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RESEARCH ARTICLE OPEN ACCESS

Antimicrobial Efficacy of Titanium Dioxide Coating in Operating Theaters at A Tertiary Care Hospital in Arunachal Pradesh

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Abstract

SmartCoat is a novel technology with titanium dioxide (TiO_2) nanoparticles, isopropyl alcohol, and distilled water as the active ingredients. TiO_2, along with water and oxygen, generates highly reactive OH radicals that can neutralize bacteria and other microorganisms and remove volatile organic compounds (VOCs). Smart coat requires air circulation and a light source for its catalytic activity. The efficacy of TiO_2 in industrial setups and dental devices has been documented. The present study aimed to evaluate the efficacy of TiO2 in preventing microbial growth in an operating theater (OT) where maximum sterility is desired to prevent sepsis and nosocomial infections. Among the four operating theaters, two were selected. Periodic swab samples taken over a period of nine months from OT 3 (Smart coated) and OT 4 (Control) showed minimal variations in terms of microbial growth in the processed swabs. The findings were statistically analyzed using a paired-sample t-test. The computed value of 't' i.e., 2.084 was lower than the critical value of 3.18 at 3 deg of freedom (df) and hence was not significant. The null hypothesis cannot be rejected (p=0.129>0.05) at the 5% level of significance. SmartCoat with TiO_2 was not effective in preventing microbial growth on biomedical devices in the OT. The product may not be suitable for operating theaters unless it is supplemented by other sterilization procedures. However, it can be used in other healthcare settings and in public places.

Keywords: SmartCoat, titanium dioxide, nanoparticles, relative light units, operation theatre, nosocomial infections, sepsis

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INTRODUCTION

Titanium dioxide (TiO_2) is a considerably effective nano-semiconductor photocatalyst that is commonly utilized in organic and inorganic compound oxidation in water and air because of its extended photostability and vigorous oxidative potential. TiO_2 is a cheap and innocuous material[1] that produces extremely reactive OH radicals in the presence of O_2 and H_2O. These OH radicals can effectively prevent bacterial growth and development.[2]

Infections associated to bacteria pose a considerable threat to the well-being of patients in the healthcare system. Infections with *Staphylococcus aureus* is the leading cause of patient morbidity. Several reports have indicated the existence of methicillin-resistant *Staphylococcus aureus* on hospital surfaces for up to 5 months. During non-lethal UV light exposure, TiO_2 nanoparticles degrade organic compounds by continuous discharge and the emergence of superoxide ions and hydroxyl radicals, which restrict the growth of methicillin-resistant *Staphylococcus aureus*.[3]

SmartCoat is a new-generation technology with the following active ingredients: TiO_2, nanoparticles, isopropyl alcohol, and distilled water. SmartCoat India Pvt. Ltd claims that it has antibacterial, antiviral, and antifungal properties and removes volatile organic compounds (VOCs). It is a deodorizing agent, and it acts as a self-cleaning agent. TiO_2 has a nano size of 2–3 nm for the greatest coverage to reacts with any light source to eradicate 99.9% of fungi, bacteria, viruses, and VOCs. According to the SmartCoat India Pvt. Ltd, 1000 relative light units (RLU) are recommended microbial levels as per the Lumitester document. The supply of light (measured in RLU) and air circulation is necessary for the functioning of this coating, as it is developed on photocatalyst technology.

There is a lack of literature on the efficacy of SmartCoat in microbial prevention in the primitive zones of health care. Various approaches with different compositions of surface coats have yet to be explained. The present study aimed to evaluate the advantage of TiO_2 coated surfaces in preventing substantial microbial growth in the OT of TRIHMS Hospital, where the maximum sterility procedure is adopted.

MATERIALS AND METHODS

This cross-sectional observational study was carried out in the Department of Microbiology, Tomo Riba Institute of Health & Medical Sciences (TRIHMS), a 300 bed state hospital located in the capital complex of Naharlagun, Arunachal Pradesh, from June to December 2020. Among the four operating theaters (OTs) at TRIHMS, two OTs were selected for the study. To avoid any bias, two OTs (OT 3 and OT 4) were selected randomly. The study proposal was approved by the institutional research committee and the institutional ethics committee.

Sampling and cultivation

One swab was taken from the OT table, bedside monitor, anesthesia machine, and operating microscope before application of TiO_2 (SmartCoat). Darcon-tipped sterile swabs hydrated with sterile water were swabbed on the surface to be tested. The test swab was then inserted in the tube, shaken to integrate in the water at the bottom of the swab tube. The swab tube was then tested using the Kikkoman Lumitester PD 20, and the results were recorded.

Thereafter, Germisep tablets were mixed in water (1 tablet in 10 L water). Germisep dissolves chlorine in water. This solution was then sprayed on the interiors of OT 3 with an electrostatic sprayer (ESS). The ESS sprays electrically charged molecules to the liquid to increase its spread and adherence over the surface .

SmartCoat and its application

The photo catalyst SmartCoat product is a liquid containing TiO_2 nanoparticles as the main ingredient, along with isopropyl alcohol and distilled water. Regardless of the surface to which it is applied, SmartCoat technology neutralizes any organic matter upon contact via its oxidative ability, which is triggered utilizing any available light.

SmartCoat was applied to the walls, floor, roof, tables, surgical items, and all equipment inside OT 3 by an ESS and supplied sufficient light and air. This was left to dry for 30 min with all lights switched on, in OT 3. After 30 min, swabs were taken from the same three sites.

The collected swabs were taken to the Department of Microbiology laboratory and were inoculated on Sabouraud dextrose agar (SDA) and nutrient agar. Readings of culture media were

Table 1. Culture reports showing growth of various microbial floras at periodical interval

Time period	Operation theatre 3	Operation theatre 4
End of 1st week	*Bacillus* Species	*Candida* species Coagulase negative *staphylococcus*
End of 2nd week	*Staphylococcus* species *Proteus Mirabilis* *Micrococcus* species	*Staphylococcus* species *Bacillus* Species
End of 1 month	*Bacillus* Species *Alcaligenes* species	*Staphylococcus Aureus* *Bacillus* Species
End of 2 month	*Moraxella* Species *Alcaligenes* species	*Staphylococcus Aureus* *Moraxella* Species
End of 3rd month	*Moraxella* Species	*Staphylococcus Aureus* *Moraxella* Species
End of 6th month	*Moraxella* Species	*Staphylococcus Aureus*
End of 9th month	*Moraxella* Species	*Staphylococcus Aureus*

Table 2. Prevalence of microbial growth in operation theatre 3 and 4

Bacterial/Fungal grown	Operation theatre 3		Operation theatre 4	
	Number of cultures	Percentage of growth	Number of cultures	Percentage of growth
Moraxella	1	11.1%	2	14.2%
Bacillus Species	2	22.2%	2	14.2%
Staphylococcus	1	11.1%	6	42.8%
Micrococcus	2	22.2%	1	7.14%
Proteus	1	11.1%	0	0%
Alcaligenes	2	22.2%	0	0%
Candida Species	0	0%	1	7.14%
CoNS	0	0%	1	7.14%
Aspergillus	0	0%	1	7.14%

performed and recorded after 24 h of incubation at 37°C. Growth was recorded, and biochemical tests were performed to identify the isolates.

Thereafter, periodic swabs were collected and cultured to identify the microbial flora. Periodical swabs were collected at the end of 1st week, 3rd week, 1st month, 2nd month, 3rd month, 6th month and 9th month after applying SmartCoat.

Statistical Analysis

Statistical analysis was performed using SPSS version 16.0. Frequencies and percentages (%) were calculated. Significant differences in antimicrobial effects were assessed using Student's t-test. Statistical significance was set at $p < 0.05$.

RESULTS

Periodic culture isolates from both OT 3 (with SmartCoat) and OT 4 (without SmartCoat) showed minimal variation. *Staphylococcus* (42.2%), *Moraxella* (14.2%), and *Bacillus* species (14.2%) were mostly isolated from the surface of OT 4. However, *Bacillus* species (22.2%), *Micrococcus* (22.2%), and *Alcaligenes* (22.2%) were most commonly observed on the OT 3 surface coated with SmartCoat. At nine months OT 3 (with SmartCoat) showed low RLU, and only *Moraxella* species were grown in one of the cultures. However, in OT 4, Staphylococcus, Moraxella, and fungi were observed.

The computed value of 't', i.e., 2.084 is lower than the critical value of 3.18 at 3 degrees of freedom (df) and hence it is not significant. Therefore, the null hypothesis cannot be rejected ($p=0.129>0.05$) at the 5% level of significance.

DISCUSSION

Titanium dioxide is a heterogeneous

Table 3. Significance of differences in outcome of the antimicrobial effects

	Paired Differences				t	df	Sig.(2-tailed)
	Mean±SD	Std. Error Mean	95% CI difference Lower	Upper			
Pair 1 After-After 9 months	2.122±2036.197	1018.098	-1118.29	5361.793	2.084	3	0.129

catalyst and is becoming a preferred choice as an antimicrobial coating for dental implants, orthopedic devices, and other health care facilities to prevent microbial growth. Several combinations have been reported; unfortunately, none of these methods have scientific reliability and integration. The present cross-sectional observational study was designed to evaluate the efficacy of TiO_2 in preventing microbial growth in OTs. A wide range of studies have reported that photocatalysis is harmful to many organisms, including viruses, Gram +Ve / –Ve bacteria, algae, fungi, and protozoa, and is also effective in inactivating prions.[4] TiO_2 can kill Gram +Ve and Gram –Ve bacteria in water, air, and on surfaces of various materials.[5] TiO_2 photocatalysis is an economically feasible approach that uses water and hydrogen peroxide to fabricate an active TiO_2 surface on titanium substrates. Under UV illumination, the organic substance is degraded by producing reactive oxygen species.[6]

The amalgamation of the Ag matrix and TiO_2 nanoparticles enhances the antibacterial effect by promoting Ag ion release and increasing

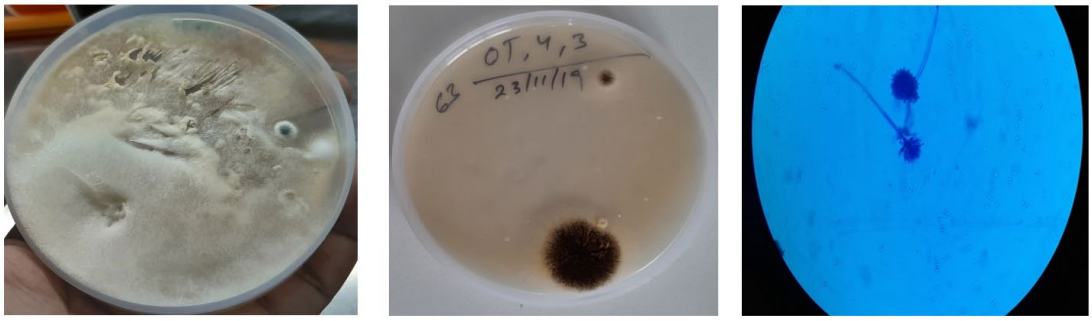

Fig. 1. Culture and stained image representing the growth of *Aspergillus Niger*.
A. Initial white colonies, B. While colonies changed to black after few days producing conidial spores. The edges of colonies appear pale yellow producing radial fissures. C. Staining image representing *Aspergillus Niger*.

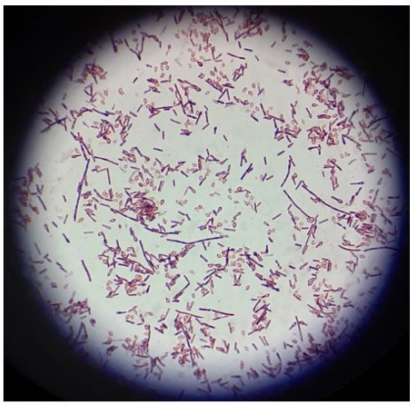

Fig. 2. Gram stain of culture isolates shows mixed growth with most bacillus species.

the negative surface charge of the coatings.[7] A study by Unosson stated that Ag- TiO_2 can increase the photocatalytic properties, and incorporation of Ag into titanium biomaterials have effective antibacterial strategies.[6] Visai et al. stated that photocatalytic sterilizing surfaces act in the absence of chemical material and electricity; instead, they require oxygen, light, and water. The surfaces of TiO_2 are nontoxic and do not impact the environment negatively. This makes TiO_2 substances a preferable option for the establishment of a health care setup.[8]

TiO_2 surfaces have two important characteristic features, self-cleaning and self-disinfection, which act against bacteria.

Degradation of organic substances by total oxidation prevents bacterial and biofilm adhesion on the surface of biomedical devices.[9] Sunanda et al. stated that irradiated TiO_2 surfaces kill bacteria in a three-step mechanism, such as cell wall invasion by reactive oxygen species, decomposition of the inner cytoplasmic membrane, and decomposition of toxic bacterial components.

In this study, the photo catalyst SmartCoat product is a liquid containing TiO_2 nanoparticles as the main ingredient, and isopropyl alcohol and distilled water, were sprayed on biomedical devices in OT 3. Periodic culture isolates from both OT 3 (with SmartCoat) and OT 4 (without SmartCoat) showed minimal variation. *Bacillus* species (22.2%), *Micrococcus* (22.2%), and *Alcaligenes* (22.2%) were the most common isolated species on the OT 3 surface coated with SmartCoat. However, in OT 4, *Staphylococcus* (42.2%), Moraxella (14.2%), and *Bacillus* species (14.2%) were commonly isolated. Nine months after application of the SmartCoat product, OT 3 (with SmartCoat) showed low RLU and only *Moraxella* species was present. However, in OT 4, *Staphylococcus, Moraxella*, and fungi were observed.

Chun et al. tested steel orthodontic wires coated with TiO_2, which remained unchanged after adhesion tests, whereas uncoated wires increased their mass by 4.97%.[10] A study by Chow Wai Leng et al. stated that samples from untreated surfaces with TiO2 and ad hoc samples were more likely to be culture positive (Methicillin-Resistant *Staphylococcus aureus* (9.2%) and gram negative bacteria (1.4%) and TiO_2 did not influence positive culture results.[11]

CONCLUSION

Application of SmartCoat in OT 3 resulted in low RLU and growth of *Moraxella* species in the cultures. SmartCoat, a TiO_2-based product, may not prevent microbial growth on biomedical devices in the OTs and may not be suitable for OTs unless it is supplemented by other OT sterilization procedures. The OT requires a maximum sterile environment to prevent sepsis and nosocomial infections. However, SmartCoat can be used in other healthcare facilities to minimize or prevent nosocomial infections.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORS' CONTRIBUTION

MU, MJ conceptualized the study. MU, TL did the data acquisition. MU, JK, MJ, TL performed data analysis and interpretated the results, wrote the manuscript and did the revision. All authors read and approved the final version of the manuscript.

FUNDING

None.

DATA AVAILABILITY

All datasets generated or analyzed during this study are included in the manuscript

ETHICS STATEMENT

The Study is approved by the Institutional Ethics Committee of Tomo Riba Institute of Health and Medical Sciences.

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