

Prevalence Of Drug-Resistant Nosocomial Pathogenic Bacterial Strains Isolated From Mobile Phones: A Cross-Sectional Study Between Microbiology Students And Other Disciplines

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The widespread use of mobile phones in daily human transactions, especially those related to the medical field, leads to the spread of microbes among different communities. The microbiology student's mobile phones could harbour various drug-resistant microbes involved in nosocomial infections to the family members. This study aimed to isolate and characterize bacteria from the mobile phones of microbiology students and other students. This cross-sectional study was performed using a random sampling technique. All data were collected using a questionnaire. Sixty samples were obtained from the surface of the mobile phones of 60 volunteers at King Saud University (KSU). Twenty-three (77%) microbiology students used their mobile phones in the toilets, compared to 23 (77%) non-microbiology students. *Staphylococcus* is the most prevalent organism followed by *Bacillus*. The isolated *S. aureus* was Ampicillin and polymyxin B resistant. It was intermediate against the tested Sulfamethoxazole and Bacitracin. *S. aureus* isolated from microbiology and non-microbiology students showed no antibiotic sensitivity changes. *S. epidermidis* showed resistance against Polymyxin B and exhibited an intermediate response against sulfamethoxazole and bacitracin. *Bacillus* sp. exhibited resistance against Erythromycin. The prevalence of bacteria was higher in microbiology students than in non-microbiology students. The mobile phones of microbiology students were contaminated with clinical pathogens. Therefore, suitable methods should be developed to prevent the outbreak of nosocomial pathogens from the laboratories.

Keywords: *Bacillus* sp; Bacteria; Drug-resistance; Mobile phone; Transmission.

Mobile phones serve as breeding grounds, making them perfect platforms for disease distribution by simple microbial dispersal in the environment, public spaces, and the workplace, or through self-inoculation through contact with one's phone and face.¹ It has been shown that healthcare personnel's cell phones can act as nosocomial infection reservoirs.² One of the most necessary

accessories for social and professional life nowadays is mobile phones (MPs). Despite their many advantages, MPs provide an excellent habitat for infectious diseases inside communities.³ During their internships at hospitals or clinical laboratories, health sciences majors' students and laboratory personnel utilize their MPs to snap images during their practices, answer calls, text messages, or

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access material from their field of expertise.⁴ Cross-contamination is more likely when MPs are used often in a variety of locations, particularly if there are no standard safety procedures or hygiene safeguards in place; should infections be found on MPs' surface, they may spread to the user's skin, other surfaces, or food, where they may thrive and multiply. Therefore, the recent research on MPs has mostly focused on nosocomial pathogen transmission and hospital-acquired illnesses.⁵⁻⁶

The use of technology in aiding students' learning has grown significantly in recent years since it appears that technology will play a major part in higher education. The utilization of technology and innovations in Education 4.0 is anticipated to offer substantial benefits to higher education establishments in Malaysia. With the advent of new technologies like paper-thin cellphones, AI, and QR codes, kids will have more time to study and develop new abilities.³ Although hand-washing helps humans lower the microbial burdens on their hands, people use their mobile phones without thinking about disinfection since they are exposed to more environmental factors.² Mobile phones frequently come into close contact with infected human body parts during phone conversations, including the hands, mouth, nose, and ears. According to a recent assessment, roughly 90.7% of Nigeria's population, or 205.4 million cellular mobile connections, were active as of early 2024.⁷ Mobile phones serve as breeding grounds, making them perfect platforms for disease spreading by simple microbial dispersal in the environment, public spaces, or the workplace, or through self-inoculation through contact with one's phone and face.²

While several microbes have been linked to mobile phone contamination, the most significant infectious agent to be isolated from mobile phones is the skin colonizer *Staphylococcus aureus* (*S. aureus*).⁸ Many previous studies have indicated that mobile phones were contaminated with *S. aureus* in healthcare workers and medical students.⁹

The number of mobile phone users in Saudi Arabia increased from 2015 to 2017. In 2015, it was estimated about 19.42 million phone users and this number increased in 2016 (20.38 million). In 2017, the number reached 21.18 million.¹⁰ In India, about 287 million people use

mobile phones and this revealed that about 85% of all telecommunication is performed using cell phones.¹¹ Healthcare workers use a mobile phone in a hospital environment under various circumstances. With all the achievements and benefits of mobile phones, it is considered a carrier of several microbes.¹² One of the studies revealed that 42% of mobile phones carried by healthcare workers and only 18% of the general public were contaminated with one or more microorganisms.¹³ Micro-flora on mobile phones of Healthcare workers may vary widely based on the exposure to the healthcare environment, and susceptibility to different antibiotics than non-healthcare workers.¹⁴ The constant handling of mobile phones by users in hospitals and microbiology laboratories makes it a hot spot for microbial healthcare-associated infection transmission. This is associated with the skin due to the moisture and optimum temperature of the human body our palms.¹⁵ These factors and the heat generated by mobile phones contribute to harboring bacteria on the device at alarming levels.¹² It was previously reported that >90% of healthcare workers' mobile phones were contaminated with microorganisms and >14% of them carried pathogenic bacteria that commonly cause nosocomial infections.¹⁶ The resistance of clinically significant bacterial pathogens to common antimicrobial therapies and the emergence of multidrug-resistant bacteria are increasing at an alarming rate, and it has become a major problem in the treatment of Gram-positive bacterial infections.¹⁷ Antimicrobial resistance in bacterial pathogens has become a worldwide challenge associated with high morbidity and mortality.¹⁸ People rarely disinfect mobile phones and remain unclean at almost all times.¹⁹ Microbiology students are working in bacteriology labs, virology labs, mycology labs, and molecular genetics labs, most of them have mobile phones while working, hence posing a serious threat to microbial contamination. The mobile phones used by microbiology students often become carriers and may serve as vectors and spread microorganisms.¹⁴ Colonized microorganisms on the devices of microbiology students may be transmitted to other family members or students, who do not have direct contact with their mobile phones, the transmitted pathogenic organisms affect the health of humans, especially immunocompromised individuals.¹⁴

The continuous handling of mobile phones by users in hospitals or microbiology laboratories by doctors, or students, makes it a critical point for the transmission of pathogenic bacteria, that colonized in the mobile phone may be transmitted to other individuals, those pathogenic organisms affect the individuals, especially immunocompromised cases and if the organisms were drug-resistant, the situation becomes more alarming as it becomes almost impossible to treat because of the limited drug options available.² There are germs on cell phones that can spread to patients and cause sepsis.²⁰ The microbiology students working in the laboratories have contact with many types of pathogenic bacteria.² The present study aimed to

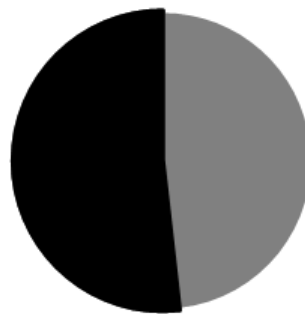
investigate the presence and the rate of antibiotic resistance of pathogenic bacteria on mobile phones that microbiology students frequently use compared to other students.

MATERIALS AND METHODS

Experimental design

This study was performed at the Department of Microbiology, King Saud University (KSU), Riyadh, Saudi Arabia. Sixty samples were collected from the mobile phones of the microbiology student volunteers (n = 30) and other department students (n = 30) based on accredited questionnaires for data collection.¹⁶ The

Determination of bacteria on the surface of mobile phones



■ Micobiology Student M ■ Other student

Fig. 1. Determination of bacteria on the surface of the mobile phones

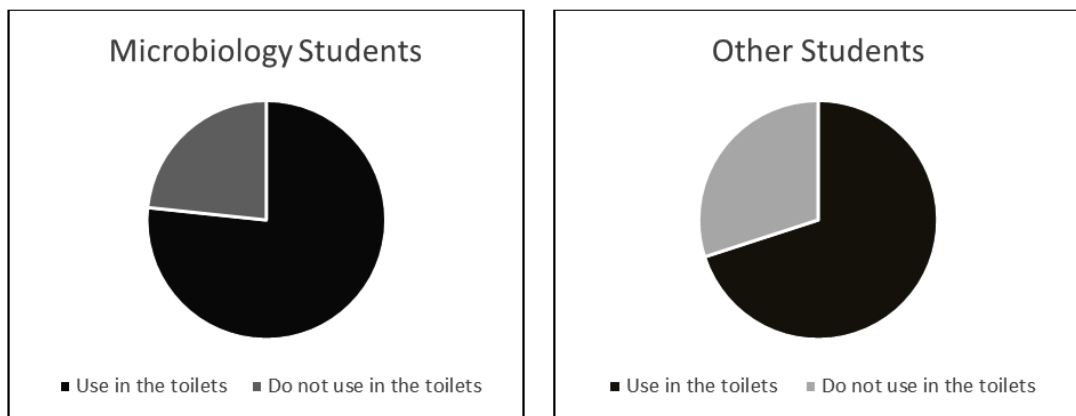


Fig. 2. Use mobile phones inside the toilet among microbiology students and others

questionnaire included variables such as the use of mobile phones in toilets, the use of disinfectants to clean the surface of the mobile phones, and the use of mobile phones in the laboratory.

Characterization of bacteria

A total of sixty sample were collected from mobile phone using sterile cotton swab with brain heart infusion broth (Thermo Fisher Scientific, USA) for 2 hours at 37°C, followed by 10-fold serial dilution on 0.9% sterile normal saline.²¹ Then 0.1mL of an appropriated dilution (10³) was inoculated into nutrient agar (Oxoid, UK) and inoculated at 37°C overnight. The pure bacterial isolates were obtained after repeated plating techniques on nutrient agar. The isolated strains were identified using colonial morphology and biochemical tests. Moreover, the identification of isolated strains was confirmed using an automated system Microscan. Two Microscan devices were used to identify bacteria. The instruments used were, “The Siemens MicroScan® Walk Away 96si” from “King Saud Chest Hospital bacteriology laboratory” and Beckman Coulter Microscan® Walk Away from King Khalid University Hospital (Model No.:3251-2654A).²²⁻²³

Antibiotic susceptibility analysis

The antibiotic susceptibility test was performed as described previously with minor modifications. An antibiotic sensitivity test was performed using multiple antibiotic discs. The bacterial suspension of each bacterium was in a concentration equivalent to McFarland 0.5 and was applied on Mueller-Hinton agar with 4% NaCl. The inhibition zone diameters were measured and interpreted according to the Clinical and Laboratory Standards Institute (CLSI). The organisms were classified as resistant (>18 mm), intermediate (d” 18 mm), and susceptible (e” 21 mm).²⁴

RESULTS

Determination of bacteria on the surface of mobile phones

Out of 60 mobile phones, bacterial growth was obtained in 56 (93%) mobile phones. In this study, 90% of mobile phone microbiology students (n=27) and 96% of students from other categories (n=29) carried microorganisms in their mobile phones. The variation between microbiology and

Table 1. Characteristics of bacterial colonies on nutrient agar medium

Sample\ characteristics	Margin	Elevation	Pigmentation	Size	Shape
25-M*	Entire	Raised	Cream	Tiny	Circular
4-M	Undulate	Flat	Cream	Large	Irregular
22-M (1)	Undulate	Flat	Cream	Large	Irregular
7-O**(1)	Filiform	Flat	Cream	Tiny	Circular
24-O	Lobate	Raised	Cream	Large	Circular
22-M	Entire	Raised	Cream	Medium	Circular
6-O	Entire	umbonate	Cream	Medium	Circular
2-O	Lobate	Raised	Cream	Medium	Circular
8-M (2)	Undulate	Flat	Cream	Large	Irregular
2-M	Entire	Raised	Cream	Medium	Circular
12-M	Entire	umbonate	Red	Medium	Circular
10-O	Undulate	Raised	Cream	Large	Irregular
17-O	Undulate	Umbonate	Yellow	Tiny	Irregular
9-M	Undulate	Flat	Cream	Large	Irregular
6-M	Entire	Umbonate	Cream	Medium	Circular
11-M	Entire	Convex	Yellow	Tiny	Circular
12-O	Entire	Convex	Yellow	Tiny	Circular
24-M	Entire	Raised	Cream	Medium	Circular
21-O	Undulate	Flat	Cream	Large	Irregular

*Microbiology students, ** Other students

Table 2. Morphological characters of the bacteria isolated from the mobile phones of microbiology and other students

Sample No.	Shape	Gram staining
2-O**	Bacilli	+***
12-O	Spirillum	+
7-M*	Bacilli	+
6-O	Grape shape like cocci in clusters	+
22-M (2)	Bacilli	+
10-O	Bacilli	+
2-M	Cocci	+
6-M	Cocci	+
3-O	Bacilli	+
24-M	Filamentous or spirillum	+
21-O	Bacilli	+
17-O	Cocci	-.****
25-M	Long bacilli in chains	+
22-M	bacilli chains	+
24-O	Bacilli	+
9-M	Bacilli	+
3-M	Grape shape like cocci in clusters	+
4-M	Bacilli	+
8-M	Bacilli	+
12-M	Tetrad	+

*Microbiology students, **Other students, ***Gram positive bacteria. **** Gram-negative bacteria.

non-microbiology students was not statistically significant ($p>0.05$) (Fig 1).

Questionnaire analysis

Sixty samples were obtained from the surface of the mobile phones of 60 volunteers at King Saud University (KSU). A total of 23 (77%) microbiology students used their mobile phones in the toilets, while 7(23%) did not use them in the toilets. About 21 (70%) non-microbiology students used their mobile phones in the toilets. About 9 (30%) microbiology students used disinfectants to clean their mobile phones regularly, while 21(70%) did not clean their mobile phones during the study period. Only 7(23%) non-microbiology students used disinfectant to clean mobile phones. In the microbiology lab, 90% ($n=27$) of the microbiology students followed standard operating procedures and did not use mobile phones and only 3 persons used mobile phones Fig 2.

Analysis of cultural characteristics of bacteria

The morphological properties of isolated drug-resistant bacteria were determined. The margin of the isolate was undulate, entire, and lobate. The elevation of the isolated colonies is depicted in (Table 1). Red and yellow pigments were observed.

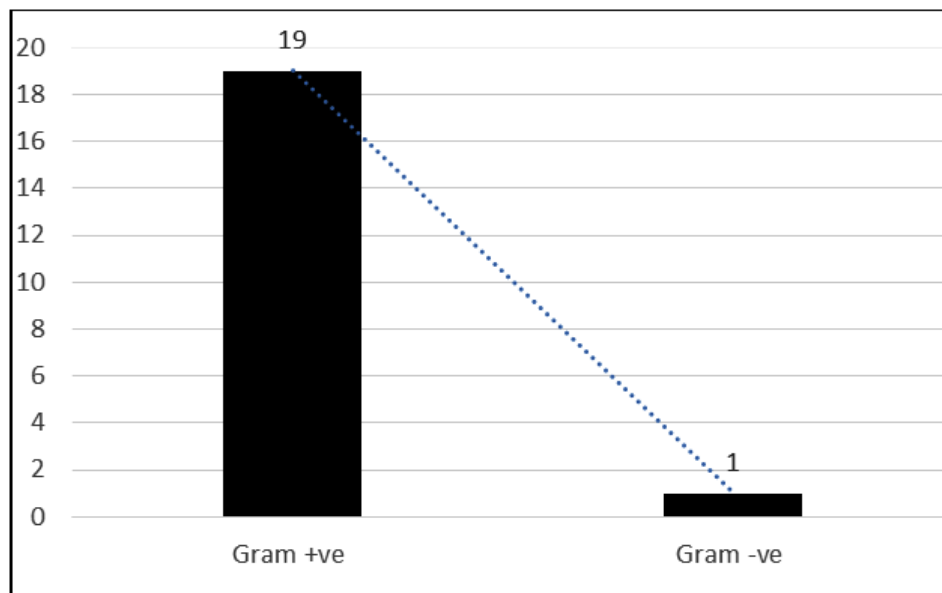


Fig. 3. Types of bacteria according to Gram stain

Morphological features of the bacteria isolated from mobile phones

Most isolated bacteria were Gram-positive; only one organism was a Gram-negative strain (Fig. 3). One actinomycete strain was observed in this study. Most characterized bacteria were rod-shaped bacilli, followed by grape-like cocci, filamentous, and Tetrad shape (Table 2).

Identification of bacteria from mobile phones using an automated Microscan device

Staphylococcus is the major strain identified in this study and was predominant on the skin surface. So, naturally, mobile phones are exposed to *Staphylococcus* sp. *Staphylococcus aureus* was found in three samples, and *Staphylococcus schleiferi*, and *Staphylococcus*

epidermidis were also detected. Moreover, other bacterial species such as *Micrococcus* sp., *Rothia mucilaginosa*, and *Pantoea agglomerans* were identified (Table 3) (Fig 4).

Antibiotic susceptibility of the bacterial strains

Antibiotic sensitivity of *S. aureus* strains isolated from mobile phones. The isolated *S. aureus* was Ampicillin and polymyxin B resistant. It was intermediate against the tested sulfamethoxazole and Bacitracin. *S. aureus* isolated from microbiology students, and non-microbiology students showed no variation in antibiotic sensitivity patterns. All *Staphylococcus aureus* strains were vancomycin and gentamicin-sensitive (Table 4). The *S. epidermidis* isolate showed resistance against Polymyxin B and exhibited an intermediate response against sulfamethoxazole and bacitracin (Table 5). The isolated *Micrococcus* sp. exhibited resistance against polymyxin B, whereas it showed an intermediate response against sulfamethoxazole and was sensitive against other tested antibiotics (Table 6). The isolated strains, *Rothia mucilaginosa*-12-M, and *Pantoea agglomerans*-3-O were sensitive against the tested antibiotics. *Bacillus* sp. isolated from the mobile phones of the microbiology students exhibited sensitivity except for Erythromycin (Table 7).

β-lactamase producing Staphylococcus strains

β-lactamase producing *Staphylococcus* strains were isolated from the students associated with microbiology and other subjects. Antibiotic susceptibility analysis between coagulase-positive and coagulase-negative *Staphylococcus* was depicted in Table 8. β-lactamase producing

Table 3. Identified bacteria by Microscan devices based on the morphological, biochemical, and drug-resistance pattern using an automated Microscan device

Sample No.	Result
11-O** (2)	<i>Staphylococcus aureus</i>
11-O	<i>Staphylococcus aureus</i>
3-M*	<i>Staphylococcus aureus</i>
8-M	<i>Staphylococcus schleiferi</i>
6-O	<i>Staphylococcus epidermidis</i>
11-M	<i>Micrococcus</i> sp.
2-M	<i>Micrococcus</i> sp.
12-M	<i>Rothia mucilaginosa</i>
3-O	<i>Pantoea agglomerans</i>

*(M) Microbiology students; ** (O) Other students

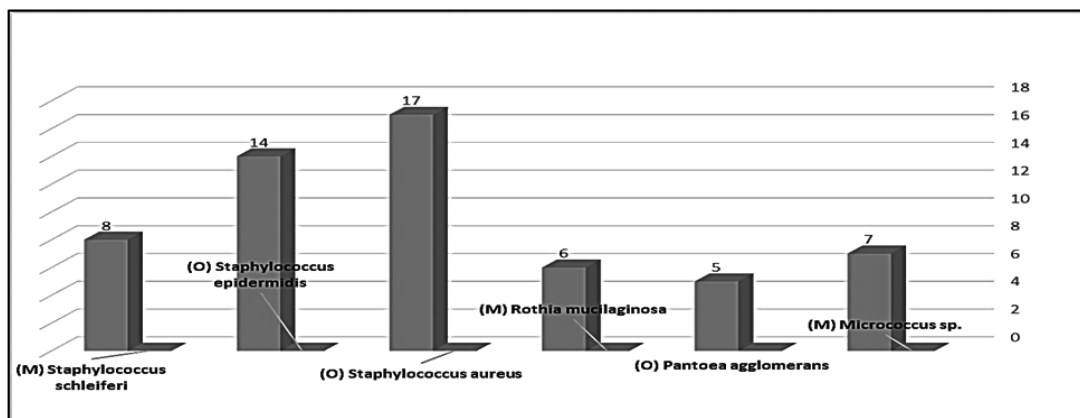


Fig. 4. Identified bacteria by Microscan devices based on the morphological, biochemical, patterns. (M) Microbiology students, (O) Other students

Staphylococcus strain was sensitive to Gentamicin and Vancomycin, whereas resistant to Ampicillin.

DISCUSSION

This study investigated bacterial contamination on microbiology and other students’

mobile phones at King Saud University. Tagoe and colleagues (2011) found microbial contamination on 100 phones due to poor hygiene.²⁴ We found bacteria on 56 (93%) phones, including 27 (90%) from microbiology students and 29 (96%) from others. Many students in both groups used their phones in the toilet, indicating inadequate cleaning.

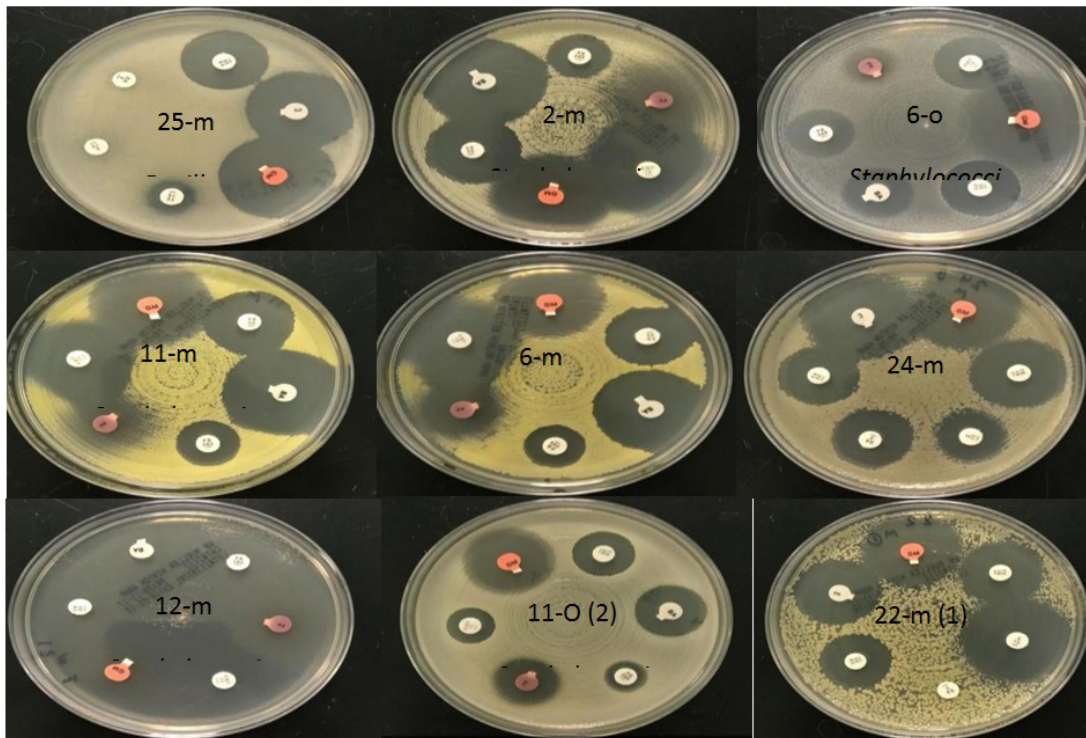


Fig. 5. Antibiotic susceptibility of the bacterial strains

Table 4. Analysis of drug resistance pattern of opportunistic *S. aureus* strains isolated from the surface of the mobile phone

Samples	Antimicrobial Agent	Antibiotics μg or U	Zone of inhibition diameter (mm)	Susceptibility
<i>S. aureus</i> -11-O* (2)	Ampicillin (AMP)	10 μg	15	R
	Sulfamethoxazole	50 μg	20	I
	Bacitracin (BA)	8 U	20	I
	Vancomycin (VA)	30 μg	18	S
	Polymyxin B (PB)	300 U	11	R
	Gentamicin (GM)	10 μg	25	S
<i>S. aureus</i> -11-O*	Ampicillin (AMP)	10 μg	15	R
	Gentamicin (GM)	10 μg	20	S
	Vancomycin (VA)	30 μg	19	S
<i>S. aureus</i> -3-M**	Ampicillin (AMP)	10 μg	14	R
	Vancomycin (VA)	10 μg	23	S
	Gentamicin (GM)	30 μg	25	S

*Non-microbiology students; ** Microbiology students; R – resistant; S – sensitive

Our results showed significant differences among microbiology students: 23 (77%) used phones in toilets, 7 (23%) didn't, and others (non-microbiology students) 21 (70%) did. Matthew Olsen and colleagues (2021) found that 52% of participants (n=86) used their devices in the bathroom, emphasizing the unhygienic environments where mobile devices and smartphones are constantly utilized.²⁵

Only 9 (30%) microbiology students cleaned their phones regularly with disinfectant, while 21 (70%) didn't. Among non-microbiology students, 7 (23%) used disinfectant, and 23 (77%) didn't. In the microbiology lab, 90% (n = 27) of microbiology students followed standard operating

procedures and didn't use mobile phones; only 3 did. Zakai and others showed significant differences in disinfectant use between microbiology students 9 (30%) and others 21 (70%), similar to non-microbiology students 7 (23%) who used the disinfectant too, while 23 (77%) did not use it.¹⁶

All these previous results revealed inadequate cleaning of mobile phones. In the present study, 56 (93%) mobile phones were contaminated with bacteria, 27 (90%) were obtained from microbiology students, and 29 (96%) were obtained from other students. In contrast, another study in Nigeria was reported by Amala, S. and I. Ejikema, who Found that contamination rates (80.6%),²⁶ and another study conducted

Table 5. Analysis of drug resistance pattern of opportunistic *S. epidermidis* and *S. schleiferi* strains isolated from the surface of the mobile phone

Samples	Antimicrobial Agent	Antibiotics (µg or U)	Zone of inhibition diameter (mm)	Susceptibility
<i>S. epidermidis</i> -6-O	Ampicillin (AMP)	10 µg	20	R
	Sulfamethoxazole	50 µg	15	I
	Bacitracin (BA)	8 U	18	I
	Vancomycin (VA)	30 µg	20	S
	Polymyxin B (PB)	300 U	18	R
	Gentamicin (GM)	10 µg	33	S
<i>S. schleiferi</i> - 8-M	Ampicillin (AMP)	10 µg	30	S
	Vancomycin (VA)	30 µg	29	S
	Gentamicin (GM)	10 µg	31	S

I – Intermediate; R – Resistant; S – Sensitive

Table 6. Analysis of antibiotic susceptibility pattern of opportunistic *Micrococcus* strains isolated from the surface of the mobile phone

Samples	Antimicrobial Agent	Antibiotics µg or U	Zone of inhibition diameter (mm)	Susceptibility
<i>Micrococcus</i> sp.-2-M	Ampicillin (AMP)	10 µg	33	S
	Sulfamethoxazole	50 µg	20	I
	Bacitracin (BA)	8 U	33	S
	Vancomycin (VA)	30 µg	27	S
	Polymyxin B (PB)	300 U	18	R
	Gentamicin (GM)	10 µg	30	S
<i>Micrococcus</i> sp.-11-M	Ampicillin (AMP)	10 µg	28	S
	Sulfamethoxazole	50 µg	20	I
	Bacitracin (BA)	8 U	30	S
	Vancomycin (VA)	30 µg	25	S
	Polymyxin B (PB)	300 U	16	R
	Gentamicin (GM)	10 µg	30	S

I – Intermediate; R – Resistant; S – Sensitive

by Algmami, A. A. M, found that the prevalence of organisms in students' mobile phones was (60.8%).²⁷

Several studies have demonstrated that the most common Gram-positive bacterium isolated from mobile phone surfaces is *Staphylococcus*.²⁸

Our finding also identified *Staphylococcus* as the major strain which is a greater concern due to its virulence. Staphylococci were the most represented bacteria, making mobile phones susceptible to contamination due to normal skin saprophytes.²⁹ *Staphylococcus aureus*,

Table 7. Analysis of antibiotic susceptibility pattern of *Bacillus* sp. isolated from the surface of the mobile phone

Samples	Antimicrobial Agent	Antibiotics (µg or U)	Zone of inhibition diameter (mm)	Susceptibility
<i>Bacillus simplex</i> -24-M	Vancomycin (VA)	30 µg	23	S
	Trimethoprim	2.5 µg	35	S
	Tetracycline (TE)	10 µg	25	S
	Clindamycin (DA)	2 µg	23	S
	Erythromycin (E)	15 µg	20	I
	Gentamicin (GM)	10 µg	32	S
<i>Bacillus clausii</i> -25-M	Vancomycin (VA)	30 µg	24	S
	Trimethoprim	2.5 µg	32	S
	Tetracycline (TE)	10 µg	11	R
	Clindamycin (DA)	2 µg	>25	S
	Erythromycin (E)	15 µg	>25	S
	Gentamicin (GM)	10 µg	33	S
<i>Bacillus megaterium</i> -22-M	Vancomycin (VA)	30 µg	21	S
	Trimethoprim	2.5 µg	26	S
	Tetracycline (TE)	10 µg	23	S
	Clindamycin (DA)	2 µg	>25	S
	Erythromycin (E)	15 µg	32	S
	Gentamicin (GM)	10 µg	30	S

I – Intermediate; R – Resistant; S – Sensitive

Table 8. Antibiotics susceptibility analysis between coagulase-positive and coagulase-negative *Staphylococcus*

Categories	Antibiotic	Disk content	Microbiology students	Other students	
Coagulase positive <i>Staphylococcus</i>	<i>S. aureus</i> (O-11)	Gentamicin	10 µg	-	S
		Ampicillin	10 µg	-	R-BLAC*
		Vancomycin	30 µg	-	S
	<i>S. aureus</i> (M-3)	Gentamicin	10 µg	S	-
		Ampicillin	10 µg	R (BLAC*)	-
		Vancomycin	30 µg	S	-
Coagulase negative <i>Staphylococcus</i>	<i>S. epidermidis</i> (O-6)	Gentamicin	10 µg	-	S
		Ampicillin	10 µg	-	S
		Vancomycin	30 µg	-	S
	<i>S. schleiferi</i> (M-8)	Gentamicin	10 µg	S	-
		Ampicillin	10 µg	S	-
		Vancomycin	30 µg	S	-

* (BLAC) = Beta-lactamase positive.

Staphylococcus schleiferi, and *Staphylococcus epidermidis* were determined. Other bacterial species identified included *Micrococcus sp.*, *Rothia mucilaginosa*, and *Pantoea aggl merans*. β -lactamase producing *Staphylococcus* strains were isolated from both microbiology and other students, in this study. Panganai, T. and P. Hamadziripi study showed that seventeen (68%) of mobile devices were contaminated with E coli, (75%), Staphylococci (38%), and Streptococcal (21%) which are pathogens that have a potential of causing nosocomial infections.⁴

The isolated bacteria in this study showed resistance against certain antibiotics but not against Vancomycin and Gentamycin. Recent studies have determined the prevalence of microbial contamination of mobile cell phones among human populations and individuals.³⁰⁻³³ Also, according to Sadeeq's study. both the automated system and disc diffusion technique, antibiotic susceptibility patterns performed for *P. aeruginosa*, *Pseudomonas stutzeri* (*P. stutzeri*), *Aeromonas* spp., *Acinetobacter baumannii* (*A. baumannii*) that collected from the surfaces of mobile phones showed that all isolates were susceptible to all tested antibiotics.^{34, 35}

CONCLUSIONS

Mobile phones of both microbiology students and others of King Saud University were found to be contaminated with bacteria. The pervasiveness of pathogenic bacteria from the mobile phones of microbiology students has been determined, and the result was compared with other students. The determined bacterial strains were more resistant to ampicillin than other tested antibiotics. The absence of cleaning behavior for mobile phones is a major factor in transmitting bacteria from the mobile phone to others or different environments. Moreover, disinfectants could reduce the microbial load on the mobile phone surface. Students should clean their hands with disinfectants before handling the mobile phone. It is important to implement standard guidelines for using mobile phones. Further studies are required to analyze the drug-resistant gene, and mechanism of action, including β -lactamase production. Finally, more studies are needed to

determine the survival time of pathogens on cell phones.

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Ethics Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement

This study did not involve human participants, and therefore, informed consent was not required.

Clinical Trial Registration

This research does not involve any clinical trials.

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