1. INTRODUCTION

Health and hygiene are the primary requirements for human beings to live comfortably and work with maximum efficiency. Despite progress in public health and hospital care, infections continue to develop in hospitalized patients and healthcare workers. Infections may be transmitted from various sources in hospitals. One such source is dissemination of pathogens from biomedical products. Biomaterial-centered infection is a dreaded complication associated with the use of biomedical products. Hospital based medical products may carry pathogenic microbial strains of both Gram-positive and Gram-negative bacteria (Gottenbos et al., 2003). Biomedical products for healthcare are a culmination of the worldwide research into medical textiles and biomaterials. It is divided into eight parts covering the main areas of basic biomaterials, healthcare and hygiene products, infection control and barrier materials, bandaging and pressure garments, wound-care materials, implantable and medical devices and smart technologies (Anand et al., 2005). The products of these medical textiles and biomaterials include, i) health care and hygiene products in hospitals made of cotton and polyester (surgical clothing, uniforms, bedding blankets, pillow cases), ii) bandage and wound dressing materials made of cotton (Wound care absorbent pad, bandages simple inelastic, Gauze), polyamide (plasters, wound care absorbent pad), viscose (gauze), polypropylene (plasters) iii) implantable textiles made of polyester (cardiovascular implants), polyamide (artificial ligaments and soft-tissues), silk suture materials (Rigby et al., 1997) iv) implantable materials (Geetha et al., 2010) made of silicone (urinary catheters, CSF catheters, ureteral stents and tracheal stents) PTFE (cardiovascular prosthesis) polyurethane (intravascular catheters)

Biomedical products in hospital are highly associated with patients and healthcare workers in their daily routine work. A major concern for healthcare workers is the problem of transmission of pathogens from these biomedical products. This includes penetration of biological liquids and associated bacteria into the hospital fabric materials. Harmful pathogens in these fluids can reach and penetrate the skin of surgeons and/or patients, with an associated potential for
fabrication of coatings that prevent microbial adhesion: antimicrobial effect of biomedical products

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Infection (Altman et al., 1991). Secondly, bandage and wound dressing materials carrying both aerobic and facultative anaerobic bacteria may also be disseminated among the patients and workers. Thirdly, biomedical textile implants like cardiovascular grafts, artificial ligaments, suture materials and biomedical implantable devices like ureteral stents, urinary catheters, CSF shunts and dental implants often undergo microbial colonization (Zahedi et al., 2009).

1.1 Biomedical product associated infections

About half of the 2 million cases of nosocomial infection that occur each year are associated with indwelling devices (Darouiche, 2001). Activities within the hospitals often make contaminated textile materials a source for further microbial contamination. Hospital Acquired infections (HAIs) or Health-care Associated Infections have become a major concern because of the risk they present to patients and their relatives. It is estimated that around nine percent of patients have acquired an HAI during a hospital stay. The effect of HAI ranges from an extended length of stay, discomfort, permanent disability and death (Xiao-dong and Russell, 2009).

1.2. Surface colonization of microbes on biomedical products

Implantable materials

The essential factor in the evolution and persistence of infection is the formation of biofilm around implanted devices (Costerton et al., 1999). Soon after insertion, a conditioning layer composed of host-derived adhesins (including fibrinogen, fibronectin, and collagen) forms on the surface of the implant and invites the adherence of free-floating (planktonic) organisms. Bacterial cell division, recruitment of additional planktonic organisms, and secretion of bacterial products (such as the glycocalyx) follow. A three-dimensional structure of biofilm finally evolves that contains complex communities of tightly attached (sessile) bacteria (Costerton et al., 2003).

Non-implantable materials

In hospitals numerous solid surfaces are likely to be contaminated with microbes including the textile materials in staff uniforms, patient gowns, drapes,
curtains, bed sheets, pillow cases and pillows. Due to the suitability of temperature and humidity in the environment exposure to microbial contamination further increases the probability of pathogen acquisition. This is a state in which microbes such as viruses or bacteria invade body tissues and increase the risk of disease (Xiao-dong and Russell, 2009).

1.3. Clinical management and treatment of device-related infections

Treatment of these infections is associated with high complication rates and places an enormous burden on both the patient and healthcare workers. In most cases, the objective can be achieved with both antibiotic therapy and surgical intervention. About two thirds of infections are caused by either *Staphylococcus aureus* or coagulase-negative Staphylococci. Methicillin-resistant Staphylococci are variably susceptible to older antibiotics (doxycycline, trimethoprim–sulfamethoxazole, quinolones, and clindamycin) (Darouiche, 2004). Administration of prophylactic antibiotic therapy to prevent colonization is also common practice during surgical insertion of most biomaterials. However, antimicrobials administered systemically or orally often fail to reach the site of infection, again decreasing the success of antimicrobial chemotherapy (O’Gara and Humphreys 2001).

1.4. Antimicrobial resistance

Treatment of device-related infections is very difficult because of the increasing resistance to antibacterial agents. The development of antibiotic-resistant bacteria has increased at a frightening rate since the introduction of antibiotics in the 1940s. The emergence of resistance among nosocomial pathogens can also be attributed to the increasing number of immune-compromised patients and disease-control practices within the hospital environment (Cosgrove and Carmeli 2003).

1.5. Accepted clinical therapy

Accepted clinical practice often includes combination therapy in which two or more antimicrobials are used to treat biofilm-associated infections (Saginur *et al.*, 2006). This approach comes from standard clinical practice, such
that a broader spectrum of activity is achieved and lower concentrations of the antimicrobial are required, resulting in more effective therapy and decreased resistance (Gorman and Jones 2002).

1.6. Methods to prevent biomedical product associated infections

At present, conventional systemic therapies, using standard antimicrobial agents, represent the main strategy for the treatment and prevention of medical device associated infection. However, as detailed above, the available antibiotic therapies are usually ineffective because of the phenomenon of multidrug resistance and the resilient nature of adherent biofilm bacteria. As a result, effective eradication of the infection often necessitates the removal of the implant and its substitution. These limitations of conventional chemotherapy in the treatment of medical device-related infections have prompted the development of novel approaches, complementary to traditional bactericidal or bacteriostatic mechanisms. These approaches, detailed below, focus on the development of bioactive, anti-infective or antimicrobial devices, which inhibit bacterial adherence or growth by the presence or elution of antimicrobial agents (McCann et al., 2008).

1.7. Antimicrobial biomaterials

In an effort to combat biofilm-associated infections on the surfaces of implantable and non-implantable medical devices, many research groups and manufacturers have explored surface modification technologies to overcome bacterial colonization and infection. Various methods have been employed to modify polymer surfaces and load antimicrobial agents into medical products, with the ultimate aim to produce bacteria-inhibitory and bactericidal surfaces. A bacteria-inhibitory surface discourages or prevents both bacterial colonization and proliferation, whereby a bactericidal surface elutes bactericides using controlled drug-release mechanisms. These surfaces are relatively low cost, have long shelf-lives, are easily sterilized and do not affect the overall function of a device (Lin et al., 2001). Examples include immersion, coating, matrix loading and drug–polymer conjugates.
On non-implantable materials (textile materials of staff uniforms, patient gowns and wound dressings) different antimicrobial agents (silver, copper, zinc, antibiotics and disinfectants) were treated to retard the transmission of hospital acquired infections (Xiao- dong and Russell, 2009). Antimicrobial textile finishes were used to avoid the microbial degradation of textile fibres (avoids biofouling of outdoor textiles), limit the incidence of bacteria, reduce the formation of odor following the microbial degradation of perspiration, and protect users by avoiding the transfer and spread of pathogens (Mucha et al., 2002).

1.8. Problems associated with antimicrobial biomaterials

The problem with straightforward antimicrobial loading into an implantable medical device by coating or immersion is the generation of resistance. As release of standard antibacterial agents from the surface of the medical device is not coordinated with exposure to bacteria, leaching of sub-inhibitory levels of the antimicrobial results, which is generally insufficient to prevent infection but increases the risk for selecting antimicrobial resistant strains (McCann et al., 2008). The increased use of non-implantable antimicrobial textiles has raised concerns about resistance and other issues. N-halamine treatment results in a substantial amount of adsorbed chlorine (or other halogens) remaining on the surface of the fabric in addition to the covalently bonded N-halamines. Such residual adsorbed halogen (e.g. chlorine) produces an unpleasant odour and discolours fabrics, which has proven problematic for such a promising antimicrobial system in the textile industry. Antimicrobial textiles finished with disinfectants like quaternary ammonium compounds (QACs) and polyhexamethylene biguanides (PHMB) leads to bacterial resistance. Bacterial resistance to triclosan has been well documented and is of great concern (Russell, 2004). Furthermore, when exposed to sunlight in the environment, triclosan breaks down into 2, 8-dichlorodibenzo-p-dioxin which is chemically related other toxic polychlorinated dioxins (Larsen, 2006). The risks of localized argyria and cytotoxicity to keratinocytes and fibroblasts have also been cited (Chen and Schluesener, 2008). Dev et al., (2009) reported that traces of silver have
been found in the blood and urine of the patient who was treated with a dressing containing nano-crystalline silver.

1.9. Reason for the present study

Even though all type of antimicrobial agents used for coating the devices were proved to be more effective in antibacterial activity, still due to above mentioned factors they are not considered as biocompatible. Hence, these problems led to study the effects of introducing antimicrobial substances at the surface level of biomedical devices and products based on the factor described by Saginur et al., (2006). They reported that the accepted clinical practice to treat biofilm-associated infections was the use of combination therapy in which two or more antimicrobials are blended at different combinations. This approach comes from standard clinical practice, such that a broader spectrum of activity is achieved and lower concentrations of the antimicrobial are required, resulting in more effective therapy and decreased resistance (Gorman and Jones, 2002). Similarly, Boeckh et al., (1990) suggested, expansion of the antibacterial spectrum by combining quinolones with other antibacterial agents for preventing biofilm formation.

Therefore for the first time, in the present research, different combinations of antibacterial compounds showing synergism to fabricate the implantable and non-implantable materials by surface coating were studied. To determine the sustained release of drugs from the fabricated materials (Matl et al., 2008) and to enhance antibacterial activity (Gollwitzer et al., 2003); appropriate drug-carriers (beta-cyclodextrin, DL-Lactic acid and tocopherol acetate) were blended with antibacterial agents. Among the drug combinations, one is a fluoroquinolone compound and the other is nitroimidazole compound which has good antimicrobial activity against aerobic and facultative anaerobic microorganisms. The combination therapy of these two groups of drugs managed to accept the factors determined by Boeckh et al., (1990), Gorman and Jones (2002) and Saginur et al., (2006). The character of synergism mainly depends on the mode of action of a drug. Both of these compounds act on the DNA of bacteria, targeting
the inhibition of DNA synthesis and replication. Since the mode of action of fluoroquinolone and Nitroimidazole are same these two drugs proves the synergism. One major application of antimicrobial finish in medical products is to help maintain sterile environments. Antimicrobial treatment for biomedical products are necessary to avoid cross infection by pathogenic microorganisms; to control the infestation by microbes; to arrest metabolism in microbes in order to reduce the formation of odour; to safeguard the product from staining, discoloration and quality and over all to increase the standard of hygiene in hospitals and healthcare centers.

1.10. OBJECTIVES

Taking into consideration of the above facts, the present research work was designed with the objective of developing a process for rendering antimicrobial treatment to the biomedical products. Also, the study aims to determine the effect of the cross-linking of antimicrobial agent to the product substrate on the antimicrobial efficacy, durability, persistence and comfort properties. The objectives are as follows

1. To investigate the surface colonizing ability of challenge bacteria on biomedical materials using exit-challenge test
2. To assess the synergistic effect of the fluoroquinolone and nitroimidazole drugs on the DNA of challenge bacteria
3. To evaluate the persistence of antibacterial activity during the drug releasing condition from the drug and carrier coated biomedical products
4. To characterize the drug and carrier coated biomedical materials using FTIR, SEM and tissue reactions
5. To compare, validate and evaluate the durability of the reactive drug treated textiles and microencapsulated textiles using the standard (AATCC-100 and AATCC-124) methods
6. To explore the differences among the treated and untreated biomedical textile materials based on their physical parameters