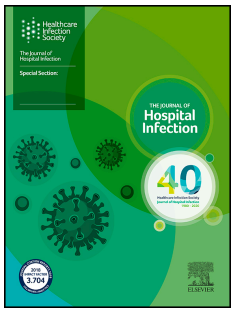

Pilot randomised experimental study evaluating isopropyl alcohol and UVC radiation in the disinfection of healthcare workers' smartphones

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Pilot randomised experimental study evaluating isopropyl alcohol and UVC radiation in the disinfection of healthcare workers' smartphones

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Summary

Smartphones in medical settings pose infection risks due to harbouring pathogenic bacteria. This pilot study assesses the effectiveness duration of sanitisation methods, focusing on 70% isopropyl alcohol wipes and UVC boxes, aiming to obtain preliminary data on the reduction in Total Bacterial Load 3 hours post-sanitisation. A randomised monocentric trial with two intervention arms (wipes and UVC boxes) was designed. As participants, healthcare workers from three wards at Fondazione Policlinico Universitario "A. Gemelli" IRCCS Hospital were recruited, stratified by ward, and block randomised within each ward to control confounders. Seventy-one healthcare workers, mostly nurses (62%) were included in the study. Initial bacterial load reduction was significant with both disinfection techniques, but after 3 hours both methods showed increased bacterial levels, with wipes displaying potentially higher residual efficacy (p=0.056). To adequately size a trial (89% power, significance level 0.05) for assessing the residual efficacy of alcohol-impregnated wipes compared to UVC boxes at 3 hours post-sanitisation, 503 professionals per group were required. This study highlights the necessity for guidelines on hospital smartphone sanitisation and educational initiatives for healthcare workers and patients. Further studies, adequately sized, are necessary to determine optimal sanitisation intervals and assess pathogen transmission risks.

Keywords: smartphone, disinfection, alcohol wipes, UVC, bacterial load

Introduction

Inanimate surfaces can serve as reservoirs for pathogenic microorganisms; furthermore, they may constitute a means of transmission of such microorganisms from the environment to humans [1]. Smartphones have become a fundamental tool in our daily lives and clinical practice, often kept in close contact with the body and, in particular, with the hands. Given that modern smartphones are equipped with large touch screens, requiring repeated finger contact, they are more susceptible to contamination by microorganisms compared to non-smartphones. [2]. Furthermore, it is quite common for microorganisms to transfer between surfaces and humans, as evidenced by the fact that the microbiota found on smartphones resembles that observed on the hands of healthcare workers. [3,4].

It has been estimated that between 9% and 25% of smartphones are contaminated with pathogenic bacteria. [1,5]. The primary pathogens isolated from the surfaces of smartphones include *Staphylococcus aureus*, coagulase-negative *Staphylococci*, *Micrococcus* species, *Pseudomonas* species, and *Escherichia coli*. [1,6]. Hence, high-touch devices pose an increased risk of causing and transmitting infections within the nosocomial setting, particularly in units where the most vulnerable patients are hospitalized. [7].

In the literature, some observational studies assessing the effectiveness of various sanitisation methods in reducing the bacterial load of high-touch devices are available (7). Some of these studies have considered chemical disinfection, comparing wipes impregnated with various disinfectant solutions, such as 70% isopropyl alcohol, quaternary ammonium derivatives, and chlorine derivatives, indicating a superiority of the former [8–10].

On the other hand, other studies have evaluated physical disinfection based on the use of UVC radiation lamps, which function to induce damage to the nucleic acids of pathogens, resulting in the inhibition of their reproductive and growth capabilities [9,11].

As highlighted by Bhardwaj *et al*., while antibacterial wipes ensure immediate decontamination, are ready-to-use, and cost-effective, UVC lamps take longer for disinfection, yet they are more effective as UV light kills a broader spectrum of bacteria and have a longer lifespan, as they can be used for numerous disinfection cycles [7].

Concerns about potential damage to the smartphone due to repeated disinfection have been alleviated by major manufacturers, prompted by the SARS-CoV-2 pandemic, who have issued dedicated guidelines, indicating 70% isopropyl alcohol and UVC radiation as two safe and effective disinfection methods [12].

The issue of potential concerns arising from UV radiation exposure, given its carcinogenic potential, can be mitigated by employing lamps housed in specialised boxes designed to optimise the dispersion of UV radiation. These boxes also halt the lamp's operation if opened before the disinfection cycle is completed [13,14].

To our knowledge, real-world evidence comparing the residual effect of these two methods on the bacterial load of mobile phones is not available, as all existing studies are conducted in the laboratory with pre-established bacterial inocula, the reduction of which by the disinfectant is monitored over time, and involve laptops [8] , tablets [10], and keyboards (1–4,15).

Primary objective

The primary objective of the pilot study is to obtain preliminary data regarding the reduction in the average Total Bacterial Load 3 hours after the sanitisation intervention. These data will be instrumental in appropriately designing a subsequent trial to assess whether, on the smartphones of healthcare workers at the Fondazione Policlinico Universitario "A. Gemelli" IRCCS, where the experimentation is conducted, wipes impregnated with 70% isopropyl alcohol are more effective than UVC boxes in reducing the Total Bacterial Load immediately after and at 3 hours post-sanitisation.

Secondary objective

- Determine the change in the average Total Bacterial Load at 3 hours post-sanitisation compared to the value recorded before sanitisation.

- Quantify the presence, before sanitisation, immediately after sanitisation, and at 3 hours post-sanitisation, of the following multi-resistant pathogens: Methicillin-Resistant *Staphylococcus aureus* (MRSA), Extended-Spectrum Beta-Lactamase (ESBL)-producing *Enterobacteriaceae*, Carbapenem-Resistant *Enterobacteriaceae* (CRE), and Vancomycin-Resistant *Enterococci* (VRE).

Methods

Study design

Randomised monocentric pilot study with two parallel arms. The two arms consist of:

1. Healthcare workers whose smartphones were disinfected using a chemical method (70% isopropyl alcohol wipes);
2. Healthcare workers whose smartphones were disinfected using a physical method (UVC box).

To exclude confounding factors of environmental origin arising from the different distribution of pathogens and variations in temperature and relative humidity between various departments, stratification was performed by department. Within each identified department, block randomisation was conducted with block size calculated based on the number of healthcare workers consenting to participate in the study. An allocation ratio of 1:1 was employed for the two study devices to ensure a balanced distribution of participant characteristics in each group, including compliance to hand hygiene.

Population

Healthcare professionals of any age and professional category working in the Neonatology, Geriatric Internal Medicine, Anesthesia, Resuscitation, and Intensive Therapy departments of the Fondazione Policlinico Universitario A. Gemelli IRCCS.

Duration of the study

The study lasted for 2 months.

Inclusion criteria

- Being a healthcare professional in the Neonatology, Geriatric Internal Medicine, Anesthesia, Resuscitation, and Intensive Therapy departments of FPG;
- possession of a smartphone;
- carrying the smartphone throughout the duration of the working shift;
- providing consent to participate in the study;
- willingness to present for a control sampling 3 hours after sanitisation.

Procedures

The procedures envisaged an initial recruitment phase (M0), an intervention and sampling phase (M1), and an analysis phase of the collected samples (M2)).

M0. Recruitment phase

At the time of recruitment:

- Participants were provided with the information sheet, and informed consent was obtained.
- Within the identified strata, sequences were created for randomisation to one of the two treatment arms based on the number of participants consenting to the study.

M1. Intervention and sampling phase

- On the day or days of data collection, two technicians visited a designated workspace identified by the nursing coordinator. Data collection began within 3 hours of the end of the recruited healthcare workers' shifts.

  It was decided to sample devices at 3 hours by taking the shortest shift duration of health care workers (6 hours) as a reference: it was therefore deemed acceptable to sanitise one's smartphone at least once in the middle of a shift and it was decided to determine whether it was possible to balance logistical needs with the rise in device bacterial load.

- At the agreed-upon time, healthcare workers visited the designated sampling area, where technicians sampled the smartphones of the participants, both on the screen with Tryptic

Soy Agar (TSA) plates (to determine Total Bacterial Load) and on the back surface with a swab (to determine the presence of multi-resistant pathogens). This moment is identified as "PRE". Sampling was done only at the center of the screen and back so as not to affect differently, by mechanical action, sampling that was subsequently conducted on the upper and lower parts of the screen and back surfaces (**Fig. 1**).

[Insert Fig.1]

- Chemical disinfection: for each participant, the technician opened a new wipe with 70% isopropyl alcohol and passed it three times on the screen, three times on the back surface, and three times on each side of the smartphone. After allowing 5 minutes for the smartphone to dry, a new sampling was performed to assess the baseline bacterial load and the presence of multi-resistant pathogens after disinfection (identified as “T0”). Sampling was repeated 3 hours after sanitisation using the same methods (identified as “T1”).
- Physical disinfection: the technician placed the participant's smartphone inside the UVC box, closed the lid, and activated the disinfection using the "on" button. After 3 minutes, the technician opened the UVC box, rotated the smartphone by 180°, closed the box, and pressed the "on" button again. Upon completion of the disinfection cycle, the technician extracted the smartphone from the box and proceeded to a new sampling to assess the baseline bacterial load and the presence of multi-resistant pathogens after disinfection (identified as “T0”). Sampling was repeated 3 hours after sanitisation using the same methods (identified as “T1”).

M2. Analysis phase of the collected samples

- The collected samples were incubated for 24 or 48 hours (depending on whether determining Total Bacterial Load or assessing the presence of multi-resistant pathogens; for the latter, the incubation time varied based on the type of pathogen). Bacterial colonies were counted and the presence of multi-resistant pathogens was determined.

Collection, recording and statistical analysis of data

Interventions

The tested devices include Klerwipe™ 70/30 IPA Blended with WFI from Ecolab and UV SANITIZE ULX – 1059 from Ulsonix, both CE marked.

Collection and analysis of biological samples

To assess Total Bacterial Load (TBL), plates containing a non-selective Tryptic Soy Agar (TSA) culture medium from Liofilchem S.r.l, (TE) Italy were employed. The "RODAC-WEIGHT" system, sterile, with a standard weight and a sampling duration of 10 seconds, ensured an objective and reproducible outcome. The plate's position during the three sampling phases ("PRE", "T0," and "T1") is depicted by the red circle in **Figure 1**.

After sampling, TSA plates were incubated at 37°C for 48 hours, with an initial reading after 24 hours. Colonies, if present, were counted after 24 hours of incubation and marked on the back of the Petri dish with a marker to facilitate enumeration if colonies formed an uncountable layer. The colony count included all colonies grown on the plate, and the TBL concentration was expressed as the number of colony-forming units per 24 cm^2 (CFU/24 cm^2).

For the sampling of multi-drug resistant pathogens, sterile swabs (APTACA SpA) were used. The swab was streaked during the three sampling phases ("PRE", "T0," and "T1"), as described in **Figure 1**.

After sampling, the swab was immersed in Tryptic Soy Broth (TSB) for 48 hours at 37°C. The presence of growth was assessed by the turbidity of the culture medium. Subsequently, positive samples (indicating growth) were inoculated onto selective plates for the detection of:

1. Methicillin-Resistant *Staphylococcus aureus* (MRSA) - CHROMID MRSA SMART by BIOMERIEUX ITALIA SpA;
2. Vancomycin-Resistant *Enterococci* (VRE) - CHROMID VRE by BIOMERIEUX ITALIA SpA;
3. Carbapenem-Resistant *Enterobacteriaceae* (CRE) - CHROMID CARBA BIOMERIEUX ITALIA SpA;
4. Extended-Spectrum Beta-Lactamase (ESBL)-Producing (ESBL) - CHROMID ESBL BIOMERIEUX ITALIA SpA.

After sampling, MRSA and CRE plates were incubated at 37°C for 24 hours, while VRE and ESBL plates were incubated at 37°C for 48 hours. The grown colonies were identified using the Vitek 2 compact system by BIOMERIEUX ITALIA SpA.

All samples were stored at the Hospital Hygiene Unit.

Ethical Board approval

Personal data of enrolled subjects were processed according to Italian law, in compliance with Legislative Decree 196/03 and all other relevant regulations. All data was exported in a pseudo-anonymised form for statistical analysis. The study received approval from the Local Ethics Committee (Comitato Etico Territoriale Lazio Area 3) with ID 6015.

Statistical analysis

The participants, research staff, and physicians were informed of the study group assignment after randomisation.

Sample size definition

For the pilot study, 71 healthcare workers from the aforementioned departments were recruited. This sample size was chosen due to the potentially high variability in the observed Total Bacterial Load. Therefore, a larger sample was deemed necessary than is typically seen in pilot studies to gather more precise and accurate measures of central tendency and dispersion[16].

Analysis

Position and dispersion statistics for the Total Bacterial Load at 3 hours post-sanitisation were calculated for each method to appropriately size a definitive trial. Inferential exploratory analyses were conducted to compare the two techniques.

Changes in the average Total Bacterial Load recorded for the two treatments at 3 hours were compared using the Wilcoxon signed-rank test, as the distribution of sample means for the variables considered was non-normal.

Exploratory analyses included calculating changes in Total Bacterial Load between the “PRE” (pre-sanitisation) and “T1” (3 hours) times and the “T0” (post-sanitisation) and “T1” times using the Mann-Whitney U test. Descriptively, the prevalence of multi-drug resistant pathogens (MRSA, ESBL, CRE, VRE) on smartphones at “PRE”, “T0”, and “T1” times was reported for each method.

Significance was considered for p-values < 0.05.

Statistical analyses were conducted using STATA 18 (StataCorp, USA).

Sample size calculation for sizing the subsequent trial was performed using the two-sided Mann-Whitney U test with Monte Carlo simulations with PASS 2021 software.

Results

The sampling involved 71 healthcare workers (median age 35 years; IQR 29 - 44) distributed similarly among the Neonatal Intensive Care, Geriatrics, and Intensive Care departments. Most participants were nurses (62%), followed by physicians (21%), and medical residents (approximately 17%). No statistically significant differences were observed in the considered variables between the two treatment arms (**Table I**).

[Insert Table I]

The total bacterial load was nearly eradicated following the use of wipes (median 1; IQR (0 - 5)) and UVC boxes (median 0.5; IQR (0 - 2)), increasing again after 3 hours post-sanitisation to a level not significantly different from the pre-sanitisation for both methods (**Table II**). Specifically, three hours after sanitisation, the total bacterial load values on smartphone surfaces treated with UVC boxes (median 22.5; IQR (10 - 37)) were higher than the values on smartphones sanitised with alcohol-impregnated wipes (median 10; IQR (4 - 23)). This indicates a greater residual effectiveness of the disinfectant in wipes, albeit at the threshold of statistical significance (p=0.056) (**Tables II-III**).

[Insert Table II]

[Insert Table III]

Methicillin-resistant *Staphylococcus aureus* was isolated from a healthcare worker's smartphone before sanitisation with wipes; the same device tested negative immediately after sanitisation and again positive for the same pathogen after 3 hours. Methicillin-resistant

279 *Staphylococcus haemolyticus* was isolated from another healthcare worker's smartphone 3
280 hours after sanitisation with wipes, while the two previous samplings showed no contamination.
281 Based on the estimates obtained, to adequately size a trial for assessing the residual efficacy of
282 alcohol-impregnated wipes compared to UVC boxes at 3 hours post-sanitisation, 503 operators
283 per treatment group are required. These dimensions would achieve an 80% power to detect an
284 average difference of 4.5 (standard deviations assumed in the two groups: 30 and 18 as per
285 preliminary data) using a Mann-Whitney U test with a significance level (alpha) of 0.05. These
286 results are based on 2000 Monte Carlo samples from the normal distribution.
287
288

Discussion

The primary aim of this pilot study was to collect data on the total bacterial load on the screens of healthcare workers' smartphones three hours after two different sanitation interventions to determine an appropriate sample size for a future and more extensive experimental investigation on this topic in a hospital setting. The results revealed, for both sanitation methods employed, a similar reduction in bacterial load values immediately after sanitation ("T0"). However, a higher residual effect, approaching statistical significance, was observed on surfaces treated with wipes impregnated with 70% isopropyl alcohol 3 hours after sanitation ("T1"). Several examples in the literature highlight the effectiveness of both methods in sanitising smartphones [5,7,10,11,13,17,18].

One of the earliest notable studies in this field was conducted in 2010 at the Manipal College of Dental Sciences in India [18]. The authors examined the effectiveness of wipes impregnated with 70% isopropyl alcohol on 50 mobile devices, observing a statistically significant reduction in Colony Forming Units (CFU) compared to unsanitised devices, with an approximately 87% reduction in total bacterial load immediately after disinfection. Another study conducted in Germany by Egert *et al.* [5] demonstrated an equally significant reduction in CFU by sanitising smartphones using wipes containing ethanol and isopropyl alcohol, resulting in a bacterial load decrease close to 95% immediately after cleaning. Scientific evidence has also emphasised the need to wipe at least 3-5 times for proper decontamination [19].

Regarding the disinfection process using UVC irradiation, the results obtained in the short report published by Muzslay *et al*. [11] in 2018 represent the initial data on the use of this device. The study employed the D6000TM device, allowing decontamination on both sides of tablets and reducing the bacterial count to below the detection limit within a few minutes of disinfection.

Literature evidence diverges on which of the two methods is more effective.

In a cross-sectional study conducted in an Indian dental clinic[9] the two different sanitisation methods used in our study were simultaneously evaluated on a sample of 30 smartphones, resulting in an immediate reduction in bacterial contamination on the analyzed surfaces of 79.89% for isopropyl alcohol and 71.00% for UVC irradiation with no significant differences (p=0.884). Similar results were also obtained by Huffman *et al*.[17] , who compared the use of alcohol or hydrogen peroxide wipes with UVC irradiation and found that disinfection twice a day with UVC was not superior to that performed with wipes. A study by Lieberman *et al*. [13], however, showed a significantly greater reduction percentage for UVC irradiation. Nevertheless, in this study the comparison was made with two sprays of 70% ethanol subsequently rubbed on both sides of the smartphone with clean absorbent paper.

As expected, an increase in bacterial count was observed in both groups 3 hours after sanitisation, and this increase was statistically significant compared to the value recorded immediately after sanitisation. Additionally, a difference in mid-term efficacy (3 hours) between the two methods was detected, bordering statistical significance in favor of wipes impregnated with isopropyl alcohol.

This occurrence can be explained by referring to the residual disinfectant effect of alcohol. Indeed, as highlighted in the literature, wipes impregnated with 70% isopropyl alcohol and 2% chlorhexidine have shown a residual antimicrobial effect up to 6 hours after disinfection when these experiments are conducted in the laboratory with artificial contaminations. In clinical practice, however, repeated and continuous device contaminations may occur, reducing the observed residual effect duration [10]. In contrast, it is known that UVC irradiation does not possess a residual effect (27,28). Additionally, UVC rays penetrate poorly into cracks or crevices in smartphone cases, increasing the risk of post-sanitisation cross-contamination [7,17].

Regardless, the use of 70% isopropyl alcohol-impregnated wipes is more intuitive and practical than UVC boxes, making it easier to use them repeatedly throughout the work shift.

In addition to cell phone screens, there are numerous other high-touch surfaces in the hospital environment that contribute to defining a cumulative bacterial load: multiple devices with diagnostic function monitors that involve constant interaction with the hands of health care workers (e.g., at intensive care units, in operating rooms). It is important for the manufacturer to place clear guidelines on how to sanitize these devices.

The results obtained from this study allow for several considerations.

It is widely known that smartphones in hospital settings act as potential carriers for healthcare-associated infections [20], posing a significant risk, especially for immunocompromised individuals. Concurrently, the increasingly widespread integration of smartphones and tablets into clinical practice is an established phenomenon and, as highlighted in this real-world study, contamination from these devices is associated with work activity (e.g. contact with patients, environmental surfaces, uniform pockets, and hands).

Nevertheless, few facilities have adopted specific procedures for their proper sanitisation. This scenario emphasises the need, at a macro level, for interventions by policymakers and health authorities aimed at issuing guidelines and specific directives. Such regulation would be focused on ensuring the correct and safe use of these devices, now essential in daily work life, with a view to effectively controlling infections.

At a meso level, promoting the implementation of specific continuous training programmes on this topic is recommended within healthcare management, targeting healthcare professionals. Results from a survey conducted in an intensive care unit at a South African hospital [21] indicate that lack of awareness, absence of specific procedures, and fear of damaging one's smartphone during disinfection are the main barriers reported by healthcare professionals on

this topic. These efforts should be accompanied by initiatives aimed at increasing adherence to hand hygiene practices and environmental disinfection procedures.

At a micro level, raising awareness among healthcare professionals about sanitisation methods is of crucial importance. This awareness not only aims to promote good practices in infection prevention but also acts as a catalyst to positively influence patient education. This provides healthcare professionals with additional tools to prevent the spread of infections, placing them in an essential role that significantly contributes to public health protection.

The results should be interpreted in light of the assessments of the strengths and weaknesses of the study. An intrinsic limitation lies in the evaluation and comparison of only two disinfection methods, although these represent the most effective modalities according to the literature. However, to our knowledge, this pilot study, despite being preliminary, is the first to provide data on the variation of bacterial load over time using a real-world approach instead of employing controlled inoculation. Moreover, this study managed the potential confounding effect of some environmental, organisational, and behavioral variables, thanks to the use of block randomisation with stratification by sampling department. Another critical aspect could be the decision to sample different areas of the front part (screen) of smartphones in the three study phases ("PRE", "T0," and "T1"). This choice is related to the need to perform the maximum number of samplings on the same surface without the previous samplings affecting the subsequent ones through mechanical removal of any pathogens present by placing the plate on the surface itself. However, it is important to emphasise that all procedures were performed by the same prevention and laboratory technicians, thus reducing variability in behaviors during sample collection or laboratory material preparation.

Further studies are essential to determine the most appropriate sanitisation time interval for both methodologies as well as to investigate long term contamination, taking into account the

behavior of healthcare workers during their work shift. In addition, it is necessary to quantify the risk of transmission not only of already known multidrug-resistant bacteria and fungi but also of new emerging species (e.g., *Candida Auris*), examining the direct connection with the incidence of nosocomial infections.

Conclusion

Currently, universally accepted guidelines are lacking to limit and control the contamination of mobile devices in healthcare. However, our pilot study has highlighted that the use of wipes containing 70% isopropyl alcohol appears to be a more effective method than UVC boxes for short-term disinfection of smartphones, albeit at the limits of statistical significance. These results provide a preliminary foundation for determining an appropriate sample size, a prerequisite for conducting a larger study useful in establishing optimal times for proper and safe disinfection.

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Conflicts of interest

None

Ethics

None

Funding statement

None

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	Tot	Wipes N=37	UVC box N=34	p-value
Age (median; IQR)	35 (29 - 44)	35 (29 - 43)	37 (30 - 45)	0.316
Gender (N, %)				0.209
M	26 (36.62)	11 (40.74)	16 (59.26)	
F	45 (63.38)	26 (57.78)	19 (42.22)	
Profession (N, %)				0.638
Physician	15 (21.13)	9 (60.00)	6 (40.00)	
Nurse/Physiotherapist	44 (61.97)	23 (51.11)	22 (48.89)	
Medical resident	12 (16.90)	5 (41.67)	7 (58.33)	
Department (N, %)				1.000
Neonatal Intensive Care Unit	23 (32.39)	12 (52.17)	11 (47.83)	
Geriatrics	23 (32.39)	12 (50.00)	12 (50.00)	
Intensive Care Unit	25 (35.21)	13 (52.00)	12 (48.00)	

Table I. Socio-demographic variables related to the enrolled and randomised healthcare workers in the two treatment arms.

	WIPES Total Bacterial Load (median; IQR)	UVC BOX Total Bacterial Load (median; IQR)	p-value
PRE	12 (4 - 30)	11 (5 - 27)	0.791
T0	1 (0 - 5)	0.5 (0 - 2)	0.201
T1	10 (4 - 23)	22.5 (10 - 37)	0.056

Table II. Median Total Bacterial Load and its correspondent measure of dispersion for the two considered methods at each sampling time.

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	WIPES Variation in Total Bacterial Load (median; IQR)	p-value	UVC BOX Variation in Total Bacterial Load (median; IQR)	p-value
PRE-T0	9 (3 - 24)	<0.001	9 (4 - 26)	<0.001
T1-T0	5 (2 -23)	<0.001	19.5 (8 - 36)	<0.001
T1-PRE	-1 (-20 - 7)	0.424	6 (-10 - 26)	0.274

532 **Table III**. Variation in Total Bacterial Load between the sampling moments for the two
533 methods.

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545 **Figure 1:** sampling of the screen and back surface of smartphones using TSA plates and
546 swabbing before sanitization, immediately after sanitization, and 3 hours after sanitization.

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Fig. 1: sampling of the screen and back surface of smartphones using TSA plates and swabbing before sanitization, immediately after sanitization, and 3 hours after sanitization.