the November sampling. There was no pattern in terms of presence, numbers, or location of contaminants across the period of sampling in this study. The transient nature of the contamination is shown in Figures 3(a) to (f), which illustrates bacteria isolated from one mobile phone across multiple sampling events.



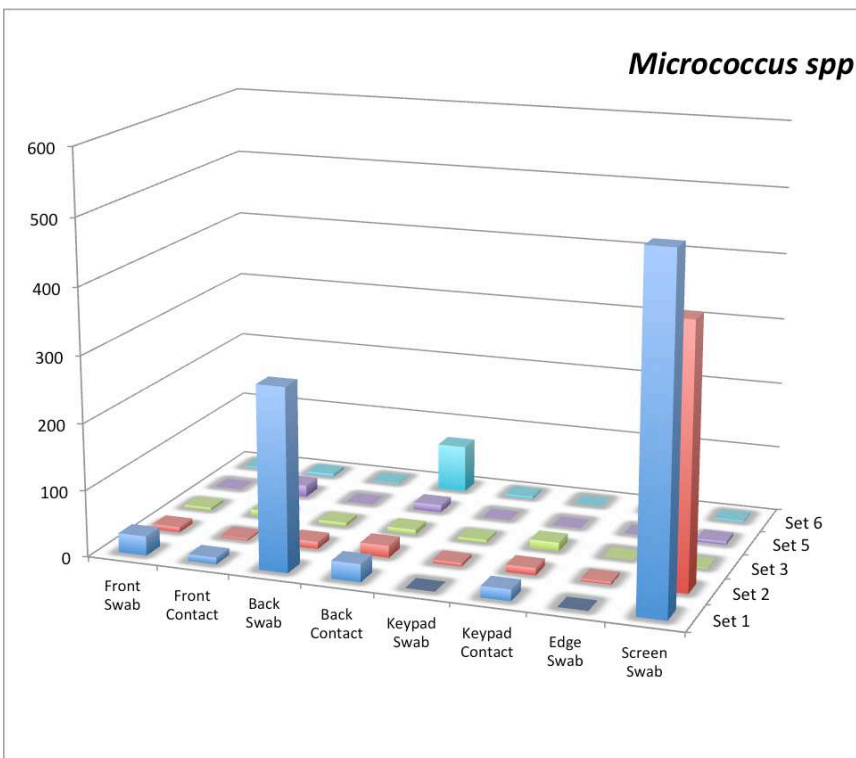
**Figure 3(a):** Bacterial contamination of one mobile phone on multiple sampling events: MRSA.



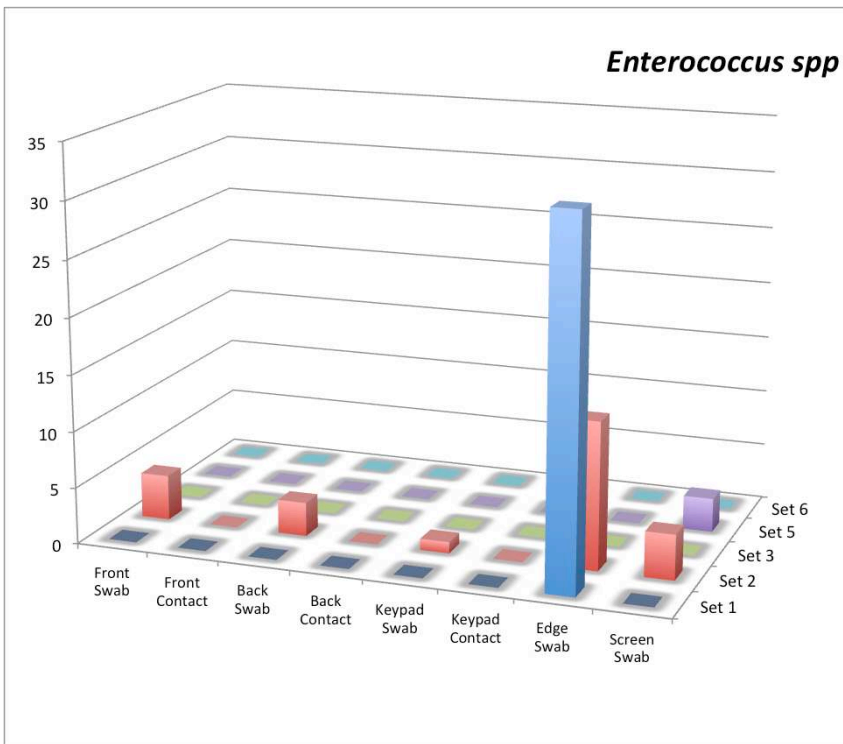
**Figure 3(b):** Bacterial contamination of one mobile phone on multiple sampling events: *S. aureus*.



**Figure 3(c):** Bacterial contamination of one mobile phone on multiple sampling events: Coagulase-negative *Staphylococcus* spp.

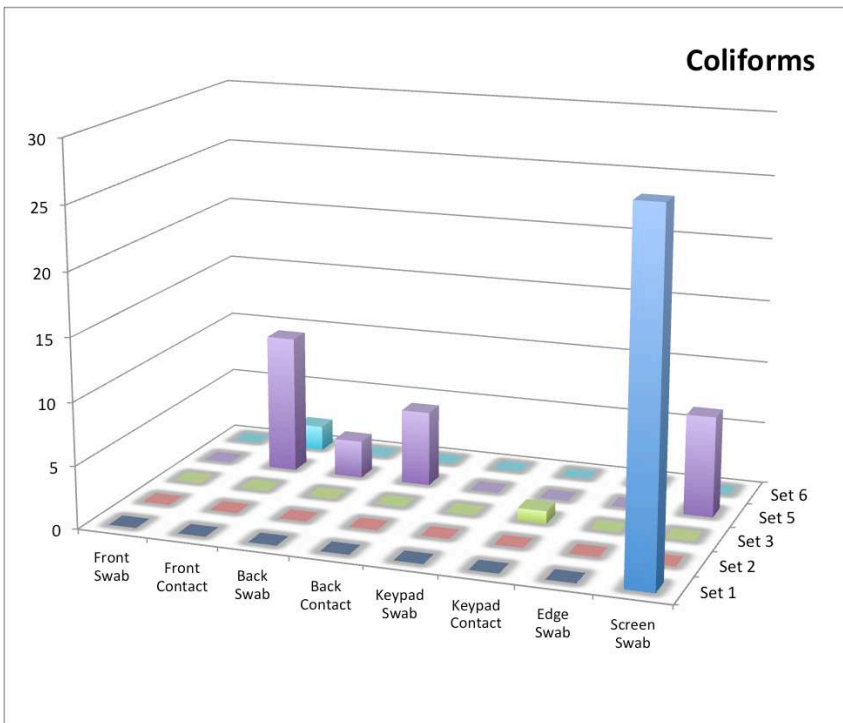


**Figure 3(d):** Bacterial contamination of one mobile phone on multiple sampling events: *Micrococcus* spp.



**Figure 3(e):** Bacterial contamination of one mobile phone on multiple sampling events:

*Enterococcus spp.*



**Figure 3(f):** Bacterial contamination of one mobile phone on multiple sampling events: Coliforms.

Group 1's devices were cleaned with alcohol wipes in the laboratory after the October sampling point, the results from just 11 days later found contamination levels remained higher than those found at three previous sampling points (March, April and May). The literature acknowledges that the numbers of microorganisms on handheld devices, including pathogens, are reduced by cleaning with alcohol, but not totally removed. Kilic et al (2009) found that only 33% of mobile phones that were cleaned at least once a week with alcohol were contaminated, albeit solely with *S. epidermidis*. Whilst Jayalakshmi et al (2008) established that 70% isopropyl alcohol disinfected nearly all mobile phones in their study (129/132), with a gross reduction in the number of organisms on the remaining three. However, Ramesh et al (2008), found that it was the act of daily cleaning, not the cleaning method used (alcohol versus dry cloth) that was significantly associated with amount of growth. Singh et al (2010) carried out a similar study to Ramesh et al (2008), by sampling devices cleaned by their user using both alcohol and dry cloths, and also found no significant difference in the bacterial rates of the participants' phones, irrespective of their cleaning regime. However, after cleaning in the laboratory with 70% isopropyl alcohol, the overall bacterial load was reduced by around 87%, with 42% of the phones showing no growth. This questions the efficiency of alcohol as a cleaning agent for mobile phones and indicates that further investigation is needed into the optimal disinfection methods for these devices.

As a response to poor hygiene practices in healthcare settings, Goldblatt et al (2007) called for strict regulations regarding where mobile phones should be used, and similarly Ulger et al (2009) concluded that limiting mobile phone usage was required. In a study of healthcare workers (HCWs), 73% recognized the need to restrict the use of mobile phones (Srikanth et al 2010). However, when a proposal limiting use of devices to less than three times in a working day was suggested only 29% would have adhered to it based on their current practice; 57% handled their phone more than three times, and 14% using their phone in excess of 20 times in a working day. Indeed, a number of commentators suggest the benefits mobile phones bring makes banning their use in healthcare settings unrealistic and impractical (Borer et al, 2005; Srikanth et al, 2010).

Despite the weight of evidence concerning the microbial transmission potential of mobile devices this does not seem to be translated into workable guidance or advice on use or cleaning of mobile devices for staff and patients (Brady et al, 2011). This is unsurprising given the absence of hospital

standard disinfection guidelines for personal items like mobile phones and manufacturers warning explicitly against using cleaning agents (Jeske et al, 2007; Gunasekara et al, 2009; Datta et al, 2009; Singh et al, 2010).

Despite evidence that these devices do not cause interference with medical equipment (Ramesh et al, 2008), findings that resulted in relaxation of the restrictions on their use in healthcare settings, no guidance has been given on their disinfection. In the UK the Department of Health have published two separate documents specifically on the use of mobile devices in the healthcare environment (DH, 2009; 2011), yet neither make any reference to the devices' infection potential.

This study sampled a small number of devices of one specific design, which may limit generalizability, nevertheless the approaches used for sampling, culturing and cleaning suggest that the infection potential is greater than previously thought.

### **Key Points**

- Sampling strategies using a combination of swabbing and contact plates for determining bacterial contamination of mobile phones are more likely to isolate microorganisms.
- Bacteria that contaminate mobile phones are transient, not resident.
- Optimal disinfection methods for mobile phones have yet to be determined.
- The actions and behaviours of healthcare workers, in relation to their mobile phones, requires further examination to determine the impact they may have on microbial transmission and infection risk.
- An evidence-based infection control policy for the use of mobile phones in health care setting is required, but further research is needed to inform this.

### **Conclusion**

The findings from this study suggest that mobile phones are contaminated with significant numbers of transient pathogenic bacteria, indeed far more than has previously identified. This study was not designed to ascertain the clinical risks that might occur from transmission, merely establish the most reliable and valid approach for testing microbial contamination on mobile phones. The existing evidence, and these findings, are in agreement that microorganisms growing on mobile

devices have the potential to be transferred into healthcare environments if used, although the probability that contamination will occur is as yet unknown. Further observational research is needed to ascertain the actual risk of contamination posed by mobile phones use by healthcare staff when undertaking normal duties. In the absence of a more effective alternative we would concur with other authors and recommend cleaning devices with 70% isopropyl alcohol. This advice is advocated on the basis that cleaning is used in combination with strict concordance with hand washing and infection control measures. Additional laboratory sampling of mobile phones, and evaluation of disinfection methods, is needed to confirm the efficacy of sampling techniques and optimum cleaning methods. This research is urgently needed to inform the development of robust evidence-based infection control policy on the use of mobile devices within healthcare settings.

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