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RESEARCH ARTICLE

Bacterial Contamination of Digital Panoramic Dental X-Ray Equipment

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Background: Digital panoramic dental X-ray equipment (PDX) is frequently used by patients and dental workers for diagnosis and examination in dental institutions; however, infection control has not been properly implemented. Therefore, in this study, we aimed to systematically review the potential risk of cross-infection in the dental environment by investigating the contamination level of general aerobic bacteria and *Staphylococcus aureus*, which are important in hospital infections, in PDX areas that people mainly contact.

Methods: This survey was conducted from March to May 2023 and covered one general hospital, three dental hospitals, and nine dental clinics equipped with PDX. Bacteria samples were collected from the left-handle, right-handle, forehead support, and head side support as the patient's contact areas, as well as the X-ray exposure switch and left-click mouse button as the dental hygienist's contact areas of the PDX. The collected bacteria were spread on Petrifilm, and colonies formed after 48 hours of culture were counted.

Results: General aerobic bacteria and *S. aureus* were detected in all areas investigated. Significant differences in bacterial counts between different regions of the PDX were observed in both groups ($p<0.001$). The detection rates of general aerobic bacteria ($p<0.001$) and *S. aureus* ($p<0.001$) were significantly higher in the contact areas of patients than those of dental hygienists. A positive correlation was observed between the forehead and the temple region in terms of general aerobic bacteria and *S. aureus* detection ($r=1$) ($p<0.01$).

Conclusion: Taken together, the presence of many bacteria, including *S. aureus*, detected in PDX indicates that PDX has a potential cross-infection risk. Our results therefore highlight the need for the development of appropriate disinfection protocols for reusable medical devices such as PDX and periodic infection prevention training for hospital-related workers, including dental hygienists.

Key Words: Bacteria, Contamination, Dental radiography, Infection control, Panoramic

Introduction

1. Background

The term "hospital-required infection" or "nosocomial infection" was first mentioned in "In-Hospital Infection Control", published by the American Hospital Association in 1968, as a microbial infection that occurred in a hospital[1]. Currently, this term has been replaced by a generic term called healthcare-associated infection, expanding to include not only patients but also hospital-related workers with infections in all medical-related institutions, such as nursing homes outside hospitals[2]. In Korea, research on infection control in hospitals began in 1991 and has become increasingly important over time[3]. *Staphylococcus aureus*, a major causative agent of medical-related infections, causes a wide range of clinical conditions, including bacteremia, endocarditis, and osteomyelitis[4]. In particular, as resistance to antibiotics increased, methicillin-resistant *S. aureus* (MRSA) emerged, and later vancomycin was developed as a treatment for MRSA; however, vancomycin-

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resistant *S. aureus* also appeared[5]. The increased incidence of infected patients in medical institutions caused by these antibiotic-resistant bacteria has emerged as a global public health problem[6].

The rapid spread of COVID-19 (coronavirus disease-19), which first began in Wuhan, China, in 2019, led the World Health Organization (WHO) to declare a global pandemic in 2020 by announcing its official name due to its high pathogenicity and infectiousness, which continues to this day with mutations[7,8]. Since the COVID-19 pandemic, the importance of infection prevention and management has emerged in most medical institutions and infection-related organizations, and with this opportunity, related studies are being actively conducted along with the need for an infection control system[9-11]. COVID-19 is an infectious disease that poses a high risk of air infection, and dental institutions are at high risk of cross-infection due to the presence of large amounts of droplets and aerosols[12]. After the COVID-19 pandemic, the number of patients decreased significantly as anxiety about dental care increased[13]. Therefore, when respiratory infections such as COVID-19 and flu are prevalent, infection control at dentistry is very important compared to other medical institutions.

With the development of digital radiography devices, many dental institutions are currently using examination methods through radiography to diagnose patients and establish treatment plans. In particular, dental panoramic X-ray imaging, which can check the overall condition of the teeth and jawbones, is used for diagnosis and examination in most visiting patients, so it is very frequent[14]. However, for dental panoramic photography, the risk of cross-infection is high because the skin directly contacts both the patient and the dental healthcare worker. Many studies have been conducted on the infectivity and bacterial contamination of devices and equipment used in dental treatment rooms, such as dental chairs and handpieces, and both patients and dental healthcare workers recognize the importance of infection control[15-17]. However, since the panoramic imaging device is located separately in a radiographic room outside the dental treatment room, awareness of the importance of infection control is low despite contact with many people, and related research is insufficient.

2. Objectives

COVID-19 has increased interest in and awareness of hygiene among many people. The control and prevention of infection in dental institutions are more important[18]. It is equally important to recognize the importance of infection control on dental radiography devices with which people frequently come into contact. Therefore, in this study, we visited randomly selected dental institutions and attempted to investigate the degree of bacterial contamination according to the contact area of digital panoramic dental X-ray equipment (PDX). By identifying *S. aureus*, an important causative agent of general aerobic bacteria (GAB) and medical-related infections, we aimed to present the need for infection control in radiation equipment and raise awareness among dental healthcare workers.

Materials and Methods

1. Subjects of this study

This study was conducted on PDX currently used in general hospitals, dental hospitals and clinics in Gyeongsangbuk-do from March 24 to May 5, 2023. The subjects of the investigation are a total of 13 PDXs: one from one general hospital, three from two dental hospitals, and nine from eight dental clinics. During panoramic X-ray imaging, the areas where the patient and the dental hygienist (operator) mainly came into contact were selected, and microorganisms were collected from the area. The contact areas of the patient were as follows: (1) left-handle, (2) right-handle, (3) forehead support, (4) head side support. The contact areas of the operator were as follows: (1) X-ray exposure switch, (2) left-click mouse button (Fig. 1).

2. The methods of this study

A SWABON M-Swab kit (Microgiene, Suwon, Korea) was used to collect microorganisms by the PDX site. It was collected by rubbing 10 times with cotton swabs sterilized with up, down, left, and right sides of each area, and then placed in an individual transport medium containing 10 ml of physiological saline and sealed. The samples were equalized for 15 seconds with a vortex mixer and then 2 ml of the bacterial dilution solution was inoculated onto an Aerobic Count Plate and Staph Express Count Plate of

Fig. 1. Bacterial detection sites on a digital panoramic dental X-ray equipment. (A) Left-handle, (B) right-handle, (C) forehead support, (D) head side support, (E) X-ray exposure switch, and (F) left-click mouse button.

Table 1. Levels of General Aerobic Bacteria and *Staphylococcus aureus* in Each Part of Digital Panoramic Dental X-Ray Equipment (Unit: CFU/ml)

Bacteria	Part of the PDX	No.	Minimm	Median	Maximm	Mean rank	p-value
GAB	Left-handle	13	1.50	9.00	94.00	31.69[a,e]	<0.001
	Right-handle	13	0.50	27.00	76.50	41.77[a,d]	
	Forehead support	5	28.50	59.50	69.00	57.40[b,d]	
	Head side support	10	5.00	33.00	118.00	48.05[b,d]	
	X-ray exposure switch	13	0.00	2.50	29.50	18.92[e]	
	Left-click mouse button	13	0.50	4.00	40.00	23.81[e]	
S. aureus	Left-handle	13	1.00	3.50	59.00	34.27[a,b]	<0.001
	Right-handle	13	0.00	16.50	96.50	41.42[b,c]	
	Forehead support	5	16.00	32.50	104.50	58.60[c]	
	Head side support	10	3.00	15.75	34.00	44.95[b,c]	
	X-ray exposure switch	13	0.00	1.00	10.50	21.50[a]	
	Left-click mouse button	13	0.00	2.00	6.00	20.92[a]	

PDX: digital panoramic dental X-ray equipment, GAB: general aerobic bacteria.
The difference in letters a, b, c, d, and e mean that there was a significant difference in Dunn's post-test with multiple comparison test.
p-value obtained by Kruskal-Wallis test.

3M™ Petrifilm™ (3M Korea, Seoul, Korea) for GAB and *S. aureus*. The plates were cultured in a 35±1°C incubator for 48 hours. The CFU/ml of red and red-violet colonies formed in GAB and *S. aureus* were counted, respectively.

3. Statistical analysis

The normality of the data was confirmed using the Shapiro-Wilk test. The difference in the CFU/ml of bacteria by PDX site was investigated by performing Kruskal-Wallis H verification, and the post-test was performed using the Dunn test. The difference in the CFU/ml of bacteria by PDX site between hospital-level or higher institutions and dental clinics was confirmed using the Mann-Whitney U test. In the PDX, the Mann-Whitney U test was used to verify the difference in bacterial count between patient contact and dental hygienist contact. The correlation between GAB and *S. aureus* by site of PDX was confirmed by Spearman sequence correlation analysis. All analyses were analyzed at the level of α=0.05 with IBM SPSS statistics ver. 27.0 (IBM Corp., Armonk, NY, USA).

Results

1. GAB and *S. aureus* depending on PDX areas

Significant differences were identified in the CFU/ml of GAB according to the PDX area ($p < 0.001$). A significantly

higher GAB was found in the patient's contact areas, right-handle, forehead support, and head side support, compared to the operator's contact area, X-ray exposure switch, and left-click mouse button ($p<0.05$). No significant differences were found in the left handle area, which is the area in contact with the patient, compared to the operator contact area ($p>0.05$; Table 1, Fig. 2).

Significant differences were also identified in the CFU/ml of *S. aureus* according to the PDX sites ($p<0.001$). A significantly higher *S. aureus* was found in the patient's contact areas, right-handle, forehead support, and head side support compared to the operator's contact areas, X-ray exposure switch, and left-click mouse button ($p<0.05$). No significant difference was observed in *S. aureus* between left and right-handles ($p>0.05$; Table 1, Fig. 3).

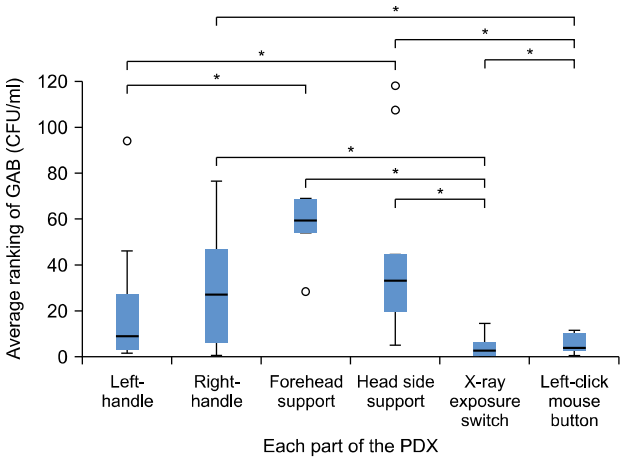

Fig. 2. The mean rank of general aerobic bacteria (GAB) by part of digital panoramic dental X-ray equipment. *Significant differences between groups.

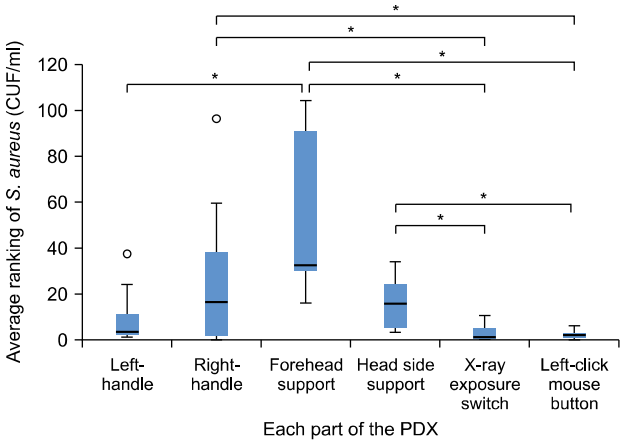

Fig. 3. The mean rank of *Staphylococcus aureus* by part of digital panoramic dental X-ray equipment (PDX). *Significant differences between groups.

2. Differences in GAB and *S. aureus* between the contact areas of the patient and the dental hygienist

We identified differences in GAB and *S. aureus* by dividing the contact area between the dental hygienist, the main operator of PDX, and the patient. As a result, there was a significant difference between the contact area between the patient and the dental hygienist in both GAB and *S. aureus* ($p<0.001$; Table 2).

3. Correlation between GAB and *S. aureus* by PDX area

A significant correlation was confirmed between GAB and *S. aureus* in the left-handle ($r=0.946$, $p<0.001$) and the right-handle ($r=0.941$, $p<0.001$), respectively. Significant correlations between left-handle and right-handle were confirmed between GAB and GAB ($r=0.700$, $p<0.001$), between GAB and *S. aureus* ($r=0.630$, $p<0.05$), and between *S. aureus* and *S. aureus* ($r=0.608$, $p<0.05$). Significant correlations between forehead support and head side support were identified between GAB and GAB ($r=-1.000$, $p<0.001$), between GAB and *S. aureus* ($r=-1.000$, $p<0.001$), and between *S. aureus* and *S. aureus* ($r=1.000$, $p<0.001$). The GAB detected in head side support was significantly correlated with the GAB of the left-click mouse button ($r=-0.689$, $p<0.05$), and with the *S. aureus* of forehead support ($r=1.000$, $p<0.001$), and with the *S. aureus* of head side support ($r=0.721$, $p<0.05$). The *S. aureus* detected in the head side support was significantly correlated with the *S. aureus* of the X-ray exposure switch

Table 2. Levels of GAB and *Staphylococcus aureus* per Contact Area by the Patient and Dental Hygienist of the Digital Panoramic Dental X-Ray Equipment

	Mean rank (CFU/ml)		p-value
	Patient	Dental hygienist	
GAB	42.01	21.37	<0.001
S. aureus	42.11	21.21	<0.001

GAB: general aerobic bacteria.
p-value obtained by performing the Mann-Whitney U test.

Table 3. Correlation between GAB and *Staphylococcus aureus* by Digital Panoramic Dental X-Ray Equipment Areas

		GAB						*S. aureus*					
		Left-handle	Right-handle	Forehead support	Head side support	X-ray exposure switch	Left-click mouse button	Left-handle	Right-handle	Forehead support	Head side support	X-ray exposure switch	Left-click mouse button
GAB	Left-handle	1.000											
	Right-handle	0.700**	1.000										
	Forehead support	−0.100	−0.300	1.000									
	Head side support	0.262	0.394	−1.000**	1.000								
	X-ray exposure switch	0.145	−0.116	−0.821	0.268	1.000							
	Left-click mouse button	0.047	−0.313	−0.200	−0.689*	0.039	1.000						
S. aureus	Left-handle	0.946**	0.681*	−0.100	0.166	0.236	0.064	1.000					
	Right-handle	0.630*	0.941**	−0.500	0.438	−0.066	−0.463	0.608*	1.000				
	Forehead support	−0.700	0.100	0.100	1.000**	−0.051	−0.900*	−0.700	0.600	1.000			
	Head side support	0.012	0.406	−1.000**	0.721*	0.207	−0.548	0.055	0.511	1.000**	1.000		
	X-ray exposure switch	0.276	0.128	−0.700	0.500	0.721**	−0.050	0.336	0.156	−0.100	0.634*	1.000	
	Left-click mouse button	0.064	−0.172	0.200	−0.480	−0.192	0.613*	0.068	−0.201	−0.100	−0.560	−0.291	1.000

GAB: general aerobic bacteria.
The correlation was analyzed by Spearman rank correlation coefficient. *$p < 0.05$, **$p < 0.01$.

(r=0.634, $p<0.05$). The GAB detected in the X-ray exposure switch was significantly correlated with the *S. aureus* detected in the same area (r=0.721, $p<0.001$). The GAB detected in the left-click mouse button was significantly correlated with the *S. aureus* (r=−0.900, $p<0.05$) of the forehead support and with the *S. aureus* (p=0.613, $p<0.05$) of the left-click mouse button, respectively (Table 3).

Discussion

1. Interpretation and comparison to previous studies

The PDX, which is provided in most dental institutions, is an essential device for diagnosis and examination, and patients and dental workers come into contact with each other frequently[14]. With the development of various medical radiation equipment, including PDX, their use has increased, and research on the risk, safety, and management of patient exposure doses is being conducted steadily[14,19]. However, despite the contact of many people, there is insufficient evaluation of the microbial contamination of equipment or research on the level of awareness of infection control among medical workers. In particular, studies on the risk of cross-infection in intraoral digital imaging among dental radiation equipment are often conducted, but there are few studies on extracoral radiation equipment[20].

In dental clinics, dental hygienists mainly guide and photograph patients regarding PDX use. Therefore, we identified the microbial contamination of PDX by distinguishing between the part that the patient comes in contact with and the part that the dental hygienist comes in contact with. Consequently, *S. aureus*, an important causative agent of medical-related infections, as well as GAB, was detected at all sites of the PDX where the patients and dental hygienists were in contact. This is consistent with previous findings that Staphylococci were detected in both periapical and panoramic X-ray machines[21]. In particular, the CFU/ml of bacteria was highest in PDX's forehead support, followed by the head side support area. Because the presence or absence of forehead support and head side support varies depending on the PDX model, many bacteria were detected even though the number of subjects was small. Both of these areas are considered to be highly contaminated with bacteria because they are the areas that the patient's hair mainly touches. Studies isolating and analyzing *S. aureus* from humans showed that more than 70% were present in the hair, and it was also reported that antibiotic-resistant bacteria were isolated from the hair of inpatients[22,23]. Therefore, in PDX, forehead support and head side support are areas that can cause cross-infection; therefore, it is necessary to disinfect each patient or manage it using disposable films.

Among the PDX handles in contact with the patient, bacteria were measured more on average in the right-handle than in the left-handle. This is presumed to be the result of the microorganisms being buried while using the right hand, as there are far more right-handed than left-handed people. This can also be predicted from the results of a study on microbial contamination of the hand measured before, after, and during the cooking process of restaurant cooks, which showed that microbial contamination of the right hand was higher than that of the left hand[24].

In the PDX contact microbial contamination results, the mean rankings of GAB and *S. aureus* were approximately twice as high in patients as in dental hygienists. This is thought to be due to the fact that the area in contact with the equipment was narrower for dental hygienists than for patients. However, *S. aureus* was also identified in the X-ray exposure switch of the PDX, and the left-click mouse button of the computer was used to check the radiographs or send photos. Moreover, a significant correlation between GAB and *S. aureus* was observed at most of the PDX sites. These results suggest the cross-infection may occur not only in patients but also in dental healthcare workers, including dental hygienists. As dentistry is a medical institution that is frequently exposed to blood and saliva and has a very high risk of cross-infection with aerosols, the emergence of *S. aureus* may cause purulent infections in dentistry patients, which may be fatal for immunocompromised patients[4,25].

2. Suggestion

As a result, as many bacteria were detected in PDX, which generally have a low awareness of infection control, this study can be presented as a basis for the need for infection control in places or equipment that are easy to miss.

3. Limitations

In this study, we investigated the contamination of PDX limited to GAB and *S. aureus*, but did not identify various types of microorganisms such as facultative anaerobes and fungi observed in dental clinics. Additionally, this research was conducted in some dental institutions extracted from convenience in some areas of Gyeongsangbuk-do, and each institution did not confirm how to control PDX infection. In the future, evaluating microbial contamination of PDX according to the level of awareness and practice of infection control by dentists or dental hygienists will be necessary.

Notes

Conflict of interest

Ji-Hyun Min has been journal manager of the *Journal of Dental Hygiene Science* since January 2023. Ji-Hyun Min was not involved in the review process of this study. No potential conflict of interest relevant to this article was reported.

Ethical approval

Not applicable.

Author contributions

Conceptualization and funding: Ki-Rim Kim. Supervision and Formal analysis: Ji-Hyun Min. Experiments: Lee-Rang Im. Data acquisition: Lee-Rang Im. Writing–original draft: Lee-Rang Im. Writing-review & editing: Ki-Rim Kim and Ji-Hyun Min.

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Data availability

Raw data is provided at the request of the corresponding author for reasonable request.

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