EMERGING TECHNOLOGIES

An evaluation of conventional cleaning and disinfection and electrostatic disinfectant spraying in K-12 schools

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ABSTRACT:

Background: Microbes endemic to student desks can survive for long periods and infect students. The effectiveness of conventional cleaning and disinfection practices and electrostatic disinfectant spraying were examined.

Methods: Six K-12 schools in Southeastern Ontario participated in the study. The viable microbial loads on 100 student desks were assessed via Replicate Organism Detection and Counting (RODAC) plates before and after cleaning and disinfection procedures.

Results: The adjunctive effect of electrostatic disinfectant spraying was tested on 36 desks. Mean pretest colony-forming units (CFUs) per desk were 126.8 (SD 95.7), after conventional cleaning and disinfection mean CFUs were 73.4 (SD 93.0) ($t = 4.0$, $P = 0.0003$), and subsequent electrostatic disinfectant spraying further reduced mean CFUs to 54.2 (SD 85.0) ($t = 2.6$, $P = 0.02$). The independent effect of electrostatic disinfectant spraying without an intervening conventional cleaning step was tested on 64 desks. Mean pretest CFUs were 106.4 (SD 94.5) and after electrostatic disinfectant spraying mean CFUs decreased to 62.9 (SD 87.1) ($t = 3.3$, $P = 0.001$).

Conclusions: Conventional and electrostatic disinfection methods were both effective in increasing the hygienic state of student desks. Electrostatic disinfection spraying improved hygienic state when conducted after conventional cleaning and disinfection and when used independently.

KEYWORDS:

Cleaning; Disinfection; School; Electrostatic Spray

INTRODUCTION

Schools are rife with numerous and various bacteria, viruses, and fungi [1,2]. Student desktops in K-12 schools are contaminated with bacteria such as *Streptococcus* and *Staphylococcus* and viruses such as influenza and norovirus [1,2]. Many bacteria and fungi pathogens can live on desks for months and influenza, common cold, and noroviruses for days [3]. Effective cleaning and disinfection of classrooms can neutralize these pathogens and reduce student absenteeism [1].

Conventional cleaning and disinfection in schools involves manually applying cleaning and disinfection solutions and wiping with cloths. This method has variable effectiveness in schools [1,2]. Spray-and-wipe cleaning and disinfection procedures in healthcare settings frequently do not achieve the desired level of decontamination [4].

Newer technologies such as ready-to-use wipes, ultraviolet light towers, and hydrogen peroxide fogging units are being used for the cleaning and disinfection of hospitals [5-7]. The electrostatic spraying of disinfectants is a newer technology, which could be readily used in schools [8]. The electrostatic sprayer sends a negatively charged plume of disinfectant that envelopes sprayed objects and the charged particles repel each other on surfaces leading to more uniform disinfectant coverage. The disinfectant plume can also reach locations where pathogens are not readily accessible to manual spray bottle and wiping procedures.

The study objective was to assess the effectiveness of conventional cleaning and disinfection and adjunctive and independent use of electrostatic spray disinfection technology on the general hygienic state of student desks.

METHODS

General hygienic state sample collection

The six schools in the study were a convenience sample from Southeastern Ontario. The 20 classrooms sampled ranged from kindergarten to high school. The viable bacterial and fungal

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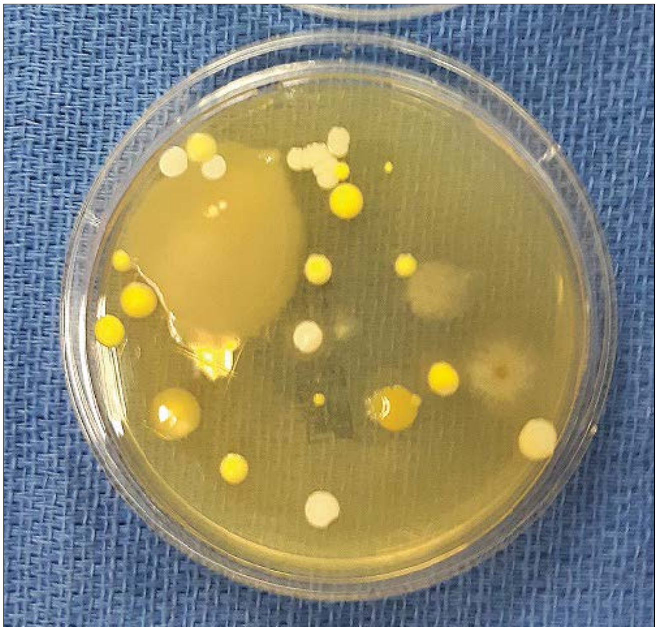

FIGURE 1: Replicate Organism Detection and Counting (RODAC) agar plate, which was sampled from a student desk at the end of the school day before cleaning and after five days incubation.

loads on 100 student desks were assessed using Replicate Organism Detection and Counting (RODAC) agar plates. Thirty-six desks were sampled at baseline, after conventional cleaning and disinfection, and again after electrostatic disinfection. An additional 64 desks were sampled at baseline and after electrostatic disinfection without an intervening conventional cleaning and disinfection step.

The study was conducted December 2018 to March 2019. Desks were sampled at the end of the school day before cleaning and disinfection interventions. After cleaning and disinfection interventions were conducted, RODAC sampling took place after ~30 minutes in order to allow the desks to dry completely. Sampling was conducted on the lower middle portion of desktops where students have the most contact with the desk. Pretest and later samplings on the same desk were taken close to one another. Samplings could not be taken from the exact same location due to possible contamination from the initial sampling with agar plates.

RODAC plates allow for surface sampling of bacteria and fungi which grow on the agar medium. The RODAC plate brand used was Remel Contact Sterile Tryptic Soy Agar with Lecithin and Polysorbate 80 (OXOID, Cat # R111800). This brand provided a general assessment of microbial contamination and measured general hygienic state. The plates were in sterile packaging, stored at 2-8°C, and transported to, within, and from schools in a cooler. Prior to use, the plates were warmed to room temperature for 15-20 minutes in the original packaging. The RODAC plate bags were opened while wearing sterile disposable surgical gloves on sterile towels. A gloved index finger was used to press the agar surface firmly against the desk for five seconds while ensuring the plate did not slide. Sample code, date, and time were written on the agar bed plate with a permanent marker. The RODAC plate samples were transported to CREM Co labs in Mississauga, Ontario (*http://www.cremco.ca/*) within 18-20 hours of collection and incubated aerobically at 36±1°C for five days. Total colony-forming units (CFUs) were manually counted for each plate after incubation (Figure 1). In cases where microbial colonies were too numerous to count, a value of 250 CFUs was assigned [9].

Cleaning and disinfection interventions

School-employed custodians were instructed to clean and disinfect classrooms in their usual manner. Custodians were asked about cleaning methods and the products they used. In all schools, this method was cleaning and disinfecting in one step; referred to as one clean. Schools used spray bottles and cloths or solution, bucket, and cloth with hydrogen peroxide or quaternary ammonium solutions. Electrostatic spray disinfection technology consisted of an electrostatic sprayer and quaternary ammonium disinfectant solution containers mounted on a portable cart [8]. A skilled manufacturer's representative or a trainee under their supervision used the electrostatic spray disinfection technology to spray the classrooms.

Statistical analysis

Repeated Measures ANOVA with Dependent T-test multiple comparisons tested the effectiveness of conventional cleaning and disinfection and the subsequent use of electrostatic spray disinfection technology. The Repeated Measures analysis allowed for comparisons of the same dependent variable on the same desks for pretest, conventional, and electrostatic conditions. Dependent T-tests were also used to assess the disinfection effect of electrostatic spraying without an intervening conventional cleaning and disinfection step. Repeated Measures ANOVAs were also used to assess the differential effect of independent conventional and electrostatic disinfection procedures. The StatView 5 statistical package was used to analyze the data.

RESULTS

RODAC plate control samples

The examination of the adjunctive effectiveness of electrostatic spraying involved the use of 108 RODAC plates to assess pretest, conventional, and electrostatic conditions over 36 desks. The assessment of the independent effectiveness of electrostatic spraying, where there was no conventional cleaning and disinfection step, used 128 plates to assess pretest and electrostatic conditions over 64 desks. The first RODAC plate in each package of 10 was marked as a control sample to ensure no contamination occurred during the manufacturing, storage, sampling, and/or transportation to and from the lab. There were a total of 24 control samples and no control sample indicated any viable microbial life following incubation for five days.

Adjunctive effectiveness of electrostatic spray disinfection technology

Cleaning and disinfection procedures, in general, decreased viable microbial counts on 36 student desks ($F = 19.5$, $P < 0.0001$).

TABLE 1: Dependent T-Test Multiple Comparisons for Cleaning and Disinfection Procedures

Condition Comparisons	Mean Difference	t-Value	df	P value (2-tailed)	95% Lower Confidence Limit	95% Upper Confidence Limit
Pretest-Conventional Cleaning	53.4	4.0	35	.0003	26.6	80.2
Pretest-Electrostatic Spray	72.5	5.1	35	< .0001	43.5	101.5
Conventional Cleaning – Electrostatic Spray	19.1	2.6	35	.02	3.9	34.4

Desktops were less contaminated after conventional cleaning and disinfection (t = 4.0, P = 0.0003) and desks were even less contaminated when electrostatic spray disinfection followed conventional cleaning and disinfection (t = 2.6, P = 0.02) (Table 1). Mean pretest CFUs were 126.8 (SD 95.7), after conventional cleaning and disinfection mean CFUs were 73.4 (SD 93.0), and subsequent electrostatic disinfectant spraying further reduced mean CFUs to 54.2 (SD 85.0) (Figure 2).

Independent effectiveness of electrostatic spray disinfection technology

In order to test the independent effect of electrostatic disinfectant spraying, 64 desks were sampled before and after electrostatic spraying without an intermediary conventional cleaning and disinfection step. Independent use improved general hygienic state of student desks (t = 3.3, P = 0.001). Mean pretest CFUs were 106.4 (SD 94.5) and after electrostatic disinfectant spraying mean CFUs decreased to 62.9 (SD 87.1) (Figure 2).

The differential effectiveness of conventional cleaning and disinfection and electrostatic disinfectant spray procedures when used independently was examined. Both cleaning and disinfection methods, when used independently, were effective in decontaminating student desks (F = 23.5, P < 0.0001); however, no difference in effectiveness was found between the two methods (F = 0.88, P = 0.35) (Figure 2).

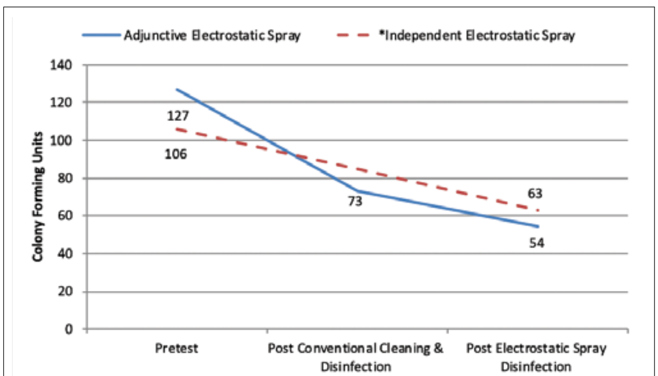

FIGURE 2: Effects of conventional cleaning and disinfection and electrostatic disinfectant spraying on general hygienic state

***No intervening conventional cleaning and disinfection step. Adjunctive Electrostatic Spray N = 36; Independent Electrostatic Spray N = 64.**

DISCUSSION

Student desks were found to be contaminated with viable microbes before cleaning and disinfection were conducted. This highlights the need for effective cleaning and disinfection of student desks [1,2]. Efficacious cleaning and disinfection would help to prevent the spread of infectious illnesses such as colds, pharyngitis, influenza, and intestinal ailments amongst students, teachers, and their families and community [1-3].

The results indicated conventional cleaning and disinfection procedures were effective in reducing viable microbes on student desktops. There was an additive disinfection effect when electrostatic spray disinfection followed conventional cleaning and disinfection. In schools where electrostatic disinfectant spraying was conducted without an intervening conventional cleaning and disinfection step, levels of viable microbes were decreased. Electrostatic spray disinfection technology increased general hygienic state when used independently and when used in conjunction with conventional cleaning and disinfection procedures.

When the independent effectiveness of conventional cleaning procedures and electrostatic spray were compared, no differences were found. This was for a single application and it is thought multiple episodes of electrostatic spray disinfection without intervening wiping would result in a buildup of debris on desks that would promote the growth of pathogens and reduce the effectiveness of electrostatic disinfectant spraying over time. Electrostatic spray disinfection technology is not recommended as a replacement for conventional cleaning and disinfection, rather as an adjunctive disinfection intervention. Electrostatic disinfectant spray use might be especially beneficial during influenza and other infectious outbreaks in schools to increase the frequency of disinfection. The cleaning and disinfection of healthcare settings may be more effective with the adjunctive use of electrostatic disinfectant spraying. The use of electrostatic spray disinfection technology in healthcare settings needs to be rigorously evaluated before being implemented.

In the present study, viral loads were not directly assessed as this would have been prohibitively expensive. Bacteria and fungi are generally hardier than viruses and improved hygienic state can be considered indicative of reduced viral loads [3]. RODAC plate testing, while less expensive than viral testing, was costly and limited both the number of desks that could be assessed, and the ability to examine differences between student grade levels and conventional cleaning practices. Issues associated with access make it difficult to conduct such research in K-12 schools. Schools are cautious with regard to student safety and one school board withdrew due to concerns about potential custodian union issues. Interestingly, in general, custodians seemed to be pleased there was interest in school cleaning and disinfection practices.

School administrators and custodial managers have the responsibility to prevent and control infectious diseases in schools and to protect students, teachers, and the public by ensuring the most effective cleaning and disinfection practices are used. A first step would be to assess pathogen types and levels in schools. The next step would be to rigorously evaluate current cleaning and disinfection practices: Equipment, detergents and disinfectants, cleaning schedules, and staff training. This research initiative, in conjunction with an extensive literature review and lab investigations would aid in the development of a best practices cleaning and disinfection program for schools. In Ontario, the Provincial Infectious Diseases Advisory Committee developed an evidence-based, best-practice document for cleaning and disinfection in healthcare settings [10]. The development of effective and standardized cleaning and disinfection guidelines and standards for schools would have both health and fiscal benefits. It is recommended the Ontario ministries of Education and Health develop evidence-based best practices for cleaning and disinfection in schools.

CONCLUSION

When used independently, both conventional cleaning and disinfection and electrostatic disinfectant spraying were successful in disinfecting student desks. Electrostatic disinfectant spraying further improved hygienic state when conducted after conventional cleaning and disinfection procedures.

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