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Infectious Keratitis in Saudi Arabia: A Review of Epidemiology, Pathogen Patterns, Risk Factors, Complications, and Antimicrobial Resistance

Jawaher M. Alshehri
Optometry Department, Faculty of Applied Medical Sciences, Al-Baha University, Al-Baha, Saudi Arabia.
***Email :** j.alshehri@bu.edu.sa

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ABSTRACT

Infectious keratitis is a severe corneal infection and a leading cause of corneal blindness worldwide. It poses significant public health and economic burdens in both developed and developing countries. Prompt diagnosis and treatment are critical to avoid complications such as corneal scarring, vision loss, or even the complete loss of the eye. This review aims to consolidate available data on infectious keratitis in Saudi Arabia, focusing on its epidemiology, causative organisms, clinical presentation, and predisposing factors. Additionally, the review highlights the increasing concern of antimicrobial resistance, an emerging threat in managing this condition. The review examines recent studies and clinical outcomes, identifying research gaps, particularly in viral and Acanthamoeba keratitis, and the lack of nationwide epidemiological data. Recommendations include enhancing public health education, improving early detection and intervention practices, and monitoring resistance patterns to reduce the impact of infectious keratitis. Addressing these issues is essential to minimise the burden of infectious keratitis, improve patient outcomes, and decrease long-term complications in Saudi Arabia.

INTRODUCTION

Infectious keratitis, an infection of the cornea, is a severe ophthalmic condition that poses a significant risk to vision. As the cornea is a crucial structure responsible for focusing light and maintaining the eye's clarity, any compromise to its integrity can result in devastating visual impairment (Hsiao *et al.*, 2016, Austin *et al.*, 2017, Watson *et al.*, 2019). Infectious keratitis is recognized as the leading cause of corneal blindness globally, affecting both developed and developing countries (Ung *et al.*, 2019). This condition is considered a medical emergency, requiring prompt diagnosis and treatment to avoid serious complications, including permanent vision loss and, in severe cases, the complete loss of the eye (Bourcier *et al.*, 2003, Cabrera-Aguas *et al.*, 2022). Corneal morbidity resulting from infectious keratitis represents a significant global health issue (Gopinathan *et al.*, 2002, Leck *et al.*, 2002), impacting both vision-related quality of life due to vision loss and health-related quality of life due to the pain experienced during acute phases (Arunga *et al.*, 2019).

The aim of this review is to summarize the epidemiology, causative organisms, clinical presentation, and predisposing factors of infectious keratitis in Saudi Arabia based on available data and recent studies.

The review also explores clinical outcomes and highlights the growing concern of antimicrobial resistance. Furthermore, it identifies gaps in the literature and offers recommendations to improve patient outcomes and reduce the impact of infectious keratitis in Saudi Arabia.

Etiology and Diagnostic Challenges in Infectious Keratitis:

Infectious keratitis can be caused by a wide variety of pathogens, including bacteria, fungi, viruses, and parasites (Cabrera-Aguas *et al.,* 2022, Leck *et al.,* 2002, Gopinathan *et al.,* 2002, Bharathi et al., 2003, Athmanathan et al., 2002, Sharma et al., 2000, Green et al., 2008). The prevalence of these pathogens varies geographically and seasonally. While bacterial and fungal infections dominate, viral keratitis and Acanthamoeba infections, though less frequent, are significant causes of corneal blindness, particularly in developed nations (Ting *et al.,* 2021b). Environmental factors, healthcare access, and socioeconomic conditions contribute to the regional variability in microbial causes of keratitis (Leck *et al.*, 2002, Alreshidi et al., 2024).

Diagnosing infectious keratitis can be challenging due to the similar clinical features shared by infections caused by different pathogens. Identifying the specific causative microorganism is essential for guiding effective antimicrobial therapy and ensuring the best possible treatment outcome (Alkatan *et al.*, 2012).

A comprehensive diagnostic approach is required, involving a detailed patient history, slit-lamp examination, and microbiological testing. Corneal scrapings are typically taken for culture and staining to identify the causative organism. While clinical signs can provide useful clues, laboratory confirmation is critical for ensuring accurate diagnosis and appropriate treatment (Bartimote *et al.,* 2019, Cabrera-Aguas and Watson, 2023, Cabrera-Aguas *et al.,* 2022, Ngo *et al.,* 2020). Initial treatment typically involves the use of empiric broad-spectrum antibiotics to target a wide range of potential pathogens until the specific organism is identified. (Watson *et al.*, 2019, Tan *et al.,* 2017, Fernandes *et al.*, 2015). Once culture results are available, treatment is adjusted to target the identified microorganism more effectively. In severe cases, such as those involving corneal perforation or cases that do not respond to medical treatment, surgical intervention, including corneal transplantation, may be required (Ting *et al.*, 2021b). The management of infectious keratitis is complicated by the risk of misdiagnosis, which can lead to inappropriate treatment and worsen the patient's condition. Rapid and accurate identification of the pathogen, followed by prompt and tailored treatment, is crucial in preventing complications such as corneal scarring, vision loss, and the need for surgical intervention (Bartimote *et al.*, 2019)

Regional Disparities in the Incidence of Infectious Keratitis:

Recent research on the incidence of infectious keratitis remains limited, with the majority of studies conducted over a decade ago (Ung *et al.*, 2019, Erie *et al.*, 1993, Upadhyay *et al.*, 2001). The global burden of infectious keratitis varies significantly across regions, influenced by factors such as climate, socioeconomic status, and access to healthcare. In developed countries, incidence rates are relatively low. For example, reports from the United States show an incidence of 2.5–27.6 cases per 100,000 people annually, while in England the rates range from 34.7 to 40.3 per 100,000, and in Australia, the incidence is around 6.6 per 100,000 (Jeng *et al.,* 2010, Ting *et al.,* 2021a, Erie *et al.,* 1993, Seal *et al.*, 1999, Ibrahim *et al.*, 2012, Green *et al.,* 2019, Ung *et al.,* 2019). In contrast, developing countries, particularly in Asia and Africa, face much higher incidence rates due to poorer access to healthcare, lower socioeconomic conditions, and higher occupational risks.

For instance, South India has reported incidences as high as 113 per 100,000, while Bhutan, Burma, and Nepal have reported even higher rates at 339, 710, and 799 per 100,000, respectively (Ting *et al.*, 2021b, Upadhyay *et al.*, 2001, Gonzales *et al.*, 1996, Ung *et al.*, 2019, Whitcher *et al.*, 2001, Ting *et al.*, 2021a).

Epidemiology of Infectious Keratitis in Saudi Arabia:

The prevalence and incidence of infectious keratitis in Saudi Arabia have been the focus of several studies, each highlighting various aspects of the disease's epidemiology across different regions and populations.

A 10-year study conducted at security forces hospital in Riyadh analyzed 181 eyes from 179 patients, with an average age of 40.1 years, to investigate infectious keratitis. The findings showed that 27.6% of cases were caused by gram-positive organisms, 19.3% by gram-negative organisms, and 7.2% by fungi (Al Hadlaq and Al Harbi, 2023). In another study conducted between 2011 and 2014 at a tertiary care eye hospital, 2,037 bacterial isolates were examined. The study found that gram-positive bacteria accounted for 91.4% of cases, including Staphylococcus epidermidis (27.4%), coagulase-negative staphylococci (8.2%), Staphylococcus aureus (6.8%), and Streptococcus pneumoniae (4.5%). The most common gram-negative isolate was Pseudomonas aeruginosa (38.4%) (Al-Dhaheri *et al.*, 2016). Similarly, a retrospective study at a tertiary care hospital in Riyadh examined 177 cases of bacterial keratitis between 2015 and 2018, with Staphylococcus epidermidis being the most frequently isolated organism (34.5%) (Almizel *et al.*, 2019). A 13-year retrospective study (2007–2019) at a tertiary eye care centre reviewed 263 cases of bacterial keratitis, with 64.3% of cases being culture-positive. Staphylococcus epidermidis and Streptococcus pneumoniae were the predominant pathogens (Almulhim et al., 2023). In Qassim Province, a cross-sectional study of 100 patients suspected of keratitis revealed that 54.8% of corneal swabs were culture-positive, with Pseudomonas aeruginosa (25.2%) and Staphylococcus aureus (15.7%) being the leading bacterial causes (Aldebasi *et al.*, 2013). A study in Southern Saudi Arabia investigated cosmetic contact lens-associated ulcerative keratitis. Among the 46 cases, 19.5% were laboratory-confirmed infectious keratitis. Pseudomonas was the most common organism (66.6%), followed by Staphylococcus species (22.2%) (Abdelkader, 2014).

Childhood infectious keratitis has also been examined. A retrospective study conducted between 2000 and 2010 at a tertiary referral eye hospital in Riyadh reviewed 68 cases of childhood infectious keratitis. The study found that gram-positive bacteria were responsible for 67.8% of culture-positive cases, with Streptococcus pneumoniae being the most frequently isolated organism (Al Otaibi et al., 2012). Another study conducted at Dhahran Eye Specialist Hospital between 2010 and 2020 analyzed 59 pediatric patients with non-viral microbial keratitis. Corneal scrapings showed positive growth in 43.6% of cases, with gram-negative organisms accounting for 47.1% of isolates. Pseudomonas aeruginosa (41.2%) and Staphylococcus aureus (11.8%) were the most common pathogens (Alwohaibi *et al.*, 2022). A more recent study from a tertiary care hospital in Riyadh reviewed 43 cases of pediatric bacterial keratitis over 13 years. The study found that 60.5% of cases were culture-positive, identifying coagulase-negative Staphylococcus (23.1%), Pseudomonas (23.1%), and Streptococcus pneumoniae (19.2%) as the most common causative organisms (Alsarhani *et al.*, 2024).

Fungal keratitis has been a prominent focus in many studies. A 20-year retrospective observational study at King Khaled Eye Specialist Hospital in Riyadh identified 124 cases of fungal keratitis. The most common organisms were Aspergillus spp. (29.8%), Trichophyton spp. (16.1%), and Candida and Fusarium spp. (Jastaneiah *et al.,* 2011). Another study at the tertiary care eye hospital analyzed 2,300 patients with suspected infectious keratitis over four years and identified 87 cases (3.8%) of fungal keratitis based on positive fungal cultures. Aspergillus species were the most common filamentous fungi, followed by Fusarium and Trichophyton species, while Candida albicans was the most frequent yeast. Additionally, mixed fungal and bacterial infections were observed in 28.7% of patients, demonstrating the complexity of some cases (Alkatan *et al.*, 2012). Further studies have highlighted the epidemiology of fungal keratitis. In three hospitals in Riyadh, a study of 100 patients with suspected fungal keratitis revealed that 52% tested positive, with Aspergillus spp. (44.23%), Candida spp. (17.30%), and Fusarium spp. (17.30%) being the most frequently identified species (El-Tahtawi, 2015). A rare case of fungal keratitis caused by Gjaerumia minor, an uncommon yeast, was also reported at Aseer Central Hospital in Southern Saudi Arabia (Al-Falki *et al.,* 2018).

A recent retrospective study at King Khaled Eye Specialist Hospital examined infectious keratitis cases across all age groups. This study reviewed 134 eyes from 126 individuals and identified 24 cases of Acanthamoeba keratitis, 22 cases of bacterial keratitis, 24 cases of fungal keratitis, 32 cases of herpetic keratitis, and 32 cases of bacterial co-infections (Alreshidi *et al.*, 2024).

Clinical Manifestations of Infectious Keratitis:

Infectious keratitis manifests through a wide range of clinical signs and symptoms, which vary depending on the causative pathogen. Across studies conducted in Saudi Arabia, the most commonly reported clinical features included corneal infiltrates, epithelial erosion, hypopyon, corneal edema, and corneal ulcers (Al Hadlaq and Al Harbi, 2023, Alreshidi *et al.,* 2024).Bacterial keratitis was often characterized by corneal ulceration, hypopyon, dense infiltrates, lid and conjunctival edema, and anterior chamber inflammation. Patients typically presented with severe pain, redness, photophobia, discharge, tearing, and sometimes blepharospasm, along with significant vision impairment (Almizel *et al.*, 2019, Aldebasi *et al.*, 2013, Alreshidi et al., 2024, Abdelkader, 2014). In fungal keratitis, hallmark signs included gray-white corneal infiltrates, stellate lesions, epithelial defects, corneal ulcers, and hypopyon (Fig. 1). Common symptoms were persistent eye pain, tearing, blurred vision, photophobia, and redness (Alkatan *et al.,* 2012, Jastaneiah *et al.,* 2011, Al-Falki *et al.,* 2018, El-Tahtawi, 2015, Alreshidi e*t al.,* 2024). Acanthamoeba keratitis was notably marked by severe pain that was disproportionate to the clinical signs. A key diagnostic feature was the presence of a ring-shaped stromal infiltrate. Other signs included epithelial defects, radial keratoneuritis, perineuritis, and endothelial plaques (Figs. 2A and 2B), all of which are indicative of an Acanthamoeba infection (Alreshidi *et al.,* 2024). In pediatric keratitis, clinical features often included large infiltrates, corneal ulcers, hypopyon, and anterior chamber reactions. Children may exhibit symptoms such as eye pain, tearing, poor vision, and photophobia. However, their inability to clearly express these symptoms can lead to delays in diagnosis (Alsarhani *et al.,* 2024, Al Otaibi *et al.,* 2012, Alwohaibi *et al.,* 2022).

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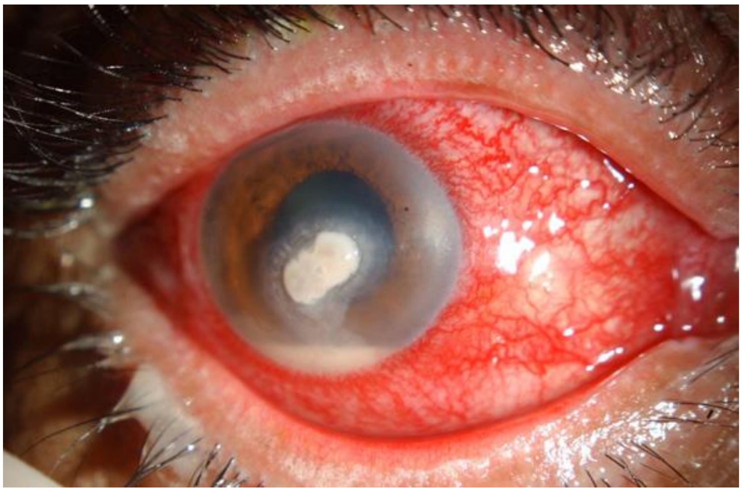

Fig. 1: Fungal keratitis. It shows a thick corneal infiltrate along with hypopyon, both caused by fungal pathogens. Source: (Alkatan *et al.,* 2012)

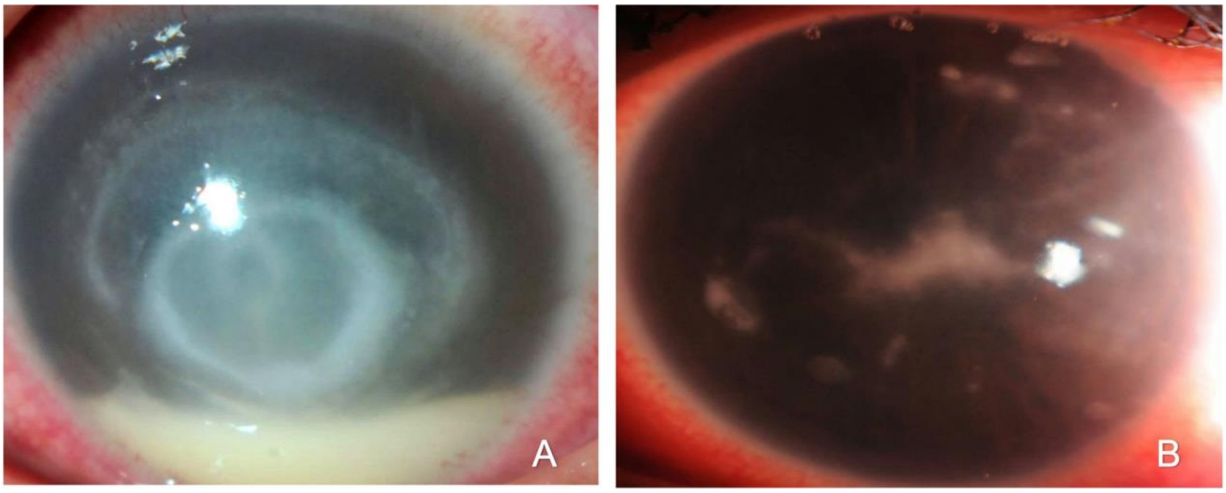

Fig.2: Acanthamoeba keratitis. It shows ring infiltrate lesion (A), and endothelial plaques lesion (B) caused by acanthamoeba pathogens. Source: (Alreshidi *et al.*, 2024)

Key Predisposing Factors for Infectious Keratitis:

Understanding the predisposing factors of infectious keratitis is essential for effective prevention and management. Several studies have identified a variety of risk factors associated with infectious keratitis in Saudi Arabia.

Contact Lens Use:

Contact lens use was widely recognized as a significant risk factor for infectious keratitis in Saudi Arabia, as highlighted by numerous studies. It was responsible for 24.6% to 30% of overall infectious keratitis cases in some studies (Al Hadlaq and Al Harbi, 2023, Alreshidi *et al.,* 2024), and contributed to 7.9% to 44.4% of bacterial keratitis cases (Almizel *et al.*, 2019, Aldebasi *et al.*, 2013). In pediatric populations, contact lens use was a key factor, accounting for 16.1% to 35.6% of infectious keratitis cases (Al Otaibi *et al.*, 2012, Alwohaibi *et al.*, 2022, Alsarhani *et al.*, 2024). Furthermore, contact lens wear has been shown to significantly increase the risk of developing Acanthamoeba keratitis, a serious and often more challenging form of the infection (Alreshidi *et al.,* 2024).

Ocular Trauma:

Ocular trauma was frequently reported as a leading predisposing factor, particularly in cases involving exposure to vegetative materials, agricultural activities, or foreign objects like stone chips and metal splinters. Ocular trauma played a significant role in fungal keratitis cases (20.9%–

30.76%) (Jastaneiah *et al.,* 2011, El-Tahtawi, 2015, Alkatan *et al.,* 2012, Khairallah *et al.,* 1992), and was also a major factor in pediatric infectious keratitis, with reported rates ranging from 27.1% to 44.2% (Al Otaibi *et al.,* 2012, Alwohaibi *et al.,* 2022, Alsarhani *et al.,* 2024). In bacterial keratitis studies, ocular trauma contributed to 21.7% to 38.4% of cases (Al Hadlaq and Al Harbi, 2023, Almizel *et al.*, 2019, Aldebasi *et al.*, 2013, Almulhim *et al.*, 2023).

Ocular Diseases:

Ocular diseases had been implicated in 23.2 to 40.2% of overall infectious keratitis cases in some studies (Al Hadlaq and Al Harbi, 2023, Alreshidi *et al.*, 2024), 11.3 to 29.4 of bacterial keratitis cases (Almizel et al., 2019, Aldebasi et al., 2013, Almulhim et al., 2023), and 11.9 to 23.3 of pediatric infectious keratitis cases (Al Otaibi *et al.*, 2012, Alwohaibi *et al.*, 2022, Alsarhani *et al.*, 2024).

Ocular Surgeries:

Ocular surgeries were identified as another significant predisposing factor, accounting for 29.1% of infectious keratitis cases (Alreshidi *et al.*, 2024), 26.92% to 38.7% of fungal keratitis cases (Jastaneiah *et al.*, 2011, El-Tahtawi, 2015), and 7.0% of bacterial keratitis cases (Aldebasi *et al.*, 2013). In pediatric keratitis, ocular surgery was a factor in 5.1% to 7.0% of cases (Alwohaibi *et al.*, 2022, Alsarhani *et al.*, 2024).

Systemic Diseases:

Systemic diseases also played a significant role, contributing to 39.5% of infectious keratitis cases overall (Alreshidi *et al.*, 2024), and between 10.2% and 20.6% of childhood infectious keratitis cases (Al Otaibi *et al.*, 2012, Alwohaibi *et al.*, 2022).

Other Predisposing Factors:

Other notable predisposing factors for infectious keratitis in Saudi Arabia included the use of topical steroids, improper lens hygiene, extended contact lens wear, and specific environmental conditions. The region's hot and dry climate, frequent exposure to dust, and engagement in agricultural activities - particularly in rural areas- also played a critical role in the development of this condition (Aldebasi et al., 2013, Abdelkader, 2014, Tabbara *et al.,* 2000, Khairallah *et al.,* 1992). Furthermore, exposure to contaminated water has been identified as a distinct risk factor, particularly for Acanthamoeba keratitis (Alreshidi *et al.*, 2024).

Visual Outcomes and Complications of Infectious Keratitis:

The visual outcomes of infectious keratitis observed in studies conducted in Saudi Arabia vary significantly based on the severity of the infection and the timeliness of treatment. While many patients demonstrated notable improvements in visual acuity following treatment, some cases resulted in lasting visual impairment due to corneal scarring and other complications.

Studies on fungal keratitis in Saudi Arabia have reported a range of severe complications, including significant corneal scarring, extensive ulcers, secondary glaucoma, and corneal graft failure. In more advanced cases, fungal endophthalmitis and corneal perforation were observed, often requiring surgical intervention. Therapeutic penetrating keratoplasty (PKP) was frequently necessary, either as a standalone procedure or in combination with others, such as vitrectomy, peripheral iridectomy, or subtotal iridectomy. In the most severe cases, uncontrolled fungal infections compromised the integrity of the globe, leading to enucleation or evisceration. Some cases progressed to phthisis bulbi, a condition characterized by eye shrinkage and vision loss. Additionally, some patients developed fungal scleritis and panophthalmitis, requiring enucleation to prevent further complications (Jastaneiah *et al.,* 2011, Khairallah *et al.,* 1992, Alkatan *et al.,* 2012, Mohammad *et al.,* 2006). In bacterial keratitis, complications included visually significant corneal scarring, poor visual outcomes, corneal perforation, cataracts, non-healing epithelial defects,

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corneal neovascularization, endophthalmitis, and hypotony (Almulhim *et al.,* 2023).

Pediatric keratitis commonly led to corneal scarring, with additional complications including poor visual outcomes, astigmatism, cataracts, corneal perforation, corneal neovascularization, non-healing epithelial defects, endophthalmitis, and graft failure. Some cases required further interventions such as penetrating keratoplasty, deep lamellar keratoplasty, photorefractive keratectomy, and phototherapeutic keratectomy. Severe visual impairment in children has been highlighted as a risk if early recognition and management are not implemented (Al Otaibi *et al.,* 2012, Alsarhani *et al.,* 2024, Alwohaibi *et al.,* 2022).

Ocular Surgery-Related Infectious Keratitis:

Infectious keratitis is a serious complication that can arise after various ocular surgeries, posing significant risks to both corneal graft survival and visual outcomes. Studies have shown that post-surgical keratitis can lead to severe complications, including graft failure.

A retrospective case series at King Khaled Eye Specialist Hospital reviewed cases of primary pediatric penetrating keratoplasty (PKP) performed between January 1990 and December 2005. This study found that culture-positive bacterial keratitis developed in 17.3% of the 202 primary keratoplasties performed. Gram-positive organisms were present in 91.4% of infected eyes, with Streptococcus pneumoniae being the most frequently isolated, accounting for 77.6% of all bacterial isolates. Poor visual outcomes were prevalent, with no cases achieving a final visual acuity of 20/40 or better, and 65.7% of cases resulting in visual acuity limited to hand motions or worse. The study emphasized the high risk of graft failure and poor visual outcomes in cases of bacterial keratitis post-PKP, highlighting the importance of rigorous postoperative monitoring (Wagoner *et al.*, 2007a). In a prospective study involving 258 phototherapeutic keratectomy procedures at the same hospital, bacterial keratitis developed in 1.2% of eyes during a follow-up period of 1 to 24 months. All cases occurred in eyes with climatic droplet keratopathy, with Streptococcus pneumoniae and coagulase-negative Staphylococcus identified as primary pathogens. Two cases involved multiple bacterial species, and visual outcomes were significantly reduced, with final acuity ranging from 20/125 to 20/400 (Al-Rajhi et al., 1996). A separate retrospective study reviewed 102 patients who developed bacterial keratitis after penetrating keratoplasty (PK), from a total of 2,103 PK procedures performed between January 1998 and December 2002. Bacterial keratitis was found in 4.9% of cases, with gram-positive bacteria being the most prevalent (83.3%), primarily Staphylococcus epidermidis and Streptococcus pneumoniae. Gram-negative bacteria, including Pseudomonas aeruginosa, accounted for 16.7% of isolates. Post-infection, only 37.3% of grafts remained clear after a mean follow-up of 985 days, and only 8.2% of cases achieved a final visual acuity of 20/40 or better (Wagoner *et al.*, 2007b). In another case, a 20-year-old woman developed infectious keratitis after the implantation of intrastromal corneal ring segments (ICRSs) for keratoconus. Despite aggressive topical antibiotic treatment, the stromal infiltrates worsened, leading to the removal of the ICRSs to control the keratitis and prevent corneal melting. Cultures revealed Streptococcus viridans, and while the patient responded well to treatment, stromal scars remained in both corneas (Chaudhry *et al.,* 2010). However, a retrospective study at King Khaled Eye Specialist Hospital evaluated the incidence of infectious keratitis following amniotic membrane transplantation (AMT) for persistent corneal epithelial defects. Out of 142 AMT procedures performed between January 2003 and June 2004, no cases of early-onset infectious keratitis occurred within the first 30 days post-surgery (Al-Kharashi *et al.*, 2005).

Antibiotic Sensitivity and Resistance in the Management of Infectious Keratitis:

Antibiotic resistance has become a significant challenge in the management of infectious keratitis, with various studies demonstrating increasing resistance among ocular pathogens.

One study, conducted over an 18-month period at King Abdul-Aziz University Hospital in Riyadh, examined the bacterial spectrum in corneal infections and their antibiotic susceptibility patterns. Of the 200 corneal specimens analyzed, 33.5% were culture-positive, with 79.1% of isolates being Gram-positive bacteria. Predominant organisms included coagulase-negative Staphylococci and Streptococcus pneumoniae. Gram-negative bacteria accounted for 20.9% of isolates, with Pseudomonas aeruginosa being the most common. Importantly, all isolated bacteria demonstrated sensitivity to ofloxacin, a fluoroquinolone (Begum *et al.*, 2006).

A retrospective study at King Saud University in Riyadh, spanning 13 years (2007–2019) and involving 162 patients, evaluated the antibiotic resistance profile of bacterial keratitis. The study showed excellent susceptibility of both Gram-positive and Gram-negative bacteria to fluoroquinolones and trimethoprim-sulfamethoxazole, with Gram-negative bacteria displaying higher overall susceptibility. However, the emergence of resistant bacterial strains, particularly to vancomycin, was noted. While Pseudomonas and Moraxella demonstrated complete sensitivity to fluoroquinolones (ciprofloxacin and levofloxacin), tetracycline, and trimethoprim-sulfamethoxazole, Pseudomonas exhibited varying resistance to antibiotics such as ceftazidime, ofloxacin, and gentamicin. The study also revealed increasing resistance among Gram-positive bacteria, with Staphylococcus aureus and coagulase-negative staphylococci showing resistance to oxacillin and moxifloxacin over time. Notably, Staphylococcus epidermidis showed a rise in moxifloxacin resistance from 0.9% to 12.7%, while oxacillin resistance in Staphylococcus aureus increased from 14.8% to 27.8% (Alsarhani *et al.*, 2023). Additionally, concerning resistance patterns were observed for Pseudomonas aeruginosa (Alsarhani *et al.*, 2023, Alwohaibi *et al.*, 2022).

Another study examined antibiotic susceptibility patterns in patients with bacterial keratitis. It confirmed that Gram-positive isolates, such as Staphylococcus epidermidis and other coagulase-negative staphylococci, remained sensitive to vancomycin. However, resistance to oxacillin and moxifloxacin increased over time, with oxacillin resistance in Staphylococcus aureus rising from 14.8% in 2011 to 27.8% in 2014, and moxifloxacin resistance in Staphylococcus epidermidis increasing from 0.9% to 12.7% (Al-Dhaheri *et al.*, 2016).

These findings were further supported by another study, which highlighted significant antibiotic resistance among bacterial keratitis pathogens, particularly Staphylococcus aureus and Pseudomonas aeruginosa. While all Gram-positive cases were sensitive to vancomycin, Staphylococcus epidermidis showed 7.27% resistance to chloramphenicol. Additionally, resistance to penicillin and ampicillin was found in 90% and 89.83% of cases, respectively. All Streptococcus pneumoniae isolates were resistant to gentamicin, whereas Staphylococcus aureus showed 100% sensitivity to erythromycin (Almizel *et al.*, 2019). Research from King Khaled Eye Specialist Hospital reinforced these trends, noting the prevalence of Staphylococcus epidermidis and Pseudomonas aeruginosa as the most common isolates, with resistance patterns increasing over the years (Al-Shehri *et al.*, 2009). Given these alarming resistance patterns, the increasing

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reliance on fourth-generation fluoroquinolones and fortified antibiotics for treating severe bacterial keratitis cases has been noted (Alahmadi *et al.,* 2021).

Regarding fungal keratitis, a case series involving Trichophyton schoenleinii found that these infections were often resistant to topical amphotericin B and miconazole but showed sensitivity to topical natamycin (Mohammad *et al.,* 2006).

Challenges in Understanding the Full Scope of Infectious Keratitis in Saudi Arabia:

Despite the existing body of research on infectious keratitis in Saudi Arabia, several notable gaps persist. One key limitation is that most studies are retrospective in design, which makes it difficult to assess direct relationships or observe long-term patterns. Additionally, much of the research is concentrated on specific hospitals or regions, leading to an absence of comprehensive nationwide epidemiological data. Furthermore, while bacterial and fungal keratitis are well-documented, there is a relative lack of studies addressing viral and Acanthamoeba keratitis. Another area that requires more attention is the socioeconomic impact of infectious keratitis, particularly in relation to patients' quality of life and the economic burden of treatment. Lastly, although antimicrobial resistance poses a growing challenge in the management of infectious keratitis, comprehensive studies on resistance patterns across Saudi Arabia remain insufficient.

Conclusion

Infectious keratitis continues to pose a significant public health challenge in Saudi Arabia, affecting a broad range of individuals, including contact lens users, individuals with ocular trauma, and those with preexisting eye conditions. This review highlights the diverse etiologies of infectious keratitis, with regional studies demonstrating diverse patterns in pathogen prevalence in Saudi Arabia. Despite improvements in diagnosis and treatment, complications such as corneal scarring, vision loss, and the increasing threat of antimicrobial resistance remain pressing concerns.

To address the burden of infectious keratitis, several key recommendations arise from the findings of this review. Initially, public health initiatives should focus on educating the population about proper contact lens hygiene and the dangers of ocular trauma, especially in rural and agricultural environments where such risks are elevated. Raising awareness in these high-risk groups could significantly reduce the incidence of infections. Healthcare providers should prioritize early detection and swift intervention. By equipping primary care and emergency personnel with the knowledge to recognize the early symptoms of infectious keratitis and by enhancing referral systems to specialized care, severe complications can be mitigated. Additionally, regular monitoring of antimicrobial resistance patterns is essential. Ongoing surveillance will allow for more effective and up-to-date treatment guidelines, ensuring that therapies remain effective against emerging resistance. Lastly, research should focus on identifying risk factors unique to the Saudi population, such as environmental and occupational hazards that heighten the risk of infectious keratitis. Addressing these critical areas can help reduce the overall burden of infectious keratitis, resulting in better visual outcomes, fewer long-term complications, and an improved quality of life for those affected.

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