JIDC | THE JOURNAL OF INFECTION IN DEVELOPING COUNTRIES

Original Article

Comparison of keypads and touch-screen mobile phones/devices as potential risk for microbial contamination

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Abstract

Introduction: Touch-screen mobile phones/devices (TMPs/Ds) are increasingly used in hospitals. They may act as a mobile reservoir for microbial pathogens. The rates of microbial contamination of TMPs/Ds and keypad mobile phones (KMPs) with respect to different variables including use by healthcare workers (HCWs)/non-HCWs and the demographic characteristics of users were investigated.

Methodology: A total of 205 mobile phones/devices were screened for microbial contamination: 76 devices belonged to HCWs and 129 devices belonged to the non-HCW group. By rubbing swabs to front screen, back, keypad, and metallic surfaces of devices, 444 samples were collected.

Results: Of 205 mobile phones/devices, 143 (97.9%) of the TMPs/Ds and 58 (98.3%) of the KMPs were positive for microbial contamination, and there were no significant differences in contamination rates between these groups, although TMPs/Ds had significantly higher microbial load than KMPs ($p < 0.05$). The significant difference in this analysis was attributable to the screen size of mobile phones ≥ 5". Microbial contamination rates increased significantly as phone size increased ($p < 0.05$). Higher numbers of coagulase-negative Staphylococci (CNS) were isolated from KMPs than TMPs/Ds ($p = 0.049$). The incidence of *Enterococcus* spp. was higher on the KMPs of HCWs, and methicillin resistant CNS was higher from the TMPs/Ds of non-HCWs ($p < 0.05$). Isolation of CNS, *Streptococcus* spp. and *Escherichia coli* was higher from the TMPs/Ds of HCWs ($p < 0.05$).

Conclusions: We found no significant difference between TMP/Ds and KMPs in terms of microbial contamination, but TMP/Ds harboured more colonies and total microbial counts increased with screen size.

Key words: Mobile phones; touch-screen mobile phones; keypad mobile phones, microbial contamination; healthcare workers.

J Infect Dev Ctries 2015; 9(12):1308-1314. doi:10.3855/jidc.6171

(Received 31 October 2014 – Accepted 17 May 2015)

Introduction

Mobile phones are indispensable accessories in professional and social life. However, they are frequently used in environments with a high bacterial presence and may act as mobile reservoirs for microbial pathogens of nosocomial and other infections [1–7].

Use of mobile phones/devices by healthcare workers (HCWs) in clinical settings has become widespread. Contaminated handheld devices have the potential to be reservoirs for cross contamination of patients and other staff [8]. Among HCWs, it has been reported that medical devices such as thermometers and stethoscopes, and non-medical devices including computer keyboards, faucets, ballpoint pens, files, books, and mobile phones play an important role in the transmission and spread of microorganisms [2,5–7,9–11].

The use of keypad mobile phones (KMPs) is decreasing while touch-screen mobile phones/devices (TMPs/Ds) of various sizes are expanding rapidly. As a result, TMPs/Ds are increasingly used in hospitals, and are used more often by their owners than KMPs [8,12]. Many of these devices have a touch-screen with a single smooth surface as opposed to a keypad with separate buttons and numerous crevices [8,13]. In addition, with the rapid development of hospital information system technologies, the utilization of wireless networks and mobile touch-screen devices such as tablet Personal Computers (tablet PCs) is becoming common in clinical settings by HCWs [13].

Few studies have compared KMPs and TMPs/Ds in terms of microbial contamination in literature [8,12]. This study aimed to compare the rates of microbial contamination, of TMPs/Ds and KMPs with respect to different variables including use by

HCWs/non-HCWs and demographic characteristics of users.

Methodology

Study design and participants

A prospective cross-sectional study was conducted between January 1st and March 30, 2013, in Malatya, Turkey. A total of 76 HCWs and 129 non-HCWs subjects from two hospitals were included in the study. HCWs from different professions (physicians, nurses, laboratory/radiology workers and others) and non-HCWs who used their mobile phones during working hours in the hospital for professional and personal purposes were selected randomly for the study (Table 1). Informed consent was obtained from all participants.

Questionnaire

A questionnaire was administered to all participants to capture the demographic characteristics (age, gender, occupation, educational status) and type of mobile phone/device (Table 1).

Mobile phones/devices

All the phones/devices of the participants were recorded as KMPs and TMPs/Ds. Sampling areas were determined as keypad, front and back surfaces for the KMPs; touch-screen and back surface for the TMPs/Ds. Additionally, samples were collected from metallic surfaces of both kinds of devices, if any. By this way, the metallic and non-metallic surface types of the phones were also compared in terms of microbial contamination rates.

A total of 205 (146 touch-screen and 59 keypad) mobile phones were tested for microbial contamination. Seventy-six devices belonged to the HCW group and 129 devices belonged to the non-HCW group. The screen sizes of the touch-screen mobile phones/devices were categorized as follows: smaller than 3.0" (n = 40), 3.01–4.0" (n = 56), 4.01–5.0" (n = 8), and 5.01–10.1" (n = 42). A total of 34 mobile phones/devices had a metallic surface. All of the KMPs were smaller than 5".

Sample collection technique, Isolation and identification

A conventional swabbing technique was used to screen for the presence of microorganisms on phones/devices [8,12,14,15].

Sterile swabs were rubbed on every part of the specified area (front screen, back, keypad, and metallic surfaces) of devices. Totally, 444 samples were collected from most frequently handled parts of the phones/devices (59 samples from the keypad, 205 samples from the front surface of the device, 146 samples from the back surface, and 34 samples from the metallic areas). Each sample was inoculated onto blood agar, eosin methylene blue agar, and sabouraud

Table 1. Comparison of demographic characteristics related to keypad mobile phone (KMP) and touch-screen mobile phone/device (TMP/D) users.

Demographic characteristics	Keypad mobile phones n = 59 (%)	Touch-screen mobile phones/devices, n = 146 (%)
Age		
≤20	4 (7.0%)	30 (20.5%)
21–30	20 (34.0%)	61 (42.0%)
31–40	22 (37.0%)	27 (18.5%)
41≤	13 (22.0%)	28 (19.0%)
Gender		
Female	29 (49.0%)	65 (44.5%)
Male	30 (51.0%)	81 (55.5%)
Occupation		
Physician	1 (1.5%)	12 (8.0%)
Nurse	4 (7.0%)	4 (2.5%)
Laboratory technician	16 (27.0%)	12 (8.0%)
Radiology technician	1 (1.5%)	3 (2.0%)
Other healthcare worker	14 (24.0%)	10 (7.0%)
Non-healthcare worker	23 (39.0%)	106 (72.5%)
Education Status		
Junior high school	7 (12.0%)	9 (6.0%)
High school	10 (17.0%)	31 (21.0%)
University	41 (69.5%)	95 (65.0%)
Graduate	1 (1.5%)	11 (8.0%)

dextrose agar plates (Salubris, Istanbul, Turkey) prior to aerobic incubation at 37°C for 48 hours. Colony count was calculated using the semi-quantitative colony-forming unit (cfu) count method in which the number of colonies isolated from each mobile phone was divided by the area sampled [3,7].

Isolated microorganisms were identified using conventional microbiological methods and VITEK 2 automated system (bioMérieux, Marcy-l'Etoile, France). Antimicrobial susceptibility testing of the isolated microorganisms were performed by using the same system; patterns of resistance to major antibiotics such as methicillin, vancomycin, high-level aminoglycoside, and extended spectrum beta lactamase (ESBL) were determined according to the Clinical and Laboratory Standards Institute (CLSI) 2013 criteria.

Statistical analysis

The KMPs and TMPs/Ds were compared for all variables such as presence of microbial contamination, HCWs group and non-HCWs group, microbial load and types of microorganisms, types of isolated microorganisms, sizes and surfaces of the phones/devices, and demographic data of participants. Categorical variables were compared by Chi-square analysis and Fisher's exact test, and continuous variables were compared using the Mann-Whitney U-test.

For all analyses, Statistical Package for the Social Sciences (SPSS) version 17.0 (IBM SPSS, Armonk, NY, USA) was used and P values <0.05 were considered to indicate statistical significance.

Results

Microbial contamination

Microbial contamination was determined in 201 (98%) of all mobile phones, including 143 (97.9%) TMPs/Ds and 58 (98.3%) KMPs. The difference in microbial contamination rates between the two phone groups was not statistically significant ($p > 0.05$).

Regardless of the phone/device types, of the various surfaces of the phones, 183 of the front area samples (89.3%), 56 of the keypad samples (94.9%), 137 of the back area samples (93.8%), and 29 of the metallic area samples (85.3%) were positive for bacterial or fungal culture. There were no significant differences between the sample groups in terms of presence of microorganisms (microbial contamination). Furthermore, there were no significant differences in microbial contamination according to the type of mobile phone or between front area and metallic area.

There were no significant differences in microbial contamination rates between the front, keypad, back, or metallic areas of the KMPs ($p > 0.05$).

When TMPs/Ds were compared in terms of size, it did not affect the rate of microbial contamination (presence of microorganisms) of mobile phones/devices ($p > 0.05$). However, there was a statistically significant difference in terms of the rate of microbial contamination (presence of microorganisms) on the front, back, and metallic areas of different sizes of TMP/D ($p < 0.05$). TMPs/Ds with screen sizes ≥5.5" had higher contamination rates on the front and back surfaces ($p < 0.05$). There were no significant differences in the contamination rates for the metallic surfaces on any type of TMP/D ($p > 0.05$).

We also investigated the effects of participant (owners' of phones or devices) age, gender, occupation, and educational status on the microbial contamination rate of mobile phones. On these demographic data, no significant differences were detected in microbial contamination rate. In addition, there was no correlation between demographic characteristics of subjects and microbial contamination rates on different surfaces of their phones.

Coagulase-negative staphylococci (CNS) were the most frequently isolated organisms, detected in 359 of 444 (80.9 %) samples. Bacteria known to potentially be associated with hospital infections were isolated in 154 samples, including *Pseudomonas aeruginosa* (8), *Escherichia coli* (20), *Klebsiella* spp. (16), methicillin-resistant CNS (30), methicillin-resistant *Staphylococcus aureus* (9) and *Enterococcus* sp. (76). Pathogens and potential pathogens isolated included *Staphylococcus* spp., *Enterococcus* spp., *Acinetobacter* spp., *Pseudomonas* sp., Enterobacteriaceae, *Streptococcus* spp., Diphtheroids, and other microorganisms (Table 2).

Significantly, higher numbers of CNS were isolated from KMPs (84.5 %) than TMPs/Ds (79.2 %) ($p = 0.049$). The incidence of *Enterococcus* spp. was significantly higher on the KMPs of HCWs ($p = 0.035$), while isolation of MRCNS was significantly higher from the TMPs/Ds of non-HCWs ($p = 0.048$), and isolation of CNS, *Streptococcus* spp. and *E. coli* was significantly higher from the TMPs/Ds of HCWs ($p < 0.05$).

Table 2. Number of isolates and types of microorganisms isolated from keypad mobile phones (KMPs) and touch-screen mobile phones/devices (TMPs/Ds) of healthcare workers (HCWs) and non-HCWs.

	Keypad mobile phones (n = 59)			**Touch-screen mobile phones/devices (n = 146)**			**p *****
	HCWs group (n=35)	**non-HCWs group (n=24)**	**p ***	**HCWs group (n=41)**	**Non-HCWs group (n=105)**	**p ****	
Total number of cultivated swab samples[1]	80	56		90	218		
Positive culture	70 (88%)	52 (93%)	0.468	85 (95%)	199 (91%)	0.479	0.494
Number of distinct types of isolates							
1	11	7	1.000	26	36	**0.021**	0.081
2	22	11	0.396	19	45	0.927	**0.043**
3	20	17	0.620	22	54	0.952	**0.041**
4	9	11	0.265	12	40	0.367	**0.038**
≥5	8	5	1.000	5	27	0.074	**0.039**
Type of microorganism							
CNS	67	48	0.943	78	166	**0.039**	**0.049**
MRCNS	4	4	0.717	11	11	**0.048**	0.777
S. aureus	36	32	0.163	45	122	0.339	0.411
MRSA	1	0	1.000	0	8	0.110	0.287
Micrococcus sp.	18	9	0.480	7	33	0.119	0.062
Bacillus sp.	9	4	0.613	12	26	0.880	0.493
Diphtheroids	7	1	0.140	9	21	1.000	0.248
Yeasts	7	6	0.931	6	19	0.712	0.752
Molds	16	6	0.226	18	42	1.000	0.408
Enterococcus sp.	9	15	**0.035**	14	38	0.816	0.844
HLAR	3	3	0.635	1	12	0.118	0.122
VRE	0	0	1.000	0	1	1.000	1.000
Streptococcus sp.	14	17	0.121	11	52	**0.032**	0.578
E. coli	2	1	1.000	1	16	**0.049**	0.121
ESBL (+)	0	1	0.412	1	2	1.000	1.000
Klebsiella sp.	1	1	1.000	2	12	0.366	0.165
ESBL (+)	0	1	0.412	0	0	1.000	0.306
Proteus sp.	1	1	1.000	2	6	1.000	0.199
Pseudomonas sp.	1	1	1.000	3	3	0.363	0.476
A. baumanni/lwoffii	5	2	0.700	5	5	0.163	0.336
Other Enterobacteriaceae	4	1	0.648	4	18	0.348	0.159
Other agents[2]	5	5	0.740	3	22	0.810	0.933

[1] Samples were collected from the keypad, front, back, and metallic surfaces of keypad mobile phones, and front, back and metallic surfaces of touch-screen mobile phones. [2] Other agents; *Erysipelothrix* sp., *Moraxella* sp., *Aeromonas* sp., Pasteurella sp., *Methylobacterium* sp.; CNS, coagulase-negative staphylococci; ESBL, extended-spectrum β-lactamase; HLAR, high-level aminoglycoside resistant; MRCNS, methicillin-resistant, coagulase-negative staphylococci; MRSA, methicillin-resistant Staphylococcus aureus, p*, p** Comparison of HCWs and Non-HCWs keypad and touch-screen mobile phones/devices respectively, p*** comparison of keypad and touch-screen mobile phones/devices

Microbial load

The total number of isolated contaminating colonies was higher from TMPs/Ds (mean cfu: 46.2, median cfu: 34) than from KMPs (mean cfu: 36.8, median cfu: 21.5) ($p < 0.05$). A statistically significant difference in this analysis was attributable to the screen size of mobile phones ≥ 5". In addition, there was no difference in microbial load on the front and metallic parts of the phone between the two types of phone. A box plot comparison of the cfu median values from the various surfaces of KMPs and TMPs/Ds is shown in Figure 1.

Analysis of demographic variables and microorganism load for both phone types revealed that microbial load significantly increased as educational level ($p = 0.002$) and age ($p = 0.006$) decreased. The microbial load also increased significantly for both phone types for male subjects ($p < 0.001$) and subjects in the HCW group ($p < 0.001$).

More than one type of microorganism was isolated from 407 out of the 444 cultured samples obtained from different surfaces of the phones (91.6%). In terms of number of distinct isolates, KMPs typically harboured 2–3 varieties of microorganisms while ≥ 4 varieties of microorganisms were observed at higher frequency on TMPs/Ds ($p < 0.05$; Table.2). There were no significant differences in the number of distinct types of isolates from devices belonging to HCWs and non-HCWs.

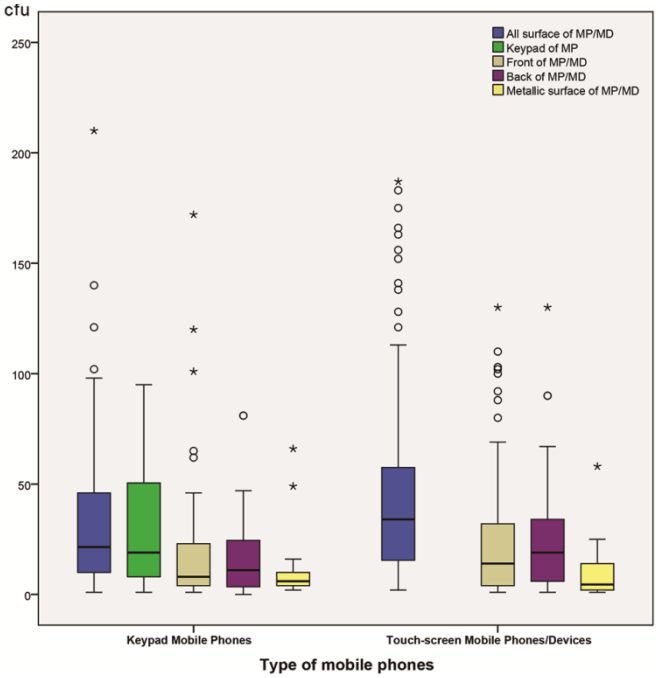
Discussion

Mobile phones/devices have become an indispensable part of our social and professional lives. While there have been concerns about the harm of electromagnetic waves emitted by these devices, recent investigations have focused on the possibility of phones acting as potential reservoirs for microorganisms, and particularly pathogens.

Of the 205 mobile phones/devices analysed, 143 (97.9%) of the TMPs/Ds and 58 (98.3%) of the KMPs were positive for microbial contamination, and there were no significant differences in the contamination rates between the two types of phone. However, TMPs/Ds had significantly higher microbial load than KMPs. Several studies have reported high contamination levels similar to those found in this study [2,5–7,16].

When presence of microorganisms was considered, participant demographic characteristics did not affect microbial contamination rates. However, microbial loads were significantly increased on the phones of subjects with lower educational levels ($p = 0.002$) and age ($p = 0.006$). In addition, male gender ($p < 0.001$) and HCW group ($p < 0.001$) were correlated with increased microbial load.

Figure 1. A box plot comparison of the cfu median values from the various surfaces of mobile phones/devices



For TMPs/Ds, while there was no difference in the microbial contamination rate (presence of microorganisms) according to the size of the screen ($p > 0.05$), there were significant differences in microbial contamination rates on the front, back, and metallic surfaces ($p < 0.05$). TMPs/Ds with screen sizes ≥5.5" had much higher microbial contamination rates ($p < 0.05$) on the metallic sections of their front and back surfaces.

KMPs typically harboured 2–3 varieties of microorganisms while ≥4 varieties of microorganisms were observed at higher frequency on TMPs/Ds ($p < 0.05$; Table 2). This result may be due to the larger size of the TMPs/Ds compared to KMPs. Nikolic *et al.* [17] reported no significant difference in the number of distinct types of microorganisms for HCWs and non-HCWs. Similarly, results of this study revealed no significant difference in the number of distinct types of microorganisms for these groups.

Other studies have compared KMPs and TMPs/Ds in terms of bacterial contamination. Pal *et al.* [8] and Mark *et al.* [18] indicated that TMPs were less contaminated than KMPs, and they were less likely to harbour pathogenic bacteria in the clinical setting. We hypothesized that TMPs would harbour less dirt and microorganisms due to their smooth surface, and KMPs would harbour more contaminating material

due to the spaces between the buttons allowing accumulation of dirt and microorganisms. Instead, we found no difference in microbial contamination rate between the two phone types. Pal and colleagues (2013) did not take into consideration the size of TMPs, and the front, back, and metallic surfaces were not examined separately. We found that the microbial contamination rates increased significantly as phone size increased, with the exception of metallic surfaces ($p < 0.05$). Similarly, Lee *et al.* (2013) reported that larger surfaces of mobile phones would allow more microbial contamination [12]. In this study, contamination rates for KMPs did not differ statistically among the front screen, metallic surfaces, and buttons ($p > 0.05$).

As Pal *et al.* (2013) and Obee *et al*. (2007) found, the conventional agar contact method is more sensitive than a swabbing technique [8,19]. However, in the agar contact method each CASO agar and nutrient agar culture plate may contact an average area of 22–25cm^2. However, mobile phones/devices of larger size cannot achieve full contact on the culture plate, thus cfu/cm^2 cannot be calculated in the cultured surfaces [8,13]. One objective of the present study was to determine the microbial load on phones/devices. The lack of contact with all surfaces with the agar contact method would have limited full examination of microbial load. Thus, the swab method was selected as it allowed investigation of microbial load according to the different sizes of TMP/Ds together with sampling of all parts of the surface areas by rubbing the swab. Harrison *et al.* (2014) also used the swabbing technique to determine bacterial load. While Pal *et al.* (2013) used cfu/cm^2 as the main criterion to compare microbial contamination rates; the swab culture method used in this study did not support investigation of this parameter.

An important difference between our study and those performed by Pal *et al.* (2013) and Mark *et al.* (2014) was our comparison of devices from HCWs and non-HCWs, while Pal *et al.* only studied devices owned by HCWs. Lee *et al.* (2013) reported that smartphones were more contaminated with bacteria than other types of phone. However, like many other studies, they examined only mobile phones that belonged to HCWs. The authors also suggested that smartphones such KMPs could belong to the smartphone category. As they did not examine the same phenomena as our group, a direct comparison should be avoided, although authors found that smartphones were dirtier due to their larger sizes and to more frequent and intensive use.

The need to clean mobile phones is well known and agents such as ethanol and isopropanol have been investigated for this purpose [20-23]. Larger equipment harbours a higher microbial load and the frequent use of these devices in hospital information systems is crucial to limit the spread of hospital infections. Tablet PC (and larger mobile device) hygiene has garnered attention, and disinfection methods and standardization protocols have been published [13,22,23]. Over time, more detailed research into mobile device infection control methods is expected to facilitate the development of guidelines. Precautions such as hand washing should be strictly followed to avoid the transmission and spread of infections (in particular nosocomial infections) due to mobile devices [7,15,17, 22]. Recommendations in the literature include the use of nanotechnology, antibacterial coatings/covers, or silver metal to reduce the contamination rate of mobile phones [4].

When pathogenic and potentially pathogenic agents were considered, the incidence of CNS in the KMP group was statistically higher compared to the TMP/D group (p=0.049). However, there were no significant differences detected between the two phone groups for other microbial agents. Analysis of the demographic data revealed higher levels of isolation of *Enterococcus* spp. from KMPs of HCWs, MRCNS from TMP/Ds of non-HCWs, and CNS, *Streptococcus* spp. and *E.coli* from TMP/Ds of HCWs (p<0.05; Table 2). In 91% of the samples taken from phones of HCWs, at least one microorganism was grown and isolated (Table 2). Many studies have reported findings similar to these results, and have emphasized that the transport of pathogenic and potentially pathogenic agents via the phones of HCWs could be an important risk factor for nosocomial infection [2,5,6,17]. In addition, along with hand washing, routine disinfection of mobile phones is strongly advised to prevent the spread of nosocomial infections [5,6,12,20,24].

A previous study found no correlation between colony counts below 2.5 cfu/cm^2 and nosocomial infections; while higher cfu values could indicate the presence of pathogens and improper hygiene at hand touch site [25]. One limitation of this study is that cfu/cm^2 could not be determined with the swab culture method used. Another limitation is that only easily cultivable bacteria, yeast, and fungi were investigated. In future studies difficult-to-culture bacteria, viruses, and parasites should be investigated in terms of microbial contamination of mobile phones/devices.

Conclusion

We found no significant difference between TMP/Ds and KMPs in terms of microbial contamination (presence of the microorganisms), but TMP/Ds harboured more colonies. Total microbial counts also increased in TMP/Ds with larger screen sizes. To minimize the risk posed by these devices, routine mobile phone/device hygiene/cleaning standards compatible with daily social and professional activities should be established. These standards should be strictly implemented, especially in hospital settings. Due to the widespread use of touch-screen mobile phones/devices, more comprehensive and detailed studies on device-disinfection methods are required to reduce infections that originate from their use.

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Conflict of interests: No conflict of interests is declared.