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Effect of Plastic Film Materials and Cleaning Frequency on Elevator Button Decontamination

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Abstract

Transmission via fomites represents a potential pathway for various pathogens to disseminate in institutional settings. In healthcare environments, elevator buttons are frequently protected with diverse plastic coverings; yet, scant data exist on how different plastic types influence disinfection efficacy. This research sought to determine the most appropriate plastic material for wrapping elevator buttons and to establish suitable cleaning frequencies. Six covering materials were evaluated: polyethylene (PE), polymethylpentene (PMP), polyvinyl chloride (PVC), and polyvinylidene chloride (PVDC) wraps; a thermoplastic polyurethane (TPU) keyboard protector; and a polyethylene terephthalate-ethylene vinyl acetate (PET-EVA) laminating film. Microbial contamination on buttons at varying time points was assessed via adenosine triphosphate (ATP) bioluminescence testing. Findings revealed that PVDC wraps exhibited greater durability than PMP, PVC, and PE materials, while also demonstrating the lowest ATP readings across all six options. Among button positions, door-close buttons recorded the highest ATP levels, followed by door-open and first-floor buttons, at one- and three-hour marks ($p = 0.024$ and $p < 0.001$, respectively). Following standard disinfection, ATP concentrations rose quickly upon contact and became significantly elevated after three hours ($p < 0.05$). These data suggest that PVDC wraps offer sufficient resilience and minimal residual contamination when used on elevator buttons. Door-close and door-open buttons emerged as the most heavily contacted areas, necessitating thorough disinfection; accordingly, cleaning every three hours or less appears advisable.

Keywords: Elevator buttons, Plastic coverings, ATP bioluminescence assay, Disinfection, Cleaning frequency

Introduction

Pathogen transmission often occurs through direct contact with infected individuals or contaminated surfaces, contributing substantially to healthcare-associated infections (HAI) [1–3]. Environmental surfaces serve as important reservoirs for microbes, enabling transfer to subsequent users [4–6]. Both Gram-positive and Gram-negative bacteria can persist for months on inert hospital surfaces, while SARS-CoV-2 has been detected for up to seven days on plastics [7–9].

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Elevators are commonplace in medical facilities, and their control buttons constitute overlooked sources of microbial buildup [10, 11]. To prevent damage from repeated bleach exposure, these buttons are routinely shielded with plastic films or wraps [12]. Such plastic coverings provide strong adherence, affordability, and minimal weight relative to commercial self-disinfecting coatings containing biocides [13–15]. Nonetheless, evidence regarding the influence of specific plastic compositions on cleaning effectiveness remains limited. Current guidelines consistently emphasize the need for thorough surface cleaning and disinfection in healthcare settings [16–18]. The ATP bioluminescence assay is widely employed worldwide for rapid assessment of cleaning adequacy and microbial burden [19, 20]. However, specific recommendations for elevator disinfection schedules have been absent, including from the Asia Pacific Society of Infection Control (APSIC) guidelines [21].

The present investigation aimed to examine the effects of various plastic coverings on elevator buttons, pinpoint the most contaminated button locations, and propose an evidence-based cleaning interval derived from ATP measurements.

Materials and Methods

Study design

This comparative study examined samples collected from the four primary elevators in a 395-bed regional hospital. Each elevator featured eleven buttons, encompassing door-close, door-open, basement 1, and floors 1–9. The third floor housed outpatient clinics and traditional Chinese medicine departments. Routine cleaning of elevator panels occurred three times daily without predetermined timing. Testing included an uncovered control (null) alongside six materials: four wraps (polyethylene (PE), polymethylpentene (PMP), polyvinyl chloride (PVC), and polyvinylidene chloride (PVDC)) and two films—a polyethylene terephthalate-ethylene vinyl acetate (PET-EVA) laminating sheet and a thermoplastic polyurethane (TPU) keyboard protector (Rt-SC03; ROTA America Inc., San Jose, CA, USA)—adapted for button panel application. Coverings were affixed to panels, followed by standard disinfection with 500 ppm sodium hypochlorite (6% bleach; Jenn Feng Chemical Works Co., Ltd., New Taipei City, Taiwan). ATP readings were obtained from button samples gathered between April 2020 and May 2020.

Investigation and sampling process

Initially, the status of the four plastic wraps on elevator panels was examined at three designated intervals (ten minutes, one hour, and three hours) following disinfection, classifying them as either undamaged or torn. Subsequently, a baseline ATP measurement was taken immediately after affixing a fresh plastic cover or film and wiping with 75% ethanol. Upon completion of standard cleaning and disinfection procedures, every button on each elevator panel was sampled by swabbing the full surface area (10.5 cm^2) first in one direction and then perpendicularly. At the same time, ATP levels from less frequently contacted regions on the panel were measured for reference. In addition to the ATP-specific swab (3M Clean-Trace System; 3M, St. Paul, MN, USA), a separate pre-moistened sterile swab was used for aerobic colony counts (ACC) (BBL CultureSwab; Becton Dickinson, Franklin Lakes, NJ, USA). The ATP test quantified overall surface contamination by activating the swab per manufacturer guidelines and recording results in relative light units (RLU). Each culture swab was placed in 1 mL of sterile saline, vortexed for 10 s, and 0.2 mL was inoculated onto tryptic soy agar (Creative Microbiologicals, Taipei County, Taiwan). Plates were incubated at 35 °C for 48 h, after which colony numbers were enumerated. However, the ACC approach was employed solely during the initial evaluation of the six plastic materials and the bare panel (null). All procedures were performed by the same trained infection control nurse. No additional disinfection occurred while collecting sequential ATP readings from the same coverings. Fresh plastic materials were applied daily prior to commencing new testing sessions.

Statistical analysis

Data were entered into an Excel spreadsheet (Microsoft, Redmond, WA, USA) and processed with IBM SPSS Statistics (Version 20.0; Armonk, NY, USA: IBM Corp.). ATP results are presented as mean ± standard deviation (SD). Comparisons between groups were conducted via one-way analysis of variance (ANOVA) followed by Student–Newman–Keuls post hoc analysis. Differences were deemed statistically significant at two-sided p-values below 0.05.

Results and Discussion

Comparison of PE, PMP, PVC, and PVDC wraps

A total of 24 observations were made for each wrap type at ten minutes, one hour, and three hours post-disinfection. PVDC demonstrated the highest integrity (100%, 24/24), outperforming PE (66.7%, 16/24), PMP (54.2%, 13/24), and PVC (54.2%, 13/24).

Aggregate ATP readings across all elevators on various dates showed no significant variation ($p = 0.409$). When combining ATP data from all buttons after one hour of usage, PVDC exhibited the lowest levels (mean ± SD, 147.3 ± 263.6 RLU) compared to PE (220.5 ± 246.5 RLU), PVC (252.5 ± 278.3 RLU), and PMP (276.6 ± 222.8 RLU), though the difference lacked statistical significance ($p = 0.491$). Furthermore, combined ATP readings from non-button panel areas were consistently low across wraps, except at three hours (range: 19–77 RLU). By button position, the peak ATP concentrations at the one-hour mark occurred on door-close buttons (378.5 ± 301.7 RLU), then door-open (281.5 ± 282.9

RLU) and first-floor buttons (167.5 ± 146.5 RLU) ($p < 0.001$, ANOVA).

Similar patterns emerged with ACC measurements. After one hour, PVDC recorded the lowest combined counts across buttons (15 colony-forming units (CFU)/10.5 cm²), followed by PE (32 CFU/10.5 cm²), PVC (42 CFU/10.5 cm²), and PMP (58 CFU/10.5 cm²). This order persisted for three hours (PVDC: 28 CFU/10.5 cm², PE: 57 CFU/10.5 cm², PVC: 80 CFU/10.5 cm², and PMP: 115 CFU/10.5 cm²). Non-button areas maintained very low ACC levels regardless of wrap, except at three hours (range: 1–5 CFU). Highest counts were on door-close buttons at both one-hour (PVDC: 4 CFU/10.5 cm², PE: 14 CFU/10.5 cm², PVC: 24 CFU/10.5 cm², and PMP: 26 CFU/10.5 cm²) and three-hour intervals (PVDC: 16 CFU/10.5 cm², PE: 23 CFU/10.5 cm², PVC: 32 CFU/10.5 cm², and PMP: 64 CFU/10.5 cm²).

Comparison of TPU keyboard cover, PET-EVA laminating film, PVDC wrap, and uncovered panel (Null)

Throughout testing, all TPU keyboard covers, PET-EVA laminating films, and PVDC wraps maintained structural integrity. Total ATP values aggregated across elevators and dates at various intervals showed no significant differences (one hour, $p = 0.151$; three hours, $p = 0.506$). At the one-hour point, PVDC wraps displayed markedly reduced ATP levels (180.0 ± 122.1 RLU) relative to TPU keyboard covers (700.0 ± 553.6 RLU), PET-EVA laminating films (482.0 ± 275.7 RLU), and the bare panel (null) (319.1 ± 205.7 RLU) ($p < 0.001$, ANOVA) **(Table 1 and Figure 1)**. PVDC continued to show the lowest ATP at three hours, albeit without reaching significance ($p = 0.073$) **(Table 1)**. In contrast, aggregated ATP from non-button regions remained comparatively low across all materials and the uncovered panel, even at three hours (range: 19–162 RLU).

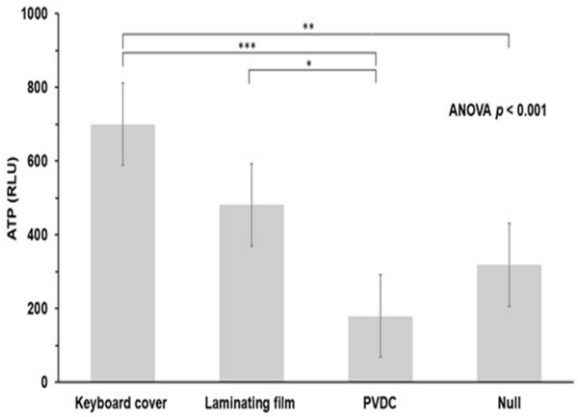

Figure 1. ATP levels on two plastic films, PVDC wrap, and bare panel (null). ATP, adenosine triphosphate; RLU, relative light unit; PVDC, polyvinylidene chloride; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 1. Comparison of ATP readings across various plastic coverings and an uncovered panel (null) (n = 144).

ATP (RLU)	TPU Keyboard Cover (n = 36) (a)	PET-EVA Laminating Film (n = 36) (b)	PVDC Wrap (n = 36) (c)	Null (n = 36) (d)	p	Post Hoc (a)
One hour	700.0 ± 553.6	482.0 ± 275.7	180.0 ± 122.1	319.1 ± 205.7	<0.001	a > c ***, a > d **, b > c *
Three hours	726.7 ± 514.1	522.6 ± 320.0	265.8 ± 208.3	464.2 ± 306.4	0.073	–

ATP, adenosine triphosphate; RLU, relative light unit; TPU, thermoplastic polyurethane; PET-EVA, polyethylene terephthalate-ethylene vinyl acetate; PVDC, polyvinylidene chloride; SD, standard deviation. a * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

ATP measurements taken at one-hour intervals showed the highest levels on door-close buttons (620.7 ± 489.3 RLU), then door-open buttons (424.8 ± 223.7 RLU), first-floor (404.8 ± 387.5 RLU), and third-floor buttons (230.7 ± 277.6 RLU) ($p = 0.024$, ANOVA) **(Table 2 and Figure 2a)**. At three hours, the values were: door-close (727.4 ± 482.3 RLU), door-open (505.9 ± 262.9 RLU), first-floor (468.1 ± 356.8 RLU), and third-floor buttons (277.8 ± 288.4 RLU) ($p < 0.001$, ANOVA) **(Table 2 and Figure 2b)**.

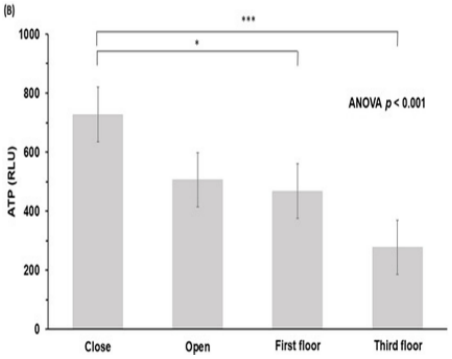

Figure 2. ATP levels across various button positions at (a) one-hour and (b) three-hour intervals. ATP,

adenosine triphosphate; RLU, relative light unit; * p < 0.05, *** p < 0.001.

Table 2. Comparison of ATP readings by button position (n = 144).

ATP (RLU)	Door Close (n = 36) (a)	Door Open (n = 36) (b)	First Floor (n = 36) (c)	Third Floor (n = 36) (d)	p	Post Hoc (a)
One hour	620.7 ± 489.3	424.8 ± 223.7	404.8 ± 387.5	230.7 ± 277.6	0.024	a > d *
Three hours	727.4 ± 482.3	505.9 ± 262.9	468.1 ± 356.8	277.8 ± 284.4	<0.001	a > c *, a > d ***

ATP, adenosine triphosphate; RLU, relative light unit; SD, standard deviation. a * p < 0.05, *** p < 0.001.

Similar patterns were observed using the ACC approach. After one hour of usage, PVDC recorded the lowest combined ACC across buttons (15 CFU/10.5 cm²), followed by bare panels (null) (22 CFU/10.5 cm²), PET-EVA laminating films (32 CFU/10.5 cm²), and TPU keyboard covers (52 CFU/10.5 cm²). This ranking persisted at three hours (PVDC: 28 CFU/10.5 cm², bare panels (null): 34 CFU/10.5 cm², PET-EVA laminating films: 41 CFU/10.5 cm², and TPU keyboard covers: 82 CFU/10.5 cm²). Non-button panel regions maintained low ACC levels across all coverings and the uncovered panel, except at three hours (range: 1–14 CFU). Peak ACC readings occurred on door-close buttons at both one-hour (PVDC: 4 CFU/10.5 cm², bare panels (null): 14 CFU/10.5 cm², PET-EVA laminating films: 16 CFU/10.5 cm², and TPU keyboard covers: 22 CFU/10.5 cm²) and three-hour points (PVDC: 16 CFU/10.5 cm², bare panels (null): 21 CFU/10.5 cm², PET-EVA laminating films: 24 CFU/10.5 cm², and TPU keyboard covers: 38 CFU/10.5 cm²).

Combined ATP readings from buttons across time points—ten minutes (410.8 ± 410.3 RLU), one hour (429.7 ± 351.1 RLU), and three hours (644.0 ± 363.4 RLU)—differed significantly (p = 0.004, ANOVA) **(Figure 3)**.

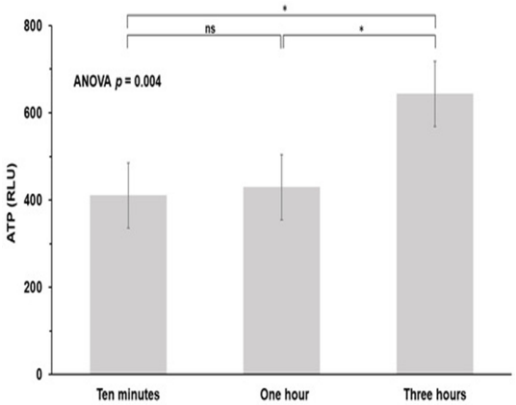

Figure 3. ATP levels at varying intervals: ten minutes, one hour, and three hours. ATP, adenosine triphosphate; RLU, relative light unit; ns, no significance; * p < 0.05.

The results of this research demonstrate that PVDC wrap exhibited superior durability and the lowest ATP readings in comparison to PE, PVC, and PMP when employed as covers for elevator buttons. Additionally, a disinfection frequency of less than three hours appeared appropriate for high-contact areas, including the door-close and door-open buttons.

In this investigation, we selected everyday plastic wraps and films due to their cost-effectiveness, particularly in resource-limited settings [22]. PVDC wraps displayed notable resistance to wear and the minimal detectable ATP levels post-use. Prior research indicates that PVDC possesses high durability, minimal moisture absorption, and resistance to mold, bacterial growth, and insects, explaining its reduced bioburden among the materials evaluated [23, 24]. In comparison, PET/EVA films possess dielectric characteristics leading to static buildup, while TPU covers may exhibit subtle surface irregularities from manufacturing variations, potentially contributing to their elevated ATP readings observed here [25, 26]. Recent approaches to mitigate surface adhesion include anti-fouling coatings, integration of antibacterial agents, or incorporation of bioactive metals [13–15, 27]. While many show potential, these methods involve substantial expenses, and issues like emerging resistance and reduced long-term effectiveness warrant additional investigation.

Multiple investigations have confirmed that hospital surfaces play a key role in transferring important healthcare-associated pathogens to patients [4–6]. Over the last ten years, evidence has highlighted the involvement of less obvious objects—like stethoscopes, keyboards, elevator buttons, and portable devices—in contact-based pathogen spread [4, 10, 21, 28–30]. This work examined high-touch elevator controls and identified door-close buttons as the most heavily contaminated, with door-open buttons next in line. Though our data did not directly assess SARS-CoV-2

transmission risk, one tracing study of infected individuals and contacts suggested transmission via contaminated elevator buttons, indicating elevators as a critical fomite to address [31]. Additionally, Bhatta *et al*. examined bacterial variety on shared surfaces among staff, patients, and visitors, finding substantial Staphylococcus aureus recovery from elevator buttons (25%), trailing only door handles (29.5%) [10]. This pattern may link to inadequate hygiene practices and suboptimal cleaning protocols.

Within the implemented traffic management measures, our observations suggested that cleaning high-touch elevator buttons every less than three hours was effective, given the quick rise in ATP after contact [32]. Such insights could inform broader, multifaceted hygiene programs. Yet, ideal disinfection schedules for non-clinical zones lack consensus, owing to limited comparative trials and the intricate microbial dynamics in medical facilities [17, 21]. Furthermore, ATP detection captures diverse organic residues, with bacteria representing just one element. Organic deposits on surfaces can nourish pathogens, and Lee *et al*. showed that lowering microbial proliferation through cleanliness helps curb transmission risks [33]. However, links between ATP quantities and actual microbial loads in hospitals vary across reports, with inconsistent findings documented [34–37]. Regarding ATP levels and relative light units (RLU), Omidbakhsh *et al*. reported robust correlation at higher ATP concentrations, though less reliable at lower ones [38]. ATP monitoring also shows reduced accuracy for minimal contamination and susceptibility to interference from various disinfectants [38]. Factors like temperature, humidity, fomite persistence, and air handling in clinical environments can markedly affect pathogen survival and spread [17, 39]. Proper management of these elements alongside rigorous hand hygiene would bolster the prevention of avoidable infections (16).

This research faces certain constraints. Initially, direct simultaneous comparisons across the six materials were not feasible due to access limited to four primary elevators. Next, variables such as user hygiene, visitor volume, ambient temperature, and humidity influenced button status; while results might differ by season, core patterns should persist. Lastly, ATP reflects organic content from microbes as well as residues like blood, proteins, and skin cells [35, 40]. Given the absence of local COVID-19 clusters in Taiwan during April to May 2020, no RT-PCR testing for SARS-CoV-2 on samples was conducted to explore ties between viral presence and ATP values.

Conclusion

The outcomes from this study endorse the use of PVDC wrap for protecting elevator buttons, owing to its adequate resilience and reduced bioburden buildup relative to the other plastics assessed. The door-close and door-open buttons represent the highest-contact points on elevator panels, suggesting that disinfection every no more than three hours could be advisable for maintaining efficacy.

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