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Review article

A review of problems of bacterial biofilm on contact lenses

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ABSTRACT

Contact lenses are a widely used and effective means of vision correction, offering relief to around the world use contact lenses. But these lenses can sometimes get colonized by microorganisms, which might lead to infections and inflammation on the eye's surface. A major concern in this context is the formation of bacterial biofilms on contact lenses, which can cause significant complications, including ocular discomfort and more serious eye conditions. This study aims to discuss how bacterial biofilms can cause eye infections related to contact lenses. Without proper treatment, these infections can lead to vision loss or, in severe cases, loss of the eye. In conclusion, biofilms are a key factor contributing to contact lens-related ocular infections and inflammation.

Keywords: Contact lenses, Keratitis, Microbial Biofilm, Ocular infections.

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1. INTRODUCTION

Biofilms matrix are complex communities of microorganisms able of colonizing into the materials of extracellular that produced by the bacteria themselves. They are ubiquitous in both natural and artificial environments, exhibiting a range of positive and negative effects [1]. Bacterial biofilm-associated infections pose significant challenges to treatment and are known as one of the main factors of stay for long repeat the infections. These biofilms often exhibit increased resistance to conventional antibiotics and can lead to tissue-associated and device-related infections, contributing to a growing global public health threat. Given these concerns, the rapid detection of biofilm-associated infections and development of novel, alternative therapeutic plans are essential for effective management and bacterial treatment [2]. Biofilms are frequently implicated in nosocomial and chronic infections. The only use antibiotics is typically fruitless in curing infections, as bacteria within biofilms have a tendency to develop high levels of antibiotic resistance [3]. Microorganisms have the ability to adhere to medical devices, leading to biofilm-associated infections that often arise during treatment. The likelihood and severity of these infections depend largely on the duration the device remains within the patient's body. Once unbinding such as planktonic bacteria attach to the surface of a medical tools, the bacteria begin form polymers which attribute a three-dimensional extracellular matrix, allowing them to irreversibly adhere and establish a biofilm structure. When biofilm reaches a critical mass on the surface of an implanted device, it trigger a host inflame-matory response, potentially resulting in implant failure [4, 2]. Multispecies biofilms exhibit characteristics that differ significantly from those of planktonic bacterial states. These features result from interspecies interactions whether cooperative or competitive and may include increased community cell density, enhanced biofilm biomass, elevated metabolic activity, greater tolerance to

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antimicrobial agents, and notable changes in spatial organization and structure [5]. The interactions within these biofilms may involve cooperation, synergy, antagonism, mutualism, competition, and resource sharing among different microbial species [6].

The development of a biofilm typically begins with bacterial adhesion to a surface, a process influenced by the presence of cations. This is followed by irreversible attachment, microcolony formation, maturation of the biofilm, and eventual dispersal of cells as planktonic bacteria [7, 8, 9]. The stages of biofilm formation are illustrated in Figure 1 (adapted from publicly available online images).

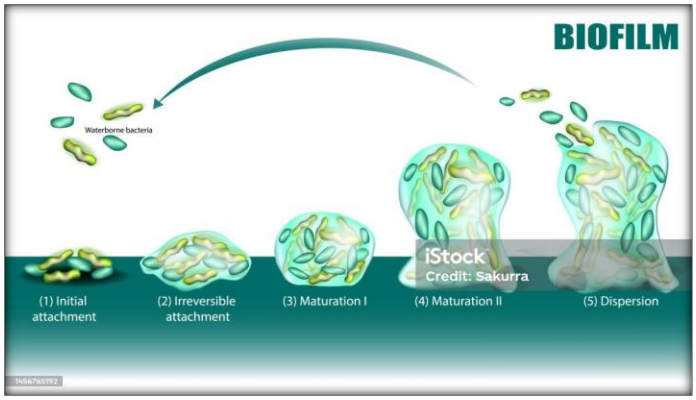

Fig 1. Stages of Biofilm formation include initial and irreversible attachment, maturation and dispersion, and finally, adhesion of newborne bacteria on surface [10].

Bacterial cells have the capacity to form biofilms in approximately 40–80% of infections [11]. Biofilm formation is typically preceded by bacterial aggregation [12] that plays a serious role in the development of infections associated with medical devices such as peritoneal dialysis catheters, urinary catheters, orthopedic implants, endocarditis, and dental biofilms. Biofilm-related infections are not always surface-associated; they can also occur in chronic infections, for example those found in cystic fibrosis, and have been observed in environmental systems, including marine and freshwater ecosystems and water treatment facilities [13,14,15].

Quorum sensing (QS) is a communication of bacterial mechanism, which regulates population-wide behaviors, including biofilm formation and virulence. QS) involves the production, detection, and response to extracellular signaling molecules known as autoinducers (AIs), which accumulate in response to increasing bacterial density and trigger gene expression once a threshold concentration is reached. Quorum sensing is typically mediated by acyl-homoserine lactones (AHLs) in bacteria of Gram negative, while autoinducing peptides (AIPs) serve a similar function in Gram-positive bacteria [16]. Through QS, bacteria coordinate biofilm development and the expression of virulence factors [17]. Therefore, disrupting QS using quorum sensing inhibitors (QSIs) presents a promising strategy for combating biofilm-related infections [18]. The mature biofilm consists of different layers, the outer layer of biofilm is a connective layer, a regulatory layer, and an internal layer [19]. Biofilm-associated infections are typically chronic and exhibit high levels of resistance to antibiotic treatment. This resistance is because of several intrinsic factors, including the presence of an extracellular matrix that impedes antibiotic penetration, reduced bacterial growth rates, modification of antibiotic targets, and enhanced horizontal gene transfer of resistance genes [20].

One of the major clinical challenges posed by bacterial biofilms is their formation on contact lenses. If not identified and treated promptly, such infections can lead to severe consequences, including vision loss or even loss of the eye [21].

2. CONTACT LENS-RELATED OCULAR INFECTIONS

Ocular infections are unfortunately associated with contact lens (CL) wear [22]. Serious threats to eye health can arise during CL use due to bacterial adhesion and subsequent biofilm production on the lens surface. These biofilms can develop into mature structures that are closely linked to keratitis. Common pathogens responsible for CL-related eye infections include *Staphylococcus aureus* (particularly methicillin-resistant *S. aureus*, MRSA), multidrug-resistant pathogenic bacteria and yeast is one of the examples [23].

Globally, over 230 million people use contact lenses either for vision correction or cosmetic purposes to alter eye appearance [24]. The epithelial cells of corneal and stromal cells normally produce different innate defense factors, i.e. antimicrobial peptides, cytokines, chemokines, surfactants, and structural proteins, which contribute to maintaining corneal health and transparency [25]. However, when contact lenses are inserted into the eye, tear film components—such as glycoproteins, lipids, and proteins—rapidly accumulate on the lens surface, creating a favorable environment for microbial colonization.

Upon contact with planktonic bacteria cells, the CL surface facilitates the formation of microcolonies, which can lead to keratitis in both humans and animals [26]. Keratitis, an inflammation of the cornea, can result in structural damage and reduced transparency of the corneal tissue. A wide variety of microorganisms can cause this condition, with *P. aeruginosa* and *S. aureus* being the most common bacterial culprits [27]. Although less frequently encountered, fungal pathogens such as *Fusarium* species and *C. albicans* are also clinically significant. Additionally, a sporadic but violent form of infectious keratitis may be caused by protozoan *Acanthamoeba*. Despite being a relatively rare complication of contact lens wear, microbes that infect keratitis remains a leading cause of vision loss and, in severe cases, blindness [28]. Figure 2 illustrates various bacterial and fungal biofilms that can form on contact lenses (adapted from publicly available online images).

On the other hand, biofilms can be associated with eye infections. They can mostly associate with different infections of ocular other than keratitis like blepharitis, cellulitis, conjunctivitis, dacryocystitis manifestations and endophthalmitis [29]. The conjunctiva and cornea are known as environments that are sterile due to their constantly washing by tears. Despite novel research reported the existence of ocular surface diverse microbiome that are rarely abundant when related to other parts of the body. The ocular microbiome plays a crucial part in ocular health maintenance as they compete with prospective pathogens for nutrients and space, helping to produce antimicrobial peptides in addition to modulation of immune responses [30,31,32,33]. Two types of CL are found: rigid type which consist of fluorosilicone acrylates or silicone acrylates, and soft type that are manufactured from hydrogel or silicone hydrogel. Generally, soft type has the major infection risk in comparison with rigid lenses. This can be attributable to the more porous surface of soft lenses and have more bacterial susceptibility when compared to rigid lenses [34].

Many factors that can develop infections that are associated with contact lens using include contact lenses that are disinfected by heat or chlorine, infrequent or no disinfection of lenses and poor compliance with hygiene instructions are considered, using of a solution of multipurpose kind that contains polyhexamethylene big-

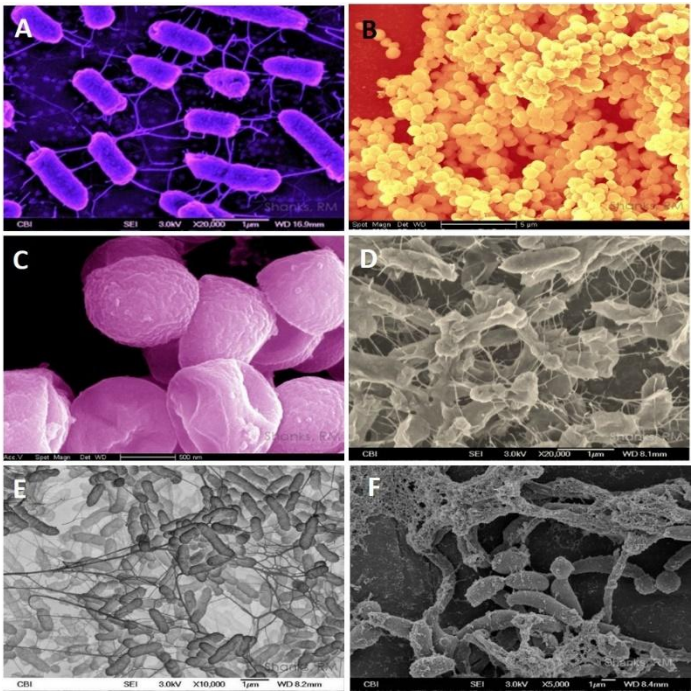

Fig 2. Illustrates different bacterial and fungal biofilms formed on contact lenses. A, *Serratia marcescens* on CL surface under scanning electron microscope (with false coloring). B, *Staphylococcus aureus* biofilm under scanning electron microscope (with false coloring). C, *taphylococcus aureus* biofilm under scanning electron microscope (with false coloring). D, *Pseudomonas aeruginosa* biofilm under scanning electron microscope (with false coloring). E, *Serratia marcescens* biofilm under scanning electron microscope (inverted image). F, Fungal biofilm on bandage contact lens under scanning electron microscope

uanidine to sterilize contact lenses and which is marketed in order to be used without the need to rub contact lenses with the solution [35], poor lens case cleanliness and no replacement of lens cases at least every 3 months [36]. All these factors are in relation to keratitis development by the lenses daily wearing. It was found that 61% of the contact lenses wearers demonstrated insufficient cleaning was found of lens storage cases, additionally, insufficient cleaning of lenses was found in 13% of wearers [37]. Keratitis reduction was reached to 49% for lenses that were exposed to simple air drying, and risk reduced to 27% by lens cases replacement minimally each three months. This can result in 62% keratitis reduction [38]. Some manufacturers of the disinfectant made replacement for their instructions to become more consistent and obvious after a variety of researches highlighted the side effect of inappropriately clean and non-replacement of lenses. Coating of CL by antimicrobial agents is one of the techniques that can manage and prevent biofilms which can offer a proactive shield where safety and comfortable CL wearing may be enhanced. Melamine is known to be added to lenses of silicone hydrogel covalently, which is considered as a brand-new cationic peptide, and it was tested to confirm its antimicrobial activity [39]. These antimicrobial drugs impede or cease microbial growth when integrated with various biomaterial types, silver had revealed a potency to act as an antibacterial agent. Adhesion reduction by at least 90% of *P. aeruginosa* perhaps occurred via coating an endotracheal tube with silver [40,41]. Disinfection of CL in consideration of ISO standards is crucial to initiate strategies that are safer and more effective to control microbial biofilms. CL infections reduction can be achieved by wiping these lenses with a clean tissue [42]. Moreover, factors which determine the nanostructured antibacterial capacity and bactericidal efficiency of a contact surface still remain ambiguous [43].

3. CONCLUSION

Biofilms play a significant role in contact lens-related ocular infections and inflammation. The use of contact lenses coated with antimicrobial agents help in reducing the rate of bacterial contamination and related ocular complications. Additionally, proper hygiene practices such as using clean tissues to dry lens cases or utilizing lens coating with silver-nanoparticle in combination with appropriate disinfectants may effectively decrease the microbial load in biofilms associated with contact lens storage.

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Conflict of interest

The authors declare that they have no conflict of interest.

Ethical Approval

This review was approved by the Scientific Committee of the Baghdad University, Baghdad, Iraq (in 14/1/2025).

Author contributions

NNY: Investigation; collecting the data; Project administration; Resources; Supervision; Validation; Writing -original draft, Conceptualization, and Writing the review and editing, and revising the manuscript. SSM: Searching of suitable journals and MKM: Writing -original draft, revising the manuscript.

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