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ORIGINAL ARTICLE

Biofilm on smartphones of healthcare professionals: pattern of device use and decontamination*

Biofilme em smartphones de profissionais da saúde: padrão de uso e de descontaminação do aparelho

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ABSTRACT

Objective: to evaluate the presence of biofilm on the protective glass films of smartphones of health professionals, to investigate the pattern of use and decontamination of smartphones in the health care environment of a medium-sized hospital. **Methods:** analytical and cross-sectional study, carried out with health professionals with smartphones. Structured interviews were carried out and the presence of biofilm on the protective glass films of smartphones was evaluated by scanning electron microscopy. **Results:** all film samples were positive for the presence of biofilm, even after decontamination with alcohol 70%. 96.4% of the participants used a smartphone in the work environment, most used the device for personal purposes and decontaminated it with alcohol 70% with irregular frequency. **Conclusion(s):** the smartphones can serve as a fomite, considering that biofilms were detected on the surface of the films. These findings point to the need for infection control policies related to the use of smartphones.

Descriptors: Smartphone; Health Personnel; Biofilms; Equipment Contamination; Decontamination; Infection Control.

RESUMO

Objetivo: avaliar a presença de biofilme nas películas de *smartphones* de profissionais da saúde, investigar o padrão de uso e de descontaminação dos *smartphones* no ambiente de assistência à saúde em um hospital de médio porte. **Métodos:** estudo analítico e transversal, realizado com profissionais de saúde que possuíam *smartphone*. Foram realizadas entrevistas estruturadas e a presença de biofilme nas películas de vidro dos *smartphones* foi avaliada pela microscopia eletrônica de varredura. **Resultados:** todas as amostras de películas foram positivas para presença de biofilme, mesmo após descontaminação com álcool a 70%. Dos participantes, 96,4% utilizavam *smartphone* no ambiente de trabalho, a maioria utilizava o aparelho para fins pessoais e descontaminavam com álcool a 70% com frequência irregular. **Conclusões:** o *smartphone* pode servir como fômite, visto que biofilmes foram detectados na superfície das películas. Esses achados apontam para a necessidade de políticas de controle de infecção relacionadas ao uso dos smartphones.

Descritores: Smartphone; Pessoal de Saúde; Biofilmes; Contaminação de Equipamentos; Descontaminação; Controle de Infecções.

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INTRODUCTION

In the health care settings, smartphones have become an object always used by professionals to facilitate communication between the team and also due to their intrinsic functions, such as calculators, flashlights, and applications developed for health care purposes[1-2]. Studies in different countries have characterized the pattern of use of these devices by professionals in health units[2-4]. In the United States of America (USA), studies showed that the majority of medical professionals (56%), from 27 specialties that are members of the Accreditation Council for Graduate Medical Education[2], and nurses (92.7%) of intensive care units[1] reported that they used smartphones during their clinical practice.

In addition to the use directly related to health care, sometimes health professionals also make use of smartphones for personal purposes in health facilities. For example, to send emails, personal text messages, read the news, access social networks, make purchases and play games during work[5].

Despite the potential benefits arising from the use of smartphones in health care settings, they can act as fomites, reservoirs of microorganisms[6]. A condition aggravated by the low adherence of professionals to Hand Hygiene (HH)[7] and by repeated touches on the screen, which favors the cross-transmission of microorganisms from the device to the hands and vice versa. Genetically identical multidrug-resistant bacteria were isolated from the hands, nostrils and devices of health professionals[8-9], which have a higher microbial load compared to that found in devices used outside health services[6].

Several studies using different methods have identified the presence of planktonic bacteria in smartphones[10-11], however, the presence of biofilm on the surface of these devices has not yet been investigated. Biofilms consist of an aggregation of sessile cells, irreversibly adhered to a substrate, to an interface or to each other, surrounded by a matrix of extracellular polymeric substances (EPS) produced by them, and which exhibit phenotypic and genotypic alterations[12]. Biofilms have been identified on several products and devices for health care[12] and on other surfaces in health service environments, which are highly touched[13]. In addition to the lack of studies to characterize the pattern of use and decontamination of smartphones by health professionals in Brazil and the need to know if the microorganisms present on the surface of smartphones are present in the form of biofilm, as this conformation increases the tolerance of bacteria to antimicrobials, thus making adequate disinfection difficult, The objectives of this study were to evaluate the presence of biofilm on the protective glass films of smartphones of health professionals, and to investigate the pattern of use and decontamination of smartphones in the health care environment of a medium-sized hospital.

METHOD

This is a cross-sectional descriptive and analytical-experimental study. It was performed in a medium-sized hospital located in the Midwest region of Brazil. The experimental part was carried out at the Multiuser Laboratory of High Resolution Microscopy (Portuguese acronym LABMIC), at the Federal University of Goiás, municipality of Goiânia, Goiás, Brazil.

Data collection took place between August and December, 2019. Health Workers (HW) working during the day in the hospital's inpatient units participated in the study. Professionals from the ward sector, adult and pediatric Intensive Care Unit (ICU) and emergency sector were invited to participate. The sample was defined by convenience, including those who had a smartphone and were working during the data collection period.

An interview script was prepared based on international evidence that addresses the assessment of the pattern of smartphone use by health professionals[1-3]. Which underwent evaluation by three experts in infection control, followed by a pilot test with HW from another hospital, which proved to be adequate to reach the objectives of the study. The script contained sociodemographic characteristics, and characteristics related to the pattern of smartphone use and decontamination.

The smartphone use pattern was defined by the following variables: the time of use of the device, if it has a protective glass film, type of film, the time of use in the health service, the purpose of use (focused on health care and/or personal use), the storage location during the working day, the functions or applications used in care and for personal purposes, and whether HH is performed before and/or after use of the device in the health service. The decontamination pattern was verified by the following variables: the decontamination performance, the method used, and the frequency. It was also asked if, at any time, there was contamination of the device with biological material, the type of material and the post-contamination conduct.

Two researchers were trained to apply the interviews and were available at the Unit during the day. The HW were invited to participate in the study during the development of their work activities, and if they agreed, they determined the best time for the interview. The interview was carried out in a place indicated by the sector's management, maintaining the privacy of the interviewees.

For HW who had smartphones with a protective glass film, and in use for a period equal to or greater than 30 days, the donation of the glass film was requested and they were reimbursed with a new film. The glass film was chosen because the composition of the touch screens of smartphones are formed by similar material and has been the most used as a protector of smartphones. After applying these criteria, 13 films were obtained, a number similar to those obtained in other biofilm analyses from other highly touched surfaces[13].

The HW removed the glass film from their device and placed it in a sterile surgical-grade paper package provided by the researcher. After packaging the film, the package was immediately sealed, coded, and sent for sample preparation.

The films were cut in half, vertically, with a diamond glass cutter (Western®, China), previously decontaminated. From the left part of the glass films, a fragment of approximately 1.5 x 1.5 cm was sectioned. The right part underwent a decontamination process, with a sterile hydrophilic gauze pad, moistened with 1.5 mL of alcohol 70% (performing unidirectional friction three times, simulating the usual decontamination process performed by most professionals). The fragments, with and without decontamination with alcohol 70%, were removed from the lower half of the glass films, as they are considered the place where they receive the greatest number of touches (Figure 1).

The collected fragments were placed in a sterilized plastic container, identified and sent to the Multiuser Laboratory of High-Resolution Microscopy (Portuguese acronym LABMIC), of the Federal University of Goiás. New glass films (n = 6) were used as controls and underwent the same procedures described for samples from professionals. Figure 2 shows the film preparation procedures.

The film fragments were subjected to the process of microbiological inactivation and fixation by immersion in a 2.5% glutaraldehyde solution overnight. The following

Figure 1. Demonstration of the sections performed on the glass films

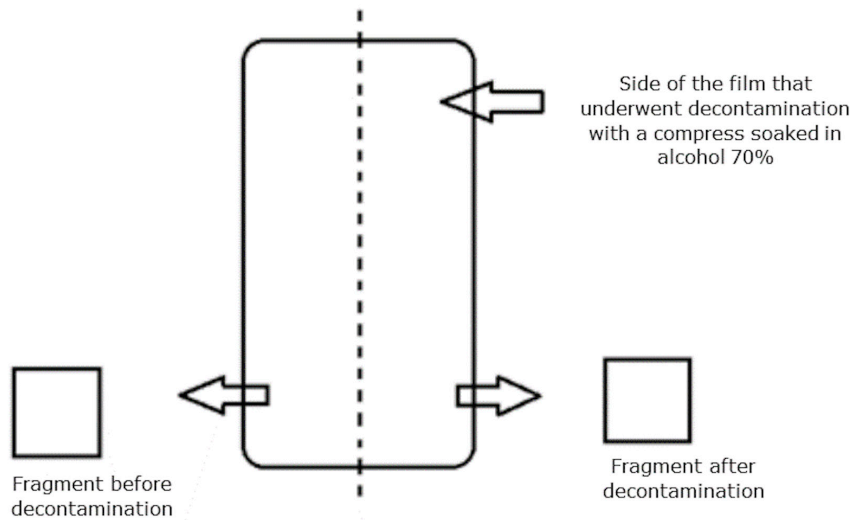


Figure 2. Sample cutting and storage procedures

Legend: Glass film provided by a health professional (A). Diamond glass cutter used to cut the films (B). Researcher cutting the film (C). Plastic container with packaged and identified film fragments (D).

morning, the 2.5% glutaraldehyde solution was removed and its residues removed by immersion in a 0.1 M phosphate buffer solution at pH 7.2, in three consecutive series of 10 minutes duration each. Subsequently, the samples were dehydrated in a gradual series of ethanol for five minutes of immersion each. Finally, they were immersed once in hexamethyldisilazane (HMDS) for six minutes to remove ethyl residues and promote complete drying. Subsequently, they were placed in metallic stubs and underwent a metallization process with conductive material (gold).

The samples were analyzed in a high-resolution electron microscope, the Jeol JSM 7100F (JEOL®, USA) with electron acceleration voltage between 5 kV to 10 Kv, in the Secondary Electron Detector (SED) mode to obtain the images. The samples were analyzed at magnifications ranging from 100 to 10,000 times and the fragments were scanned starting from the center and subdividing into four regions, performing the necessary magnifications at each point.

Data regarding the use and decontamination pattern of smartphones were included in an electronic spreadsheet and analyzed using the International Business Machines-IBM SPSS® statistical package, version 23.0. The images obtained by the Scanning Electron Microscopy (SEM) were qualitatively analyzed for the presence or absence of biofilm, and the surfaces with bacteria adhered and surrounded by an EPS matrix were classified as positive[14].

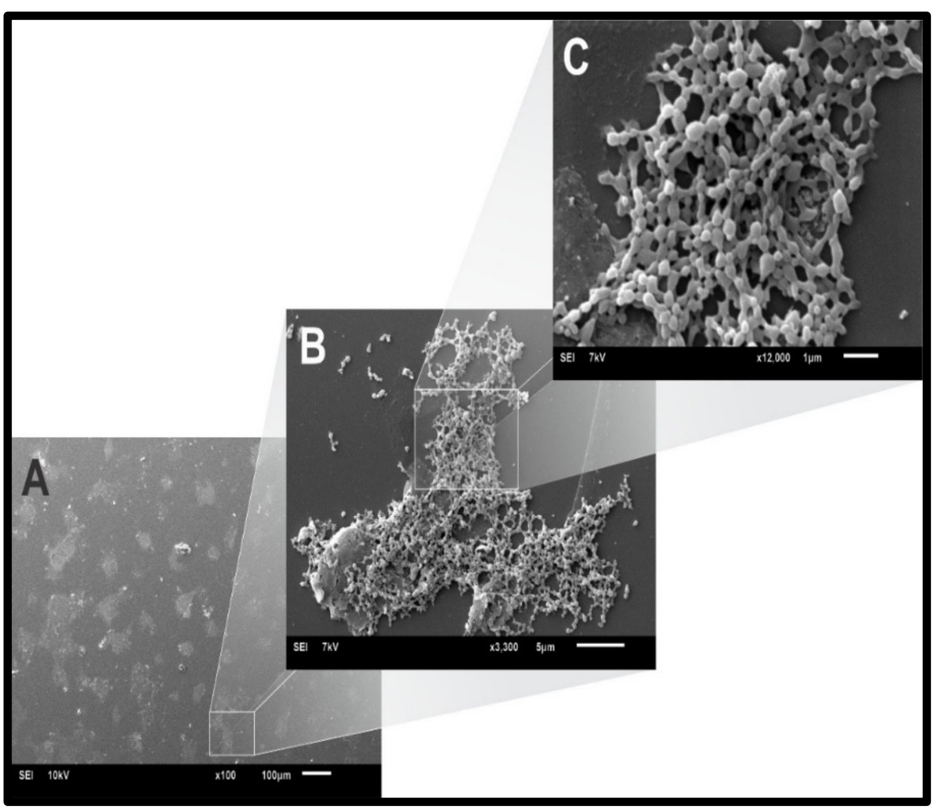
All ethical aspects regarding research with human beings were carefully observed in this study, according to resolution 466/2012. The Research Ethics Committee of the Federal University of Goiás (CAAE 11163219.0.0000.5083) approved the study protocol. All HW who were invited to participate in the study received information about its objectives and those who agreed to participate signed the Free and Informed Consent Form (FICF).

RESULTS

Thirteen films were analyzed in the study, with usage time from one to 48 months, totaling 26 fragments evaluated by SEM. Initially, the sample was analyzed at a magnification of 100X, in which it was possible to observe the biofilms diffusely distributed over the sample. By enlarging the image, it was possible to visualize the multilayered biofilm structures in all analyzed samples (Figure 3).

The fragments from the part decontaminated in the laboratory with friction with alcohol 70%, simulating the

Figure 3. Evidence of the presence of biofilm on the protective films of smartphones of health professionals



Legend: Representative Scanning Electron Microscopy (SEM) images of the 13 glass films donated by healthcare professionals, demonstrating the magnification process at each analysis point. A - The diffuse presence of biofilm on the surface of the film is observed. B and C - Increases of the same point of analysis, evidencing the presence of biofilm in multilayers.

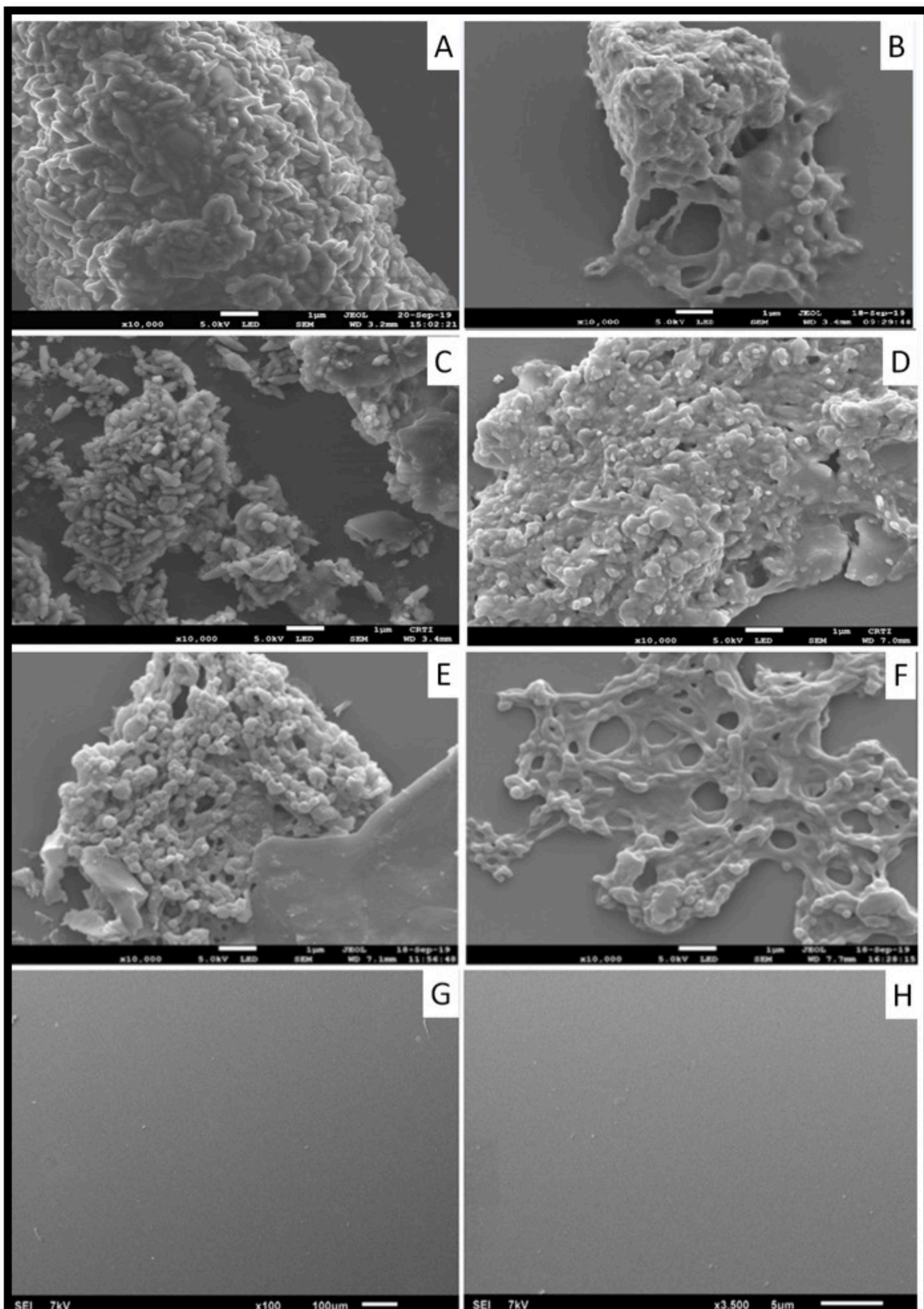
decontamination mode reported by the participants, showed biofilm in all analyzed samples, in the same pattern as the non-decontaminated ones, as can be seen in Figure 4.

In the analysis of the pattern of use and decontamination, 84 HW of different categories participated in the study, most of them from the nursing team (60.7%) and females (83.3%) (Table 1).

It was found that 81 (96.4%) HW used the device at work and 58 (69.1%), who used the device for between one and five years (Table 2). Table 2 demonstrates the pattern of smartphone use by HW.

For assistance in health care, the HW mentioned the use of different functions of the device. They highlighted the use of the calculator (n = 26 / 53.3%), the flashlight (n = 20 /

Figure 4. Evidence of the presence of biofilm on the protective films of smartphones of healthcare professionals with and without decontamination with alcohol 70%



Legend: A, B, C, and D: Fragments of protective films of smartphones without disinfection; E and F: fragments of protective films of smartphones submitted to laboratory decontamination with alcohol 70%; G and H: fragments of control samples (new and unused screen protector)..

Table 1. Sociodemographic characteristics of health workers (N = 84) who used smartphones during the development of their work activities in a hospital in the Brazilian Midwest, Goiás, Brazil, 2019

Sociodemographic characteristics	n	%
Gender		
Female	70	83.3
Male	14	16.7
Age		
22 to 30 years	23	27.4
31 to 40 years	29	34.5
41 to 50 years	19	22.6
> 50 year	13	15.5
Profession		
Nurse	27	32.1
Nursing technician or assistant	24	28.6
Doctor	11	13.1
Resident (nursing or medicine)	6	7.1
Psychologist	5	5.9
Physiotherapist	3	3.6
Pharmacist	2	2.4
Nutritionist	2	2.4
Social worker	1	1.2
Biomedical	1	1.2
Pharmacy technician	1	1.2
Phonoaudiologist	1	1.2
Time working in the institution		
1 to 12 months	32	38.1
> 1 year	30	35.7
> 5 years	12	14.3
> 10 years	10	11.9
Work shift		
12-hour day shift	48	57.1
Morning	22	26.2
Afternoon	14	16.7
Works at another health institution		
No	47	55.9
Yes	37	44.1

42.6%), the WhatsApp® application (n = 14 / 29.8%) and Google search® (n = 13 / 27.7%). For personal purposes, the main functions used in the work environment were making phone calls (n = 7 / 12.3%), using the WhatsApp® application (n = 43 / 75.4%), the Instagram® application (n = 14 / 24.6%)

Table 2. Smartphone use pattern by health workers (N = 84) in a hospital in the Brazilian Midwest, Goiás, Brazil, 2019

Use pattern	n	%
Smartphone usage time		
< 12 months	18	21.4
1 to 5 years	58	69.1
> 5 years	8	9.5
Has protective film		
Yes	66	78.6
No	18	21.4
Type of protective film		
Glass	57	86.4
Gel	7	10.6
Plastic	2	3.0
Protective film usage time		
< 1 month	16	24.3
1 to 6 months	19	28.7
7 to 11 months	16	24.3
> 12 months	15	22.7
Use of smartphone at work		
Yes	81	96.4
No	3	3.6
Estimated hours of daily use		
< 1 hour	3	3.7
1 to 2 hours	11	13.6
> 2 to 3 hours	16	19.7
> 3 to 4 hours	14	17.3
> 4 hours	37	45.7
Smartphone storage place during work shift		
Coat/unisex	53	63.1
Pants/skirt pocket	18	21.4
Bag	8	9.5
Cabinet	4	4.8
Bench	1	1.2
Use for the purpose of assistance		
Yes	40	47.6
Yes. most of the time	1	1.2
Yes. minority of the time	6	7.2
No	37	44.0
Use for personal purposes		
Yes	50	59.5
Yes. most of the time	4	4.8
Yes. minority of the time	3	3.6
No	27	32.1

and the Facebook® application (n = 8 / 14.0%), in addition to using them to accompany soap operas, movies, and cooking recipes (n = 1 / 1.8% each).

Regarding HH, it was found that 46 (54.8%) and 37 (44.0%) of the participants mentioned performing the procedure before and after using the device, respectively, mainly with soap and water (n = 54 / 64.3%). Most claimed to perform smartphone decontamination (n = 76 / 90.5%), predominantly with alcohol 70% (n = 64/76.2%), with decontamination frequency ranging from daily to monthly (n = 36 / 42.9% and n = 3 /3.6%, respectively).

Two participants (2.4%) mentioned contamination of the smartphone with saliva during care, both used alcohol 70% in decontamination after exposure.

DISCUSSION

Most participants in this study were female (n = 70 / 83.3%) aged between 31 and 40 years (n = 48 / 57.1%) and from the nursing team (n = 51 / 60.7 %). Thus, confirming a greater presence of women and the nursing team in health care settings, as shown in other studies of the same nature[4,11].

The widespread use of smartphones in the health care setting was evidenced in this study, reinforcing the evidence of the use of these devices during work activities by health professionals from different categories and health units reported in other studies[1-4,6]. The predominant time of daily use was greater than four hours (45.7%), similar to the time of use in a neonatal intensive care unit[14].

Health workers (47.1%) stated the use of functions inherent to smartphones for clinical care purposes, such as the use of a calculator, flashlight and stopwatch. Functions also reported by most nurses who worked in intensive care units[1]. The calculator is often used to determine body mass index, fluid balance and adjust medication doses, and the flashlight in physical examination, for pupillary reflex and examination of the oral cavity. However, these functions are easily replaced by exclusive devices for the purpose they are intended for, restricted to the hospital environment and subject to cleaning and decontamination.

Some applications were listed to aid in health care, highlighting the use of WhatsApp®, Google®, WhiteBook®, CID 10 and Sanford®. Except for WhatsApp® and Google®, the applications mentioned by the participants in this study are mostly intended for the medical team, however there are applications aimed at the nursing team[15]. However, in the scenario studied, the nursing team, which was the biggest smartphone user, reported little about specific applications for clinical purposes.

Despite the recognized benefits of using the smartphone in health care, it can cause distractions and consequently errors[16], especially when used for personal purposes[6], which was the purpose predominantly reported by the participants of this study. Personal purposes were also identified as more prevalent use among Italian health professionals in health care settings[15].

The use of smartphones for personal purposes or to help with health care may be driven by the fact that the device is available and always "at hand", as 84.5% of workers stated to keep it close to their body (in coats and clothing pockets). This practice can increase the risk of contamination of smartphones, as the device receives a greater number of touches, and coats can also be contaminated, including resistant bacteria[17].

Despite being an object of personal use, intrinsic functions or applications aimed at health care make smartphones also a device for use in health services. Although there is no evidence of association between smartphone use and Healthcare-Associated Infections (HAI) rates, it is known that smartphones are reservoirs of microorganisms[10-11]; therefore, this association is possible. Its decontamination process is carried out by the owner and, in theory, would not be the responsibility of the institution, premise that opposes the responsibility for the prevention and control of HAI that belongs to the health institution. In this way, a shared responsibility is assumed in the standardization and compliance of smartphone decontamination measures. In this sense, it is necessary to point out that in the absence of effective decontamination measures, these devices can spread the biological risk to the workers' families. In addition, it can favor the transmission of infectious microorganisms between different institutions, as dual employment is common among health workers.

Most participants in this study (90.5%) stated that they decontaminated smartphones using alcohol 70% (of which 84.2% used liquid alcohol and 11.8% gel alcohol). However, most do not have a decontamination routine, ranging from daily to monthly. This data, added to other studies, demonstrate a great variation in the frequency of decontamination[6,14], presenting a gap regarding the adequate frequency and the best method for these devices. The contamination of the smartphone with biological material, such as the patient's saliva, was reported by two participants (2.4%) and the procedure adopted was decontamination with alcohol 70%. This demonstrates that in addition to the usual contamination by the device owner's touches, it can be contaminated with biological material directly from the patient during clinical use of the smartphone.

Decontamination by means of ultraviolet light (*CleanSlate®* UV), in 30-second cycles, was investigated in devices previously contaminated by bacteria and fungi. No viable bacteria were recovered after the process. When tested on devices used in clinical practice by health professionals, there was a statistically significant reduction in the number of devices contaminated by bacteria immediately before (19.76%) and after (4.65%) the application of ultraviolet light (p = 0.002). The authors point out the use of this decontamination method as more effective than the practices usually adopted for this purpose[18]. However, there is a lack of studies evaluating the effectiveness of approved germicides for decontamination of other surfaces in the health environment, as well as a sanitary regulation in this regard in Brazil.

Another aspect that deserves attention is that for decontaminating a Health Product, cleaning is recommended prior to the use of alcohol. This is because the subsequent use favors bacterial adherence through the fixation of proteins, and reduces the effectiveness of the product, contributing to the formation of biofilm[19]. The participants did not mention this conduct, but it may have contributed to the findings of this study of biofilm formation in all the glass films analyzed, regardless of the frequency and decontamination practices adopted. It is worth noting that this way of life offers greater resistance to antimicrobials, antiseptics and sanitizing agents, making it more difficult to decontaminate the device[20]. The present study is a pioneer in the identification of biofilm in protective glass films of smartphones, therefore, this possibility is correlated with other surfaces that are highly touched in a hospital clinical environment[13].

Conventional cleaning and disinfection processes and products are ineffective in reaching the cells in biofilm, due to the protection provided by this structure[21-22]. Which may require 50 friction movements (28 g/cm^2 pressure) to remove approximately the same amount of planktonic bacteria removed in just one friction under the same condition[20]. Therefore, it is believed that in the studies that evaluated contamination of smartphones, the devices that did not have isolated vegetative microorganisms, might have biofilm on their surface and the practice of decontamination with alcohol 70% would not be effective in the already consolidated structure. The identification of biofilms on the surface of smartphones raises new barriers in the decontamination processes of these devices.

It must be considered that protective films can help reduce the transmission of microorganisms through smartphone use, because they can be replaced. The results of this study point to the need to establish the time of safe use of the same protective film with an adequate decontamination routine from the first use, avoiding the development of biofilms, issues that will be unveiled in future studies.

Low adherence referred to HH regarding the handling of smartphones in the health care environment was verified. Most of the HW (45.2%) reported not performing the HW before using the device. This habit, associated with the failure of this technique after contact with patients or after procedures that involve risk of contact with secretions[23] increases the possibility of contamination of the device and development of biofilm. The lack of HH after contact with the device (56%) increases the possibility of transmission of microorganisms present in contaminated devices[6,10-11] and even the biofilm itself, to the hands of professionals, and from them to patients[24].

The World Health Organization establishes five moments to perform HH, as a strategy to reinforce the moments when the technique is essential. Which are: 1) before contact with a patient; 2) before performing aseptic procedures; 3) after risk of exposure to body fluids; 4) after contact with a patient; and 5) after contact with the areas close to the patient[25]. However, among these moments is the use of the smartphone, triggered for actions such as using the flashlight for a clinical examination, recording an image, consulting clinical-diagnostic guides, scales or even checking notifications and personal distractions. A study on the use of smartphones in the neonatal ICU showed that all professionals in the study were aware that these devices can be reservoirs of microorganisms, but only 56% reported washing their hands after using the device[14]. The microbial diversity isolated from smartphones[10] and its wide use led to the proposition of a sixth moment to reinforce to the health professional the need for HH before and after handling the smartphone (Figure 5).

CONCLUSION

The biofilm was evidenced on protective films of smartphones that are widely used by HW, both for health care purposes and for personal purposes. The application of alcohol 70%, simulating the most common decontamination practice, did not show any action on the biofilm, indicating the need for further studies on optimal smartphone decontamination.

The results of this study suggest that usage policies, decontamination routines and replacement of protective films be developed and implemented in health institutions, to avoid the formation of bacterial biofilms in a device that is an extension of the hands of health professionals, thus reducing the possibility of HAI caused by pathogens present in these devices. In addition, the introduction of the sixth moment in the five established by the World Health Organization for the practice of HH, before and after the use of smartphone, is a strategy that can reinforce adherence to HH and promote safer use of the device in environments of health care.

Acknowledgements

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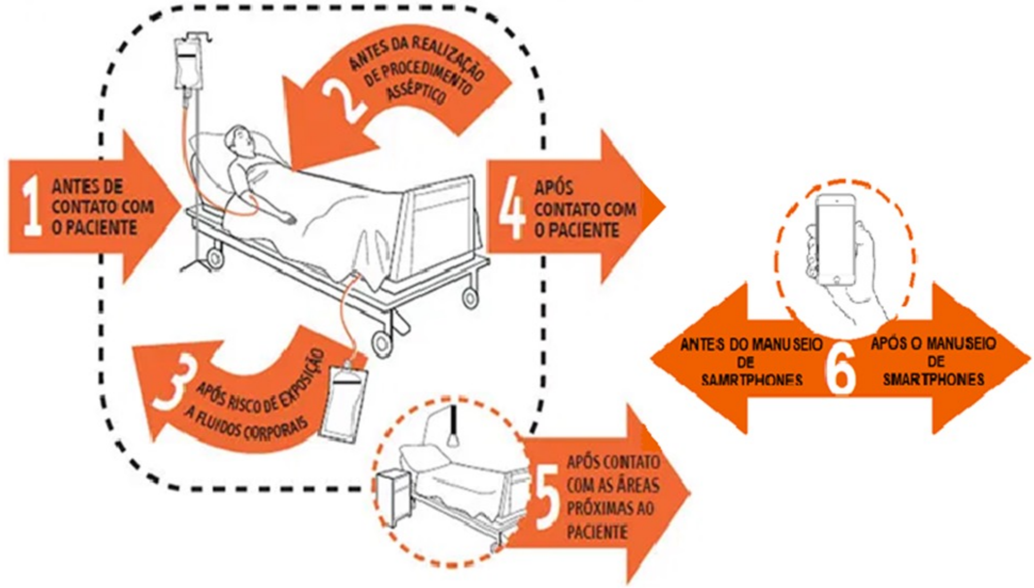
Figure 5. Demonstration of the sixth moment to alert health professionals to sanitize their hands before and after using the smartphone



Notes: 1 Before contact with a patient. 2 Before performing aseptic procedure. 3 After risk of exposure to body fluids. 4 After contact with a patient. 5 After contact with the areas close to the patient. 6 Before smartphone handing / After smartphone handing

Source: World Health Organization (2009), adapted by the authors, 2021

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