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THE ROLE OF SMART FINISHES IN REDUCING THE SPREAD OF INFECTION IN HOSPITAL ISOLATION ROOMS

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ABSTRACT

Hospitals are considered a place for people to recover and protect themselves from diseases and epidemics that have spread recently, and perhaps the internal environment plays an important role in the hospitalization process by preventing infection from the patient or to him in order to protect others, and one of the most important of those spaces in hospitals, the importance of which has been demonstrated in this last period is the isolation rooms for patients, and their internal environment constitutes an important focus in the process of recovery and controlling of infection fight, which forces this matter to search for finishing materials and raw materials that do not interact with viruses and do not stimulate their reproduction or spread, and perhaps the matter may require the intervention of the highest limits of intelligence in materials. One of the most important technological revolutions is nanomaterials and raw materials, which have sparked widespread controversy and spread in various fields, and finishing materials have witnessed a large part of this intelligent development in the composition of these

KEYWORDS: Smart materials, nanotechnology, patient isolation rooms, spread of infection.

دور التشطيبات الذكية في الحد من انتشار العدوي بغرف عزل المرضي

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الملخص

تعتبر المستشفيات هي مكان استشفاء الانسان وحمايتة من الامراض والاوبئة التي انتشرت مؤخرا ،ولعل البيئة الداخلية تلعب دورا هاما في عملية الاستشفاء من خلال منع العدوي من والي المريض بهدف المحافظة علي الاخرين ،ومن أهم تلك الفراغات الموجودة بالمستشفيات والتي ظهرت أهميتها في تلك الفترة الاخيره ،هي غرف عزل المرضي ،وتشكل بيئتها الداخلية محورا هاما في عملية الاستشفاء والسيطره علي مكافحة العدوي،مما يضطر هذا الامر للبحث عن مواد تشطيب وخامات لاتتفاعل مع الفيروسات وغير محفزة لتكاثرها أو انتشارها ،ولعل الامر قد يستدعي تدخل أعلي حدود الذكاء في المواد ،ومن أهم ثوراث التكنولوجيا هي المواد والخامات النانويه التي أثارت جدلا وانتشارا واسعا في شتي المجالات وحظت مواد التشطيب بجانب كبير من هذا التطور الذكي في تركيب تلك الخامات .

الكلمات المفتاحية : المواد الذكية، النانو تكنولوجي، غرف عزل المرضي، انتشار العدوي

1. INTRODUCTION

One of the most important and greatest blessings of God Almighty upon man is health, and the primary goal of hospitals is compliance with recovery, so the goal and purpose of hospitals must be achieved to the fullest extent, and the research deals with clarifying the role of the internal environment of isolation rooms for patients in healing properly without any harm from or to the surrounding environment, but despite the recent technological development on the other hand, diseases and epidemics have spread that may affect humans and their risks through infection from another person or contact with patients. Sometimes people are infected with infectious diseases from hospitals while receiving treatment, which makes the primary goal of establishing hospitals is contrary to reality.

2. Research problem

- Inadequacy and problems arose in the isolation rooms of existing hospitals, resulting in a rise in deaths due to the events prior to Corona pandemic, which occupied public opinion at the time.
- The lack of isolation rooms in existing hospitals, which forced the Egyptian state to search for alternative rooms in buildings that have nothing to do with health care, such as university cities.
-The lack of this type of research, but most of the research was volunteered for hospitals in general, which urges the researcher to shed light on this type of important gaps.
-The growth of infectious bacteria and viruses on the interior surfaces of patient isolation rooms, which delays the patient's recovery, and he may become infected again while receiving the necessary treatment

3. Research objective

-Trying to achieve a safe and sound internal environment in which design mechanisms and standards are documented using smart finishing materials.
-Providing ideal solutions that would increase the efficiency of patient isolation rooms in existing hospitals, so that they can perform their function for which they were created to confront any new epidemics.
-Displaying smart materials that contribute primarily to combating infection in patient isolation rooms in existing hospitals.

To achieve the goal, it is necessary to study the properties and composition of some smart materials and nano-technological materials, compare their advantages, and use the most appropriate ones in the interior finishing of patient isolation rooms.

4. Research importance

Consolidating and demonstrating the role of architecture in confronting the spread of the epidemic, through its development in studying the standards of spaces, their locations of distribution, as well as the development of finishing materials

5. Definitions

Below is a table showing some definitions related to the research paper.

Table (1) shows the definitions related to the research, prepared by the researcher

1	**Pandemic and The epidemic**	Pandemic is a Greek word that means the generality and people, meaning it is used when there is a disease that affects entire nations in several countries at the same time [1] **As for the term epidemic** An epidemic is a phenomenon that occurs in a specific place on a very large scale, transcends borders and affects a large number of people. [2] From the above, the researcher can confirm that the previous two terms are related to each other, as the epidemic is part of the pandemic, and the presence of the pandemic confirms the existence of the epidemic and not the other way around.
2	**Safe isolation room**	It is a space that does not cause any spread of infection and is capable of containing and combating infection through internal elements such as smart finishes, upholstery, and ventilation systems.. [3]
3	**Smart isolation room**	It is that space through which the patient can interact with internal elements without touching, such as remote sensing, such as opening and closing doors independently, lighting the room independently, and using faucets simply by sensing the distance. . [4] From the above, the researcher can conclude that smart architecture has a great role in finishing materials for isolation rooms and operating techniques for internal elements, which works to limit the spread of infection.
4	**Nano**	The word “nano” is an ancient Greek word derived from the word “nanos”, which means the part in a thousand million. It is a study of the phenomena of physical and chemical properties when materials are reduced to an infinite degree. [5] **As for** Nanotechnology is technologies manufactured with the smallest unit of measurement for dimension known to man Nano in architecture can be defined as materials and raw materials made from extremely small particles due to changing their properties.
5	**Patient isolation rooms**	It is a functional space designated for the detention, monitoring, and residence of some cases of patients with infectious diseases, which requires the protection of the patient or those around him, depending on the type of infection. [6] It can be defined as the designated unit with the most stringent and preventive measures to protect the patient and those around him from the spread of infection within the hospital spaces.

6. Design considerations for patient isolation rooms

Below is a table(2) showing the design considerations for the Egyptian and American codes.

Table (2) shows the design standards for patient isolation rooms, prepared by the researcher

Egyptian code 2021	The Egyptian Code for Design Standards for Hospitals (Part One 2021) stipulates a set of requirements for patient rooms in general. Including the following, as in Table (2): [7] -At least one isolation room must be provided in each nursing station. -The number of patient isolation rooms shall not be less than one room for every 20 regular residence rooms. -The number of patient isolation rooms shall not be less than one room for every 12 emergency beds. -The number of patient isolation rooms shall not be less than one room for every 8 beds in intensive care. -Entry to the patient isolation room is through a hall that includes some services such as a hand sterilization sink and a nursing supplies tray, through which the patient can be followed up through the glass partition without entering the isolation room, as it is not preferable to constantly enter and leave those critical rooms. -The room must contain a private bathroom for the patient and a sink, without going out into the hallway. -The location of the room should be in the opposite direction to air currents and movement areas on roads and corridors. -The door of the isolation room must open in the direction of the lowest pressure, meaning that in the case of a room with negative atmospheric pressure, the door must open in the direction of the room and not in the direction of the corridor or the road, and it should open in the direction of the door and the corridor in the case of positive pressure, since in this case the atmospheric pressure in the corridors and roads is less from inside the room, to avoid transmission of infection. -Do not install window handles so that other people cannot open them. Rather, opening these windows is limited to people who are specialized and responsible for those windows, and they must be tightly closed, so as not to disturb the air pressure in the room. -Ventilation must be mechanical in these rooms and not natural, in order to filter the incoming or outgoing air, depending on the type of room.
American code updated 2020	The dimensions of the isolation room must be 3.6 x 7.2, including the bathroom, restroom, and outdoor hall, which were modified in the latest update for the year 2020 following the events of Corona 2019, to the following: [8] -The dimensions of the isolation room must be 3.9 x 7.8, including the bathroom, restroom, and hallway. The net height of the room must not be less than 2.7 m.- -Isolation rooms must overlook a suitable external environment, given the length of the patient's isolation period. -These rooms must not contain patient-specific closets or storage areas at all to avoid the growth of viruses and bacteria. -It is necessary to avoid corners with right or sharp angles in patient isolation rooms.

6.1. Types of patient isolation rooms

Standard isolation rooms: Which does not require air pressure control and does not require a number of times the air should be changed. It is used when the patient is suspected and is prepared for detention until the illnesses he has are determined, whether they are contagious or not.

Environmental protection room: It is used to isolate patients with compromised immunity for fear of any external infection that may affect them. [9-11]

Negative pressure isolation room: It is used to isolate a patient carrying an infectious disease through the air in addition to its role as a hospital., as in Figure (1), (2)

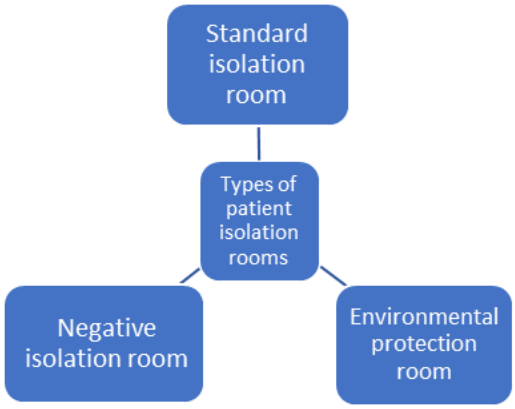


Figure (1) shows the types of patient isolation rooms by researcher

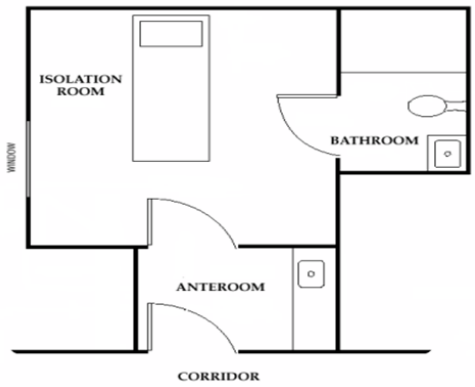


Figure (2) shows the horizontal layout of the positive isolation room [12]

6.2. Some architectural problems found in patient isolation rooms in Egyptian hospitals:

There are not enough isolation rooms in hospitals and they are not ready either.-

-With the recent increase in the number of infected people, the use of individual residence spaces has been changed and converted into isolation rooms that do not meet specifications. [13]

-The lack of visibility of the patient in the isolation room due to the solid brick partitions, which makes observing the patient by opening the door of the room and entering directly to patient, and this is undesirable according to the recommendations of the American code.

-The windows are not tightly fixed and allow air and external pollutants to leak inside isolation rooms.

-Use unsuitable finishes for floors that are easy to clean, prevent pollution and fungi, and are not affected by disinfectant materials.

-The presence of seams and separations in the floors and between floors and walls which helps the presence of bacteria and microbes and leads to the transmission of infection.

-Failure to take into account that the corners of the cabinets' connection to the walls are circular, thus leading to accumulation of viruses that are difficult to disinfect and clean because they are not sealed with the floors.
Failure to adhere to avoiding right and sharp angles in the corners of patient isolation rooms.-
Lack of a clear and safe path for waste in hospitals.-
Finishing and building materials are not fire resistant.-
Noise and its anxiety to the patient. -
Lack of call systems for nursing staff. -

7. Design standards to limit the transmission infection in patient isolation rooms

Transmission of infection to a patient while in a hospital is serious and must be avoided completely or minimized. Medical and technological development has led to the discovery of many diseases related to biological pollution within hospitals and thus how to eliminate them. The hospital's design is an essential element of the strategy to combat infection. Therefore, the design of the hospital needs to consider separating contaminated rooms and clean areas. The role of the architect here is undoubtedly to reduce the touch patient's handling of internal objects in the vacuum as unlocking and closing lighting through keys, etc., such as water taps and otherwise, and the finishing of the floors is one of the most useful factors for bacteria survival and proliferation due to difficulty in removing them with detergents, figure (3), [14]

Figure (3) shows infection control elements inside the vacuum of patient isolation rooms-Prepared by the researcher

7.1. Sources of transmission of infection in patient isolation rooms

Infection is transmitted from one person to another through the air or contact...etc. As for the architectural aspect, it is the transmission of infection through several reasons, the weakest of which may be ventilation, because ventilation in patient isolation rooms is impossible to be natural, and the role of finishes comes as one of the factors that help the growth of viruses on traditional surfaces, as in Figure (4),[15]

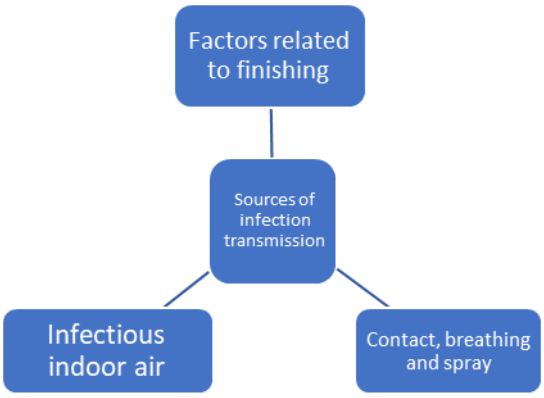


Figure (4) shows infection control elements inside the vacuum of patient isolation rooms, Prepared by the researcher

8. Indoor environment

8.1.Sources of transmission of infection in patient isolation rooms:

It is about the design of the internal space of the patient's isolation room (floors, walls, ceilings, openings, cabinets, and also colors, as well as controlling any external problems such as combating noise and heat and achieving natural lighting), and to design and implement these elements, there must be well-studied requirements and plans using modern and different building materials and finishes that are easy to maintain, which in turn it combats the transmission of infection and treats contamination of the surrounding environment. This requires widespread awareness among architects, through the collaboration of more than one specialty in addition to the architectural specialty. Among the specialties that require the finishing of these rooms is the specialty of mechanical engineering in order to properly design the mechanical ventilation elements as well as maintain them, which requires good quality constantly in hospitals. [16]

8.2.Sources of transmission of infection in patient isolation rooms:

Of course, natural ventilation did not have a role in patient isolation rooms like other spaces, as the goal of isolation rooms is to restrict the patient's freedom so that the infection is not transmitted through the air.

-**Lighting:** Lighting is a very important factor in reducing the risk of patients falling. If the lighting intensity level is less than the required limit, it may lead to the patient falling. Also, as a matter of energy conservation, natural lighting can be integrated with artificial lighting to reach the stage of homogeneity.

-**Noise**: Increasing sound levels at night beyond the recommended values disrupts sleep during the night and thus increases sleepiness the next day. It is either external or internal noise.

-**Thermal comfort:** Although ventilation inside patient isolation rooms is mechanical, it also requires treatments for the room covers to create a thermally moderate environment, which greatly reduces energy consumption. The treatments are represented in the walls, openings, and final ceilings.

- **Finishes:** Architectural finishes are the factor that helps show the proportions and characteristics of the architectural space. They also play a vital role in hospital buildings, and can contribute to creating a healthy environment safe from risks. Floors, walls and ceilings must have flat surfaces and be made of finishing materials without any joints as possible. Finishing materials must also be chosen carefully so that they do not cause confusion to the patient, [17] such as extreme contrast in color and texture, and they must be slip-resistant, resistant to flame and chemicals, resistant to noise, resistant to the transmission of infection and germs, and easily cleanable. Finishes include

the following: (Walls and what is in them from openings for windows and doors - ceilings - cabinets - partitions), Figure (5), (6).

Figure (5) shows the smart finishing elements inside the patient isolation room space, prepared by the researcher

Figure (6) shows the smart finishing elements inside the patient isolation room space prepared by the researcher

First: The walls of the patient isolation room:

It must be considered that the finishing of the room walls should be made of materials that prevent the growth of bacteria, are easy to clean, and without breaks, so as not to create an interactive environment with bacteria. Here are some suggested materials that can be used in the interior walls of patient isolation rooms, as in Table (3)

Table (3) showing the types of smart infection control materials that can be used in walls, prepared by the researcher

	Material type	**Description**	**Its appropriate place in the patient's isolation room**
1	Nano coatings that fight bacteria and viruses	They are materials that are painted on surfaces to destroy bacteria, which helps reduce the use of disinfectants, especially in health care environments, using methods that support cleanliness. Nano antimicrobial and antibacterial materials have been used on all floors and walls of operating rooms in one of the hospitals in the city of Gosa. [18]	The walls and floors of the patient isolation room can be painted with these materials to combat viruses
2	Self-cleaning coatings	Lotus effect is a hydrophobic coating. This coating is suitable for most surfaces that are regularly exposed to sufficient amounts of water. such as rain water. Bathroom spaces and many spaces exposed to wetness, as in Figure (7).  Figure (7) shows the idea of the lotus flower working in paints and repelling water [19]	It can be used to paint the walls and floors of the bathroom of the patient's isolation room, as it works on self-cleaning through water scattered from the patient during use.
3	Anti-fingerprint coatings	It is a nano-processed coating material[1]It can be painted on surfaces to give it new properties, including resistance to fingerprints, Figure (8)  Figure (8) shows the fingerprint-resistant coating [19]	It can be used on walls because it is not affected by the patient's infected hands touching the walls, so they do not leave any traces.

Second: Ceilings of the patient isolation room:

Suspended ceilings in isolation rooms and sterile rooms must extend from wall to wall without any partitions whenever possible or open connections that allow plankton to collect in them or bacterial particles to pass through them. [20]The lighting and ventilation units in these rooms must be installed recessed, tightly and flush with the ceiling surfaces to prevent dust leakage, with the

necessity of sound insulation for industrial ventilation corridors. The following is a table of materials suitable for ceilings, as in Table (4)

Table (4) showing the types of smart infection control materials that can be used in ceilings, prepared by the researcher

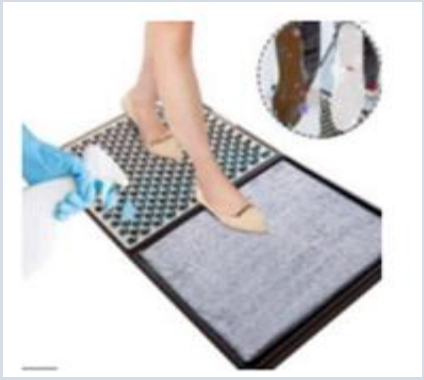
	Material type	Description	Its appropriate place in the patient's isolation room
1	Treated matte aluminum coil	It consists of thin aluminum coils treated to reduce their shiny surface. They are available in different sizes and fixed widths, Figure (9)  Figure (9) shows aluminum coils without partitions for the ceilings of patient isolation room spaces [22]	It can be used in the ceilings of patient isolation rooms, as the ceilings also need to be without joints as a result of the patient's breathing movement at the top of the bed, as it is a direct and perpendicular movement on the ceiling. One of the previous virus-resistant coatings can be added to these chips to increase their effectiveness.

Third: Patient isolation room floors and cabinets:

Floor finishing must be made of materials that are easy to clean, without joints, not affected by disinfectants, prevent the formation of fungi, withstand heavy service, and are non-slip, and that it is easy to maintain, repair and replace, so that it is always in good condition. [22].

All joints, if any, must be welded to prevent the accumulation of bacteria and to prevent damage resulting from water leakage. Carpets and rugs must not be used in isolation rooms. The corners of the cabinets' connection to the floors and to the walls must be circular to prevent the accumulation of dust, and they must be easy to clean, fumigate, and disinfect, and must be well sealed. The following is a table showing some of the smart materials that can be used on floors, as in Table (5)

Table (5) shows the types of smart infection control materials that can be used on floors and cabinets.

	Material type	Description	Its appropriate place in the patient's isolation room
1	Frosted epoxy floor paint	It is a modern liquid coating material that can be poured on existing floors, [1], and when it reaches the sclerosis phase it becomes resistant to friction and wild, and the goal of its nomination is that without joints it does not become a fertile environment for the growth of bacteria and viruses, as in figure (10)  **Figure (10)** shows epoxy floors without joints [22]	It can be used on patient isolation room floors, as they are characterized by being without joints, which leads to the accumulation of bacteria and viruses. They can be sanded to reduce their shiny surface as well as to be slip-resistant.
2	Smart advanced carpets	It is a rubber wool carpet immersed in sterile water before walking on the floor of the vacuum, which works to disinfect plankton from the feet, as in Figure (11).  **Figure (11)** shows smart carpets[23]	It can be used in the hallway preceding the patient isolation rooms, where it works to sterilize the feet of the medical staff while entering and exiting the patient's isolation room to receive treatment.
3	Cabinet installation technology	Cabinets can be installed at the same level as the wall without protruding, to avoid the difficulty of cleaning and the presence of plankton, Figure (12)  **Figure (12)** shows the meeting of the skirting with the wall and floor[23]	It is used on patient-isolating vacuum floors due to its ease of cleaning and aesthetic appearance

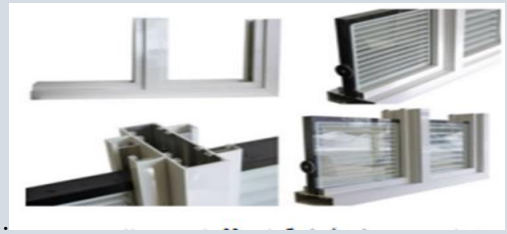
Fourth: Openings in the patient isolation room:

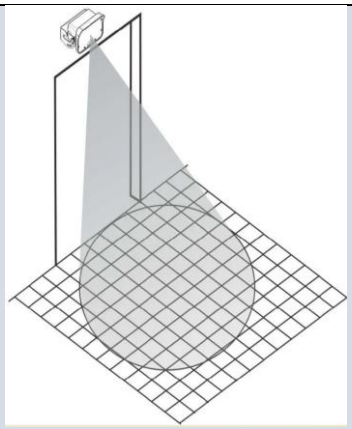
As for the openings in patient isolation rooms, they must be tightly closed to prevent any type of air carrying infection from leaking from inside the room to the outside.

As for the doors: Make sure it is made of cleanable materials and the direction of its opening is in the direction of least pressure

As for your windows: It must be transparent to ensure natural lighting and the patient's contact with the external environment. [23-25]It must be permanently sealed so that the patient cannot open it, and it can be opened by technicians for maintenance and the like. The following is a table showing the smart treatments for the openings, as in Table (6)

Table (6) showing the types of smart infection control materials that can be used for openings, prepared by the researcher

	Material type	Description	Its appropriate place in the patient's isolation room
1	Smart windows	They are windows composed of successive layers of glass treated against absorption and transmission of heat. [25] It can be controlled for complete vision or not, as well as internal shading between the glass spaces, through remote control, as in Figure (13). As for the window handles of the patient isolation room, there are no handles because they are permanently sealed  Figure (13) shows smart windows [25]	It can be used in the patient's isolation room, as the windows must be transparent for the patient to communicate with the external environment, and the ease of use through the remote control allows the patient not to move a lot inside the room.
2	Coating the glass with titanium oxide	They are panels of glass coated with titanium dioxide, which helps in self-cleaning the glass and getting rid of contaminants stuck on the glass panels, as in Figure (14).  **Figure (14)** shows the mechanism of self-cleaning glass [25]	It can be used to paint the previously suggested glass inside the patient's isolation room, as it can self-clean itself upon exposure to sunlight, and it can also be used in observation glass.
3	Smart doors	They are doors that open automatically as soon as they sense the presence of people in front of them, as in Figure (15).	It is used in the doors of the patient isolation room and the doors of the separating hallway, to ensure that the patient does not come into contact

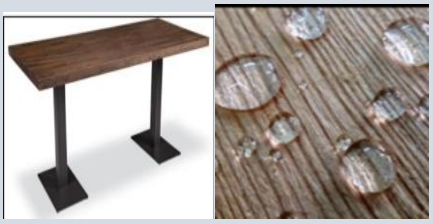
		 **Figure (15)** shows how smart doors work [26]	through the handles, which requires canceling them.
4	Smart handles	It is possible to install smart handles for opening and closing doors that operate by gesture only, as in Figure (16)  **Figure (16)** shows the self-locking handles [26]	It can be installed on patient isolation vacuum doors, whether the door of the room, the bathroom, or the hallway separating the isolation room from the hospital hallway

Fifth: Furnishing elements in the patient isolation room:

The following table.(7) : shows the elements of bedding and fabrics suitable for isolation rooms for patients that do not interact with microbes and viruses

Table (7) showing the types of smart infection control materials that can be used in mattresses, prepared by the researcher

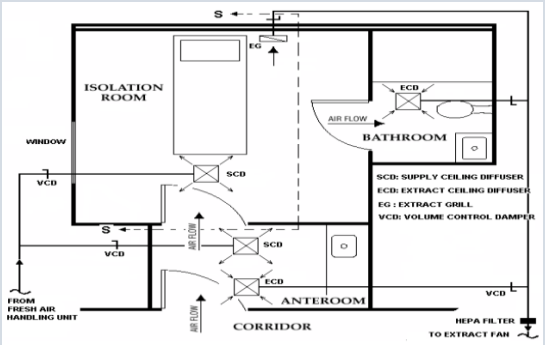
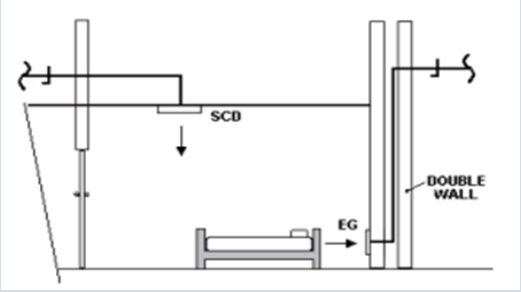
	Material type	Description	Its appropriate place in the patient's isolation room
1	Smart textiles	This fabric is distinguished by the fact that it achieves many features and functions such as:(Water repellent - wrinkle resistance - dust resistance and easy cleaning - ultraviolet ray prevention - resistance to bacteria, fungi and rot - increased and improved durability, as in Figure (17) 	It can be used in curtains, if any, inside spaces. It can also be used in bedding for patients in isolation rooms

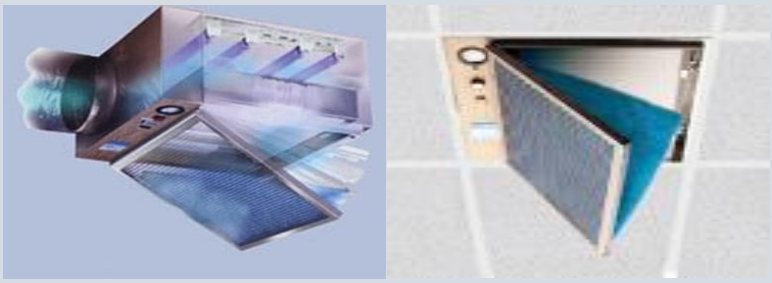
		Figure (17) shows infection-fighting fabrics [27]	
2	Smart toilet	The smart toilet is characterized by not requiring the patient to use the patient's hands to use it, but rather works with just a signal, as in Figure (18)  **Figure (18)** shows a smart toilet that works by gesture [28]	It is preferable to use it in the bathroom of the patient's isolation room to avoid contact with him
3	Smart taps	They are faucets that operate by remote sensing. Once the hands are placed under the faucet, it starts pumping water, as in Figure (19).  **Figure (19)** shows a smart faucet that works by remote sensing [28]	It is used in the bathroom for washing the patient's hands in the isolation room
4	Nano treated wood	It is nano-treated wood, which makes the surface water repellent and non-absorbent, as in Figure (20)  **Figure (20)** shows wood treated with nano and its water resistance [28]	It can be used in patient tables, storage places such as cupboards, etc., as well as work surfaces

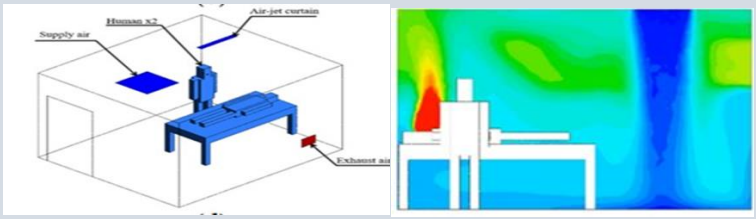
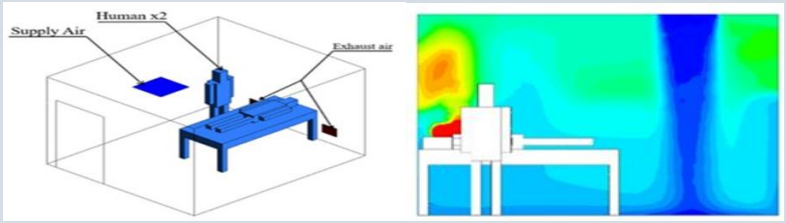
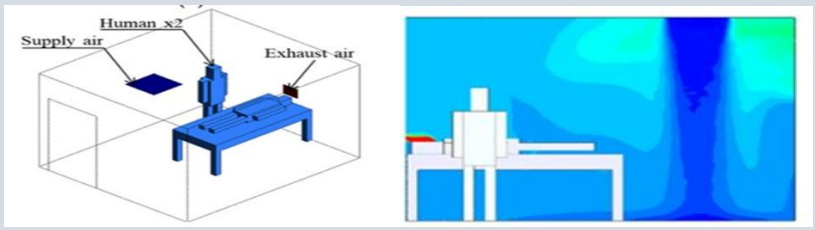
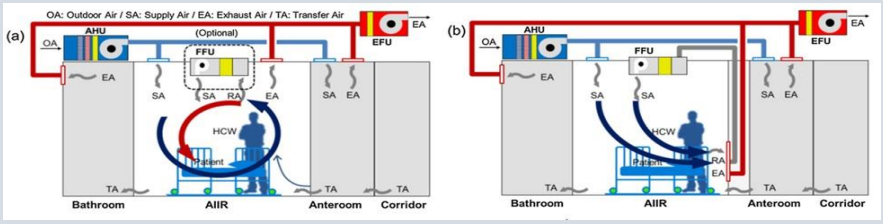
Sixth: Mechanical ventilation and indoor air quality in the patient isolation room:

1- **Mechanical ventilation:** Naturally, ventilation in patient isolation rooms must be mechanical ventilation, whether by pumping or suction, through special devices responsible for ventilation and cooling within the internal space of the patient isolation room, to prevent the transmission of infection. The following are special considerations for mechanical ventilation to combat infection, as in table (8) [1]

Table (8) showing the requirements for industrial ventilation and the air purification mechanism, prepared by the researcher

Special considerations for mechanical ventilation of patient isolation rooms		
1	Room ventilation rate	Previously, the room was ventilated by changing the room air 6 times per hour, but according to the new regulations of the American Institute of Architects, which are effective as of January 2021, the room air must be changed 12 times per hour and changed at a rate of 10 times per hour for the separation room (hallway) and bathroom.
2	Air distribution	In general, the mechanical air system inside the room must be designed to achieve the following points: • Achieving the largest mixing ratio of fresh air entering with room air to reduce the concentration of microbes in the room. • Do not allow any of the drawn air saturated with infection to pass into any other places or spaces in the hospital • Preventing air stagnation inside the room. This can happen if there is a part of the room that does not benefit from the incoming air. This is considered mainly from the architectural shape of the room, which must take into account the absence of parts in which the air can stagnate. For example, according to an example, a cavity can result in the wall. To stagnation of air in this cavity depending on its depth and dimensions. [29] Preventing immediate or rapid return. This happens when the air outlet is very close to its entrance. It is necessary to choose the location of the air inlet for the room so that it does not impede the movement of air. For example, the air inlet should not be placed behind a cabinet or above a television set hanging on the ceiling, as shown in Figure (21), (22).  **Figure (21)** shows the distribution locations of air pumps and air intakes [29]  **Figure (22)** is a section showing the locations of the air intake and pump distribution [29]

3	Recycling	It is better to supply the room with conditioned air through its own unit and an independent extractor fan, and not through central units that feed a group of rooms, for several reasons, including:
4	Fans and handling units	• Simplifying the automatic control system in addition to the possibility of feeding the unit through the backup electric generator in the event of a power outage, as well as completely separating the air passages of the isolation room from the rest of the rooms. • It is possible to feed each type of isolation room through a central air pump unit as well as a central exhaust fan. • It is prohibited to use the air system, through which the rate of incoming air is controlled based on the room temperature, as changing the amount of air will affect the pressure inside the room. [30]
5	Air filtration	As previously mentioned, the air must be purified through filters before expelling it to the outside air. The following are some points that must be taken into consideration regarding air filtration: • Care should be taken to choose the location of the filter so that it purifies all the air drawn from the room, meaning that it is installed on the main intake air passage, allowing the purification of the air drawn from the isolation room, the separation room, and the bathroom. A carbon filter can also be added, which ensures the quality of the indoor air to absorb odours. • The filter must be checked periodically to detect any cracks or tears in the filter, and if any exist, it must be replaced. • An audio and visual alarm must be added through the electrical control system, to indicate that the filter is clogged and needs to be replaced. • A spare mobile filter unit must be provided for use in emergency situations, if the suction fan stops working, as in Figure (23).  **Figure (23)** shows the shape of filters that purify polluted air. [30] An electric gauge must be added to continuously indicate the room pressure to ensure that the room pressure is negative, as in Figure (24)  **Figure (24)** shows one of the types of barometer and its location in the room. [30]

6	Effect of air intake locations	Mechanical studies have proven that exhaust air intake locations can also counter the spread of infection within the vacuum of the patient isolation room. [1] She emphasized that all of them are always behind the patient's head to be close to the patient's breathing source, and the following is Figure (25), (26), (27), showing the shape and intensity of the spread of the infection depending on the change in the places of air intake. **First case:**  **Figure (25)** shows the location of the air intake under one side of the patient's head [30] **The second case:**  **Figure (26)** shows the location of the air intake on both sides of the patient's head [30] **Third case:**  **Figure (27)** shows the location of the air intake directly behind the patient's head [30] From the above, we conclude that the location of the air intake hole has a role in the spread of infection as a result of the movement of air towards the place of suction. It should be noted that the single hole directly behind the head (the third case) is better than the two previous cases. Below is Figure (28), a section showing the location of the intake hole and its effect.  **Figure (28)** section showing the effect of the locations of the air intake holes[31]

2. Indoor air quality

Indoor air quality means purifying it of toxic emissions and gases that may be present in the patient's isolation room. In the past, the mechanism of mechanical ventilation for patient isolation rooms was identified. [32] As for the role of smart finishes, the following table shows the smart elements that support maintaining the purity and quality of indoor air, as in Table (9).

Table (9) showing the mechanisms used to ensure the quality and sterilization of indoor air, prepared by the researcher

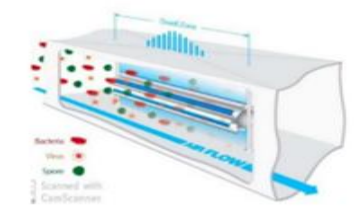
	Material type	Description	Its appropriate place in the patient's isolation room
1	Smart lighting	Through technological development, ultraviolet lamps have been developed, [1], It works to purify and sterilize indoor air by eliminating viruses and germs, in addition to its role in artificial lighting, as in Figure (29)  **Figure (29)** shows smart ultraviolet lighting that supports air purification [32]	They can be used as an alternative to traditional lamps due to their multi-tasking role
2	Smart dust	They are miniature sensors or sensors the size of dust particles, no more than a centimeter in size. They operate completely independently and can conduct two-way communications. Their transmission reaches up to 100 meters. When the smart dust is distributed in appropriate places, it has significant effects. It also works to purify the indoor air from any microbes suspended in the air. It will be It has tremendous scientific applications soon, as shown in Figure (30).  **Figure (30)** shows what smart dust looks like under a microscope [32]	It can be used by spreading it in the internal space of patient isolation rooms
3	Ultraviolet sterilization	It is a device that emits special waves of ultraviolet rays that can kill germs as soon as they are exposed As in Figure (31)	It is used in the hallway of the patient's isolation room, which is designated as a work surface for the medical

		 **Figure (31)** shows a sterilizer device that is an alternative to the traditional sink for medical staff[33]	staff instead of traditional sinks
4	Robotic sterilization	Technology has made huge leaps, as it could manufacture a mobile robot that can move inside spaces to sterilize them by emitting ultraviolet rays. As in Figure (32)  **Figure (32)** shows the smart robot [33]	It can be used for daily sterilization of patient isolation rooms.
5	Sterilization gates	It is a human-sized corridor through which a person can pass, emitting rays and lights that work to sterilize the person and the clothes he is wearing, as in Figure (33).  **Figure (34)** shows the personal sterilization gate [34]	It can be used in the hallway separating the roads and isolation rooms, to sterilize the medical staff during entry and exit, and to sterilize the patient if he leaves the room.

<u>Seventh: Smarter complementary elements in the patient isolation room:</u>

The following table (10) : shows the extent of the development of technology, such as artificial intelligence, in various aspects that serve the individual and society, as it can be used in isolation rooms as follows.

Table (10) showing the development of artificial intelligence to meet human needs, prepared by the researcher

	Material type	Description	Its appropriate place in the patient's isolation room
1	Enhanced virtual reality	Artificial intelligence has been able to invent glasses that can be worn by humans and live in another virtual world through holograms and the embodiment of people, as in Figure (35)  **Figure (35)** shows communication with people through enhanced virtual reality [35]	It can be used for a patient isolated in the room for family visits and to prevent him from feeling lonely. It meets humanitarian needs, in addition to combating infection by not allowing visitors to enter the patient to ensure their protection.

10.Applied study:

A sample was chosen for the applied study, which was a patient isolation room in Al-Manzala General Hospital in Dakahliya Governorate, where the researcher was born. The study was conducted for the fever department, which is designated for isolating patients with infectious diseases

Table (11) shows a description of the study sample and the numbers of the researcher

Fever Department building at Al-Manzala General Hospital, Dakahliya Governorate		
1	Description of the building	The building is of a structural type. It was established in 1965 and was designated for chest diseases. Then it was renovated in 2005 and became designated for detaining suspected cases of infectious diseases such as fever, tuberculosis, and infectious diseases through breathing and spray.
2	Number of floors	The building consists of two floors, ground and first floor -The ground floor contains services for health care, a pharmacy, nursing, security and administration rooms -The first floor contains 6 individual isolation rooms, 3 triple wards, 2 nursing stations, and clean and unclean warehouses
3	Area	The ground floor has an area of 375- -The first floor is an upper floor with an area of 407 square meters due to the protrusions on the facades

10.2 Problems in patient's isolation room under study (from the researcher's point of view)

-There is no separating hall between the hallway and the isolation room, but direct entry to the isolation room.
-The openings are not tight, as they are all easy to open with regular hand handles, which affects the spread of infection easily.
-There are no differences in pressure between the roads and the isolation room, but the pressure is completely equal, which affects the spread of infection easily.
-There is a terrace attached to the patient's isolation room, which contradicts its name and nature as an isolation room.
-The absence of any precautionary measures such as banners and directional signs on the external doors of the isolation room
-The interior finishes are traditional, there are no interior materials to combat infection, as in Table (12)

Table (12) showing the analysis of the internal space elements of an existing patient isolation room, prepared by the researcher

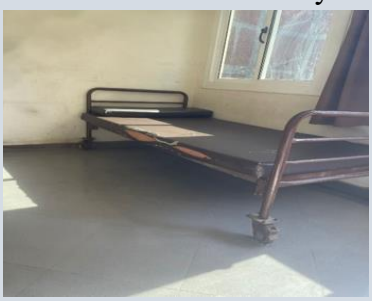
Analysis of internal space elements of a single patient isolation room		
1	Room walls	Through the field visit, it was found that the walls are made of ord.inary plastic paint, traditional and washable for easy cleaning. Figure (36)  **Figure (36)** shows Room walls by the researcher
2	Bathroom walls	The bathroom walls are made of regular ceramic tiles, with partitions without any treatments, Figure (37)  **Figure (37)** shows Bathroom walls by the researcher
3	Room ceiling and the bathroom	During the field visit, it was found that the ceiling of the room and the bathroom was made of regular suspended gypsum tiles, measuring 40*40 cm, and that viruses and bacteria could accumulate in the joints on them as a result of the patient's breathing direction perpendicular to the ceiling, which makes the ceiling a fertile environment for the accumulation of viruses, Figure (38)

		 **Figure (38)** shows Room ceiling and the bathroom by the researcher
4	Room floors	During the field visit, it was found that the floors are made of natural Gondola marble, size 40*40 cm, and have joints, which makes them vulnerable to the accumulation of bacteria and viruses, Figure (39)  **Figure (39)** shows Room floors by the researcher
5	Chamber cabinets	The cabinets are traditionally of the same type as the natural Gondola marble floor, and in an upright shape, which affects the accumulation and reproduction of bacteria and viruses and the difficulty of cleaning the corners from plankton, Figure (40)  **Figure (40)** shows Chamber cabinets by the researcher
6	Room and bathroom openings	**Firstly, the doors:** The binding is made of ordinary wood, with a washable lacquer coating, with ordinary handles and no automatic control for opening and closing. Figure (41)  **Figure (41)** shows doors in isolation room by the researcher **Secondly, the windows**: Made of aluminum sections with transparent glass, 3 mm thick, which directly transmits light and heat, with the ability to open and close the windows easily without any obstacles, Figure (42)

		 **Figure (42)** shows windo in isolation room by the researcher
7	Room furnishings	It does not have any smart brushes or anti-infection materials, but rather is made of traditionally painted iron, Figure (43)  **Figure (43)** shows Room furnishings by the researcher
8	Sanitary appliances in the bathroom	The appliances are of the traditional type, as well as the faucets. The toilet and wash basin are of the footed type and not the hanging type, which contains around the foot bacterial and viral plankton, Figure (44)  **Figure (44)** shows Sanitary appliances in the bathroom by the researcher
10	Lighting switches	Of the traditional type, which makes the keyboard face a fertile environment for infection as a result of direct contact, Figure (45)  **Figure (45)** shows Lighting switches by the researcher
11	Industrial ventilation	It is just central cooling and there are no machines to extract and purify the exhaust air before expelling it, but rather direct intake through windows and vents that are easy to open, Figure (46)

		 **Figure (46)** shows Industrial ventilation by the researcher
12	curtains	Traditional curtains of the leather type that are able to retain the mist resulting from the breathing process, , Figure(47)  **Figure (47)** shows curtains by the researcher
13	locks	The handles are of the traditional type, which is not suitable for the room and transmits infection easily through person-to-person contact Figure (48)  **Figure (48)** shows locks by the researcher
14	Handrail	The handrail is of the traditional type of wood material and is susceptible to infection from one person to another, Figure(49)  **Figure (49)** shows Handrail by the researcher

11 . Results

First: Results of the theoretical study:

-Designing patient isolation rooms is not limited to architectural engineers only, but requires the collaboration of most disciplines, such as mechanical engineering, programming, and bioengineering.

-Through the theoretical study, it was found that the codes only care about dimensions and spaces, without any recommendations for finishes

-Taking into account the design principles, such as geometric formation, occupancy rate, furnishings and finishes, has a major role in preventing the spread of infection

-The state must pay attention to developing such previously studied cases so that they are fully compatible with nine patients while facing a future epidemic.

- Filtering the air before it leaves the outside air is one of the most important factors in combating the spread of infection, which confirms the role of mechanical engineering.

- All precautions and measures for finishing isolation rooms can be generalized to the rest of the types of spaces because the isolation room is the most sensitive space to the spread of infection.

- Previous research provides an indicative model for the development of internal finishes of patient isolation rooms, for infection control in large proportions.

- The more patient isolation rooms contain observation windows, the better to reduce entry times for medical staff and thus reduce the chances of infection.

-The psychological aspect of the patient must be considered in creating a comfortable living environment that interacts with the environment through external views

- Regular residence rooms can easily be converted into single rooms by adding some modifications, the most important of which are the lobby and mechanical ventilation.

- Existing hospitals can make some modifications to develop patient isolation rooms, as hospitals are always flexible in their design

- Smart materials are not limited to finishing materials, but also to building materials-

Second: Results of the field study:

-Through previous research and study, it was found that the individual patient isolation room does not meet any specifications, and there is no means of combating infection, except that the materials are easy to clean only.

- Through the field study, it was shown that the spaces can be redesigned and transformed into ideal isolation rooms

-The previous room is not related to the patient isolation rooms, but is considered an individual residence room, which is incompatible with the fever department, which is designated as a functional building to combat fevers such as smallpox, tuberculosis, Crohn's disease, and others, which cause future epidemics that may occur.

-Through the previous horizontal projection of the fever department building, the flexibility of the design is demonstrated, making it scalable and easy to develop according to specifications.

-The geographical location of the previously studied case is located in a dense residential and educational area, which confirms the necessity of tightening the openings

12 . Recommendations

-Architectural designers must consider the flexibility of the architectural design of hospitals, including the regularity of spaces and sufficient height, for future expansion.

- It is necessary to have a specialized team to maintain air filters and filters to ensure their safety and efficient operation
-The state must develop hospitals and build buildings for complete isolation rooms, separated from hospitals, designated for treating epidemics
- Connecting ventilation filters with alarm devices that predict the expiration of the filter or its damage and the need to change it, in order to reduce periodic traffic on the filters and thus reduce the times technicians come into contact with the patient's isolation room.
-It is necessary to consider the geographical location of these epidemic control buildings, and to set strict requirements for movement near them to prevent the spread of any epidemic.
- Designers of health care buildings must take into account the heights of the floors in order to prevent any future modifications, such as mechanical ventilation requirements, while converting regular rooms into isolation rooms, if there is flexibility in the design and there are no structural obstacles.
- During development, it is necessary to deal with the most advanced finishing materials-
-It is necessary to create a special code for patient isolation rooms that takes into account all aspects of architectural design and all means of combating infection
-Forming a special team to periodically visit these types of buildings, to maintain them and inspect their conditions by following up on the systems.
-Finishing engineers and specialists must use the latest technologies that will reduce patient contact inside the isolation room
- The state must pay attention to the existing health care buildings and develop them to keep pace with modern developments instead of demolishing and rebuilding, after ensuring that the buildings are capable of development and taking into account the economic aspects.

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