Integrating biomedical materials and design strategies for effective infection prevention in healthcare facilities.

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ABSTRACT
In recent years, the prevalence of health problems has increased, thereby necessitating a heightened focus on infection control in healthcare facilities. Therefore, the field of Infection Prevention and Control (IPC) has reached a stage of maturity, and there is a growing emphasis on integrating biomedical materials and developing innovative strategies to enhance infection prevention in medical settings.

This research aims to formulate a design strategy that minimizes the risk of infection and ensures patient safety by exploring the application of biomaterials in hospitals. Specifically, the investigation will examine the most recent advancements in biologic materials and their potential applications in healthcare settings. The study concludes that the compatibility between architectural design strategies and the utilization of biomaterials is crucial in reducing infection rates in hospitals.

Key words: Biomaterials, IPC, Design Strategies, Healthcare Facilities

The Research Aim
Investigating the classification of biomaterials in healthcare facilities is a crucial aspect of ensuring effective infection control measures. However, integrating biomedical materials into existing design infrastructure can pose significant challenges. It is essential to explore innovative design strategies that can minimize the risk of cross-contamination in healthcare facilities. By doing so, we can create a safer and more hygienic environment for both patients and healthcare workers.

METHODOLOGY
This investigation employs a descriptive and analytical methodology to examine the utilization of biomaterials within healthcare facilities and to conduct an analytical assessment of the strategies employed in hospital design and their impact on infection reduction.

I INTRODUCTION
The basic ideas of Infection Prevention and Control (IPC) in hospitals [1] were realized in the 19th century and implemented into normal hospital procedures in the second half of the 20th century, as it became obvious that antibiotics alone were not able to prevent mortality and morbidity from HAIs (Healthcare Associated Infections) [2]. The percentage of countries with a national IPC system remained constant between 2017–2018 (64.5%) and 2021–2022 (61.3%). However, the number of countries that have selected at least one trained IPC worker has increased significantly that have selected at least one trained IPC. (21% vs 72.6%), [1],[2]
Healthcare-associated infections (HAIs) represent a significant challenge in healthcare settings, as they can result in severe illness and death. As such, it is imperative that healthcare facilities adopt infection prevention and control measures to contain the spread of HAIs and safeguard the well-being of all personnel working within the facility. This is emphasized by the World Health Organization (WHO) in its guidelines and recommendations on infection prevention and control in healthcare settings. [1] (2011), All factors that contribute to the propagation of HAIs can heighten the risk of transmission, making it increasingly challenging to maintain adequate infection control measures. Insufficient healthcare facilities and infrastructure, such as the absence of isolation rooms or inadequate ventilation systems, can further exacerbate the spread of infection [3].

According to a report from the World Health Organization, 55 healthcare facilities in 14 countries across four regions (Eastern Mediterranean, Europe, Southeast Asia, and Western Pacific) reported nosocomial infections in 8.7% of hospitalized patients [1]. The highest incidence of nosocomial infections was reported in healthcare facilities located in the Eastern Mediterranean region, at 11.8%. Additionally, Southeast Asia had a 10% incidence, while Europe had a range of 7.7% and 9.0% across the two regions. It is estimated that over 1.4 million people worldwide suffer from infectious diseases as a result of nosocomial infection [4]. One study involved 428 patients who were admitted to 13 intensive care units at four institutions. The rate of hospital-acquired infections (HAIs) was found to be 36.7%. The study also classified intensive care unit ICU-acquired infections (75.8%) and ward-acquired infections (33.1%). The rate of reduction of infections with HAIs was found to be greater than that of isolation-acquired infections in existing epidemic hospitals, with an average reduction of 36.7% [5] [6]. Countries such as Egypt have implemented effective measures for controlling disease outbreaks, including the early identification of cases, meticulous contact tracing, and the isolation of patients in emergency disease control centers. Furthermore, health care facilities have established robust infection prevention and surveillance mechanisms through well-defined procedural processes. [7]

LITERAL REVIEW:

Recently, design strategies have led to an increasing recognition of the impact that the built environment can have on patient outcomes. As a result, hospital design has shifted to incorporate elements that promote healing and wellness, including the use of daylight and natural ventilation. These design strategies not only create a more pleasant and comfortable environment for patients, but also play a critical role in preventing the spread of infectious diseases. [9,8].

1.1 DESIGN STRATEGIES ON HOSPITAL AND IPC:

1.1.1 NATURAL LIGHTING

Hospitals were furnished with ample windows and unobstructed corridors to allow an abundance of natural sunlight and fresh air to permeate the facilities. It was believed that this measure facilitated the eradication of pathogenic microorganisms and hindered the propagation of infectious diseases. Furthermore, patients were often encouraged to spend time outside in designated hospital gardens or on porches to further benefit from the salutary effects of sunlight and fresh air [2].

The effects of windows on hospital lighting are significant, particularly in relation to the role they play in reducing the length of stay for patients following surgery. Research has shown that the utilization of landscape elements can decrease this duration by 8%, and the introduction of
natural daylight has been demonstrated to increase levels of dopamine, leading to a reduction in pain perception of 22%. Unfortunately, prolonged exposure to artificial lighting within patient rooms can result in adverse physical and psychological impacts such as eye strain, headaches, fatigue, and depression. Therefore, it is crucial that the incorporation of windows and natural light sources is considered during the development and design of healthcare facilities. [10].

In addition, diffuse natural light near windows in buildings can also kill bacteria within five to seven days [10]. It is imperative to acknowledge that the eradication of microorganisms by direct sunlight through glass may vary depending on the layer of bacteria to which they are exposed. The thickness of the layer of bacteria determines whether the bacteria will be killed within minutes or hours. It is important to note that not all microorganisms are affected by daylight in the same manner [11].

Direct sunlight in killing microorganisms and bacteria Fig 2 [2]. Double-glazing and indirect sunlight shown to be effective in reducing hemolytic bacteria over a two-week period without the use of antibiotics. FIG 2 The importance of direct sunlight in killing microorganisms and bacteria [2]

1.1.2 SOCIAL DISTANCING

Architects must ensure that waiting areas, lobbies, stairways, and corridors are sufficiently spaced to maintain a social distance of at least one meter. This is because droplets of airborne particles travel only a short distance (no less than one meter, before settling on the surface to maintain a safe distance and minimize contact transmission [12]. It is imperative that corridors be redesigned to incorporate conversation corners equipped with benches. The distinction between regular communication and long-range aerial dispersal is contingent upon the size of the droplet [13]. Designers typically refrain from incorporating double-bank corridors, closed-end lobbies, waiting rooms, and other areas with minimal or no ventilation. The Centres for Disease Control and Prevention (CDC) has stipulated that the design of lobbies and corridors must be examined to accommodate beds, trolleys, crouches, and chairs while maintaining a safe distance [2] [14] Fig 3.

The UK Health Department proposed a minimum width of 2.5 m for hospital areas, which is insufficient for safe separation. This is to provide for 0.3 m of bilateral freeboard and 1 m minimum intervals in social distancing owing to non-straight-line human movement[2] [15].

1.1.3 NATURAL VENTILATION

Recent research has indicated that an appropriate ventilation rate is a critical factor in reducing the spread of airborne illnesses in healthcare facilities and public areas [16].

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Ventilation systems are the right to design strategies for hospitals. The use of high-efficiency particulate air (HEPA) [1] filters can also help reduce the spread of airborne infections in hospitals because closed-end corridors can trap pollutants and reduce the air quality in buildings. Additionally, open-ended corridors supply natural light and a sense of spaciousness, thereby improving the overall aesthetics of the building. By incorporating courtyard design into a building's ventilation system, it is possible to reduce energy consumption and improve indoor air quality. Additionally, it can create a HEPA filter, also known as high-efficiency particulate absorbing filters and high-efficiency particulate resistance filters, provide a more comfortable environment for patients, staff, and visitors.

The orifice model is commonly used to explain airflow through windows and other wide openings, whereas the power law is frequently used to explain airflow via ventilation elements Fig 4 [17].

Table 1: Natural ventilation strategies in hospitals adapt [19]

<table>
<thead>
<tr>
<th>Ventilation</th>
<th>principle</th>
<th>Most sufficient</th>
<th>Less sufficient for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural</td>
<td>Thermodynamic floating Wind velocity</td>
<td>Climate with external temperatures near to the room’s temperature</td>
<td>Climates that are humid and hot</td>
</tr>
<tr>
<td>Single sided</td>
<td>Thermodynamic buoyancy Wind velocity</td>
<td>Rooms with only one side opening</td>
<td>Locations with little wind and a modest temperature difference</td>
</tr>
<tr>
<td>Cross</td>
<td>Wind pressure</td>
<td>Rooms that have openings on greater than one side</td>
<td>Low wind pressure climate</td>
</tr>
<tr>
<td>Stack</td>
<td>Thermal buoyancy</td>
<td>Rooms with windows on one side of the façade and on the top</td>
<td>Climate in which the outside temperature is higher than the inside temperature</td>
</tr>
<tr>
<td>Hybrid</td>
<td>Thermodynamic stability Wind pressures</td>
<td>Rooms whose natural forces are insufficient to generate enough ventilation</td>
<td>Climates near to the room’s designed temperature where natural driving forces can supply sufficient ventilation</td>
</tr>
</tbody>
</table>

Fig. 4. The Natural ventilation system in hospital [17]

Appropriate ventilation strategies can play a crucial role in reducing the spread of infectious diseases. However, it is important to note that regular cleaning and maintenance of ventilation systems can help to reduce the risk of spreading infections. Additionally, proper ventilation can improve indoor air quality and overall health. Table 1. [18].

1.1.4 HOSPITAL SINGLE-PATIENT ROOMS IN DESIGN AWARDS:

Several studies have explored the effects of reducing the incidence of health insurance infections in patient rooms. The likelihood that a patient would become infected with any pathogen or colonize in a hospital setting was compared to the likelihood that the patient would have multiple patient bedrooms or an open ward design. Single-step treatment of patients’ le steps.

The relationship between the space of a patient's room and infection in a hospital setting found that the main factor was the size of the occupied patient room at the time of treatment, which was
measured as length × breadth. Compared to 180 square feet[20].
The results of multivariate research show that the minimum distance between beds (1 m) is a major risk factor for outbreaks related to health care.[21]

1.1.5 HAND HYGIENE:
Hand hygiene is a critical aspect of infection prevention and should be accessible throughout the unit. There are two water-free systems available for hand hygiene: one that utilizes a sink with hot and frozen water, a faucet, and cleansing agents, and another that employs antiseptic rubs to reduce microorganisms. Hand hygiene is a crucial measure in reducing microorganism transmission and infection in healthcare settings, and it is considered to be the most effective single measure to achieve this goal [4]. To enhance hand hygiene compliance and create a safe and hygienic environment, design strategies such as the accessibility of hand rub dispensers and proper placement of hand-rubbing stations have been implemented. These design strategies aim to minimize the risk of infections and ensure the well-being of both patients and healthcare workers.

2. BIOMATERIAL AND IPC STRATEGIES:
Regarding the use of suitable materials to cover internal surfaces in hospitals, the use of flexible finishing materials and building techniques is critical. These materials must be simple to clean and resilient to cleaning processes, [21], allowing for greater adaptability and customization in hospitals. The choice of prevention method depends on the desired properties of the resulting biomaterial, such as improved mechanical strength, enhanced biocompatibility, or increased antimicrobial activity. As shown in fig 5, flexible finishing materials such as lightweight fabrics, movable partitions, and adjustable lighting fixtures are suitable for these applications[22].

2.1 ADVANCED SMART MATERIAL BASED NANO SENSORS FOR VIRAL DETECTIONS
The utilization of smart material-based nano sensors involves three distinct sorts of modules, including detectors, transducers, and receptors that generate digital data. For example, targeted molecules can bind to the receptor sites of biological molecules that have already been recognized by a biologically sensing component. [23] In order to prevent the spread of infection, it is recommended to use indicator materials with copper plating or infusion for touching contaminated surfaces, such as bed rails, balcony railings, and stair handrails. Additionally, it is important to plan and place sinks in a manner that facilitates cleaning and prevents waste from entering delicate healthcare settings [2], [15].

2.1.1 ACTIVE COATING BIOMATERIALS
The synthesis of antiviral and antimicrobial coating materials in non-woven textiles has resulted in the development of high-quality air filtration systems. Active biomaterials are materials that have been pre-coated with antibacterial substances, which may be organic or inorganic. These substances are effective in decreasing infections by killing bacteria on contact[24]. The release of antimicrobial substances from active-releasing areas and the immobilization of antimicrobial substances on contact-active surfaces are two ways in which these materials function.

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There are several types of active nano materials, including silver nanoparticles, zinc oxide, and copper. As follow Fig 6 [25]:

**Fig. 6** Varieties of Antiviral Coatings and Their Mechanisms of Action[25].

2.1.1.1 **SILVER NANOPARTICLES (AG NPS)**

Silver nanoparticle biomaterial coatings are utilized due to their exceptional antimicrobial efficacy against a broad spectrum of microorganisms, including viruses, fungi, gram-negative and gram-positive bacteria, drug-resistant bacteria, as well as the ability to generate reactive oxygen species and disrupt ATP synthesis and DNA replication.

2.1.1.2 **GOLD NANOPARTICLES (AuNPs)**

Gold nanoparticles (AuNPs) possess both antibacterial and antifungal properties and have been established for over two millennia in medical applications. AuNPs demonstrate superior antibacterial action against gram-negative bacteria due to their thinner cell walls and more stable electrostatic connections.

Recently, AuNPs have been utilized in the development of a multivalent therapy against HIV-1 by conjugating them with mercaptobenzoic acid to bind with human T cells.

2.1.1.3 **ZnO NPS AS ANTIBACTERIAL AGENT’S BACTERIA**

ZnO nanoparticles (NPs) are widely utilized as antimicrobial agents owing to their attractive properties, such as a large surface area, small particle size, high surface reactivity, and the capacity to absorb UV radiation. These properties contribute to the antibacterial activity of ZnO NPs, which is primarily achieved through the modification of cell membrane structure and the eventual disruption of cell stability.

2.1.1.4 **CUSOLID PARTICLES**

For millennia, solid copper and its alloys have been used as an antibacterial agent. They have excellent antibacterial properties in both aquatic systems and on dry surfaces. Controlled clinical trials have been conducted to assess the impact of antimicrobial copper surfaces on microbial burden and HAI acquisition, the United States Environmental Protection Agency officially recognized five families of copper-containing alloys as possessing antibacterial properties, which can effectively eliminate 99.9% of bacteria within a two-hour period [26]. Furthermore, the implementation of copper surfaces in healthcare facilities has been shown to significantly reduce the incidence of healthcare-associated infections (HAIs), with a 58% decrease in HAI rates observed when preventing microbial attachment and creating biofilm through the adoption of a surface topology with nanoscale features. The utilization of these materials and design strategies in medical facilities can also result in cost savings [27] [28]. More proteins are denatured and adsorbed by Cu2O than by CuO, and infectious deactivation, as shown in Fig 7 occurs through direct interaction with cuprous substances rather than via reacting oxygen radicals or copper ions.
2.1.5 PLASTIC AND POLYMER SUBSTANCES

Biomaterials exhibit varying behaviour and life cycles on various surfaces, with plastic and polymers displaying distinct characteristics. Specifically, virus infections are more stable on plastic surfaces. As a result, the same virus type can survive on copper surfaces for up to four hours[9] whereas it can persist on glass and steel for up to three days. In contrast, porous materials such as cotton, leather, and polystyrene allow the virus to persist for 24 hours. Given these differences, architects should carefully consider the materials they select, the specifications for those materials, and the treatment of surfaces in the design of buildings.

2.2.1 BIO-ANTIBACTERIAL PAINTS:

Bio-cote is an effective antimicrobial paint that boasts over 99% resistance to microbes. It is one of the market's leading paint solutions for resisting Mold, fungus, and bacteria. Researchers in Australia have developed a breakthrough in paint technology by creating a solar paint that can convert water vapor into hydrogen and oxygen, resulting in improved indoor air quality[22].

2.2.1.3 TiO2 TITANIUM DIOXIDE

Organic-inorganic hybrid materials consisting of bovine serum albumin (BC), silica, and crystal titanium dioxide (TiO2) were developed. These materials, known as BC-SiO2-TiO2/Ag, possess both photoactive and antibacterial properties, making them promising candidates for various applications. The photoactive BC-SiO2-TiO2 membranes demonstrated remarkable TiO2-loading dependent photocatalytic activity towards crystal violet dye. When the dye was placed as an overlayer on the membrane, 97% of the dye was destroyed after 50 minutes of UV Ultra violet exposure. Expanded polystyrene (EPS) is another versatile material with improved heat resistance and pressure durability. It is also lighter than conventional polystyrene and can be recycled into grey panels for use as insulation in facades, floors, and ceilings. EPS is an ideal material for these applications due to its excellent insulating properties, as Table 2.

Fig.8 TiO2 Biomaterial for biostatic, biocidal, contact-active, self-cleaning, antibacterial surfaces.

<table>
<thead>
<tr>
<th>Finishing materials</th>
<th>Nature</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromogenic Glass</td>
<td>The building's attributes exhibit diversity, comprising of transparent conducting substrates with EC films on top, and an electrolyte that operates as an insulator for electrons, while accommodating small cations (such as H+, Li+, or Na+) within its structure. [32]</td>
<td>Give an aesthetic appearance and control of the light</td>
</tr>
<tr>
<td>Self-cleaning Glass</td>
<td>chemically treated and coated with titanium oxide</td>
<td>Pollution resistance and infection control.</td>
</tr>
</tbody>
</table>

Table 2 Antibacterial Coating materials natural and design application
The substance was strategically placed between the two layers of the aerogel material, and it responds to thermal stimuli by coagulating and transforming into a semi-transparent state.

The nature of windows is such that they undergo transformation according to the demands of space, providing thermal insulation and privacy.

Coagulate Glass

silver nanoparticles may attach to the surface of glycoproteins on the virus and then reduce the fusion process [30]. Silver nanoparticle coated polyurethane condoms have also been developed to inhibit infectious viruses [31].

Interaction with hemagglutinin
Preventing viral attachment
Cell binding/penetration
Inhibiting accumulation of reactive oxygen species

Fig 10 Illustrations coagulation mechanisms in glass and silica-coated tubes

Silver nanostructure

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Interaction with hemagglutinin
Preventing viral attachment
Cell binding/penetration
Inhibiting accumulation of reactive oxygen species

Fig 11 Silver nanoparticle coated polyurethane condoms.

Copper nanostructure

ionic copper which can be easily sprayed on as paint or plastic film covers onto various surfaces. [33]

Generation of reactive oxygen species

Fig 12 Copper nanostructure anti bacteria covering on hospital surface

Titanium nanostructure

Sol-gel is a highly efficient and adaptable technique for the production of thin films, boasting numerous advantages such as a low processing temperature, uniformity, the potential for large-scale coating, and a low processing temperature. [34]

Generation of reactive oxygen

HSV-1, Influenza virus, species (ROSs)

Fig 13 sol-gel for thin film preparation attracted unsuitable substances.

Carbon-based nanoparticle

The processes, including cell wall penetration, agglomerate formation, reactive oxygen generation, interaction between negatively charged surfaces and positively charged capsids, and mechanical disruption of capsids, are key to understanding the phenomenon.

Hydroxyapatite, Ag-carriers

Phosphoric acid double salt possesses a robust adsorption capacity, significant specific surface area, favourable nontoxicity, and stable chemical properties, which make it an optimal combination of efficiency and lasting slow release properties[35].

Gold nanostructure

It is being investigated whether gold nanoparticle-based vaccines could serve as a substitute for acute respiratory syndrome, due to their capacity to obstruct hemagglutinin and attract negatively charged cell membrane bilayers through electrostatic attraction.

Antibacterial textile

It was reported that the incorporation of nano-additives into the antibacterial textile imbued it with antibacterial properties, thereby enabling its application to hospital clothing.

Table 1 Application in interior design and Use

<table>
<thead>
<tr>
<th>Antimicrobial textile</th>
<th>Application in interior design</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanowires Silver Cotton</td>
<td>Anti-bacteria, - Super Hydrophobicity, - UV light resistant, - High electrical conductivity.</td>
<td>Curtains, Upholstery, - Table linen.</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Copper Nanoparticles</td>
<td>Nylon</td>
<td>-Anti fungal.</td>
</tr>
<tr>
<td>Gold Nanoparticles</td>
<td>Wool</td>
<td>-UV light resistant.</td>
</tr>
<tr>
<td>Silver Nanoparticles</td>
<td>Cotton Nylon Polyester Silk polyamide other synthetics</td>
<td>-Anti bacterial activity.</td>
</tr>
<tr>
<td>Nanoparticles of Titanium dioxide and silicon oxide</td>
<td>Cotton Polyester</td>
<td>Thermal stability surfaces - long lifetime.</td>
</tr>
<tr>
<td>Copper Nanoparticles</td>
<td>Nylon</td>
<td>-Anti fungal.</td>
</tr>
<tr>
<td>Gold Nanoparticles</td>
<td>Wool</td>
<td>-UV light resistant.</td>
</tr>
</tbody>
</table>
III. CASE STUDIES FROM INTERNATIONAL HOSPITALS:
The selection of case study analysis for infection control programs utilizing biomaterials must adhere to strict criteria. The successful implementation of such programs in other healthcare facilities must be analyzed and the key factors contributing to their success must be highlighted. These models serve as exemplary examples for other facilities to follow.

3.1-AYDIN MENDERES HOSPITALS:
The Ayden Adnan Mandirs Hospital, an integral part of the BRICKER project, aims to present a practical, adaptable, and highly efficient solution for the renovation of existing public buildings. The goal of the BRICKER project is to furnish a cost-effective and health-oriented solution for the development process, which was previously tested through a Builder Design simulation program for full hospitalization. The simulation program aimed to incorporate suitable materials to improve the design process.

Design Strategies and Biomaterial application:
- **Natural lighting:**
  We carried out the installation of sun control films on the windows of the east and west facades and replaced the glass on the windows. The glass was substituted with self-cleaning glass and double glass was utilized in the inpatient rooms to ensure a more comfortable and secure environment for patients and staff.
- **Natural ventilation:**
  In cases where the inherent ventilation of a room is insufficient to provide adequate air circulation, appropriate window dimensions for natural ventilation and the incorporation of technical antibacterial air filtration systems should be considered.
- **Social Distance inside Wards:**
  The distances between the patients’ beds have been calibrated in accordance with the guidelines set forth by the World Health Organization, and at present, there are only two beds present in the room.
- **Thermal control:** The interface was constructed using panels made of Piton Polymer, a lightweight and innovative type of concrete with low density. These panels provided aesthetic, mechanical, and thermal control properties. In addition, the panels were made of lightweight Thermojet-Izolux plaster and gypsum, which effectively reduced heat transfer by up to 70-50% from external factors Fig 14 ..

![Fig 14 Ayden Adnan Menderes Hospital using materials in the exterior façade.](image1)

![Fig 15: Internal biomaterial finishing insulation or waterproof coating Single.](image2)
• **Hand Hygiene:** Hand washing basins and a convenient sanitizer have been installed within the room to enhance hygiene and maintain a clean environment. Fig 16.

Fig 16 Hand Hygiene inside wards

3.2-TERRASA DE HOSPITAL:
- The development phase of the Energy Simulation Program was successfully executed for four disease rooms utilizing SketchUp software.

- **Natural lighting:**
  The healthcare facility has replaced its outdated windows with advanced smart aluminum frames and low-emission double glass, known as Chromogenic Glass. This state-of-the-art glass combination not only leads to a significant decrease in thermal losses by 70%, but also reduces sunlight by 70%. Fig 17.

- **Natural ventilation:**
  The hospital upholds international standards in natural ventilation, with cross ventilation efficiently facilitated between the main building and the inpatient building.

- **Social distance inside Wards:**
  The bed arrangements were adjusted in accordance with the guidelines set by the World Health Organization, and patients residing in wards with more than two beds were provided with Antibacterial textile (Nanowires Silver Cotton) as a protective barrier. This material boasts of anti-bacterial, super hydrophobic, and UV light resistant properties.

- **Thermal control:**
  The utilization of block walls and plaster coatings was incorporated into the design of the rooms. It should be noted that the interior walls and bathrooms were excluded from the simulation model. To improve energy efficiency, exterior room walls can be adjusted with 4mm polystyrene and acrylic paint, which can effectively minimize thermal conductivity losses by 50%. Fig 18.

• **Hand Hygiene:**
  The introduction of hand washing measures within the hospital's primary thoroughfares has been implemented after the onset of COVID-19.

Fig 17 windows with smart aluminum frames

Fig 18 San Martino Hospital using Insulation panels and using polystyrene & acrylic paint.

3.3-SAN MARTINO HOSPITAL
The building with the highest level of efficiency, adaptability, and potential for future growth is the extension.

- **Natural lighting:**
  Balconies covered with external walls, and it is recommended to install insulation panels with a thickness of three VIP standard, providing a UV value of 0.158 W/m2k for external walls. Furthermore, low-emission windows made of coagulated glass should be utilized.
Natural ventilation: the exterior facade was designed to enhance its thermal efficiency through natural ventilation, while also facilitating maintenance by utilizing an isolation system on the exterior windows.

- Social distance:
The hospital adjusted the patient's quarters and emphasized the special distancing after the coronavirus pandemic Fig 19.

![Image](image_url)

Fig 19 External Façade and wards plan for San Martino Hospital explain The patient rooms.

- Thermal control:
The process involved piloting the full deck Plus Energy simulation software, identifying standard elements for thermal bridges and exterior walls.
The southern facade features external paint, gypsum thickness, hollow block thickness, vacuum antenna, and inner paint, while the northern facade features external paint, gypsum thickness, hollow block thickness, vacuum pneumatic thickness, and internal paint Fig 19.

- Hand Hygiene:
The hospital used smart hand hygiene systems.

III DISCUSSION

The analysis uncovered a close association between design strategy and building materials in design projects. A significant correlation exists between design strategy and building materials and their impact on the IPC ratio, with certain elements such as external insulation, finishing technology, and ventilation affecting the IPC rate.
The analytical study indicated that the success of these cases was contingent upon the compatibility between design strategies and the judicious selection of biomaterials. It was uncovered that design strategies which prioritized energy efficiency and sustainability were more likely to achieve desired outcomes when complemented by environmentally friendly and BIO-building materials. Table 3 [36]
IV. CONCLUSION

The integration of biomaterials into the flow design of the hospital space is of utmost importance in improving IPC (Infection Prevention and Control) measures. Careful planning of room arrangements, corridors, and entrances can optimize the movement of people and resources, minimizing the risk of cross-contamination and enhancing the implementation of infection control practices. The selection of materials and surfaces is equally critical in preventing the spread of pathogens. Incorporating biomaterials into hospital design presents both potential benefits and challenges that should be thoroughly examined.

V. RECOMMENDATION:

It is recommended that Egyptian hospitals adopt the IPC strategies by integrating design and biomaterials:

- A comprehensive IPC code should be developed, encompassing design methodologies and the types of biomaterials utilized in healthcare facilities.
- To minimize the risk of infection transmission, plated or copper-infused materials should be utilized for frequently touched surfaces, such as bed rails and staircase handrails.
- Furthermore, the design of Hand sinks should incorporate self-clean materials to prevent waste spills in sensitive care environments and facilitate cleaning processes.
- Utilize high-smoothness and high-solidity de-coagulant mixtures or cement screed for plastering, and follow with the application of specialized cover materials, such as paints, to minimize the presence of tiny voids and enhance surface smoothness.
- To improve the hygiene of public areas and hospitals, install sensors on entry curtains and doors to facilitate automatic closing and opening. This reduction in contact with hinges also helps to prevent the transmission of bacteria.

In addition, incorporate motion-detecting sinks to further minimize the risk of

<table>
<thead>
<tr>
<th>San Martino Hospital</th>
<th>Turin De Hospital</th>
<th>HOSPITALS Biomaterial</th>
<th>Case study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coagulate Glass</td>
<td>Chromogenic Glass</td>
<td>Self-cleaning Glass, double glass on inpatient room</td>
<td>Artificial Lightening</td>
</tr>
<tr>
<td>Inside all Diagnostic spaces</td>
<td>windows with Smart aluminum frames</td>
<td>Suitable window size, Good ratio of natural light</td>
<td>Natural ventilation</td>
</tr>
<tr>
<td>Isolation system on exterior windows</td>
<td>Few spaces in administration and Clinics</td>
<td>Single sided ventilation</td>
<td>Ventilation</td>
</tr>
<tr>
<td>between the main building and the inpatient building</td>
<td></td>
<td>Cross ventilation</td>
<td>Stack ventilation</td>
</tr>
<tr>
<td>Artificial ventilation</td>
<td>Artificial ventilation</td>
<td>Artificial ventilation elements with technical antibacterial filters</td>
<td>Hybrid ventilation</td>
</tr>
<tr>
<td>Thermal control in side hospital spaces</td>
<td>Social distance</td>
<td>Anti bacteria floor, Silver nanoparticle, Anti bacteria floor</td>
<td>Corridors</td>
</tr>
<tr>
<td>Not available</td>
<td>Available</td>
<td>Not adapted to last recommendation of WHO</td>
<td></td>
</tr>
<tr>
<td>Hand hygiene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paint, gypsum thickness, hollow block thickness</td>
<td>Polystyrene and acrylic paint, Waterproof coating</td>
<td>Single layer thickness 0.3</td>
<td>Interior finishing</td>
</tr>
<tr>
<td>Nanoparticles of Titanium dioxide and silicone oxide</td>
<td>Interface insulation material</td>
<td>Exterior finishing</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 "An Analytical Study of the Intrapartum Crowding (IPC) Ratio According to Design Strategies and Biomaterials: A Case Study"
transmission and incorporate controls and equipment with minimal horizontal surfaces and nooks/crevices to prevent the accumulation of debris and the spread of infection.

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- **Conflicts of Interest:** The author declares there is no conflict of interest.

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