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Original Research

Exploratory Study of Bacterial Contamination of Different Surfaces in Four Shopping Malls in Sharjah, UAE

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ABSTRACT

Introduction: Frequent touch surfaces encountered in shopping malls can play a role in transmission of microbial pathogens and the dissemination of infectious diseases. This study aims at assessing the bacterial contamination of such surfaces in 4 large shopping malls in Sharjah, UAE. **Materials and Methods:** A total of 224 samples were collected from 4 different malls in Sharjah, UAE, in 2014, using sterile cotton swabs. The swabs were transferred and spread on Nutrient agar plates and incubated for 48 h at 37°C. Colony forming units were counted for each plate, then isolated and identified using colony morphology, differential staining, and growth capabilities on different types of media.**Results:** Out of all collected samples, 192 (amounting to 86%) were positive (contaminated with bacteria). In each mall, more than 80% of all sampled surfaces were contaminated with bacterial growth. The highest bacterial density was found on food courts' trays, food courts tables' surfaces, and food tray handles. Comparing the average bacterial count from all surfaces in the 4 different malls under study, a significant result was observed, with one-way repeated measures ANOVA yielding the following: $F(3) = 3.42$, $P = 0.024$. The highest mean bacterial counts were in the malls with the highest numbers of visitors/m^2. **Conclusion:** Nearly, every single sampled surface yielded a moderate to the heavy degree of bacterial contamination. This is cause for concern because infection risk depends to a large extent on infectious doses of pathogens. Consequently, cleaning services in shopping malls should be improved, and the public should be educated on the best hygiene-related precautions to be taken in malls.

KEY WORDS: Bacterial contamination, shopping malls, surface contamination

INTRODUCTION

It is well-known that pathogens can be spread throughout the population by many ways. Air, water, and soil are all common mediums. People may also pass pathogens directly to each other through physical contact or through indirect contact, involving, among others, contaminated surfaces or objects.

Frequent touch surfaces (or formites) include: door knobs and handles, handrails, tables, chairs, cups, dishes, cutlery, trays, washroom surfaces, computer input devices, and other electronic devices with buttons, phones, office supplies, and children's toys. All these surfaces and more are formites that people come into regular contact within malls. Most people judge cleanliness from the external appearance of such surfaces and objects, not realizing that hundreds of microbes may exist on them. Linking microbes only to medical equipment and different surfaces in healthcare facilities, such as research laboratories, hospitals and clinics, is a common mistake [1]. Shopping malls are places that are visited by people of all ages,

from different cultures, and with varied health status; if one is carrying a virulent pathogen that may be transferred through indirect contact, there is always a probability that this person may infect others by transferring the infectious microorganisms to various surfaces and objects in the mall.

A number of studies were conducted to investigate the bacterial contamination on different surfaces like those encountered in malls. One study investigating hand washing among female college students examined the bacterial contamination in one of the female restrooms. The study reported that the faucet handles of the sink contained the greatest number of bacteria (167 colonies), followed by the toilet seat (108 colonies), whereas the least amount of bacteria was found on the door handle (2 colonies) [2]. In another study, the investigators explored the biogeographical patterns of bacteria across different surfaces in public restrooms. Swabs were taken from ten different surfaces, such as door handles into and out of the restroom, faucet handles, soap dispenser, toilet seat, and toilet floor. The results showed that human skin associated bacteria dominated the microbial communities in all the samples collected from these surfaces [3].

Further studies investigated the presence of bacteria on surfaces other than those of restrooms. Research shows that large numbers of bacteria can exist on surfaces that malls visitors come in contact with regularly, such as ATM machines [4], shopping carts [5], restaurant menus [6], elevator buttons [7], escalator handrails [8] and gadget shop surfaces and displayed devices, such as mobile phones, computer keyboards, and computer mice [9,10]. In shopping malls, computer keyboards, computer mice, and mobiles are displayed to all visitors to try and to touch, which can increase the possibility of transferring infectious pathogens to users getting in contact with such surfaces if they were not regularly and properly disinfected.

A number of studies considered the types of microorganisms encountered on surfaces accessible to the public. In one study, swabs collected from ATM keypad surfaces showed a substantial count of food-borne disease organisms [11]. In another study, swabs were collected from different places (offices, internet cafes, homes, buildings, and supermarkets) in the city of Jeddah, Saudi Arabia. Swabs collected from shopping carts' handles and elevator buttons were positive for bacteria in 93% and 96% of samples, respectively. The positive samples were dominated with Coagulase-negative Staphylococci (84-87%), Gram-positive bacilli (55-60%), *Staphylococcus aureus* (11-14%), *Pseudomonas* spp. (10%) and Gram-negative bacilli (8%) [5]. In a further study, which included 10 restaurants, it was found that 70% of table surfaces were contaminated by coliforms while 20% of table surfaces were contaminated by *Escherichia coli* [12].

In shopping malls, parents consider the play areas and toy shops as places for entertaining their children. An infected child can be a source of infection to children playing with the same toy he touched, rendering toys a serious source of cross-contamination as shown by a study in 2004, where surface contamination of different toys in a pediatric hospital was investigated. The study included seventy children's toys made of different materials, like plastic, metal, fabric, and others. Cultures obtained from the toys were all positive for at least one microorganism, such as Coagulase-negative staphylococci (78% of toys); *Bacillus* spp. (37%); *Staphylococcus aureus* (18%); alpha-hemolytic Streptococci (11%); and *Pseudomonas* spp. (9%) [13].

Another source of surface contamination in shopping malls is the makeup testers. A study, that included 73 samples from different used makeup products (such as eyelashes, lipsticks, foundation and eye shadows), showed that out of the 73 samples collected at least 10 samples were contaminated. Contaminated samples tested positive for one or more of the following: *Candida* spp., *Staphylococcus aureus*, and *E. coli* [14]. The probability of surface contamination of cosmetic products is of course augmented by displaying different samples of these products as testers for shoppers.

In the United Arab Emirates, the year-round prevailing hot weather conditions render the closed and air conditioned shopping malls an attractive choice for both entertainment and shopping activities for residents and tourists. This study tries to explore the level of bacterial contamination on different surfaces in shopping malls. The findings of this study should help in shedding light at the hygienic practices in shopping malls and how to improve them.

MATERIALS AND METHODS

Sampling

A total of 224 samples were collected from four different malls in Sharjah, UAE, in 2014. The 4 malls were chosen randomly from a list of all malls in Sharjah. From each mall, 56 samples were collected off different surfaces, like escalator handrails, elevator buttons, makeup testers in cosmetics-selling shops, different gadgets in electronics-selling shops, buttons of ATM machines, surfaces of different electronic arcade games, surfaces of several toys in toy shops, shopping carts handles, surfaces of tables in the food courts, and from different surfaces in the restrooms. Details of the samples collected from the different surfaces in each mall are presented in Table 1.

Table 1: Detailed sampling plan for samples collected from different surfaces in each mall, Sharjah 2014

Surface	Number	Surface	Number
Escalator handrails	3	Elevator buttons:	
Make up testers:		Inside elevator button	2
Lipstick	2	Outside elevator button	1
Foundation powder	2	Shopping cart handles	4
Gadget shops:		Food court:	
Laptops	2	Food court tables	4
Cameras	2	Restaurant menus	4
Restrooms:		Bottom surface of food trays	2
Outside door handle	2	Upper surface of food trays	2
Inside door handle	1	Food trays handles	2
Soap container	3	ATM keypads	4
Toilet seat	3	Playground electronic gadgets	4
Sink tap handle	3	Toys from toy stores	4

Bacterial Growth and Counting

An area of 5 cm by 5 cm was swabbed off each surface under study using a sterile cotton swab moistened with sterile distilled water that was immediately returned into a labeled tube of nutrient broth. The tubes were sealed and transferred in an ice-filled container to the lab within 2 h of collection. In the lab, each swab was aseptically transferred from the test tube and were spread on nutrient agar plates. The plates were incubated for 48 h at 37°C. The resulting colony forming units (CFUs) were counted for each plate, and the number of colonies in each plate was then converted to CFU per 25 cm^2 [15].

One-way repeated measures ANOVA was conducted to compare the mean bacterial counts (in CFU/25 cm^2) from the 4 malls under study.

Isolation and Identification of Bacterial Colonies

The grown bacterial colonies were morphologically compared based on size, color, margins, and elevation. Distinct colonies based on colonial morphology were considered as different colonies and were then transferred to new agar plates to get pure cultures. After pure cultures were obtained, colonies were observed for size, texture, color and hemolytic reactions. Colonies were identified using differential staining (Gram-stain, acid-fast stain, and endospore stain). Different media were used for growing the isolated colonies: Tryptic soy agar, eosin methylene blue agar, mannitol salt agar, and MacConkey agar. The bacteria were speciated using the isolated colonies [16].

RESULTS AND DISCUSSION

This study revealed that out of 224 collected samples, 192 samples, amounting to 86%, were positive, meaning that they were contaminated with bacteria. In each mall, the percentage of surfaces contaminated with bacterial growth was above 80% of all sampled surfaces.

As shown in Table 2, all swabs collected from the ATM keypads, toys stores, food court tables, food trays, and restrooms toilets were positive for bacterial growth. Around 75% or more of the swab samples collected from nearly all other surfaces were positive for bacterial growth. Only in case of swab samples collected from restrooms soap containers and escalator handrails did the percentage of positive samples drop to 58% and 50%, respectively.

These results agree to some extent with previous research investigating the bacterial contamination of public surfaces. A study in the USA showed that all samples from tabletops in the studied restaurants were contaminated with bacteria, with 70% of samples showing total coliforms [13]. In the study by AlGhamdi *et al.*, all samples recovered from computer keyboards, mice, shopping cart handles and elevator buttons, collected from different places of Jeddah, Saudi Arabia, were found to be contaminated with mixed growth of bacteria [5]. In another study examining the handrails of escalators in the public metro rail system in Washington, D.C., about 67% of samples were contaminated with bacteria [8]. These findings support the results obtained by the current study and call attention to the high levels of contamination of various public surfaces.

The average number of bacteria (CFU/25 cm^2 surface area) on the different surfaces from the four malls under study are presented in Figure 1. The figure shows that the highest bacterial density was found on different surfaces in the malls' food courts, such as the upper surface of food trays, food court tables' surfaces, and food tray handles. The average number of bacterial colonies on these surfaces was 1552.63 CFU/25 cm^2 (around 62 CFU/cm^2), 1244.13 CFU/25 cm^2, and 879.75 CFU/25 cm^2, respectively. The bacterial count on the surfaces of shopping carts handles, playground equipment, restaurant menus, ATM keypads, toys from toys stores, restrooms toilet seats, and restrooms sinks tap handles ranged from 500 to 800 CFU/25 cm^2. The least contaminated surfaces, such as, restrooms doors, soap containers, makeup testers, elevator buttons, and escalators handrails, had bacterial count <500 CFU/25 cm^2.

Table 2: Proportion of swab samples from the different surfaces showing positive bacterial growth, Sharjah 2014

Different types of surfaces swabbed in all 4 malls	Total number of swabs	Number of positive swabs	Percent of positive swabs
Food court tables	16	16	100
Restaurant menus	16	14	87.5
Bottom surface of food trays	8	8	100
Upper surface of food trays	8	8	100
Food trays handles	8	8	100
Restrooms outside door handles	8	7	87.5
Restrooms inside door handles	4	4	100
Restrooms soap containers	12	7	58
Restrooms toilet seats	12	12	100
Restrooms sink tap handles	12	9	75
Gadget shops equipment	16	14	87.5
Playground electronic gadgets	16	15	94
Toys from toy stores	16	16	100
Make up testers	16	12	75
ATM keypads	16	16	100
Shopping carts handles	12	9	75
Elevator buttons	12	10	83
Escalator handrails	12	6	50

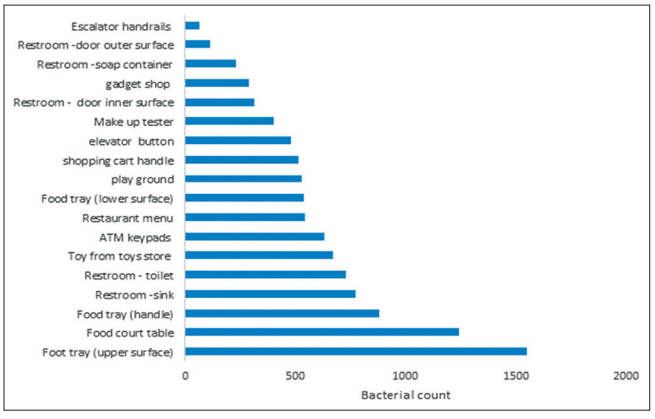

Figure 1: Average number of bacteria (CFU/cm^2 surface area) on the different surfaces from the four malls under study, Sharjah 2014

Food-court tables and food trays may be good venues for bacterial growth, because of the behavior of food-court workers, who collected the food trays, threw the leftover food into the nearest waste-bin, then used wet dish-clothes to clean the tables and the food trays quickly. These dish-rags were used during the worker's shift without replacement, rendering them a very good medium for bacterial growth and bacterial contamination. On the other hand, restaurant menus are handled all the time by many mall visitors as well as food-court workers, make them subject to high bacterial contamination.

The results depicted in Figure 1 agree to some extent with other studies that investigated bacterial contamination on surfaces found in various public places. In one study, the numbers of heterotrophic plate count bacteria recovered from restaurant tabletops reached 141 CFU/cm^2 [12], which is higher than the present study. On the other hand, a study conducted in Australia reported that bacteria were found at 10^2-10^5 CFU/m^2 (max. 10 CFU/cm^2) on food court tables in a shopping mall, which is a much lower result than that conveyed by the present study [17] In a further study, the number of heterotrophic bacteria on shopping cart handles ranged between 6 and 133 CFU/cm^2 [18], which is comparable to the present study that reported around 20.8 CFU/cm^2 on shopping cart handles (520 CFU/25 cm^2).

Regarding restrooms, a study conducted in the US at a small, private liberal arts college reported that amount of bacteria found on faucet handles was the highest at 167 CFU/4in^2, followed by the toilet seat 108 CFU/4in^2, whereas the least amount of bacteria was found on the door handle 2 CFU/4in^2 [2]. As 4 square inches are about 25.8 cm^2, then these results can be easily compared to the present study, where much higher bacterial counts were reported. The difference in results, while quite substantial, can be explained away on the basis of the different study setting. Public restrooms in UAE shopping malls are accessed by large numbers of visitors of all ages, cultures, and social classes, and of course of variable hygienic practices, which may understandably render these restrooms much more contaminated with bacteria than others elsewhere.

Comparing the average bacterial count from all surfaces in the 4 different malls under study, a significant result was observed, as shown in Table 3. The means and standard deviations are presented in the table, together with the average number of visitors per square-meter in each mall. Seeing as the sampling procedures were repeated in all 4 malls, one-way repeated measures ANOVA was conducted to compare the mean bacterial counts (in CFU/25 cm^2) from the 4 malls. A significant difference with a large effect size was observed, with $F(3) = 3.42$, $P = 0.024$, Wilk's Lambda = 0.84, and multivariate partial eta squared = 0.16. It is of notable importance that the highest mean bacterial counts were in the malls with the highest numbers of visitors/m^2 (malls 3 and 2). This result shows that cleaning and sanitization practices in shopping malls need to adjust to visitors' density, with more frequent cleaning efforts required during weekends and vacations than during regular weekdays.

Table 3: Comparison of mean bacterial counts from the 4 malls under study, Sharjah 2014

Mall	Number of collected samples	Mean bacterial count (in CFU/25 cm^2)	Standard deviation of bacterial count (in CFU/25 cm^2)	Number of visitors/m^2
Mall 1	56	404.88	705.00	0.34
Mall 2	56	678.87	858.59	0.69
Mall 3	56	782.57	925.74	1.06
Mall 4	56	419.04	674.26	0.36

The qualitative analysis of bacterial isolates from the different surfaces swabbed in the present study revealed the abundance of normal skin flora. Indeed, around 99% of the positive samples included non-pathogenic bacteria of skin flora such as *Staphylococcus epidermidis* and other Coagulase-negative Staphylococci. On the other hand, around 64% of samples included catalase-positive Gram-positive bacilli, commonly called "diphtheroids" or "coryneform" bacteria. While historically regarded as non-pathogenic, lately these bacteria have been increasingly implicated as the cause of significant infections [19]. Only two samples were positive for *Staphylococcus aureus*, which is usually regarded as a potentially pathogenic microorganism. Table 4 depicts the isolated species of bacteria and the percentage of positive samples contaminated with them.

The prevalence of skin bacteria on restroom surfaces is not surprising as most of the surfaces sampled come into direct contact with human skin, and previous studies have shown that skin-associated bacteria are generally resilient and can survive on surfaces for extended periods of time [20]. On the other hand, contrary to many studies examining public surfaces, especially those where food is presented [3,12,21], no coliforms or other foodborne pathogens such as species of *Aeromonas*, *Enterobacter*, *Escherichia*, *Klebsiella* or *Salmonella* were detected. This was an unexpected finding, and warrants a follow-up study for further examination with more sophisticated detection methods.

The findings of this study do not necessarily mean that surfaces, such as were included in the study, are consistently safe. The abundance of skin flora in such high numbers as shown in this study, and the presence of Gram-positive diphtheroids in nearly two-thirds of the samples are indicators that transmission of pathogenic bacteria from the skin of infected persons to the surfaces in question is more than plausible. In this case, such surfaces will be highly dangerous media for transferring pathogenic bacteria from infected persons to others coming into contact with these contaminated surfaces.

Table 4: Isolated species of bacteria and percentage of contaminated positive samples

Isolated bacteria	Percentage of positive contaminated samples
Gram-positive coagulase-negative staphylococci	
Staphylococcus epidermidis	99.0
Staphylococcus hominis	78.6
Staphylococcus warneri	71.9
Staphyloccus aureus	0.01
Corynebacterium spp. (diphtheroids)	64.1

CONCLUSION

The results of this study confirm that various surfaces in shopping malls could serve as media for disease transmission of pathogenic microorganisms. Nearly, every single sample tested yielded a moderate to the heavy degree of contamination. Human-associated bacteria dominated most public surfaces; however, the presence of diphtheroids in nearly two-thirds of the samples is cause for concern. Furthermore, it is well known that infection risk is mainly dependent on infectious doses of pathogens; hence the large bacterial loads detected on nearly all surfaces may be regarded as a time bomb with high potential of causing outbreaks of common pathogens like *Staphylococcus aureus* or enteropathogens.

The association between the number of mall visitors per m^2 and mean bacterial count from various surfaces of the mall is cause for action. Mall cleaning services should be adjusted following the pattern of crowding, and health superintendents, sanitary officers. The public awareness of certain important sanitary practices, like hand washing, using waterless alcohol-based hand sanitizers if hand-washing facilities are not available, and using a tissue, or coughing and sneezing into the arm, not the hand, should be raised.

This study has a number of limitations, among them the limited number of malls included in the study, and the limited number of public surfaces examined in each mall. A further follow-up study is important to address species identification of the entire microbial communities. Further questions for research include for example, determining if the potential for infection shown in this study indicated an actual risk of disease transmission; and if the use of various surface-treatment methods can reduce the bacterial load of highly contaminated surfaces significantly.

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