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Research Article

Evaluation of antimicrobial properties in coatings for operating room surfaces

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ABSTRACT

This article highlights the crucial significance of upholding sterility in operating rooms (ORs) to minimize infection risks and uphold patient safety. Putting a spotlight on the pivotal role of antimicrobial coatings, the research delves into the examination of four frequently used coatings—polyurethane, acrylic, alkyd, and epoxy—across various surfaces within ORs. The study evaluates the antimicrobial properties of these coatings against 20 contaminant bacteria, uncovering diverse impacts on different strains. While these coatings may not inherently possess antimicrobial characteristics, formulations enriched with agents like 1,2-benzisothiazol-3(2H)-one (BIT) and 2-octyl-2H-isothiazol-3-one (OIT) demonstrate active resistance against bacterial growth. The results highlight the efficacy of acrylic and epoxy coatings, specifically in impeding bacterial proliferation. These findings affirm the practical utility of antimicrobial coatings in vital healthcare settings, providing valuable insights into their potential to elevate hygiene, safety, and efficiency in ORs. The study advocates for ongoing exploration of innovative coatings and antimicrobial agents, underscoring the importance of adhering to cleaning protocols and healthcare regulations for optimal effectiveness.

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1. INTRODUCTION

Creating and maintaining a sterile environment in an operating room (OR) is paramount for reducing the risk of infections and ensuring patient safety. Modern clean operating rooms must meet specific requirements for layout, floor, walls, and facilities, as well as selecting building materials and addressing hand washing room considerations [1]. The careful selection of building materials for the OR floor and walls plays a crucial role, with a focus on incorporating antimicrobial properties to enhance hygiene. Among the preferred materials for the OR floor, certain types of vinyl flooring are engineered with antimicrobial features, providing an easily cleanable and impermeable surface that resists bacterial growth. Flooring, formulated with antimicrobial agents, contributes to a durable and hygienic surface, resistant to chemicals and easy to clean [2]. For the walls of the OR, antimicrobial paints with additives inhibiting bacterial and fungal growth are applied to enhance hygiene [2, 3]. Solid surface wall systems, such as non-porous and seamless wall panels, are chosen to prevent microbial growth, offering ease of maintenance.

In the construction and maintenance ORs, the strategic application of various coatings, such as polyurethane, acrylic, alkyd, and epoxy, is essential to meet the specific demands of this critical healthcare environment. Polyurethane coatings, prized for their durability and chemical resistance, find utility in surfaces requiring robust protec-

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tion against chemicals and frequent cleaning, such as cabinets and medical equipment [4]. Acrylic coatings, known for their quick drying time and versatility, may be chosen for walls or ceilings in ORs where a fast-drying and easy-to-apply solution is advantageous. With low odor and toxicity, acrylic coatings contribute to a cost-effective and aesthetically pleasing environment [5].

Alkyd coatings, being oil-based, are suitable for metal surfaces within the OR, offering reliable adhesion and protection against corrosion [6, 7]. They are commonly applied to metal components of furniture and medical devices. Epoxy coatings, renowned for exceptional durability and chemical resistance, are prevalent in ORs, particularly on floors and walls. The impermeable surface created by epoxy coatings resists chemicals, stains, and microbial growth, meeting the stringent hygiene requirements of operating rooms [8]. Each of these coatings plays a vital role in enhancing the functionality, durability, and cleanliness of different surfaces within the operating room, contributing to the overall safety and efficiency of healthcare practices. While not inherently possessing antimicrobial properties, these coatings can contribute significantly to creating a hygienic environment in ORs [9]. Some formulations of coatings can be enriched with antimicrobial agents like silver ions, imparting the surfaces with the ability to resist the growth of bacteria and fungi actively [10–12]. This is particularly advantageous when applied to surfaces requiring frequent cleaning.

Establishing antimicrobial surfaces could be one of the keys to helping prevent further contagious incidents and breakouts. An antimicrobial surface must ensure that pathogenic contamination is eliminated or lowered to a minimum. Different antimicrobial agents are often added to coating formulas to prevent microbial growth. There are now various antimicrobial substrates on the market. It is worthwhile investigating the efficacy and precision of these products. Meanwhile, the use of antimicrobial agents is expanding, as is research into their antibacterial characteristics and components [11]. This study has designed an experiment to test the antimicrobial properties of polyurethane, acrylic, alkyd, and epoxy coatings. It has been investigated whether the bacteria will survive or proliferate, and if they don't, how long will it take to be diminished on a surface coated with the substances. This study has been conducted on four types of coatings, observing 20 types of contaminant bacteria.

2. MATERIALS AND METHODS

2.1. Materials

Four different types of coatings used frequently in hospitals and ORs surfaces (polyurethane, acrylic, alkyd, and epoxy) were purchased from commercial sources. The information and the ingredients of the coatings investigated are listed in Table 1. For evaluation of the surfaces antibacterial effectivity 20 different microorganisms were used (Table 2). The microorganisms were obtained from ATCC culture collection.

2.2. Samples Preparation

Coatings were administered to four wooden panels measuring 5×5 cm each and allowed to dry for a period of 10 hours at room temperature (Fig. 1). This procedure was repeated three times. The panels were subsequently sterilized via autoclave, and bacterial suspensions were sprayed onto the surfaces, left to dry at room temperature. Sampling was conducted after 24 hours of bacterial attachment.

2.3. Evaluation of Antimicrobial Activity

For this research, a total of 20 diverse microorganisms were employed to contaminate the four coated panels. Subsequent to the contamination, the surface was allowed to stand undisturbed for 24 hours before repeating the swab sampling. The results were quantified as $\log_{10}$kob/cm^2 through the generation of serial dilutions with maximum recovery diluent. These diluted samples were then inoculated onto plate count agar (tryptone glucose yeast agar CM0325, Oxoid). using the spread plate technique and incubated at 37°C for 24 hours.

3. RESULTS AND DISCUSSION

This study aimed to evaluate and determine the duration of the antimicrobial effect of different coatings that can be used operating rooms and hospitals. The data obtained from polyurethane and acrylic, coated panels at the end of 6 hours are shown in Table 3. The data obtained from alkyd, and epoxy coated panels at the end of 6 hours are shown in Table 4.

Examining the antibacterial properties of polyurethane, acrylic, alkyd, and epoxy coatings reveals varying impacts on different bacterial strains. Polyurethane coating is most effective against *Listeria monocytogenes 3b* but less so against *Proteus mirabilis*. Acrylic coating significantly reduces *Staphylococcus aureus* counts, while *Salmonella typhimurium* shows the least response. Alkyd coating strongly affects *Staphylococcus aureus* but minimally impacts *Methicillin resistant S.aureus*. In the case of epoxy coating, *Streptococcus epidermidis* experiences the greatest reduction, while *Salmonella typhimurium* exhibits a less pronounced response. The coatings, ranked by their average percentage reduction in bacterial counts across all tested strains, exhibit varying levels of antibacterial efficacy. Acrylic coating leads with an impressive average reduction of 94.26%, followed closely by Alkyd and Epoxy coatings at 90.79% and 90.58%, respectively. In contrast, Polyurethane coating shows a somewhat lower average reduction at 74.79%. Based on the polyurethane ingredient list, it appears that the antibacterial properties of polyurethane coating may not be directly attributed to the listed components. The primary antibacterial effects might be due to the physical characteristics of the coating or other factors not explicitly mentioned in the provided ingredient list.

The Acrylic ingredient list contains antimicrobial agents such as 1,2-benzisothiazol3(2H)-one (BIT), Zinc Pyrithione [13], and 2-octyl-2H-isothiazol-3-one (OIT). These components likely contribute to the observed antibacterial

Table 1. Coatings ingredient used within the scope of the study.

Polyurethane-hardtop XP		Acrylic-jotashield topcoat silk	
Ingredient	**Concentration**	**Ingredient**	**Concentration**
Xylene	≥10–≤15	Alcohols, C16-18 and C18-unsatd., ethoxylated	≤0.1
N-butyl acetate	≤10	1,2-benzisothiazol-3(2h)-one (BIT)	<0.05
Ethylbenzene	≤5	zinc pyrithione	≤0.024
Titanium dioxide	≤5	2-octyl-2h-isothiazol-3-one (OIT)	≤0.0024
Hydrocarbons, C9, aromatics	≤4.1		
N-butyl methacrylate	<1		
2-Propenoic acid, 2-methyl-, 2- (dimethylamino)ethyl ester, polymer with butyl 2-propenoate, compd. with polyethylene glycol hydrogen maleate C9-11-alkyl ethers	<1		
Decanedioic acid, 1,10-bis (1,2,2,6,6-pentamethyl-4-piperidinyl) ester, mixt. with 1-methyl 10- (1,2,2,6,6-pentamethyl-4-piperidinyl) decanedioate	≤0.3		
Oleic acid, compound	≤0.1		
Maleic anhydride	≤0.1		
Alkyd - Pilot II		**Epoxy - Jotamastic 80**	
Ingredient	**Concentration**	**Ingredient**	**Concentration**
Hydrocarbons, C9-C12, n-alkanes, isoalkanes, cyclics, aromatics (2–25%)	≥25–≤50	Epoxy resin (MW ≤700)	≥10–<25
Titanium dioxide	≥10–≤25	Titanium dioxide	≤10
Xylene	≤3	Hydrocarbons, c9-unsatd., polymd	≤10
Hexanoic acid, 2-ethyl-, zinc salt, basic	≤0.3	Xylene	≤10
		2-methylpropan-1-ol	≤5
		Benzyl alcohol	≤3
		Ethylbenzene	≤3
		Epoxy resin (MW 700–1200)	≤3
		2-Propenoic acid, 2-methyl-, 2- (dimethylamino)ethyl ester, polymer with butyl 2-propenoate, compd. with polyethylene glycol hydrogen maleate C9-11-alkyl ethers	≤0.3
		Oleic acid, compound	≤0.1

Table 2. Bacterial cultures used in antimicrobial analysis

Microorganism	Gram type
E.coli	Gram negative
E.coli O157	Gram negative
Bacillus subtilis	Gram positive
Bacillus cereus	Gram positive
Staphylococcus aureus	Gram positive
Methicillin resistant *S.aureus*	Gram positive
Vancomycin resistant Enterococcus faecium	Gram positive
Streptococcus epidermidis	Gram positive
Listeria monocytogenes 3b	Gram positive
Salmonella enteritidis	Gram negative
Salmonella typhimurium	Gram negative
Campylobacter jejuni	Gram negative
Geobacillus stearothemophilus	Gram positive
Shigella flexneri	Gram negative
Cronobacter sakazakii	Gram negative
Pseudomonas aeruginosa	Gram negative
Proteus mirabilis	Gram negative
Acinetobacter baumanii	Gram negative
Vibrio parahemolyticus	Gram negative
Yersinia enterocolitica	Gram negative

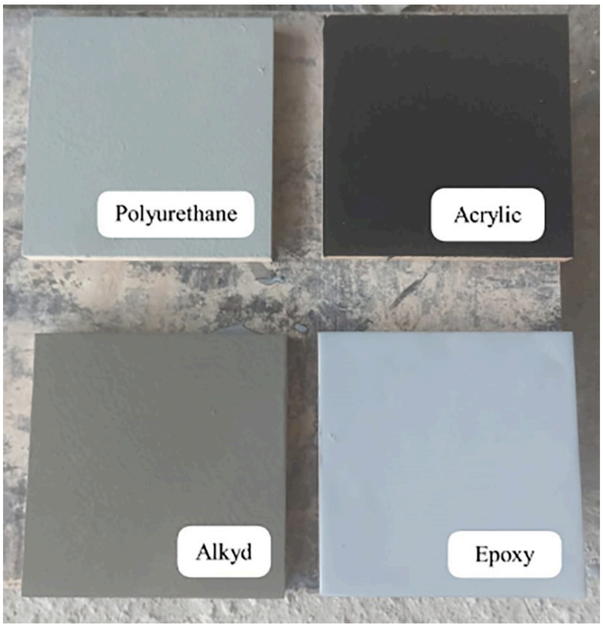

Figure 1. Polyurethane, acrylic, alkyd, and epoxy coated panels.

Table 3. Bacterial growth dynamics on polyurethane and acrylic surfaces over time

Bacteria name	Polyurethane					Acrylic		
	Initial count	Logarithmic level	2. h	4. h	6. h	2. h	4. h	6. h
E.coli	8200000	6.913813852	3700000	37000	3700	990000	9900	990
E.coli O157	6900000	6.838849091	6600000	66000	6600	820000	8200	820
Bacillus subtilis	3000000	6.477121255	2300000	23000	2300	850000	8500	850
Bacillus cereus	5500000	6.740362689	2500000	25000	2500	220000	2200	220
Staphylococcus aureus	6300000	6.799340549	2200000	22000	2200	760000	7600	760
Methicillin resistant S.aureus	6800000	6.832508913	6400000	64000	6400	100000	1000	100
Vancomycin resistant Enterococcus faecium	8900000	6.949390007	2200000	22000	2200	680000	6800	680
Streptococcus epidermidis	5400000	6.73239376	7800000	78000	7800	260000	2600	260
Listeria monocytogenes 3b	6900000	6.838849091	2800000	28000	2800	700000	7000	700
Salmonella enteritidis	1000000	6	3900000	39000	3900	460000	4600	460
Salmonella typhimurium	9200000	6.963787827	9100000	91000	9100	510000	5100	510
Campylobacter jejuni	5700000	6.755874856	7000000	70000	7000	260000	2600	260
Geobacillus stearothemophilus	6100000	6.785329835	9500000	95000	9500	770000	7700	770
Shigella flexneri	4800000	6.681241237	4300000	43000	4300	390000	3900	390
Cronobacter sakazakii	1400000	6.146128036	1500000	15000	1500	160000	1600	160
Pseudomonas aeruginosa	1700000	6.230448921	5900000	59000	5900	580000	5800	580
Proteus mirabilis	700000	5.84509804	2200000	22000	2200	820000	8200	820
Acinetobacter baumanii	3900000	6.591064607	6900000	69000	6900	430000	4300	430
Vibrio parahemolyticus	5100000	6.707570176	5000000	50000	5000	640000	6400	640
Yersinia enterocolitica	8200000	6.913813852	3900000	39000	3900	540000	5400	540

properties of the Acrylic coating. The concentrations mentioned suggest a careful formulation to provide effective antimicrobial action while minimizing potential adverse effects. BIT is a commonly utilized biocide applied to industrial products with broad antimicrobial activity [14, 15]. BIT has been shown to react with thiol-containing proteins on target microorganisms and is especially effective against actively metabolizing bacteria [16, 17]. It is widely used in food packaging, industrial and consumer products like adhesives, laundry and dish detergents, cleaning and disinfectants, air fresheners, personal care products and sunscreens, paints, and industrial lubricants [18, 19]. OIT is a coordination complex of isothiazolone and has antibacterial and fungicidal properties [20]. It is used as a biocide in cooling-tower water, paints, cutting oils, cosmetics, and shampoos, and for leather preservation [20]. According to a CLH report published by the Chemicals Regulation Division United Kingdom, 2-octyl-2H-isothiazol-3-one ex-

Table 4. Bacterial growth dynamics on alkyd and epoxy surfaces over time

Bacteria name	Alkyd					Epoxy		
	Initial count	Logarithmic level	2. h	4. h	6. h	2. h	4. h	6. h
E.coli	8200000	6.913813852	610000	6100	610	64000	640	64
E.coli O157	6900000	6.838849091	880000	8800	880	59000	590	59
Bacillus subtilis	3000000	6.477121255	630000	6300	630	18000	180	18
Bacillus cereus	5500000	6.740362689	870000	8700	870	60000	600	60
Staphylococcus aureus	6300000	6.799340549	250000	2500	250	99000	990	99
Methicillin resistant S.aureus	6800000	6.832508913	330000	3300	330	65000	650	65
Vancomycin resistant Enterococcus faecium	8900000	6.949390007	320000	3200	320	75000	750	75
Streptococcus epidermidis	5400000	6.73239376	550000	5500	550	44000	440	44
Listeria monocytogenes 3b	6900000	6.838849091	370000	3700	370	94000	940	94
Salmonella enteritidis	1000000	6	470000	4700	470	32000	320	32
Salmonella typhimurium	9200000	6.963787827	100000	1000	100	25000	250	25
Campylobacter jejuni	5700000	6.755874856	690000	6900	690	95000	950	95
Geobacillus stearothemophilus	6100000	6.785329835	380000	3800	380	58000	580	58
Shigella flexneri	4800000	6.681241237	840000	8400	840	76000	760	76
Cronobacter sakazakii	1400000	6.146128036	530000	5300	530	67000	670	67
Pseudomonas aeruginosa	1700000	6.230448921	400000	4000	400	25000	250	25
Proteus mirabilis	700000	5.84509804	220000	2200	220	91000	910	91
Acinetobacter baumanii	3900000	6.591064607	250000	2500	250	29000	290	29
Vibrio parahemolyticus	5100000	6.707570176	530000	5300	530	84000	840	84
Yersinia enterocolitica	8200000	6.913813852	220000	2200	220	24000	240	24

hibited strong antibacterial activity against *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* [21].

Alkyd coating is composed of a blend of hydrocarbons, titanium dioxide, xylene, and a zinc salt. Although hydrocarbons and titanium dioxide may not exhibit direct antibacterial properties, the inclusion of xylene [22] and the zinc salt [23, 24] suggests a potential contribution to the observed antibacterial effects. The overall performance of the coating is likely influenced by the specific formulation and interactions among these components.

The epoxy coating contains a mix of components, including some with potential antimicrobial properties. However, the overall antibacterial efficacy is likely influenced by the combination and interactions of these components. Based on this information, none of these materials are inherently antibacterial and they all require proper care and maintenance to keep them hygienic. Some products may claim to have antibacterial features, but they may not be effective or long-lasting. Therefore, it is important to follow the manufacturer's instructions and use suitable cleaners for each material. A substantial proportion of antimicrobial coatings finds widespread use in the construction industry, particularly in the creation of both interior and exterior coatings designed to provide protection against microbial threats. There is a projected significant increase in the demand for antimicrobial coatings, especially in sectors such as hospitals, operating rooms, nursing homes, daycares, and other medical applications where maintaining a stringent standard of hygiene is imperative [11, 25]. In these crucial environments, the common practice involves integrating various antimicrobials into paint formulations to enhance the resilience of products against potential microbial attacks. Antimicrobial agents play a crucial role in reducing the likelihood of microbial growth on coated surfaces, thereby ensuring a hygienic and sterile environment in medical settings [26–28]. While selecting these coatings, consideration of their compatibility with cleaning protocols, surface types, and adherence to healthcare regulations is crucial. Collaborating with infection control experts ensures that these coatings contribute effectively to the overall hygiene and safety standards of the operating room. Regular cleaning and disinfection practices further enhance the antimicrobial efficacy of these coatings, collectively fortifying the OR against potential infections.

4. CONCLUSION

This study investigated the pivotal role of antimicrobial coatings—polyurethane, acrylic, alkyd, and epoxy—in cultivating a hygienic environment within operating rooms and hospital settings. Applied strategically across diverse surfaces, these coatings significantly contributed to overall functionality, durability, and cleanliness, enhancing healthcare safety and efficiency. The experimental assessment of antimicrobial properties against 20 contaminant bacteria yielded noteworthy results. While the coatings may not inherently possess antimicrobial traits, formulations enriched with agents like BIT and OIT demonstrated active resistance against bacterial growth, emphasizing their potential in promoting hygiene. Results showed varying degrees of antimicrobial efficacy, with acrylic and epoxy coatings particularly excelling in inhibiting bacterial proliferation. The incorporation of antimicrobial agents notably enhanced the coatings ability to create surfaces resilient to microbial growth, highlighting their practical applications in critical healthcare settings like ORs.

ETHICS

There are no ethical issues with the publication of this manuscript.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

FINANCIAL DISCLOSURE

The authors declared that this study has received no financial support.

USE OF AI FOR WRITING ASSISTANCE

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PEER-REVIEW

Externally peer-reviewed.

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