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Leveraging virucidal potential of an anti-microbial coating agent to mitigate fomite transmission of respiratory viruses

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ABSTRACT

In the wake of the COVID-19 pandemic, respiratory tract infections have emerged as a significant global threat, yet their impact on public health was previously underappreciated. This study investigated the antiviral efficacy of the nano-coating agent BARRIER90, composed of silicon-quaternary ammonium compound and a naturally derived biopolymer, against three distinct respiratory viruses: Influenza A (H1N1), Adenovirus Type 1, and Enterovirus-Coxsackie B1. BARRIER90 exhibited robust and sustained virucidal activity, persisting up to 90 days post-coating, against the enveloped virus, Influenza A, with significant reduction in viral plaques. Contrastingly, its efficacy against non-enveloped viruses revealed transient activity against Enterovirus-Coxsackie B1, with almost no antiviral activity observed against Adenovirus Type 1. These findings indicate the potential of anti-microbial coatings in mitigating viral transmission through contaminated surfaces (fomites), which harbour pathogenic viruses for longer periods. Antimicrobial coatings may facilitate infection control in various settings, including healthcare facilities and shared workspaces.

Introduction

In this contemporary interconnected world, profoundly shaped by the impact of COVID-19, it is indisputable that respiratory tract infections represent a substantial global threat to our well-being, financial stability, and consequently, our way of life. Several respiratory viruses, including respiratory syncytial virus (RSV), rhinovirus, influenza virus, parainfluenza virus, adenovirus, and human metapneumovirus, are major viral causes of severe respiratory illness in India. In 2018, there were 41,996,260 cases and 3740 deaths from respiratory infections in India reported in National Health Portal of India. The World Health Organisation (WHO) suggests that there are around a billion cases of seasonal Influenza viruses annually, including 290,000 to 650,000 fatalities. Respiratory infections, notably driven by viruses like human respiratory syncytial virus (HRSV or RSV), pose significant global health challenges, particularly in children under 5 years. Its impact is particularly severe in low- and middle-income countries, where it accounts for 22 % of all acute lower respiratory tract infections (ALRI) and remains a primary cause of childhood mortality. RSV alone contributes to about 33.1 million cases annually, with a substantial proportion requiring hospitalization and leading to approx. 59,600 deaths among young children. Similarly, human parainfluenza virus (HPIV), including types 1 and 3, Rhinovirus and Adenovirus significantly contribute to respiratory illnesses, though the global estimation data are scarce (Waghmode et al., 2021). However, before the emergence of COVID-19 and despite previous challenges such as Influenza A(H1N1)pdm09, MERS and SARS-CoV-1, the impact of respiratory infections on public health was not widely acknowledged, especially among the general population. This lack of recognition persisted despite an extensive body of evidence regarding the mortality, morbidity, and economic consequences associated with respiratory tract infections (Waterer, 2023).

Influenza A (H1N1) virus, a negative-sense single-stranded RNA virus with pandemic potential, can cause severe lower respiratory tract infections (Uyeki et al., 2022). Adenovirus Type 1, a double-stranded DNA virus, causes gastrointestinal, conjunctival, or respiratory illnesses year-round, with a higher susceptibility among young individuals or individuals with compromised immune systems (Ghebremedhin, 2014). Adenoviruses are known to cause sporadic outbreaks most

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commonly in communal spaces. Enterovirus-Coxsackie B1, a positive-sense single-stranded RNA virus, can lead to conditions such as pleurodynia, myocarditis, pericarditis, and hepatitis, particularly affecting newborns and young children. Among viruses causing cardiovascular problems, Coxsackie B is the most common culprit (Muehlenbachs et al., 2015). The possible routes of transmission for the above-mentioned viruses include direct inhalation of contagious aerosols, contact with inanimate surfaces (fomites) contaminated with the virus, and direct exposure with infected individuals (Asadi et al., 2020; Lynch and Kajon, 2016; Mubareka et al., 2009; Muehlenbachs et al., 2015).

During the recent pandemic of SARS-CoV-2, the enforced implementation of lockdowns, social distancing measures, and compulsory use of masks succeeded in reducing the spread of the virus to a great extent. However, these measures led to COVID-fatigue and an economic decline, with negative effects (Caschera et al., 2022). Hospitals, long-term care facilities, clinics, and institutions like schools, nursing homes, and prisons faced significant challenges during the pandemic. Given the possibility of transmission of respiratory viruses through aerosols and their ability to spread through respiratory droplets and contaminated surfaces, it is crucial to adopt innovative strategies for mitigation and prevention (Caschera et al., 2022). These strategies must include implementation of stringent hygiene norms, research into virucidal qualities of antimicrobial coatings, and application of such coatings inside communal spaces, with a focus on their potential for antiviral protection (Rakowska et al., 2021).

Exploration of diverse antiviral and virucidal coating technologies reveal their use spanning from personal protective equipment (PPE) to medical instruments, appliances, and hygienic implements. The essence of antiviral product design lies in surface modification, wherein various compositions of antiviral and virucidal coatings are applied, employing the most promising surface modification methodologies available. To quote a few, Modak and colleagues introduced an antiviral surgical glove featuring an inner coating consisting of an anti-infective agent, such as chlorhexidine or its pharmaceutically acceptable salts, combined with a lubricating agent, engineered to rapidly dispense the anti-infective substance. This glove technology delivers revolutionary protection against viruses and other infectious agents in healthcare facility (Modak and Sampath, 1992). Larson et al., devised multivalent antiviral compounds covalently bonded to a polymer chain, demonstrating enhanced efficacy against diverse target viruses. By combining multiple iterations of bicyclic naphthoquinone and polymers, Larson significantly enhanced the antiviral properties. This approach was also utilized to reinstate inhibition against drug-resistant strains within the adamantane class of influenza inhibitors (Larson, 2013).

In line with the above strategies, it was ideated to utilise the virucidal properties of quaternary ammonium compounds (QACs), silver nanoparticles (AgNPs), chitosan, and antimicrobial enzymes (AMEs) by employing them as surface coating agents that can reduce and prevent fomite transmission. To overcome the challenges of inconsistent release kinetics and depletion of reservoirs, surfaces with the ability of contact killing were created by immobilising the microbicidal agents onto the polymer backbone (Isquith et al., 1972). BARRIER90 is one such antimicrobial coating agent that is a nanoformulation of quaternary ammonium compound (QAC) immobilised onto chitosan polymer through covalent bonding. This product has been designed and developed by Hygienetech India Pvt. Ltd., in the direction of search for antiviral solutions. This study was aimed at elucidating and rationalising the virucidal activity of the coating agent BARRIER90 against three respiratory viruses through laboratory standardized antiviral protocols. Through the tests carried out it was evident that BARRIER90 was reasonably virucidal against enveloped viruses, with moderate to little activity against non-enveloped viruses indicating an acceptable application as a surface coating to prevent fomite transmission of contagious pathogens.

Materials and methods

Compounds, cells, and viruses

BARRIER90-coated slides and uncoated slides were provided by Hygienetech India Pvt. Ltd. BARRIER90 is a nano-formulation composed of silicon-quaternary compound and a biopolymer derived from deacetylation of N-acetylglucosamine.

MDCK (FR-58 London line ATCC® strain), A549 (ATCC® CCL-185), and Vero cells (ATCC® CCL-81™ strain) were used to culture and quantify Influenza virus A/Michigan/45/2015 (H1N1), Adenovirus Type 1 (FR300) and Enterovirus-Coxsackie B1 (FR306 VR28) respectively. MDCK, A549, and Vero cells were grown in Minimum Essential Media – Maintenance Media (MEM-MM, Gibco, Thermo Fisher Scientific, India), and Dulbecco's Minimum Essential Media-Maintenance media (DMEM-MM, Gibco, Thermo Fisher Scientific, India) respectively, supplied with 10 % v/v Fetal Bovine Serum (FBS, Gibco, Thermo Fisher Scientific, India). The virus strains and cells were procured from International Reagents Resource (IRR) and American Type Culture Collection (ATCC) respectively.

Virus titration by plaque assay and Tissue Culture Infectious Dose (TCID50)

Influenza A/Michigan/45/2015 (H1N1) pdm09 virus was propagated in MDCK cells and Enterovirus-Coxsackie B1 was cultured in Vero cells. Respective cells were seeded in 12-well cell culture plate and allowed to grow overnight. Log dilutions (ten-fold) of Influenza virus and Enterovirus were made in phosphate buffered saline (PBS) and MEM MM respectively. Diluted viruses were added to the respective cell monolayer and allowed to adsorb for 1 h at 37 °C with 5 % CO_2. The first overlay containing 1 % agarose, 2X-Yeast extract – Lactalbumin hydrolysate media (2x-Yelah) and sodium bicarbonate (7.5 % v/v) was added to the cell monolayer after adsorption. The plate was incubated for 40 h (about 1 and a half days) for Influenza virus and 24 h for Enterovirus. After the incubation period, a second overlay [same composition as the first overlay + neutral red dye (0.3 % v/v) for staining] was added. Plaques were counted post 6 h of second overlay addition, for Influenza A (H1N1) virus and Enterovirus respectively. The virus titers were expressed in plaque formation units (PFU)/mL.

Adenovirus was propagated in A549 cells using DMEM MM and the titer was quantified using tissue culture infectous dose ($TCID_{50}$)/mL (REED and MUENCH, 1938).

Antiviral efficacy testing of BARRIER90

Influenza A (H1N1) and Enterovirus-Coxsackie B1 were diluted to 100 PFU/mL and 200 PFU/mL respectively and 300 μL of the virus dilution was added on both coated and uncoated slides each, followed by incubation for 30 min at room temperature. After 30 min, 300 μL of PBS and MEM MM was used to elute Influenza A (H1N1) virus and Enterovirus-Coxsackie B1 respectively. Plaque reduction assay was performed.

Adenovirus Type 1 (200 μL) at 6×10^5 $TCID_{50}$/mL was added on to both coated and uncoated slides and incubated for 30 mins at room temperature. After 30 min, 100 μL of DMEM MM was used to elute the virus and tissue culture infectious dose ($TCID_{50}$) was calculated. The procedure is depicted as a flowchart in Fig. 1.

Data analysis

The results from the efficacy testing assays are expressed as Mean ± SEM. Analysis was done using "unpaired-student t" test in GraphPad Prism software version 8.0.0 for windows, San Diego, California USA. The results were considered statistically significant, when the *"p"* value was less than 0.05.

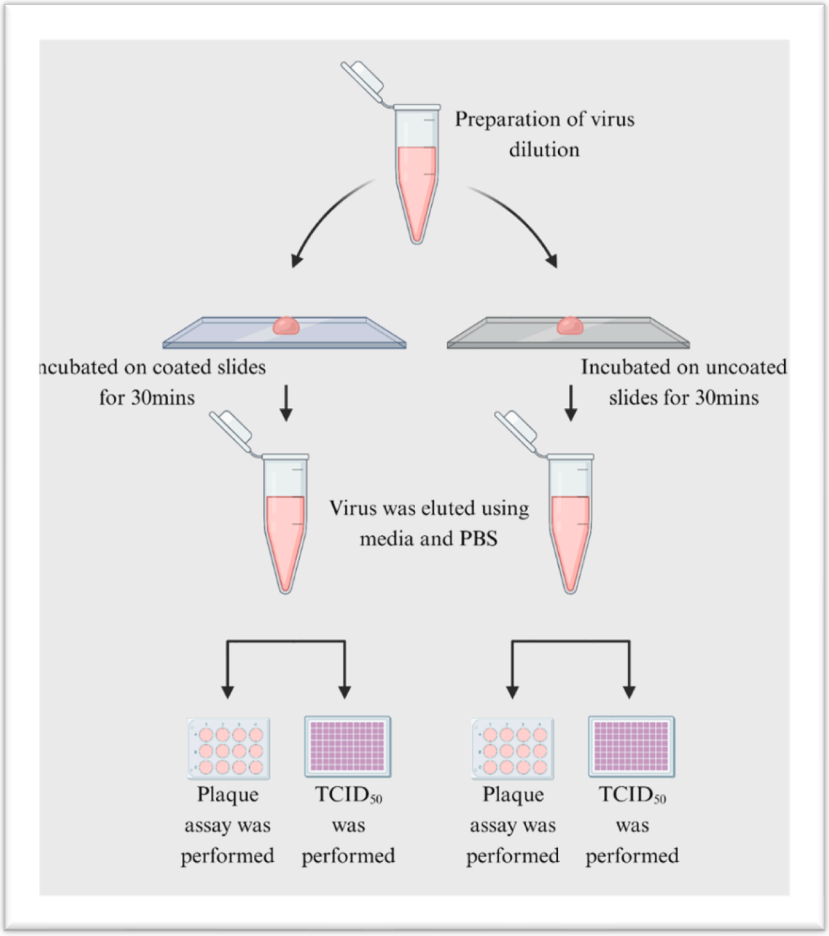

Fig. 1. Procedure for assessing the antiviral activity. Image created in biorender.com.

Results

Assessment of antiviral activity

BARRIER90 was efficacious against Influenza A (H1N1) virus

The efficacy of BARRIER90 was tested at four time-points i.e. 0-, 30-, 60-, and 90-days post-coating. During each time-point, 300 µl of diluted virus (100 PFU/ml) was added to both coated and uncoated slides. There was a significant reduction in the virus infectivity by BARRIER90 at all the intermittent testing time points across the period of three months as evident from the above table (Table 1). The results on 0th day, i.e. immediately post coating, revealed 58 % reduction in virus infectivity. There was 85 % and 92 % reduction in virus infectivity on 30th and 60th day post coating respectively. However, on 90th day the reduction in virus infectivity diminished to 59 % (Fig 2).

Table 1
Efficacy of BARRIER90 against Influenza A (H1N1) virus.

Number of days post coating	Efficacy of BARRIER90 against Influenza A (H1N1)		
	Number of plaques (Mean ± SEM)		Percentage of reduction in virus infectivity (%)
	Uncoated	Coated	
0	**56 ± 1.5**	**24 ± 1.2*** **	**58**
30	**40.5 ± 5.5**	**6 ± 1*** **	**85**
60	**75 ± 2**	**6 ± 2****	**92**
90	**38.5 ± 1.5**	**18.5 ± 3.5***	**59**

Asterisks indicate significant difference (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$) in comparison with uncoated slides. The assays were performed in triplicates using two different glass slides.

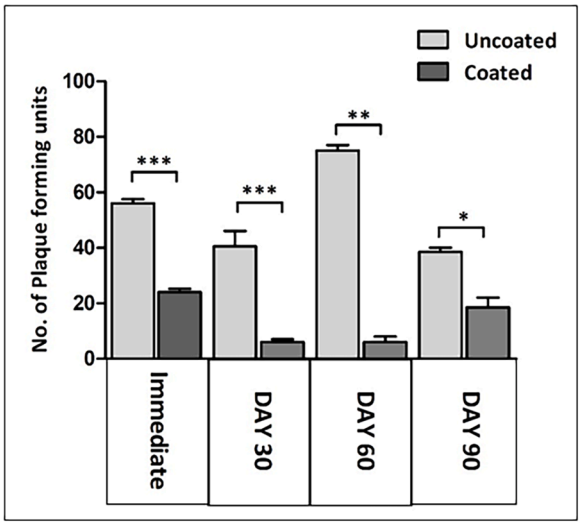

Fig. 2. Trends in efficacy of BARRIER90 against Influenza A (H1N1) virus across all four time-points; Asterisks indicate significant difference in means based on unpaired *t*- test (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.0001$) in comparison with uncoated slides.

BARRIER90 was selectively efficacious against Enterovirus-Coxsackie B1

The virus (14×10^8 PFU/mL) was diluted to 200 PFU/ml and 300 µl was added to both the coated and uncoated slides at four testing time-points i.e. 0-, 30-, 60-, and 90- days post-coating. From Table 2 it is evident that on 0th day, there was no difference in the number of plaques between the coated and uncoated slides. The efficacy of BARRIER90 started to become apparent after 30th day post coating. In batch 1 of coated slides, there was 16 % reduction in virus infectivity, however, in batch 2 of coated slides, 6 % reduction in virus infectivity was observed. On 60th day post coating, a 26 % reduction in virus infectivity was observed for batch 1 of coated slides, however, batch 2 demonstrated 13 % reduction in virus infectivity, when compared to uncoated slides. There was no difference in the number of plaques between coated and uncoated slides on 90th day post coating. The coated slides significantly inhibited Enterovirus growth on 60th day compared to uncoated slides. However, none of the other time points showed any statistically significant reduction in the virus plaque numbers compared to uncoated slide (Fig. 3).

BARRIER90 was ineffective against Adenovirus Type 1

The viral titres (Mean values of two slides) remain unchanged on both coated and uncoated surfaces over the 90-day observation period indicating that the coating agent was ineffective against Adenovirus Type 1 as evident from Table 3. Table 4 shows the percentage reduction in infection rates of all the three viruses.

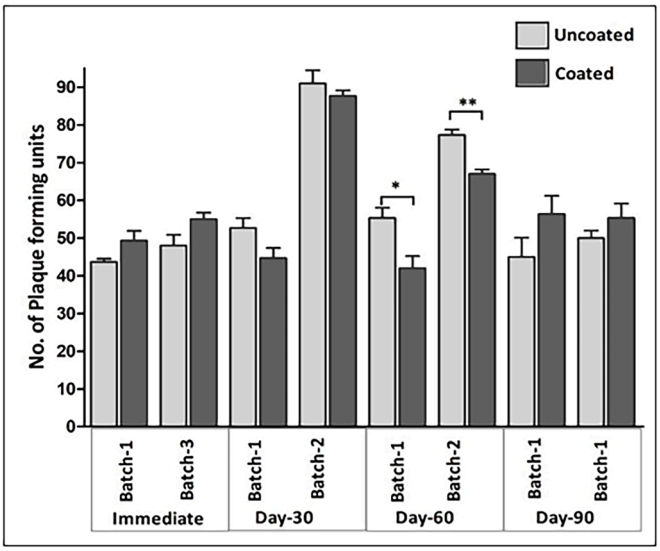

Fig. 3. Trends in efficacy of BARRIER90 against Enterovirus-Coxsackie B1 across all four time-points; Asterisks indicate significant difference in means based on unpaired 't' test (* $p < 0.05$, ** $p < 0.01$) in comparison with uncoated slides.

Table 3
Efficacy of BARRIER90 against Adenovirus Type 1.

Number of days post coating	Efficacy of BARRIER90 against Adenovirus Type 1		
	$TCID_{50}$/mL (Mean ± SEM)		Percentage of reduction (%)
	Uncoated	Coated	
0	**$6 \times 10^4 \pm 0$**	**$6 \times 10^4 \pm 0$**	0
30	**$6 \times 10^2 \pm 0$**	**$6 \times 10^2 \pm 0$**	0
60	**$6 \times 10^4 \pm 0$**	**$6 \times 10^4 \pm 0$**	0
90	**$6 \times 10^4 \pm 0$**	**$6 \times 10^4 \pm 0$**	0

Discussion

Contaminated surfaces of inanimate objects, otherwise known as fomites, significantly contribute to the spread of infections during outbreaks, posing a considerable challenge in effectively controlling the dissemination of infectious diseases (Weber and Stilianakis, 2020). Numerous epidemiological indications, laboratory studies, and disinfection interventions suggest that fomites serve as potential route for transmission of enteric and respiratory viruses. Several interdisciplinary studies investigating the transmission dynamics of viruses as fomites indicate that fomites and hands harbour enteric and respiratory viruses for varying durations, serving as potential sources of contamination. Transfer of viruses from fomites to hands and vice versa is possible and virus transmission can be interrupted by intervention through disinfection of fomites (Boone and Gerba, 2007; Kramer and Assadian, 2014). Quaternary ammonium compounds (QACs), silver nanoparticles (AgNPs), chitosan, and antimicrobial enzymes (AMEs) as surface coating agents, are commonly employed to reduce and prevent fomite transmission.

BARRIER90 is one such antimicrobial coating agent, which is a nanoformulation of quaternary ammonium compounds (QACs) immobilised onto chitosan polymer through covalent bonding. The present study was therefore designed to test the virucidal efficacy of BARRIER90-coated glass slides, against enveloped virus Influenza A (H1N1) (segmented negative sense ssRNA virus), and non-enveloped viruses, Enterovirus-Coxsackie B1 (non-segmented positive sense

Table 2
Efficacy of BARRIER90 against Enterovirus-Coxsackie B1.

Number of days post coating	Efficacy of BARRIER90 against Enterovirus-Coxsackie B1								
	Batch 1			Batch 2			Batch 3		
	Number of plaques (Mean ± SEM)		Percentage of reduction in virus infectivity (%)	Number of plaques (Mean ± SEM)		Percentage of reduction in virus infectivity (%)	Number of plaques (Mean ± SEM)		Percentage of reduction in virus infectivity (%)
	Uncoated	Coated		Uncoated	Coated		Uncoated	Coated	
Immediate	**43 ± 0.88**	**49 ± 2.6**	**0**	-	-	-	**48 ± 2.8**	**55 ± 1.7**	**0**
30	**52 ± 2.6**	**44 ± 2.7**	**14–16**	**91 ± 3.5**	**87 ± 1**	**2–6**	-	-	-
60	**55 ± 2.7**	**42 ± 3****	**21–26**	**77.3 ± 1**	**67 ± 1****	**12–13**	-	-	-
90#	**45 ± 5.1**	**56 ± 4.9**	**0**	-	-	-	-	-	-
	50 ± 2	**55 ± 3.8**	**0**						

Asterisks indicate significant difference in the means based on unpaired *t*- test (* $p < 0.05$, ** $p < 0.01$) in comparison with uncoated slides. #Repetition of the assay using different slide from batch 1.

Table 4
Comparative percentage reduction in virus infection of different viruses.

Days	% Reduction in virus infection		
	Influenza virus	Enterovirus	Adenovirus
Immediate	58	0	0
30	85	16	0
60	92	26	0
90	59	0	0

ssRNA virus) and Adenovirus Type 1 (dsDNA virus), across a period of three months starting from the day of coating.

BARRIER90 exhibited a significant activity against Influenza A virus at all the four time-points post-coating, resulting into a 57–92 % reduction in the virus infectivity, mediated either by altering the virus's ability to attach and infect the cell through changing surface glycoprotein structure, or by inducing virion membrane lysis and degradation (Hoelzer et al., 2013). BARRIER90 is a nanoformulation composed of quaternary ammonium compounds (QACs), which are known to inhibit enveloped viruses by disrupting the virus envelop, rendering the virus inactive (Shirai et al., 2000). This could be due to the strong affinity of the QACs towards the enveloped viruses, driven by hydrophobic interactions (Caschera et al., 2022). This finding is further substantiated by the research summarised by Klein and Deforet in 1983, which demonstrated the successful inactivation of enveloped viruses like the vaccinia virus using zephiran, an antimicrobial coating agent composed of QAC (Caschera et al., 2022; Muñoz-Bonilla and Fernández-García, 2012; Shirai et al., 2000; Tung et al., 2013). The results presented in J. A. Armstrong et al., demonstrate that bezalkonium chloride efficiently inhibits a wide range of viruses, including Influenza, Measles, Herpes Simplex, Variola, and Japanese encephalitis virus (Armstrong and Froelich, 1964).

BARRIER90 failed to show any significant activity against Enterovirus-Coxsackie B1 on 0th, 30th and 90th day post coating, although there was a 13 % reduction observed in plaques on 30th day. However, on 60th day post-coating, significant activity was observed, which translated into a maximum of 26 % reduction in virus infectivity compared to a maximum of 13 % reduction observed on 30th day. Intriguingly, BARRIER90 worked better on 30th day and 60th day post coating in case of both Influenza and Enterovirus, than immediately after application. Possible speculations could be, is there any change in the physico–chemical properties of BARRIER90 after coating on the glass surface? Are there any changes in the binding affinity of the coating towards the viruses with time?, etc. needs further evaluation. Addressing these speculations from the perspective of the interaction dynamics of the coating with the glass surface and the viruses will be helpful.

It has been reported that QACs normally function by forming non-structural micelles with the non-enveloped viruses, without posing too much lethal effect on these viruses (Harada et al., 2015; Hoelzer et al., 2013; Shirai et al., 2000; Tung et al., 2013). However, the reduction in virus infectivity observed in case of Enterovirus-Coxsackie B1 could be attributed to the disinfectant property of chitosan (Budragchaa et al., 2015; Wang et al., 2020, 2012; Zheng et al., 2016). Nevertheless, as the maximum activity was only 26 %, it could be due to the reported inherent resistance of the virus family, *Picornaviridae,* towards the QACs. The varying pattern of activity of BARRIER90 against the two non-enveloped viruses, Enterovirus-Coxsackie B1 and Adenovirus Type 1, can be explained through their structural disparities (Vasickova et al., 2010). Enterovirus-Coxsackie B1 (300 Å diameter) has a capsid comprising of 60 protomers, each made up of a single copy of the viral proteins VP1, VP2, VP3, and VP4 organized in an icosahedral lattice, whereas Adenovirus Type 1 (950 Å diameter) consists of a capsid comprising of 252 primary capsomeres, of which 12 pentons are found at the corners of the virus particle, and 240 hexons constitute each facet of the icosahedron. A more intricate and complex structural framework of the adenovirus (Ghebremedhin, 2014; Muehlenbachs et al., 2015), could be contributing to its greater stability in the environment, thereby conferring it resistant to the virucidal action of BARRIER90.

Several studies comparing the survival of various viruses on porous and non-porous surfaces, have shown that viruses tend to remain more stable for extended periods on non-porous materials (Abad et al., 1994; Boone and Gerba, 2007). Adenoviruses can remain viable on glass surfaces for a period of 12 weeks, whereas Coxsackie viruses can survive on similar surfaces for 3–4 weeks (Mahl and Sadler, 1975). The varying structural resilience of these viruses contributes to their stability and viability on the glass surfaces. The exposure time of the virus with the coating BARRIER90 was only for 30 min, which though could reduce the virus infectivity, the reduction was less. Therefore, it would be worth to increase the duration of virus exposure with the coated surface for longer than 30 min and study the effect, before validating the efficacy of BARRIER90. Longer exposure time of the coating materials may enhance the virucidal activity of the surfaces and help in reducing the infectivity, especially considering the non-leaching property of BARRIER90.

The transmission of viruses from fomites depends on the viability of viruses on various surfaces, driven by a range of factors including both intrinsic and extrinsic elements (Castaño et al., 2020). Intrinsic factors such as the type of virus, and the properties of the surface (fomite) play crucial role in determining the viability of the viruses. Additionally, extrinsic factors such as the surrounding environment, temperature, the medium containing the virus, and the humidity levels also influence the longevity of viruses on surfaces (Abad et al., 1994). Viruses with an outer lipid bilayer (envelope) are inherently protected, however may lose their structural integrity under the influence of severe extrinsic factors. Non-enveloped viruses on the contrary show greater resilience against environmental challenges like detergents and heat, thereby staying viable for longer durations even under harsh conditions (Abad et al., 1994; Castaño et al., 2020). This is also reflected from some of the scientific literatures reporting the preferential activity of certain QACs against the non-enveloped viruses. To quote a few, zephiran, a QAC, has been found active against reoviruses and bacteriophages, whereas some QACs failed to kill the virus completely, rather caused structural deformations as micelles, which are not certain indicators of virus inactivation. The question remains whether these non-enveloped viruses have evolved in their structural architecture to endure rigorous environmental conditions. In terms of viability, a virus is viable if it can infect the host. This infectivity is an innate nature of the virus that can be attributed to the surface glycoproteins present on enveloped viruses and the capsid proteins present on the non-enveloped viruses. As long as the structural and physical integrity of these proteins are unaltered the virus will remain infectious. To render the viruses inactive, surface coating agents must be designed to cause structural dysfunction in these crucial proteins that facilitate infectivity. Nevertheless, the future of surface active virucidals holds promising prospects for research, focussed on developing coating agents with broader spectrum of activity, against various pathogenic viruses.

From the research investigating the use of coating materials as antimicrobial agents in healthcare settings, here are the following findings. FN Nano Inc., located in the USA, has developed a groundbreaking photocatalytic paint utilizing titanium dioxide nanoparticles. This innovative paint could eradicate organic compounds such as viruses when exposed to light, effectively damaging the viral membrane (Talebian et al., 2020). Recent studies have demonstrated the effectiveness of TiO_2 nanoparticles against HCoV-NL63 across varying humidity levels. Khaiboullina et al. revealed that even under extremely high humidity conditions (85 % relative humidity), TiO_2 nanoparticles maintain their virucidal efficacy. This suggests a wide range of applications for TiO_2 NP coatings on outdoor surfaces. Furthermore, the research showcased that TiO_2-coated surfaces possess the ability to deactivate viruses even when dried virus droplets are present (Khaiboullina et al., 2020).

In terms of the potential applications of BARRIER90, it could serve as

a coating agent specifically designed for application on glass surfaces/low-friction surfaces. One of the key areas where these virucidal coating proves invaluable is in healthcare settings, where the spread of nosocomial infections is a persistent concern. By coating interiors in the hospitals and medical facilities with these virucidal agents can actively combat the fomite transmission of infections among patients, healthcare workers, and visitors. This innovative measure not only enhances patient safety but also contributes to the overall efficacy of infection control protocols within healthcare environments and other public spaces. This functional coating technology is a novel method, which can be applied in a bigger and wider setup, transforming different working spaces into virus free environment. This would help greatly in reducing the spread of viruses, with high potential of fomite transmission, especially respiratory viruses, particularly during the peak seasons. Considering the pandemic potential of these viruses, it would be worth to use the virucidal as a step towards prevention of pandemics with a huge economic implication. Overall, this technology would help safeguard the health and well-being of individuals within communities, thereby mitigating the risk of widespread disease outbreaks.

Conclusion

The findings of the present study highlight the potential of antimicrobial coatings in mitigating virus transmission through fomites, offering valuable insights for infection control in various workspaces, including healthcare facilities. This would revolutionise the current strategies of disinfection interventions practised in these settings.

Disclaimer

The nanoformulation coating BARRIER90 tested in the present study was prepared only for trial purpose, therefore repetitions of the experiments with different batches of the product is imperative to validate batch to batch consistency. Moreover, as the study involved only 30 min of virus exposure with the coated slides, experiments with extended duration of exposures are needed before validating the efficacy, especially against non-enveloped viruses.

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CRediT authorship contribution statement

Bommana Chanakya: Data curation, Investigation, Methodology, Writing – original draft. **Kavitha Karunakaran:** Data curation, Investigation, Methodology, Supervision, Writing – review & editing. **Oliver Christy Dsa:** Data curation, Investigation, Methodology. **Anil Prataprai Sanghvi:** Conceptualization, Resources, Validation. **Chiranjay Mukhopadhyay:** Project administration, Writing – review & editing. **Piya Paul Mudgal:** Conceptualization, Supervision, Project administration, Validation, Writing – review & editing.

Declaration of competing interest

He authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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