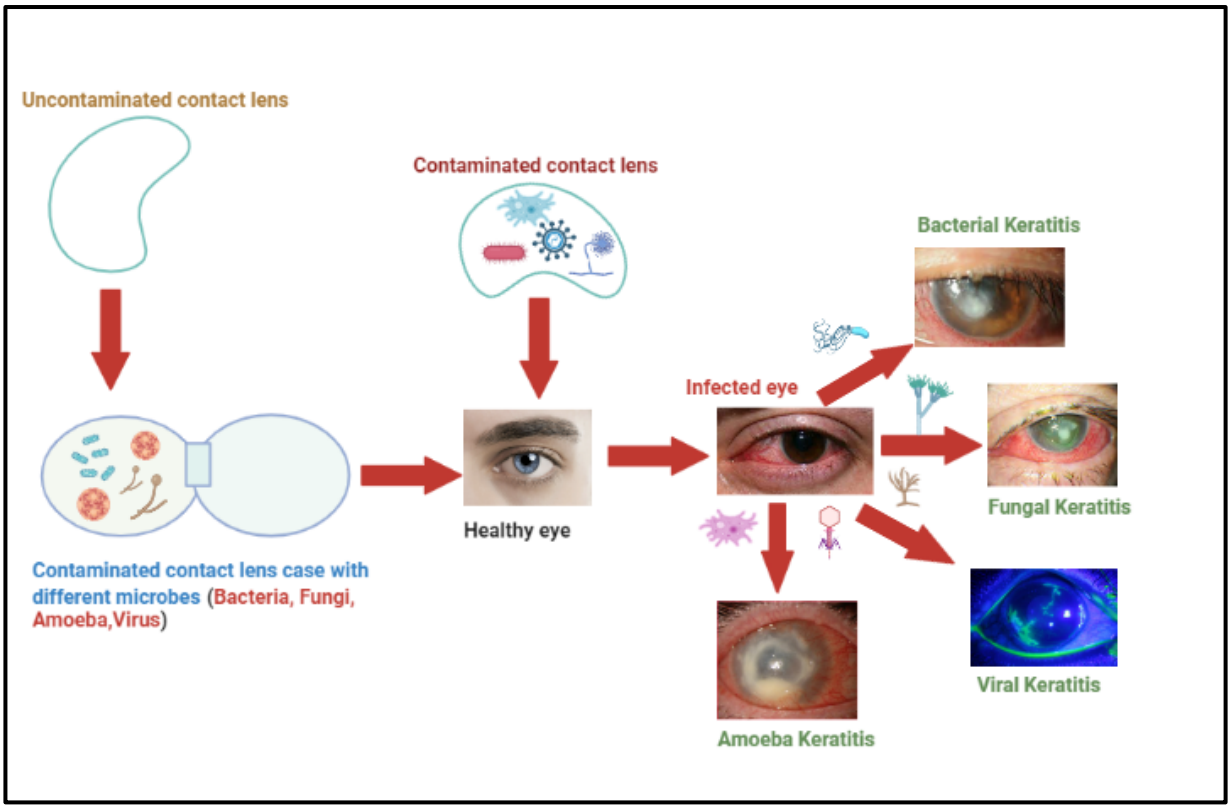
Microbial problems with contact lens and how to avoid them

Mum: one of my eyes is itchy and red!



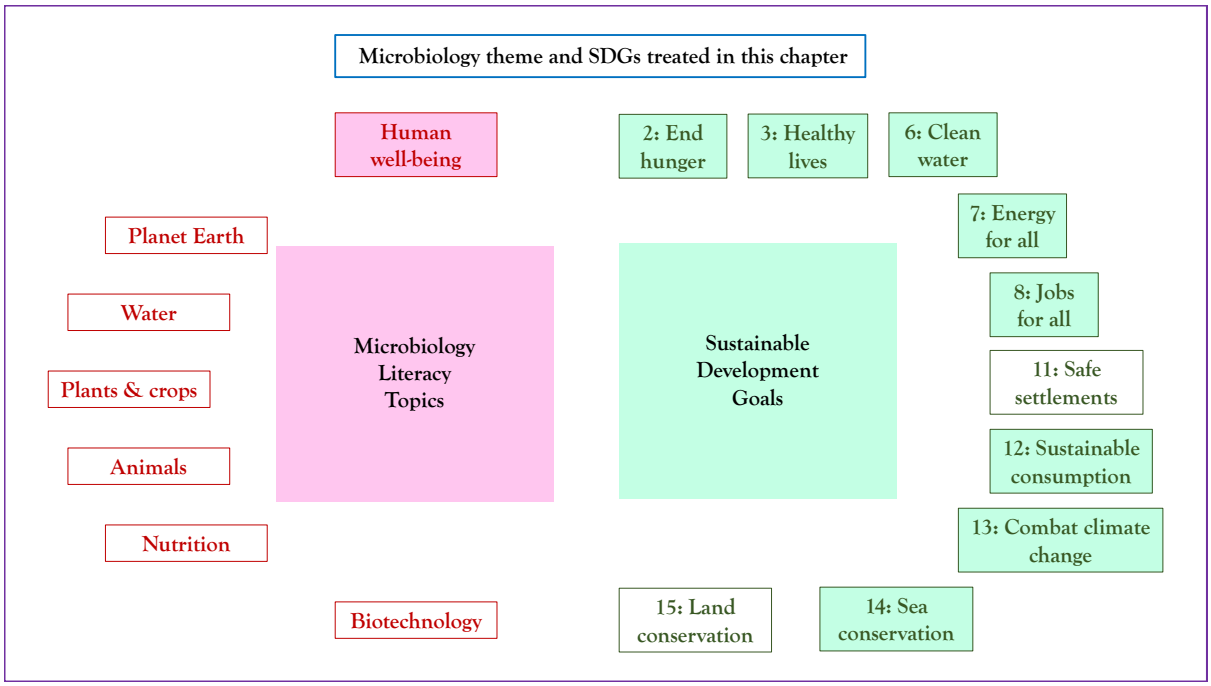
Anjali Saxena*[1], Ankita Dua*[2] and Pushp Lata[3]

[1]Bhaskaracharya College of Applied Sciences, University of Delhi, [2]Shivaji College, University of Delhi, [3]Department of Zoology, University of Delhi, India. **Authors contributed equally*

Microbial problems with contact lens and how to avoid them

Storyline

Ownership and use of contact lenses is often viewed as an essential part of modern life, providing millions of people with freedom from spectacles, improved appearance, and enhanced participation in sport, work, and social activities. For many wearers, contact lenses contribute significantly to confidence, convenience, and quality of life. Advances in lens materials and cleaning technologies have enabled extended wear, improved comfort, and correction of increasingly complex visual problems. However, contact lenses also create a unique microbial environment on the surface of the eye. Microorganisms from the skin, fingers, eyelids, storage cases, water, and the surrounding environment can colonize lenses and lens cases, forming biofilms and occasionally causing serious eye infections such as microbial keratitis. Poor hygiene practices, overnight wear, and inappropriate exposure to water substantially increase these risks. The manufacture, packaging, and disposal of contact lenses and their associated cleaning solutions additionally contribute to plastic waste, chemical pollution, energy consumption, and environmental contamination, including the release of microplastics into aquatic ecosystems. Increasing adoption of reusable lenses, improved hygiene education, biodegradable materials, and sustainable packaging may help reduce these impacts. The use of contact lenses therefore intersects with multiple Sustainable Development Goals.



The Microbiology and Societal Context: The microbiology: the ocular microbiome; microbial colonization of lenses and storage cases; biofilm formation; antimicrobial resistance; microbial keratitis and other eye infections; hygiene and disinfection practices; waterborne microorganisms such as *Acanthamoeba*; lens material science and antimicrobial coatings; wastewater contamination and microplastics from discarded lenses; biodegradation of polymers; sustainable biomaterials and packaging.

Contact lenses: the Microbiology

1. ***Introduction - Commensals of the occular surface.*** Microbiomes are communities of creatures that live on and inside the human body, including bacteria, fungi and viruses. Some components of the microbiome are dangerous and can cause disease, while many are necessary for overall health. The immune system may be activated by the microbiome to help eliminate harmful microorganisms and prevent illness. In addition to the well-known gut microbiome, the lips, skin, and eyes all have their own microbiomes,. The ocular microbiome is a relatively new and emerging field of study that might lead to new treatments and preventative strategies for certain eye diseases and disorders.

2. ***Occular Microbiome.*** The conjunctiva which is transparent tissue covering the white area of the eye, and the cornea are home to the eye's microbiota (community of microorganisms). The periocular skin microbiome includes the microbes present on the eyelids and eyelashes. Earlier studies showed that the core ocular surface microbiome in most humans consists primarily of only four species: *Staphylococcus, Streptococcus*, *Propionibacterium* and *Corynebacterium*. Until recently, it was thought that this bacterial population was very limited. While traditional culture methods identified a "core" microbiome made up of diverse *Staphylococci* species., *Propionibacterium* and diptheroids; however, advanced deep- sequencing investigations revealed a much more intricate picture. Recent research has revealed that conjunctival swabs may detect more than 500 different bacterial genera. In addition to bacteria, viruses such as the Torque teno virus (TTV) are commonly found on the healthy ocular surface. The TTV virus has been detected in many cases of endophthalmitis, although the mechanism by which it enters the eye and causes this disease remains unclear. . Merkel Cell Polyomavirus (MCP) and Human Papillomavirus (HPV) are two additional viruses found in healthy ocular microbiome. Although, these viruses, are generally considered potentially harmful, they may act as protectors in the ocular microbiome, by stimulating immune responses against other pathogens. (https://www.aao.org/eye-health/anatomy/microbiome-of-eye)

Recent advanced PCR-based investigations have identified microbial DNA “signatures” in diverse ethnic and regional populations, as well as among contact lens wearers. Several studies have demonstrated that resident commensal microorganisms on the ocular surface play an important role in maintaining ocular immune homeostasis and host defence. *Corynebacterium mastitidis*, a potential commensal organism, has been shown to evoke a commensal-specific interleukin-17 (IL-17) response from T cells in the ocular mucosa, which is important for local immunity. This commensal-specific immune response promotes neutrophil recruitment and antimicrobial peptide release in tears, thereby protecting the eye against pathogenic infections caused by *Candida albicans* and *Pseudomonas aeruginosa* (Leger AJ et al., 2017).

Contact Lens – Bioburden

A contact lens (CL) can act as a vector for microorganisms to adhere to and transfer to the ocular surface. The bioburden of contact lenses refers to the number of microorganisms present on the surface of the lenses. This can include bacteria, viruses, fungi, and other types of microorganisms. The bioburden is influenced by several factors, such as the quality of lens care products and the hygiene practices of the wearer.

Microbial corneal infection is the most serious complication of contact lens wear. Contact lens cases are a recognised as a potential source of pathogens associated with corneal ulcers. Lenses can be classified as either 'hard' or 'soft', the former category are rigid, durable and gas permeable, whereas the latter are flexible with high water content (Musgrave *et al.* 2019). The global market involved in manufacture and sale of different kinds of contact lenses caters to several parameters such as comfort, wear time, cleaning, cost of product etc. Modern CL materials have evolved from the well-known lens materials based on hydroxy ethyl methacrylate (HEMA) and silicone hydrogels. These hydrogels are grafted or incorporated various bioavailable components, such as polyvinyl alcohol hydrogels (PAH), hyaluronic acid (HA), chitosan, β-cyclodextrin, Cellulose, and other moieties.

Lack of inadequate hand washing is a major risk factor in the development of the contact lens-related microbial keratitis and hence leads to corneal inflammatory events. It is well known that pathogenic microbial contamination of contact lens, lens cases, care solution and anterior ocular components have been frequently found. The total bioburden, determined as colony- forming units per millilitre (CFU/ml) of all isolated bacteria, in a lens care system could be used as a key indicator of lens care quality (Kuo *et al.*, 2015).

Culture-based assessment of bioburden is a time-consuming process. To overcome this limitation, methods with high sensitivity and specificity, such as hybridization-based models, are increasingly used to assess bioburden (Lo et al., 2015).

Route of infection: Despite the benefits of contact lenses, they are also associated with several ocular infections. Keratitis is the most common eye infection related to contact lens wear, in which cornea becomes infected. Some contact lens- related eye infections can cause serious vision loss or even blindness.

Symptoms of contact lens related infections include.

- Blurry vision
- Unusual redness of eye
- Eye pain
- Tearing or discharge from the eye
- Increase sensitivity to light
- Feeling like there is something in the eye
- Conjunctival chemosis
- Corneal oedema

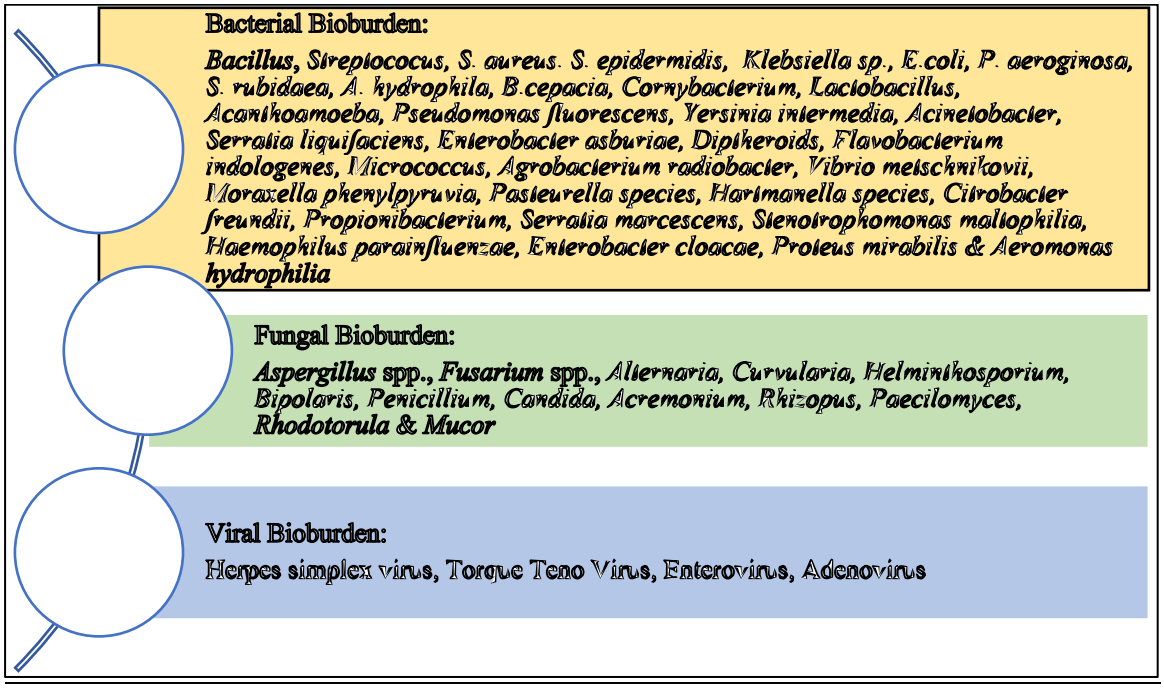
Types of Bioburden:

Bioburden is generally defined as the number of microorganisms living on a surface that has not been sterilized. Substantial bioburden is considered present when a lens, lid, or conjunctiva harbours pathogenic organisms or high levels of commensal organisms. The main problem in contact lens wear is the presence of bacteria and other microorganisms, because some contact lens wearers have developed microbial keratitis (Devonshire *et al.*, 1993).

Bacterial Bioburden

The normal microbiota of the eyelids and conjunctivae consists principally of aerobic bacteria. In 1935, Khorazo *et al.*, found that *Staphylococci* and diphtheroids (*Corynebacterium* sp.) are the

most frequent bacterial inhabitants of the normal conjunctiva. They also showed that the incidence of diphtheroid organisms increased markedly with advancing age, with the increase being most pronounced from 30 to 50 years. *Staphylococcus epidermidis*, *Staphylococcus aureus*, *Escherichia coli* and *Klebsiella* spp. were the most common microorganisms found in this study. It is important to note that the specific types of bacteria present in contact lens bioburden can vary depending on a variety of factors, such as the individual's hygiene practices, lens care products used, and environmental factors. Regular monitoring and appropriate interventions can help reduce the risk of infection.



Summary of Microbial bioburden of ocular surfaces category wise.

Protozoan Bioburden

Protozoan bioburden on contact lenses is less common than bacterial bioburden, but it is still a potential risk factor for contact lens-related infections. A few protozoan species have been identified in contact lens bioburden studies, including

Acanthoamoeba

Amoebae of the *Acanthamoeba* genus are broadly distributed in nature, living either freely or as parasites and are frequently associated with biofilms throughout the environment. These biofilms provide the parasite with protection against external aggression, thus favouring its increased pathogeny (Optom, 2011). Acanthamoebae thrives well in water supply systems and proliferates on the inside surfaces of pipes. They are also found in moist soil and mud. They may be resistant to dry environments, chlorine and many contact lenses cleansing antiseptics. They are capable of feeding on living tissues. If present in human corneal tissue, they can cause disease, which has been related to CL wear. Therefore, CL wearers using tap water to clean their contact lenses instead of the prescribed solutions, might face the risk of being infected by these parasites, which could cause resistant eye infections and endanger the cornea. Thus, continuous

monitoring of these emerging pathogens is important as they could cause serious eye infections (Klotz *et al.*, 2000).

Hartmannella: This is another type of free-living amoeba that is found in soil and water, including tap water and cooling towers. While less is known about the role of *Hartmannella* in contact lens-related infections, it has been identified in some studies of contact lens bioburden (Pinna *et al*, 2017).

Naegleria: This is another type of free-living amoeba found in warm fresh water, including lakes and rivers. It can cause a rare but deadly brain infection called primary amoebic meningoencephalitis (PAM) when water containing the amoeba enters the body through the nose. While *Naegleria* has not been commonly identified in contact lens bioburden studies, there have been a few reports of *Naegleria* keratitis associated with contact lens wear (Pinna *et al*, 2017).

It is important for contact lens wearers to follow proper hygiene and care practices to reduce the risk of contact lens-related infections, including those caused by protozoan bioburden. Proper disinfection of contact lenses and avoiding exposure to water while wearing contact lenses are important steps in preventing infection.

Fungal Bioburden

Fungal bioburden on contact lenses is less common than bacterial or protozoan bioburden, but it is still a potential risk factor for contact lens-related infections. Fungal infections of the cornea are known as fungal keratitis, and can be caused by a variety of fungal species.

Martins *et al.*, 2002 observed the presence of fungi, parasites, and bacteria in contact lens swabs cultures. It has been reported that the environment, the type of contact lens, the duration of wear and the type of CL cleansing solution determined the microbial load on the contact lenses (Raj *et al.* 2021).

Viral Bioburden

Viruses are not typically considered a major component of contact lens bioburden, as they require a host cell to replicate and are typically not found living independently in the environment. However, viruses can be present on contact lenses if the lenses come into contact with infected bodily fluids, such as tears or mucus.

Herpes simplex virus (HSV): This is a virus that causes cold sores and genital herpes, and can also cause eye infections. HSV can be spread to the eyes through contact with infected saliva, genital secretions, or other bodily fluids. Herpes simplex keratitis (HSK) results from infection with the herpes simplex virus type 1 (HSV-1) also known as human herpesvirus type 1 (HHV-1) (Kaye *et al.*, 2006). The infection usually heals without damaging the eye, but more severe infections can lead to scarring of the cornea or blindness. HSK is a major cause of blindness worldwide (Liesegang *et al.*, 2001) HSV-1, which is the type of HSV that also causes cold sores on the mouth, is the most common cause of corneal infections.

Adenovirus: This is a common virus that can cause respiratory infections, conjunctivitis (pink eye) and other illnesses. Adenoviral conjunctivitis can be spread through contact with contaminated surfaces, including contact lenses.

Enteroviruses: This is a group of viruses that can cause a variety of illnesses, including respiratory infections, meningitis, and conjunctivitis. Enteroviruses can be spread through contact with contaminated surfaces, including contact lenses**.**

Torque Teno Virus: Deep DNA sequencing has also shown the presence of Torque Teno virus (Gallon *et al.*, 2019).

Microbial Problems with Contact Lenses & How to avoid them

Since the ocular surface is continuously exposed to the environment, it already harbors a microbial population. This normal microbiota is usually non-pathogenic and aerobic and is removed by the ocular defense mechanisms. The use of contact lens has become extremely important optical resource, as they outweigh the number of advantages offered by regular spectacles by easy optical corrections and refractive errors. Daily wear lenses are also gaining popularity with single-day-use lens, as they are cleaner, more convenient and prevent pollen build-up especially hypersensitive users. Overnight wearing of lens is strongly discouraged as it increases the risk of eye problems and is considered unsafe.

Lens wear & Care Habits

Bacterial keratitis is a major issue faced by contact lens wearers, and is caused by bacterial contamination of the cornea. Species of *Pseudomonas aeruginosa* and *Staphylococcus aureus* are commonly associated with this problem. Though keratitis is non-communicable, people at risk of developing the problem often wear the contact lens overnight or for extended periods of time, do not adhere to the practices of disinfecting the lens well, use contaminated lens solution or sharing these lenses for cosmetic purposes. The lens material acts as a vector, transferring these bacterial inhabitants to the ocular surface that is extremely sensitive to their presence [Loretta B *et al.* 2010]. Two main types of materials are currently used to manufacture contact lens: hydrogel (made of gel-like water containing plastics) and silicone hydrogel (more porous and allowing extra oxygen contact with the corneal surface). A major source of contact lens contamination is improper handling.

Bacterial colonies are responsible for hydrogel lens induced inflammation and can lead to conditions such as contact lens acute red eye (CLARE), contact lens peripheral ulcer (CLPU) and infiltrative keratitis. Species associated with CLARE are *Haemophilus influenzae*, *Acinetobacter* sp., *Pseudomonas aeruginosa*, *Aeromonas hydrophila*, *Serratia liquefaciens*, *Pseudomonas putida* and others. On the other hand, *Staphylococcus aureus*, *Streptococcus pneumoniae*, *Abiotrophia defectiva*, *Acinetobacter* are known to be associated with development of CLPU and infiltrative keratitis [Szczotka-Flynn *et al.* 2010].

Several studies estimated a four-fold increased risk of infiltrative keratitis and a five-fold increased risk of microbial keratitis due to overnight wear of contact lens [Dart JK, 2008]. Also, hand disinfection and cleaning are indispensable for contact lens wearers as humans come into contact with millions of microorganisms on a daily basis. Lens case contamination can be seen to be reduced by air drying the case, using water as well as soap and matching the disinfectant solution with the similar brand lens case [Wu *et al.* 2015].

Role of Compliance

Compliance is defined as following the correct regimen of treatment recommended to prevent any complications. Complications of bioburden on lens surface, discomfort in wearing the lens are usually the end results of noncompliance with lens care and eventually lead to dropout of lens use (Bui *et al.* 2010). Several surveys have pointed out the lack of awareness of contact lens care, even healthcare professionals [Khan *et al.* 2013; Chattu & Yousef, 2013]. This points towards a need of strong recommendations for lens usage and guidelines to maintain hygiene that may prevent any complications. The most important risk factor is poor hand hygiene, which may be due to incorrect washing technique or the use of contaminated water for the same [Khan *et al.* 2013]. Major reasons for noncompliant behavior include inadequate lens care and not scheduling periodic aftercare visits in lens wearers with eyecare practioners. It is indeed required to dispense proper health education to improve this negligent behavior. Non-compliance leads to redness and swelling in the eyes along with severe keratitis [Chattu & Yousef, 2013].

Prevention of contamination

An active regimen of basic care for contact lens wear includes certain necessary precautions on a daily basis:

- Avoid sleeping while wearing contact lenses
- Wash hands before handling lenses
- No usage of water to rinse the lenses as it can act as a source of germs
- Lens should be cleaned only using disinfecting solution

Lens case contamination is also a very common occurrence and one of the solutions to this problem is the use of silver impregnated cases to avoid this issue (Amos & George, 2006). Antimicrobial agents such as silver are a definite success in preventing contamination and more such technologies are being explored to eliminate impurities at the surface (Monteiro *et al*, 2009). Silver has broad spectrum antimicrobial activity against gram-positive & gram-negative bacteria and various viruses, fungi and protozoans. Workers have concluded that silver at a definite concentration effective against bacterial contamination and biofilms. Interestingly, Lin *et al* have also explored the possibility of effect of racial differences in ocular response, that is, Asians vs Caucasians differing in ocular response to use of contact lens care solutions. Weisbarth *et al.* have also deliberated upon the use of antimicrobial agents to eliminate or lessen the quantity of microbial contamination at the surface of the lens.

References:

1. Mukamal R. 2019. 'Microbiome of eye' [https://www.aao.org/eye-health/anatomy/microbiome-of-eye].
2. St Leger AJ, Desai JV, Drummond RA, Kugadas A, Almaghrabi F, Silver P, Raychaudhuri K, Gadjeva M, Iwakura Y, Lionakis MS, Caspi RR. An Ocular Commensal Protects against Corneal Infection by Driving an Interleukin-17 Response from Mucosal γδ T Cells. Immunity. 2017 Jul 18;47(1):148-158.e5. doi: 10.1016/j.immuni.2017.06.014. Epub 2017 Jul 11. PMID: 28709803; PMCID: PMC5553552
3. Musgrave CSA, Fang F. Contact Lens Materials: A Materials Science Perspective. Materials (Basel). 2019 Jan 14;12(2):261. doi: 10.3390/ma12020261. PMID: 30646633; PMCID: PMC6356913.
4. Kuo MT, Chien CC, Lo J, Hsiao CC, Tseng SL, Lai YH, Fang PC, Chang TC. (2015). A DNA dot hybridization model for assessment of bacterial bioburden in orthokeratology lens storage cases. *Invest Ophthalmol Vis Sci* 56:445-50. [PMID: 25537200].

5. Lo J, Kuo MT, Chien CC, Tseng SL, Lai YH, Fang PC.(2016). Microbial Bioburden of Orthokeratology Contact Lens Care System. *Eye Contact Lens* 242:61-7. [PMID: 25723564].
6. Devonshire, P, Munro F.A, Abernethy C, Clark B.J. (1993). Microbial contamination of contact lens cases in the west of Scotland. *Br J Ophthalmol*, 77 ,41-45
7. Khorazo D, Thompson R. (1935). The bacterial flora of the normal conjunctiva. *Am J Opthalmol.* 18:1114
8. Optom J. (2011). Bacteria and parasite in contact lenses of asymptomatic wearers in Nigeria. Apr; 4(2): 69–74.Published online Jun 28. doi: 10.1016/S1888-4296(11)70044-9
9. Klotz, S.A, Penn, C.C, Negvesky, G.J, Butrus, S.I. (2000). Fungal and parasitic infections of the eyes. *Clin Microbiol Rev*, 13:662-685.
10. Pinna, A., Porcu, T., Boscia, F., Cano, A., Erre, G., Mattana, A 2017. Free living Amoebae Keratitis *Cornea*m36(7):785-790. doi: 10.1097/ICO.0000000000001226
11. Martins, E.N, Farah, M.E, Alvarenga, L.S, Yu, M.C, Hoflin-lima A.L.(2002). Infectious keratitis: correlation between corneal and contact lens cultures. *CLAOJ*, 28,146-148.
12. Raj, N, Vanathi, M, Ahmed N.H, Gupta, N, Lomi, N, Tandon, R. (2021). Recent Perspectives in the Management of Fungal Keratitis. *J Fungi.* 7(11):907 doi: 10.3390/jof7110907 PMCID: PMC8621027PMID: 34829196
13. Kaye S, Choudhary A. Herpes simplex keratitis. Prog Retin Eye Res. 2006 Jul;25(4):355-80. doi: 10.1016/j.preteyeres.2006.05.001. Epub 2006 Jun 27. PMID: 16807055.
14. Liesegang T.J. (2001). Herpes simplex virus epidemiology and ocular importance external icon. *Cornea* 20(1):1-13.
15. Gallon, P, Parekh, M, Ferrari, S, Fasolo, A, Ponzin, D and Borroni, D (2019). Metagenomic in ophthalmology: Hypothesis or real prospective? *Biotechnol. Rep.* 23: e00355. doi: 10.1016/j.btre.2019.e00355
16. Loretta B. Szczotka-Flynn, O.D., Ph.D., Eric Pearlman, Ph.D., and Mahmoud Ghannoum, Ph.D. 2010. Microbial contamination of contact lens, lens care solutions & their accessories: A literature review. Eye Contact Lens. 36(2):116129. PMID: 20168237
17. Szczotka-Flynn, L. B., Pearlman, E., & Ghannoum, M. (2010). Microbial contamination of contact lenses, lens care solutions, and their accessories: a literature review. *Eye & contact lens*, *36*(2), 116–129. https://doi.org/10.1097/ICL.0b013e3181d20cae
18. Dart JK, Radford CF, Minassian D, Verma S, Stapleton F. Risk factors for microbial keratitis with contemporary contact lenses: a case-control study. Ophthalmology. 2008 Oct;115(10):1647-54, 1654.e1-3. doi: 10.1016/j.ophtha.2008.05.003. Epub 2008 Jul 2. PMID: 18597850.
19. Wu YT, Willcox MD, Stapleton F. The effect of contact lens hygiene behavior on lens case contamination. Optom Vis Sci. 2015 Feb;92(2):167-74. doi: 10.1097/OPX.0000000000000477. PMID: 25951478.
20. Bui, T. H., Cavanagh, H. D., & Robertson, D. M. (2010). Patient compliance during contact lens wear: perceptions, awareness, and behavior. *Eye & contact lens*, *36*(6), 334–339. https://doi.org/10.1097/ICL.0b013e3181f579f7
21. Khan, M.H., Mybeen, S.M., Chaudhary, T.A. & Khan, S.A. (2013) Contact lens use and its compliance for care among healthcare workers in Pakistan. Indian Journal of Ophthalmology, 61 (7), 334-337. doi: 10.4103/0301-4738.97552
22. Chattu, V.K. & Yousef, D. (2013) Importance Of Compliance In Contact Lens Wear - A Study To Assess The Knowledge And Practices Among Contact Lens Users For A Healthy Vision Int J Cur Res Rev. Vol 05 (08): 104-109
23. Amos CF, George MD. Clinical and laboratory testing of a silver-impregnated lens case. Cont Lens Anterior Eye. 2006; 29:247–255. [PubMed: 17084102]

24. Monteiro DR, Gorup LF, Takamiya AS, et al. The growing importance of materials that prevent microbial adhesion: antimicrobial effect of medical devices containing silver. Int J Antimicrob Agents. 2009; 34:103–110. [PubMed: 19339161]
25. Lin MC, Yuen J, Graham AD. Contact lens care solutions: a pilot study of ethnic differences in clinical signs and symptoms. Eye Contact Lens. 2014 Jul;40(4):191-9. doi: 10.1097/ICL.0000000000000034. PMID: 24887209; PMCID: PMC4232463.
26. Weisbarth RE, Gabriel MM, George M, Rappon J, Miller M, Chalmers R, Winterton L. Creating antimicrobial surfaces and materials for contact lenses and lens cases. Eye Contact Lens. 2007 Nov;33(6 Pt 2):426-9; discussion 434. doi: 10.1097/ICL.0b013e318157f488. PMID: 17975440.
27. CDC. 2022. 'Basics of Bacterial Keratitis' [https://www.cdc.gov/contactlenses/bacterial-keratitis.html#:~:text=Bacterial%20keratitis%20is%20an%20infection,do%20not%20wear%20contact%20lenses]

Glossary

Acanthamoeba – A free-living amoeba commonly found in water and soil that can cause severe eye infections, especially in contact lens wearers.
Adenovirus – A virus that can cause respiratory infections and conjunctivitis (pink eye).
Aerobic bacteria – Bacteria that require oxygen for growth and survival.
Antimicrobial agents – Substances that kill or inhibit the growth of microorganisms such as bacteria, fungi, and viruses.
Biofilms – Communities of microorganisms that attach to surfaces and are protected by a slimy matrix.
Bioburden – The number and types of microorganisms present on a surface, such as contact lenses or lens cases.
Candida albicans – A fungal species that can cause infections in humans, including ocular infections.
Commensal microorganisms – Normally harmless microorganisms that naturally live on body surfaces such as the eye.
Compliance – Following recommended guidelines and practices for proper contact lens care and hygiene.
Conjunctiva – The transparent membrane covering the white part of the eye and inner eyelids.
Conjunctival chemosis – Swelling of the conjunctiva caused by irritation or infection.
Contact lens acute red eye (CLARE) – An inflammatory condition associated with contact lens wear, causing redness and discomfort.
Contact lens peripheral ulcer (CLPU) – A small inflammatory lesion on the cornea associated with contact lens wear.
Cornea – The clear front surface of the eye that helps focus vision.
Corneal oedema – Swelling of the cornea due to fluid accumulation.
Corynebacterium mastitidis – A commensal bacterium found on the ocular surface that may help maintain immune protection.
Disinfecting solution – A specially formulated liquid used to clean and disinfect contact lenses.
Endophthalmitis – A severe inflammation or infection inside the eye.
Extended wear lenses – Contact lenses designed to be worn continuously for prolonged periods, including overnight use.
Fungal keratitis – A fungal infection of the cornea.

Gram-negative bacteria – Bacteria characterized by a thin cell wall and outer membrane, identified by Gram staining.
Gram-positive bacteria – Bacteria characterized by a thick cell wall, identified by Gram staining.
Hand hygiene – Proper cleaning of hands to reduce the spread of microorganisms.
Hartmannella – A free-living amoeba occasionally associated with contact lens contamination.
Herpes simplex keratitis (HSK) – A corneal infection caused by herpes simplex virus.
Hyaluronic acid (HA) – A naturally occurring substance used in some contact lens materials to improve moisture retention.
Hydrogel lenses – Soft contact lenses made from water-containing plastic materials.
Infiltrative keratitis – Corneal inflammation caused by immune responses or microbial contamination associated with contact lens wear.
Keratitis – Inflammation or infection of the cornea.
Lens case contamination – Presence of microorganisms in contact lens storage cases.
Lens care system – Products and procedures used for cleaning, disinfecting, and storing contact lenses.
Microbial keratitis – A serious corneal infection caused by microorganisms.
Microbiome – The community of microorganisms living in or on the human body.
Naegleria – A free-living amoeba found in warm freshwater that can cause rare but severe infections.
Orthokeratology lenses – Special contact lenses worn to temporarily reshape the cornea and correct vision.
Periocular skin microbiome – The microorganisms present on the skin surrounding the eyes.
Pseudomonas aeruginosa – A bacterium commonly associated with contact lens-related eye infections.
Reusable lenses – Contact lenses designed for repeated use over an extended period.
Silver-impregnated lens cases – Lens storage cases containing silver to reduce microbial contamination.
Silicone hydrogel lenses – Contact lenses made from silicone-containing materials that allow higher oxygen permeability.
Staphylococcus aureus – A bacterium that can cause eye infections and inflammation.
Torque Teno Virus (TTV) – A virus commonly found on the ocular surface.
Zoonoses – Diseases that can be transmitted between animals and humans.