# Effects of the COVID-19 Pandemic on Microbial Keratitis: A 5-Year Comparative Study

*Luis Haro-Morlett, MD, Guillermo Raul Vera-Duarte, MD, Francisco Oliveros-Valdes, MD, Thelma Noemi Cortes-Moreno, MD, Arturo Ramirez-Miranda, MD, PhD, Alejandro Navas, MD, PhD, and Enrique O. Graue-Hernandez, MD, MSc*



**Purpose:** To report the clinical and microbiological profiles of microbial keratitis and its antimicrobial resistance before, during, and after COVID-19.

**Methods:** This was a retrospective case-note review of all corneal scrape specimens collected from patients with microbial keratitis from January 2018 to December 2023. Case records were analyzed for demographic characteristics, microbiological diagnosis, and antibiograms. All outcome variables were collected, stratified, and compared between 3 periods: the pre–COVID-19 group (January–December 2019), the COVID-19 group (January 2020–December 2022), and the post–COVID-19 group (January–December 2023).

**Results:** A total of 947 corneal cultures from 947 patients were reviewed. Gram-positive bacteria predominated in all periods, with no significant differences in their distribution. *Staphylococcus epidermidis* was the most frequently identified organism. *Pseudomonas aeruginosa* was the most common Gram-negative bacterium, with its incidence significantly lower in the post-COVID period. Fungal infections showed a significant increase in the post-COVID group, with Fusarium sp. being the most common fungus and showing a significant increase in incidence in the post-COVID group.

**Conclusions:** Despite a stable incidence of microbial keratitis, this study highlights a concerning trend in antibiotic resistance. Although some pathogens became less common, those that persisted have become increasingly difficult to treat. Understanding the clinical and microbiological profiles of microbial keratitis and antimicrobial resistance patterns before and after the COVID-19 pandemic is crucial for informed treatment decisions.

Received for publication June 22, 2024; revision received August 16, 2024; accepted September 1, 2024.

From the Instituto de Oftalmologia Fundacion Conde de Valenciana, Mexico City, Mexico

There is no conflict of interest. There is no funding received.

Retrospective study. The Research and Ethics Committee of the Instituto de Oftalmologia Conde de Valenciana authorized the study.

All authors contributed to the study's conception and design, commented on previous versions of the manuscript, and read and approved the final manuscript.

Correspondence: Enrique O. Graue-Hernandez, MD, MSc, Instituto de Oftalmologia Fundacion Conde de Valenciana Chimalpopoca 14, Centro, Cuauhtemoc, 06800 Ciudad de Mexico, CDMX CP 06800, Mexico (e-mail: egraueh@gmail.com).



**Key Words:** COVID-19 pandemic, microbial keratitis, microbiological profiles, antimicrobial resistance

(*Cornea* 2024;00:1–11)

The cornea is the only structure of the eye exposed to the external environment, making it vulnerable to infectious agents.[1] Infectious keratitis is the fifth leading cause of global blindness and includes a spectrum of etiological agents such as bacteria, parasites, viruses, and fungi.[2–4] Bacteria are the most common cause of infectious keratitis worldwide.[3–7] Major risk factors include the use of contact lenses, ocular trauma, immunosuppression, chronic surface pathology, and previous ocular surgeries.[8–10] Timely recognition of microbial keratitis as an ophthalmic emergency is imperative, given its potential to precipitate vision-threatening complications, requiring prompt intervention.[3,5]

The World Health Organization declared a global pandemic caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) on March 11, 2020.[11] Mexican health authorities implemented multiple health measures, including restrictions on patient admissions and consultations, limiting activities to those deemed essential, mandating the use of masks in open and closed public spaces, and requiring hand washing before any recreational or work activity. These restrictions remained in place until April 2022.[12] These changes in hygiene habits significantly affected the health system, leading to an increase in self-prescription of medications because of limited access to health care services during the COVID-19 pandemic.[13] This trend raises concerns about the improper use of medications and associated health risks. This study aims to investigate the clinical characteristics, microbiological profiles, and antibiotic susceptibility patterns of microbial keratitis cases before and after the COVID-19 pandemic.

## METHODS

A retrospective, descriptive, and analytical study was conducted, including all corneal scrape specimens from patients with microbial keratitis. The study took place at the Instituto de Oftalmologia Fundacion Conde de Valenciana in Mexico City, Mexico, from January 2018 to December 2023. Data were collected and analyzed according to the policies and regulations of our institution's Ethics and Research

Committees, and the tenets outlined in the Declaration of Helsinki. Collected data included demographic characteristics, microbiological diagnosis, and antibiograms. All outcome variables were collected, stratified, and compared across 3 periods: the pre–COVID-19 group (January–December 2019), the COVID-19 group (January 2020–December 2022), and the post–COVID-19 group (January–December 2023).

## Corneal Scrape and Antibiogram Protocol

The corneal scrapes were routinely obtained using a calcium alginate swab and inoculated in 4 solid culture media (sheep blood agar, chocolate agar, mannitol salt agar, and Sabouraud agar) and a liquid medium (brain–heart infusion) under appropriate atmospheric conditions (37°C/5% $CO_2$). Cultures were considered positive if growth of the same organism was demonstrated on 2 or more solid media, or if there was semiconfluent growth at the site of inoculation on 1 solid medium. Gram and Giemsa stains were obtained for every sample; however, a positive microscopy with negative culture was considered insufficient evidence for microorganism growth.[14]

Bacteria were identified using the Vitek Jr system (bioMerieux, France) with a GP-test Vitek card. Drug sensitivity was determined by the Kirby–Bauer method using antibiotic discs. Bacterial isolates were classified as sensitive or resistant to the tested antibiotics.

## Statistical Analysis

Analysis was conducted using GraphPad Prism version 10.1.1 for macOS (GraphPad Software, Boston, MA). Means and standard deviations were reported, and categorical data were presented as proportions using the Fisher exact test and $\chi^2$-square test. Paired *t*-tests and repeated measures one-way Analysis of Variance with post-hoc Tukey test were used to compare values. The statistical significance level was set at $P < 0.05$.

# RESULTS

A total of 947 corneal cultures were performed from 947 patients between January 2018 and December 2023, distributed as follows: 185 patients in the pre-COVID group, 558 in the COVID group, and 204 in the post-COVID group. The mean ages were 50.76 ± 21.18 years, 50.05 ± 19.88 years, and 51.3 ± 19.7 years in the pre-COVID, COVID, and post-COVID groups, respectively, with no significant differences between groups ($P = 0.34$). Sex distribution also showed no predominance between groups ($P = 0.52$). Monthly distribution did not differ significantly ($P = 0.40$), and although seasonal distribution varied slightly, with the pre-COVID group showing a summer predominance (28.6%), the COVID group in spring (25.6%), and the post-COVID group in summer (27.9%), these differences were not significant ($P = 0.71$). Demographics and monthly distribution details can be found in Table 1.

## Clinical Findings

A notable difference was observed in the time from symptom onset to treatment initiation ($P = 0.02$). The pre-COVID group had a significantly shorter duration (12.45 ± 11.60 days) compared with both COVID (21.89 ± 46.18 days) and post-COVID groups (27.36 ± 46.69 days). Purulent discharge was noted more frequently in the COVID group (89.1%) compared with the pre-COVID (52.1%) and post-COVID groups (77.9%) ($P < 0.0001$). Contact lens–associated microbial keratitis was less frequent during the COVID period (16.7%), with similar frequencies in the pre-COVID and post-COVID groups, although not significantly different ($P = 0.08$). No differences were found between groups regarding hypopyon, previous corticosteroid use, or antibiotic use ($P = 0.49$, $P = 0.07$, $P = 0.06$). Moxifloxacin was the most commonly self-prescribed or prescribed by nonophthalmic specialists among patients before consultation, followed by gatifloxacin and tobramycin. Baseline clinical characteristics are detailed in Table 2.

## Complications

However, a higher incidence of perforation was observed in the pre-COVID period compared with the COVID period ($P = 0.035$), with a similar incidence post-COVID ($P > 0.999$). Trends indicated higher rates of endophthalmitis and corneal lysis post-COVID. The incidence of endophthalmitis was highest during the COVID period (20.3%) and post-COVID period (18.2%) and lowest in the pre-COVID group (3.7%). All patients with complications required surgery (100%), with therapeutic penetrating keratoplasty being common in the pre-COVID (72.0%), COVID (47.0%), and post-COVID (66.7%) periods. Evisceration was more frequent during the COVID and post-COVID periods compared with the pre-COVID period. Further details on complications can be found in Table 3.

The microorganisms associated with complications across all periods were *Pseudomonas aeruginosa* (16.5%) and *Staphylococcus epidermidis* (15.7%), followed by *Fusarium* sp (15.7%) and *Staphylococcus hominis* (9.1%). There was no significant difference in the frequency of *S. epidermidis*, *S. hominis*, and *P. aeruginosa* across the periods ($P = 0.3161$, 0.6821, 0.4052, respectively). However, *Fusarium* sp. showed a significant increase in frequency, rising from 8.0% in the pre-COVID period to 13.7% during COVID, and reaching 34.8% post-COVID ($P = 0.0292$). The analysis found that the odds of developing a complication were 5.12 times higher with *Fusarium* sp (OR = 5.12, 95% confidence interval [CI], 2.69–9.50, $P < 0.0001$), followed by *P. aeruginosa* with 2.67 times higher odds (OR = 2.67, 95% CI, 1.56–4.59, $P = 0.0010$), and *S. hominis* with 2.26 times higher odds (OR = 2.26, 95% CI, 1.11–4.47, $P = 0.0372$). Although *S. epidermidis* was the second most common microorganism associated with complications, it did not present a significantly higher risk for complications ($P = 0.2250$).

Among patients who experienced complications, baseline clinical characteristics remained consistent across all periods for the following factors: days from symptoms to treatment (24.69 ± 25.98 days, $P = 0.2333$), hypopyon

**TABLE 1.** Patient Demographic and Ocular Characteristics by Group

| Characteristic | Pre-COVID 2019 n | Pre-COVID 2019 % | COVID 2020–2022 n | COVID 2020–2022 % | Post-COVID 2023 n | Post-COVID 2023 % | P All Periods | P Pre vs. COVID | P Pre vs. Post | P COVID vs. Post |
|---|---|---|---|---|---|---|---|---|---|---|
| Patients | 185 | 100 | 558 | 100 | 204 | 100 | | | | |
| Age (yrs) | 50.76 ± 21.18 | | 50.05 ± 19.88 | | 47.98 ± 18.85 | | 0.342 | 0.910 | 0.362 | 0.425 |
| Sex | | | | | | | | | | |
| Male | 92 | 49.7 | 257 | 46.1 | 90 | 44.1 | 0.528 | 0.396 | 0.309 | 0.681 |
| Female | 93 | 50.3 | 301 | 53.9 | 114 | 55.9 | | | | |
| Monthly distribution | | | | | | | | | | |
| January | 17 | 9.2 | 48 | 8.6 | 20 | 9.8 | 0.403 | 0.561 | 0.116 | 0.533 |
| February | 10 | 5.4 | 46 | 8.2 | 22 | 10.8 | | | | |
| March | 13 | 7.0 | 43 | 7.7 | 12 | 5.9 | | | | |
| April | 16 | 8.6 | 48 | 8.6 | 16 | 7.8 | | | | |
| May | 20 | 10.8 | 52 | 9.3 | 24 | 11.8 | | | | |
| June | 22 | 11.9 | 51 | 9.1 | 12 | 5.9 | | | | |
| July | 22 | 11.9 | 44 | 7.9 | 13 | 6.4 | | | | |
| August | 9 | 4.9 | 40 | 7.2 | 23 | 11.3 | | | | |
| September | 16 | 8.6 | 48 | 8.6 | 17 | 8.3 | | | | |
| October | 12 | 6.5 | 41 | 7.3 | 16 | 7.8 | | | | |
| November | 11 | 5.9 | 55 | 9.9 | 14 | 6.9 | | | | |
| December | 17 | 9.2 | 42 | 7.5 | 15 | 7.4 | | | | |
| Season | | | | | | | | | | |
| Winter | 44 | 23.8 | 136 | 24.4 | 57 | 27.9 | 0.717 | 0.492 | 0.608 | 0.744 |
| Spring | 49 | 26.5 | 143 | 25.6 | 52 | 25.5 | | | | |
| Summer | 53 | 28.6 | 135 | 24.2 | 48 | 23.5 | | | | |
| Fall | 39 | 21.1 | 144 | 25.8 | 47 | 23.0 | | | | |
| Ophthalmological history | | | | | | | | | | |
| None | 161 | 87.0 | 477 | 85.5 | 164 | 80.4 | 0.309 | 0.413 | 0.106 | 0.448 |
| Trauma | 8 | 4.3 | 15 | 2.7% | 6 | 2.9 | | | | |
| Bullous keratopathy | 5 | 2.7 | 7 | 1.3 | 3 | 1.5 | | | | |
| Foreign body trauma | 3 | 1.6 | 11 | 2.0 | 9 | 4.4 | | | | |
| Penetrating keratoplasty | 3 | 1.6 | 22 | 3.9 | 9 | 4.4 | | | | |
| Herpetic keratoconjunctivitis | 3 | 1.6 | 13 | 2.3 | 8 | 3.9 | | | | |
| Keratoconus | 1 | 0.5 | 10 | 1.8 | 5 | 2.5 | | | | |
| Chemical burn | 1 | 0.5 | 3 | 0.5 | 0 | 0.0 | | | | |

Data are mean ± SD unless otherwise indicated.

(45.4%, $P$ = 0.7188), contact lens use (13.8%, $P$ = 0.8325), previous corticosteroid use (38.5%, $P$ = 0.7295), and previous antibiotic use (68.5%, $P$ = 0.2606). However, the frequency of purulent discharge significantly increased, rising from 38.5% in the pre-COVID period to 90.5% during COVID and 86.7% post-COVID ($P$ <0.0001). The odds of developing a complication were 1.91 times higher with previous corticosteroid use (OR = 1.91, 95% CI, 1.28–2.85, $P$ = 0.0016) and 1.70 times higher with hypopyon (OR = 1.70, 95% CI, 1.16–2.48, $P$ = 0.0066). Despite the increase in purulent discharge frequency, it was not associated with a significant risk of complications ($P$ = 0.5388), nor was previous antibiotic use ($P$ = 0.2694). On the other hand, contact lens use was associated with a 0.53 times lower odds of developing a complication (OR = 0.53, 95% CI, 0.29–0.93, $P$ = 0.0418) but increased the odds of developing *P. aeruginosa* by 2.94 times (OR = 2.94, 95% CI, 1.67–5.11, $P$ = 0.007). The combined effect of contact lens use and *P. aeruginosa* infection resulted in an overall 1.42 times higher odds of developing a complication (OR = 1.42).

## Microbiological Profiles

Significant findings were observed in microbial keratitis microorganisms across the pre-COVID, COVID, and post-COVID periods. The overall culture positivity rate remained relatively consistent: 73.0% in the pre-COVID period (n = 135), 73.7% during COVID (n = 411), and 78.4% in the post-COVID period (n = 160) ($P$ = 0.350). Among the positive cultures, 37.8% in the pre-COVID period (n = 51), 28.0% during COVID (n = 115), and 13.8% in the post-COVID period (n = 22) had a positive smear confirmed by solid media ($P$ < 0.0001). Bacterial infections were prevalent across all periods, with rates of 90.4% in the pre-COVID period, 90.5% during COVID, and slightly lower at 79.4% in the post-COVID period ($P$ = 0.001). Gram-positive bacteria

**TABLE 2.** Microbial Keratitis Baseline Characteristics by Group

| Characteristic | Pre-COVID 2019 n | Pre-COVID 2019 % | COVID 2020–2022 n | COVID 2020–2022 % | Post-COVID 2023 n | Post-COVID 2023 % | P All Periods | P Pre vs. COVID | P Pre vs. Post | P COVID vs. Post |
|---|---|---|---|---|---|---|---|---|---|---|
| Patients | 185 | 100 | 558 | 100 | 204 | 100 | | | | |
| Days from symptoms to treatment | 12.45 ± 11.60 | | 21.89 ± 46.18 | | 27.36 ± 46.69 | | **0.029** | 0.141 | **0.021** | 0.308 |
| Eye | | | | | | | | | | |
| OD | 42 | 47.2 | 127 | 48.1 | 64 | 52.9 | 0.628 | 0.903 | 0.485 | 0.442 |
| OS | 47 | 52.8 | 137 | 51.9 | 57 | 47.1 | | | | |
| Discharge | | | | | | | | | | |
| No | 49 | 52.1 | 53 | 10.9 | 45 | 22.1 | **<0.0001** | **<0.0001** | **<0.0001** | **0.0003** |
| Yes | 45 | 47.9 | 433 | 89.1 | 159 | 77.9 | | | | |
| Hypopyon | | | | | | | | | | |
| No | 57 | 60.6 | 338 | 66.5 | 124 | 63.9 | 0.496 | 0.288 | 0.605 | 0.534 |
| Yes | 37 | 39.4 | 170 | 33.5 | 70 | 36.1 | | | | |
| Contact lens use | | | | | | | | | | |
| No | 72 | 76.6 | 194 | 83.3 | 36 | 70.6 | 0.081 | 0.162 | 0.433 | **0.048** |
| Yes | 22 | 23.4 | 39 | 16.7 | 15 | 29.4 | | | | |
| Previous corticosteroid use | | | | | | | | | | |
| No | 64 | 68.1 | 352 | 71.7 | 154 | 79.0 | 0.077 | 0.535 | 0.058 | 0.055 |
| Yes | 30 | 31.9 | 139 | 28.3 | 41 | 21.0 | | | | |
| Previous antibiotic use | | | | | | | | | | |
| No | 43 | 45.7 | 166 | 36.1 | 62 | 31.5 | 0.060 | 0.081 | **0.019** | 0.283 |
| Yes | 51 | 54.3 | 294 | 63.9 | 135 | 68.5 | | | | |
| Unknown | 45 | 47.9 | 172 | 60.6 | 62 | 47.0 | **0.002** | **0.003** | 0.413 | **0.013** |
| Single | 30 | 31.9 | 91 | 32.0 | 51 | 38.6 | | | | |
| Multiple | 19 | 20.2 | 21 | 7.4 | 19 | 14.4 | | | | |
| Which antibiotic? | | | | | | | | | | |
| Unknown | 45 | 39.8 | 171 | 55.5 | 62 | 40.8 | **<0.0001** | **0.001** | **0.017** | **<0.0001** |
| Moxifloxacin | 21 | 18.6 | 62 | 20.1 | 42 | 27.6 | | | | |
| Gatifloxacin | 11 | 9.7 | 9 | 2.9 | 1 | 0.7 | | | | |
| Tobramycin | 9 | 8.0 | 24 | 7.8 | 5 | 3.3 | | | | |
| Chloramphenicol | 7 | 6.2 | 9 | 2.9 | 8 | 5.3 | | | | |
| Netilmicin | 7 | 6.2 | 5 | 1.6 | 13 | 8.6 | | | | |
| Ciprofloxacin | 5 | 4.4 | 9 | 2.9 | 13 | 8.6 | | | | |
| Vancomycin | 5 | 4.4 | 7 | 2.3 | 2 | 1.3 | | | | |
| Besifloxacin | 1 | 0.9 | 0 | 0.0 | 2 | 1.3 | | | | |
| Ceftazidime | 1 | 0.9 | 0 | 0.0 | 2 | 1.3 | | | | |
| Neomycin | 1 | 0.9 | 12 | 3.9 | 2 | 1.3 | | | | |

Data are mean ± SD unless otherwise indicated.
Numbers in bold are statistically significant.

predominated throughout, with no significant distribution differences ($P$ = 0.943). *S. epidermidis* was the most frequent species, alongside other notable Gram-positive bacteria like *S. hominis*, *Staphylococcus aureus*, and *Streptococcus pneumoniae*, which showed consistent distribution across the periods. Gram-negative bacterial infections were notably less common post-COVID (9.4%) compared with pre-COVID (22.2%) and COVID (21.4%) ($P$ = 0.002). *P. aeruginosa*, the most common Gram-negative bacterium, had a significantly lower incidence post-COVID (5.0%) compared with pre-COVID (13.3%) and COVID (12.4%) ($P$ = 0.023). Fungal infections increased significantly post-COVID (20.6%) compared with pre-COVID (9.6%) and COVID (9.5%) ($P$ = 0.001). *Fusarium* sp. was the most common fungus, with a significant increase post-COVID (13.1%) compared with pre-COVID (4.4%) and COVID (5.1%) ($P$ = 0.001). Detailed information on microbial microorganisms is provided in Table 4.

Smears correlated with culture results at varying rates across the periods. In the pre-COVID period, 86.8% of smears had Gram stains that matched culture results, and 90.2% had morphology consistent with culture findings. During the COVID period, the correlation was slightly lower, with 60.7% of Gram stains and 84.3% of morphologies matching the culture results. The statistical analysis revealed a significant difference in the Gram stain correlations across the periods ($P$ = 0.024), suggesting a trend of decreasing correlation over time. In the post-COVID period, the correlation further decreased, with 62.5% of Gram stains and 72.7% of morphologies aligning with culture findings. However, the morphology correlation did not show a statistically significant difference ($P$ = 0.165), indicating more consistency in this aspect. None of the medical records reviewed reported smears indicative of Acanthamoeba or Microsporidiosis.

## Antibiotic Resistance

The antibiotic resistance profiles of Gram-positive and Gram-negative bacteria causing microbial keratitis were

**TABLE 3.** Microbial Keratitis Complications by Group

| | Pre-COVID 2019 | | COVID 2020–2022 | | Post-COVID 2023 | | P | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Characteristic** | **n** | **%** | **n** | **%** | **n** | **%** | **All Periods** | **Pre vs. COVID** | **Pre vs. Post** | **COVID vs. Post** |
| Patients | 185 | 100 | 558 | 100 | 204 | 100 | | | | |
| Complications | | | | | | | | | | |
| None | 158 | 85.4 | 489 | 87.6 | 171 | 83.8 | 0.363 | 0.449 | 0.676 | 0.187 |
| Yes | 27 | 14.6 | 69 | 12.4 | 33 | 16.2 | | | | |
| Perforation | 17 | 63.0 | 26 | 37.7 | 13 | 39.4 | 0.146 | **0.035** | 0.101 | >0.9999 |
| Endophthalmitis | 1 | 3.7 | 14 | 20.3 | 6 | 18.2 | | | | |
| Corneal lysis | 9 | 33.3 | 29 | 42.0 | 14 | 42.4 | | | | |
| Need for surgery | 25 | 100.0 | 66 | 100.0 | 33 | 100.0 | | | | |
| Therapeutic penetrating keratoplasty | 18 | 72.0 | 31 | 47.0 | 22 | 66.7 | 0.385 | 0.289 | **0.001** | 0.530 |
| Amniotic membrane transplantation | 2 | 8.0 | 11 | 16.7 | 4 | 12.1 | | | | |
| Conjunctival flap | 2 | 8.0 | 3 | 4.5 | 0 | 0.0 | | | | |
| Tectonic sclerocorneal graft | 2 | 8.0 | 5 | 7.6 | 2 | 6.1 | | | | |
| Evisceration | 1 | 4.0 | 11 | 16.7 | 15.2 | | | | | |
| Cyanoacrylate patch | 0 | 0.0 | 5 | 7.6 | 0 | 0.0 | | | | |

Data are numbers and percentages unless otherwise indicated.
Numbers in bold are statistically significant.

analyzed across 3 periods. Overall, resistance to antibiotics increased slightly: 19.4% pre-COVID, 24.2% during COVID, and 29.5% post-COVID for Gram-positive bacteria ($P < 0.0001$). Betalactamics showed increased resistance: 17.6% pre-COVID, 31.7% during COVID, and 34.0% post-COVID ($P = 0.001$). Penicillins also showed an upward trend in resistance: 25.9% pre-COVID, 39.4% during COVID, and 44.3% post-COVID ($P = 0.010$). Ampicillin had the highest pre-COVID resistance at 3.7%, rising to 19.8% during COVID and 49.0% post-COVID ($P < 0.0001$). Glycopeptide resistance, particularly vancomycin, increased: 1.1% pre-COVID, 13.1% during COVID, and 21.0% post-COVID ($P < 0.0001$). Protein synthesis inhibitors also increased in resistance: 23.6% pre-COVID, 24.9% during COVID, and notably to 34.2% post-COVID ($P < 0.0001$). Ciprofloxacin resistance rose: 75.6% pre-COVID, 61.6% during COVID, and 55.1% post-COVID ($P = 0.01$) for Gram-positive bacteria. Specific bacteria analysis showed vancomycin as the least resistant antibiotic for *S. epidermidis*, with resistance rates of 2.7%, 8.2%, and 8.3% during pre-COVID, COVID, and post-COVID, respectively, showing no significant change ($P = 0.506$). This pattern was also observed in other common staphylococci like *S. hominis* and *S. aureus*, where vancomycin resistance remained low without significant differences between groups ($P = 0.691$, $P = 0.727$). Resistance to fluoroquinolones in staphylococci did not significantly change across all periods.

For Gram-negative bacteria, the antibiogram revealed an increase in resistance rates from 25.5% in the pre-COVID period to 29.5% in the COVID period, followed by a slight decrease post-COVID to 16.7% ($P = 0.007$). Resistance to penicillins significantly decreased during the COVID period (50.0%) compared with the pre-COVID period (80.0%), remaining the same post-COVID ($P > 0.999$). Protein synthesis inhibitors showed a decreasing trend from pre-COVID (33.9%) to COVID (19.7%) and post-COVID (23.9%), with a significant decrease during the COVID period ($P = 0.034$). Despite these trends, there were no significant overall differences in Gram-negative bacteria. *P. aeruginosa*, as the most common Gram-negative bacterium, showed a resistance rate of up to 0% to ciprofloxacin without significant differences between groups ($P = 0.764$). Table 5 summarizes the antibiogram of Gram-positive bacteria by group, and Table 6 summarizes the antibiogram of Gram-negative bacteria by group. More details of bacteria-specific antibiograms are provided in Table 7. The most frequent microorganisms in microbial keratitis and their antibiograms reported by group are presented in Table 8.

## DISCUSSION

The COVID-19 pandemic had a significant impact on the National Health Service, leading to a prioritization of care for patients with adverse prognosis because of COVID-19 and other pathological entities. This prioritization resulted in a reduction of ophthalmologic care across the country. Although the literature indicates that conditions such as dry eyes, conjunctivitis, keratitis, and other ocular pathologies may be linked to COVID-19 infection, the overall ocular morbidity associated with this virus is considered minimal.[8–10,15] In addition, increased face mask usage during the pandemic has increased ocular irritation and dryness, a new finding with important implications for eye health and infection prevention.[16–18]

The Instituto de Oftalmología Conde de Valenciana, a reference hospital serving patients nationwide, initially closed its outpatient services during the pandemic's onset but maintained its 24/7 emergency service, ensuring continuous

**TABLE 4.** Microbial Keratitis Microorganisms Reported by Group

| Characteristic | Pre-COVID 2019 n | Pre-COVID 2019 % | COVID 2020–2022 n | COVID 2020–2022 % | Post-COVID 2023 n | Post-COVID 2023 % | P All periods | P Pre vs. COVID | P Pre vs. post | P COVID vs. post |
|---|---|---|---|---|---|---|---|---|---|---|
| Total | 185 | 100 | 558 | 100 | 204 | 100 | | | | |
| Positive culture | 135 | 73.0 | 411 | 73.7 | 160 | 78.4 | 0.350 | 0.848 | 0.236 | 0.188 |
| Bacteria | 122 | 90.4 | 372 | 90.5 | 127 | 79.4 | **0.001** | >0.999 | **0.010** | **0.001** |
| Gram + | 92 | 68.1 | 284 | 69.1 | 112 | 70.0 | 0.943 | 0.836 | 0.800 | 0.920 |
| *Staphylococcus epidermidis* | 38 | 28.1 | 117 | 28.5 | 36 | 22.5 | 0.336 | >0.999 | 0.283 | 0.172 |
| *Staphylococcus hominis* | 9 | 6.7 | 25 | 6.1 | 12 | 7.5 | 0.825 | 0.838 | 0.824 | 0.571 |
| Other CoNS | 11 | 8.1 | 18 | 4.4 | 12 | 7.5 | 0.156 | 0.119 | 0.832 | 0.146 |
| *Staphylococcus aureus* | 4 | 3.0 | 32 | 7.8 | 8 | 5.0 | 0.101 | 0.070 | 0.556 | 0.278 |
| *Streptococcus pneumoniae* | 3 | 2.2 | 5 | 1.2 | 3 | 1.9 | 0.669 | 0.415 | >0.999 | 0.692 |
| *Enterococcus faecalis* | 3 | 2.2 | 7 | 1.7 | 6 | 3.8 | 0.336 | 0.714 | 0.516 | 0.207 |
| Other streptococcus | 5 | 3.7 | 18 | 4.4 | 7 | 4.4 | 0.941 | >0.999 | >0.999 | >0.999 |
| *Granulicatella* sp | 3 | 2.2 | 12 | 2.9 | 3 | 1.9 | 0.749 | >0.999 | >0.999 | 0.575 |
| Kocuria sp | 12 | 8.9 | 30 | 7.3 | 14 | 8.8 | 0.763 | 0.577 | >0.999 | 0.601 |
| Other Gram + | 4 | 3.0 | 20 | 4.9 | 11 | 6.9 | 0.302 | 0.470 | 0.183 | 0.410 |
| Gram − | 30 | 22.2 | 88 | 21.4 | 15 | 9.4 | **0.002** | 0.904 | **0.003** | **0.001** |
| *Pseudomonas aeruginosa* | 18 | 13.3 | 51 | 12.4 | 8 | 5.0 | **0.023** | 0.767 | **0.014** | **0.009** |
| *Moraxella lacunata* | 1 | 0.7 | 5 | 1.2 | 1 | 0.6 | 0.772 | >0.999 | >0.999 | >0.999 |
| *Enterobacter cloacae* | 0 | 0.0 | 1 | 0.2 | 0 | 0.0 | 0.698 | >0.999 | >0.999 | >0.999 |
| *Serratia* sp | 4 | 3.0 | 9 | 2.2 | 1 | 0.6 | 0.321 | 0.535 | 0.183 | 0.297 |
| *Klebsiella oxytoca* | 1 | 0.7 | 3 | 0.7 | 1 | 0.6 | 0.990 | >0.999 | >0.999 | >0.999 |
| *Acinetobacter* sp | 0 | 0.0 | 1 | 0.2 | 1 | 0.6 | 0.586 | >0.999 | >0.999 | 0.482 |
| *Escherichia coli* | 1 | 0.7 | 5 | 1.2 | 0 | 0.0 | 0.360 | >0.999 | 0.458 | 0.329 |
| Other Gram − | 5 | 3.7 | 13 | 3.2 | 3 | 1.9 | 0.616 | 0.782 | 0.476 | 0.575 |
| Fungi | 13 | 9.6 | 39 | 9.5 | 33 | 20.6 | **0.001** | >0.999 | **0.010** | **0.001** |
| *Fusarium* sp | 6 | 4.4 | 21 | 5.1 | 21 | 13.1 | **0.001** | >0.999 | **0.014** | **0.002** |
| *Aspergillus* sp | 4 | 3.0 | 5 | 1.2 | 7 | 4.4 | 0.062 | 0.235 | 0.759 | **0.044** |
| *Candida albicans* | 0 | 0.0 | 5 | 1.2 | 0 | 0.0 | 0.164 | 0.340 | >0.999 | 0.329 |
| Other fungi | 3 | 2.2 | 8 | 1.9 | 5 | 3.1 | 0.696 | 0.738 | 0.731 | 0.368 |
| Negative culture | 50 | 27.0 | 147 | 26.3 | 44 | 21.6 | 0.350 | 0.848 | 0.236 | 0.188 |

Data are number and percentage unless otherwise indicated.
CoNS, coagulase-negative staphylococci.
Numbers in bold are statistically significant.

care for patients with ophthalmologic emergencies, such as microbial keratitis. The pandemic-induced changes, such as enhanced hand hygiene practices, remote work arrangements, and restrictions on nonessential activities, reduced exposure to risk factors like ocular trauma and prolonged contact lens wear. However, the indiscriminate use of antibiotics and antiparasitic drugs such as azithromycin, erythromycin, or ivermectin for COVID-19 prevention or treatment could contribute to antibiotic resistance, necessitating alternative therapies. Our study highlights an increase in resistance to betalactamic antibiotics and aminoglycosides in the post-COVID period, indicating a potential future risk of antibiotic resistance escalation. An important consideration is the impact of informal employment and self-employment in Mexico on individuals breaking COVID-19 confinement measures established by health authorities. These workers often face poor hygiene conditions, a risk factor for microbial keratitis. In addition, introducing infection-prevention protocols and using personal protective equipment have been associated with an increased incidence of dry eye symptoms.[9,16] Personal protective equipment and masks may compromise the tear film through increased evaporation, mechanical processes like ectropion because of mask tape, and altered airflow around the periocular area.

Before COVID-19, patients typically sought medical care shortly after symptom onset. However, during the pandemic, there has been a significant delay, with patients now waiting approximately twice as long after symptoms seem before seeking care.[19] This delay can be attributed to the increased role of pharmacy-based physicians, with 11.7% of the population receiving care in offices attached to pharmacies during the pandemic. In comparison, 18.7% received care

**TABLE 5.** Microbial Keratitis Antibiogram Reported by Group in Gram + Bacteria

| Characteristic | Pre-COVID 2019 Total | Sensitive | | Resistant | | COVID 2020-2022 Total | Sensitive | | Resistant | | Post-COVID 2023 Total | Sensitive | | Resistant | | p All Periods | Pre vs. COVID | Pre vs. Post | COVID vs. Post |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | n | % | n | % | n | n | % | n | % | n | n | % | n | % | | | | |
| Antibiotics | 1125 | 907 | 80.6 | 218 | 19.4 | 3559 | 2697 | 75.8 | 862 | 24.2 | 1375 | 970 | 70.5 | 405 | 29.5 | <0.0001 | 0.001 | <0.0001 | 0.0002 |
| Betalactamics | 176 | 145 | 82.4 | 31 | 17.6 | 394 | 269 | 68.3 | 125 | 31.7 | 159 | 105 | 66.0 | 54 | 34.0 | 0.001 | 0.001 | 0.001 | 0.617 |
| Penicillins | 116 | 86 | 74.1 | 30 | 25.9 | 282 | 171 | 60.6 | 111 | 39.4 | 106 | 59 | 55.7 | 47 | 44.3 | 0.010 | 0.011 | 0.005 | 0.417 |
| Ampicillin | 27 | 26 | 96.3 | 1 | 3.7 | 81 | 65 | 80.2 | 16 | 19.8 | 51 | 26 | 51.0 | 25 | 49.0 | <0.0001 | 0.065 | <0.0001 | 0.001 |
| Oxacillin | 89 | 60 | 67.4 | 29 | 32.6 | 201 | 106 | 52.7 | 95 | 47.3 | 55 | 33 | 60.0 | 22 | 40.0 | 0.061 | 0.021 | 0.376 | 0.363 |
| Cephalosporins | 31 | 30 | 96.8 | 1 | 3.2 | 82 | 69 | 84.1 | 13 | 15.9 | 51 | 44 | 86.3 | 7 | 13.7 | 0.195 | 0.107 | 0.248 | 0.808 |
| Third generation | 31 | 30 | 96.8 | 1 | 3.2 | 82 | 69 | 84.1 | 13 | 15.9 | 50 | 43 | 86.0 | 7 | 14.0 | 0.194 | 0.107 | 0.145 | >0.999 |
| Cefotaxime | 1 | 1 | 100.0 | 0 | 0.0 | 46 | 38 | 82.6 | 8 | 17.4 | 47 | 41 | 87.2 | 6 | 12.8 | 0.752 | >0.999 | >0.999 | 0.575 |
| Ceftriaxone | 29 | 29 | 100.0 | 0 | 0.0 | 34 | 29 | 85.3 | 5 | 14.7 | 2 | 1 | 50.0 | 1 | 50.0 | 0.017 | 0.057 | 0.065 | 0.310 |
| Carbapenems | 29 | 29 | 100.0 | 0 | 0.0 | 30 | 29 | 96.7 | 1 | 3.3 | 2 | 2 | 100.0 | 0 | 0.0 | 0.601 | >0.999 | >0.999 | >0.999 |
| Imipenem | 29 | 29 | 100.0 | 0 | 0.0 | 30 | 29 | 96.7 | 1 | 3.3 | 1 | 1 | 100.0 | 0 | 0.0 | 0.601 | >0.999 | >0.999 | >0.999 |
| Glycopeptides | 89 | 88 | 98.9 | 1 | 1.1 | 259 | 225 | 86.9 | 34 | 13.1 | 105 | 83 | 79.0 | 22 | 21.0 | 0.0002 | 0.0004 | <0.0001 | 0.077 |
| Vancomycin | 89 | 88 | 98.9 | 1 | 1.1 | 259 | 225 | 86.9 | 34 | 13.1 | 105 | 83 | 79.0 | 22 | 21.0 | 0.0002 | 0.0004 | <0.0001 | 0.077 |
| Protein synthesis inhibitors | 368 | 281 | 76.4 | 87 | 23.6 | 1497 | 1124 | 75.1 | 373 | 24.9 | 626 | 412 | 65.8 | 214 | 34.2 | <0.0001 | 0.637 | 0.001 | <0.0001 |
| 30S | 188 | 152 | 80.9 | 36 | 19.1 | 873 | 702 | 80.4 | 171 | 19.6 | 366 | 247 | 67.5 | 119 | 32.5 | <0.0001 | >0.999 | 0.001 | <0.0001 |
| Aminoglycosides | 90 | 67 | 74.4 | 23 | 25.6 | 255 | 188 | 73.7 | 67 | 26.3 | 107 | 56 | 52.3 | 51 | 47.7 | 0.0003 | 0.890 | 0.002 | 0.0002 |
| Gentamicin | 90 | 67 | 74.4 | 23 | 25.6 | 252 | 185 | 73.4 | 67 | 26.6 | 106 | 56 | 52.8 | 50 | 47.2 | 0.0003 | 0.890 | 0.002 | 0.0002 |
| Tetracyclines | 98 | 85 | 86.7 | 13 | 13.3 | 618 | 514 | 83.2 | 104 | 16.8 | 259 | 191 | 73.7 | 68 | 26.3 | 0.002 | 0.462 | 0.010 | 0.002 |
| Doxycycline | 19 | 17 | 89.5 | 2 | 10.5 | 214 | 166 | 77.6 | 48 | 22.4 | 100 | 60 | 60.0 | 40 | 40.0 | 0.001 | 0.380 | 0.017 | 0.002 |
| Tetracycline | 60 | 49 | 81.7 | 11 | 18.3 | 233 | 178 | 76.4 | 55 | 23.6 | 106 | 78 | 73.6 | 28 | 26.4 | 0.499 | 0.489 | 0.260 | 0.588 |
| Tigecycline | 19 | 19 | 100.0 | 0 | 0.0 | 171 | 170 | 99.4 | 1 | 0.6 | 53 | 53 | 100.0 | 0 | 0.0 | 0.810 | >0.999 | >0.999 | >0.999 |
| 50S | 180 | 129 | 71.7 | 51 | 28.3 | 624 | 422 | 67.6 | 202 | 32.4 | 260 | 165 | 63.5 | 95 | 36.5 | 0.189 | 0.318 | 0.080 | 0.242 |
| Linezolid | 60 | 60 | 100.0 | 0 | 0.0 | 173 | 173 | 100.0 | 0 | 0.0 | 55 | 55 | 100.0 | 0 | 0.0 | >0.999 | >0.999 | >0.999 | >0.999 |
| Erythromycin | 62 | 35 | 56.5 | 27 | 43.5 | 233 | 113 | 48.5 | 120 | 51.5 | 102 | 48 | 47.1 | 54 | 52.9 | 0.465 | 0.317 | 0.263 | 0.814 |
| Clindamycin | 58 | 34 | 58.6 | 24 | 41.4 | 218 | 136 | 62.4 | 82 | 37.6 | 103 | 62 | 60.2 | 41 | 39.8 | 0.846 | 0.650 | 0.868 | 0.714 |
| Fluoroquinolones | 212 | 150 | 70.8 | 62 | 29.2 | 617 | 393 | 63.7 | 224 | 36.3 | 220 | 139 | 63.2 | 81 | 36.8 | 0.145 | 0.066 | 0.102 | 0.935 |
| Ciprofloxacin | 90 | 68 | 75.6 | 22 | 24.4 | 263 | 162 | 61.6 | 101 | 38.4 | 107 | 59 | 55.1 | 48 | 44.9 | 0.011 | 0.021 | 0.003 | 0.293 |
| Levofloxacin | 62 | 40 | 64.5 | 22 | 35.5 | 180 | 115 | 63.9 | 65 | 36.1 | 58 | 41 | 70.7 | 17 | 29.3 | 0.632 | >0.999 | 0.560 | 0.427 |
| Moxifloxacin | 60 | 42 | 70.0 | 18 | 30.0 | 174 | 116 | 66.7 | 58 | 33.3 | 55 | 39 | 70.9 | 16 | 29.1 | 0.793 | 0.750 | >0.999 | 0.622 |
| Other antibiotics | | | | | | | | | | | | | | | | | | | |
| Polymyxin | 30 | 13 | 43.3 | 17 | 56.7 | 34 | 16 | 47.1 | 18 | 52.9 | 2 | 1 | 50.0 | 1 | 50.0 | 0.948 | 0.806 | >0.999 | >0.999 |
| Daptomycin | 19 | 19 | 100.0 | 0 | 0.0 | 154 | 153 | 99.4 | 1 | 0.6 | 54 | 54 | 100.0 | 0 | 0.0 | 0.788 | >0.999 | >0.999 | >0.999 |
| Nitrofurantoin | 88 | 87 | 98.9 | 1 | 1.1 | 191 | 180 | 94.2 | 11 | 5.8 | 56 | 55 | 98.2 | 1 | 1.8 | 0.120 | 0.111 | >0.999 | 0.308 |
| Rifampicin | 57 | 57 | 100.0 | 0 | 0.0 | 167 | 165 | 98.8 | 2 | 1.2 | 53 | 53 | 100.0 | 0 | 0.0 | 0.515 | >0.999 | >0.999 | >0.999 |
| Trimethoprim/sulfamethoxazole | 86 | 67 | 77.9 | 19 | 22.1 | 246 | 172 | 69.9 | 74 | 30.1 | 100 | 68 | 68.0 | 32 | 32.0 | 0.703 | 0.611 | 0.451 | 0.803 |

Data are numbers and percentages unless otherwise indicated.

in the Mexican Social Security Institute, 9% in clinics or hospitals of the Ministry of Health, 2.6% in the Institute of Security and Social Services of State Workers (ISSSTE), and 0.6% in other public facilities.[20] Because of mobility restrictions and the limited availability of specialized services, community pharmacies have become essential providers of necessary health care services to the public.[12]

In the monthly frequency distribution, a distinct pattern was observed pre-COVID, indicating a higher prevalence of microbial keratitis during the summer months (May to July) with a resurgence from December to January. These fluctuations are commonly attributed to the influence of temperature and humidity on viral particle stability and transmissibility, along with their impact on the host airway immune response.[21] However, this distribution pattern did not persist during the COVID-19 pandemic. The incidence of keratitis remained relatively consistent across seasons in the COVID group, although Choi et al reported a lower incidence of keratitis during winter.[22] This observation underscores the complex interplay between seasonal factors and disease incidence, which may be further influenced by unique environmental and epidemiological dynamics during the pandemic period.

The incidence of endophthalmitis was relatively low across all groups, but it was highest in the COVID and post-COVID groups. In contrast, Fortes et al[23] reported fewer cases during the first months of the pandemic. Therapeutic penetrating keratoplasty was the most common surgical

**TABLE 6.** Microbial Keratitis Antibiogram Reported by Group in Gram − Bacteria

| | Pre-COVID | | | | | COVID | | | | | Post-COVID | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2019 | | | | | 2020–2022 | | | | | 2023 | | | | | ***P*** | | | |
| | Total | Sensitive | | Resistant | | Total | Sensitive | | Resistant | | Total | Sensitive | | Resistant | | All Periods | Pre vs. COVID | Pre vs. Post | COVID vs. Post |
| **Characteristic** | n | n | % | n | % | n | n | % | n | % | n | n | % | n | % | | | | |
| Antibiotics | 278 | 207 | 74.5 | 71 | 25.5 | 629 | 524 | 83.3 | 105 | 16.7 | 121 | 95 | 78.5 | 26 | 21.5 | **0.007** | **0.003** | 0.447 | 0.239 |
| Betalactamics | 139 | 114 | 82.0 | 25 | 18.0 | 309 | 262 | 84.8 | 47 | 15.2 | 48 | 37 | 77.1 | 11 | 22.9 | 0.370 | 0.488 | 0.525 | 0.206 |
| Penicillins | 15 | 3 | 20.0 | 12 | 80.0 | 18 | 9 | 50.0 | 9 | 50.0 | 6 | 3 | 50.0 | 3 | 50.0 | 0.247 | 0.226 | 0.280 | >0.999 |
| Ampicillin | 12 | 3 | 25.0 | 9 | 75.0 | 13 | 7 | 53.8 | 6 | 46.2 | 5 | 3 | 60.0 | 2 | 40.0 | 0.247 | 0.226 | 0.280 | >0.999 |
| Cephalosporins | 72 | 59 | 81.9 | 13 | 18.1 | 175 | 143 | 81.7 | 32 | 18.3 | 24 | 18 | 75.0 | 6 | 25.0 | 0.719 | >0.999 | 0.555 | 0.415 |
| Third generation | 47 | 36 | 76.6 | 11 | 23.4 | 118 | 94 | 79.7 | 24 | 20.3 | 17 | 13 | 76.5 | 4 | 23.5 | 0.888 | 0.677 | >0.999 | 0.753 |
| Ceftazidime | 27 | 24 | 88.9 | 3 | 11.1 | 67 | 58 | 86.6 | 9 | 13.4 | 7 | 6 | 85.7 | 1 | 14.3 | 0.948 | >0.999 | >0.999 | >0.999 |
| Ceftriaxone | 20 | 12 | 60.0 | 8 | 40.0 | 41 | 27 | 65.9 | 14 | 34.1 | 6 | 3 | 50.0 | 3 | 50.0 | 0.722 | 0.778 | >0.999 | 0.653 |
| Fourth generation | *25* | *23* | *92.0* | *2* | *8.0* | *57* | *49* | *86.0* | *8* | *14.0* | *7* | *5* | *71.4* | *2* | *28.6* | 0.363 | 0.716 | 0.201 | 0.299 |
| Cefepime | 25 | 23 | 92.0 | 2 | 8.0 | 57 | 49 | 86.0 | 8 | 14.0 | 7 | 5 | 71.4 | 2 | 28.6 | 0.363 | 0.716 | 0.201 | 0.299 |
| Carbapenems | 52 | 52 | 100.0 | 0 | 0.0 | 116 | 110 | 94.8 | 6 | 5.2 | 18 | 16 | 88.9 | 2 | 11.1 | 0.101 | 0.179 | 0.063 | 0.292 |
| Imipenem | 27 | 27 | 100.0 | 0 | 0.0 | 57 | 53 | 93.0 | 4 | 7.0 | 9 | 8 | 88.9 | 1 | 11.1 | 0.299 | 0.300 | 0.250 | 0.532 |
| Meropenem | 25 | 25 | 100.0 | 0 | 0.0 | 59 | 57 | 96.6 | 2 | 3.4 | 9 | 8 | 88.9 | 1 | 11.1 | 0.268 | >0.999 | 0.265 | 0.351 |
| Glycopeptides | 3 | 2 | 66.7 | 1 | 33.3 | 6 | 5 | 83.3 | 1 | 16.7 | 1 | 1 | 100.0 | 0 | 0.0 | 0.732 | >0.999 | >0.999 | >0.999 |
| Vancomycin | 3 | 2 | 66.7 | 1 | 33.3 | 6 | 5 | 83.3 | 1 | 16.7 | 1 | 1 | 100.0 | 0 | 0.0 | 0.732 | >0.999 | >0.999 | >0.999 |
| Protein synthesis inhibitors | 59 | 39 | 66.1 | 20 | 33.9 | 203 | 163 | 80.3 | 40 | 19.7 | 46 | 35 | 76.1 | 11 | 23.9 | 0.074 | **0.034** | 0.289 | 0.546 |
| 30S | 59 | 39 | 66.1 | 20 | 33.9 | 195 | 156 | 80.0 | 39 | 20.0 | 42 | 32 | 76.2 | 10 | 23.8 | 0.086 | **0.035** | 0.377 | 0.674 |
| Aminoglycosides | 33 | 32 | 97.0 | 1 | 3.0 | 135 | 130 | 96.3 | 5 | 3.7 | 29 | 27 | 93.1 | 2 | 6.9 | 0.693 | >0.999 | 0.595 | 0.608 |
| Amikacin | 4 | 4 | 100.0 | 0 | 0.0 | 58 | 57 | 98.3 | 1 | 1.7 | 14 | 13 | 92.9 | 1 | 7.1 | 0.495 | >0.999 | >0.999 | 0.353 |
| Gentamicin | 29 | 28 | 96.6 | 1 | 3.4 | 77 | 73 | 94.8 | 4 | 5.2 | 15 | 14 | 93.3 | 1 | 6.7 | 0.886 | >0.999 | >0.999 | >0.999 |
| Tetracyclines | 26 | 7 | 26.9 | 19 | 73.1 | 60 | 26 | 43.3 | 34 | 56.7 | 13 | 5 | 38.5 | 8 | 61.5 | 0.522 | 0.323 | 0.454 | >0.999 |
| Tigecycline | 26 | 7 | 26.9 | 19 | 73.1 | 53 | 21 | 39.6 | 32 | 60.4 | 10 | 4 | 40.0 | 6 | 60.0 | 0.522 | 0.323 | 0.454 | >0.999 |
| Fluoroquinolones | 42 | 39 | 92.9 | 3 | 7.1 | 81 | 77 | 95.1 | 4 | 4.9 | 16 | 16 | 100.0 | 0 | 0.0 | 0.595 | 0.653 | 0.540 | >0.999 |
| Ciprofloxacin | 29 | 27 | 93.1 | 2 | 6.9 | 81 | 77 | 95.1 | 4 | 4.9 | 15 | 15 | 100.0 | 0 | 0.0 | 0.595 | 0.653 | 0.540 | >0.999 |
| Other antibiotics | | | | | | | | | | | | | | | | | | | |
| Polymyxin | 3 | 2 | 66.7 | 1 | 33.3 | 5 | 4 | 80.0 | 1 | 20.0 | 1 | 1 | 100.0 | 0 | 0.0 | 0.773 | >0.999 | >0.999 | >0.999 |
| Nitrofurantoin | 16 | 4 | 25.0 | 12 | 75.0 | 13 | 6 | 46.2 | 7 | 53.8 | 4 | 2 | 50.0 | 2 | 50.0 | 0.416 | 0.270 | 0.549 | >0.999 |
| Trimethoprim/sulfamethoxazole | 16 | 7 | 43.8 | 9 | 56.3 | 12 | 7 | 58.3 | 5 | 41.7 | 4 | 2 | 50.0 | 2 | 50.0 | 0.703 | 0.611 | 0.451 | 0.803 |

Data are numbers and percentages unless otherwise indicated.

intervention during the 3 periods. Evisceration was more common during the COVID and post-COVID periods compared with the pre-COVID period. This increased incidence is likely attributable to delayed medical consultations resulting from isolation measures or perhaps a shift in the culture of seeking medical attention.[24]

The culture development of samples from microbial keratitis cases remained relatively consistent across the groups. Bacterial infections were the most common throughout all periods. *S. epidermidis* emerged as the predominant Gram-positive bacterium, showing similar rates across all groups. Although a decrease in the frequency of *S. epidermidis*-positive cultures was anticipated because of the implementation of hand hygiene during the pandemic, no significant difference was observed.[25] The decline in Gram-negative bacterial infections, notably *P. aeruginosa*, during the post-COVID period may reflect shifts in patient demographics, health care practices, or environmental factors. However, this contrasts with the observed increase in antibiotic resistance, particularly for betalactamic antibiotics and aminoglycosides. This suggests that although certain pathogens became less common, those that persisted became more challenging to treat.

Overall, there was a general decline in the use of antibiotics from the pre-COVID period to the post-COVID period. This reduction in antibiotic use might be attributed to changes in health care practices, patient behavior, and perhaps heightened awareness of antibiotic stewardship during and after the COVID-19 pandemic. Betalactamic antibiotics showed the lowest resistance in the pre-COVID group, followed by an increase during the COVID and post-COVID periods. This trend suggests growing resistance to these antibiotics over time. Penicillins, specifically, exhibited a notable increase in resistance, from 31.8% pre-COVID to 45.1% post-COVID, with ampicillin and oxacillin showing significant increases as well. Glycopeptides experienced a significant increase in resistance from pre-COVID to post-COVID. The antibiogram revealed elevated resistance to antibiotics, a phenomenon observed globally. Consistent with previous studies, heightened imipenem and vancomycin

**TABLE 7.** Microbial Keratitis Antibiogram Reported in Bacteria by Groups

| | Pre-COVID 2019 | | | | | COVID 2020–2022 | | | | | Post-COVID 2023 | | | | | *P* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Sensitive | | Resistant | | Total | Sensitive | | Resistant | | Total | Sensitive | | Resistant | | All Periods | Pre vs. COVID | Pre vs. Post | COVID vs. Post |
| Characteristic | n | n | % | n | % | n | n | % | n | % | n | n | % | n | % | | | | |
| Gram + | | | | | | | | | | | | | | | | | | | |
| *Staphylococcus epidermidis* | | | | | | | | | | | | | | | | | | | |
| Ampicillin | 2 | 2 | 100.0 | 0 | 0.0 | 4 | 2 | 50.0 | 2 | 50.0 | 4 | 1 | 25.0 | 3 | 75.0 | 0.223 | 0.467 | 0.400 | >0.999 |
| Vancomycin | 37 | 36 | 97.3 | 1 | 2.7 | 110 | 101 | 91.8 | 9 | 8.2 | 36 | 33 | 91.7 | 3 | 8.3 | 0.506 | 0.452 | 0.358 | >0.999 |
| Gentamicin | 37 | 29 | 78.4 | 8 | 21.6 | 110 | 83 | 75.5 | 27 | 24.5 | 36 | 21 | 58.3 | 15 | 41.7 | 0.092 | 0.825 | 0.081 | 0.058 |
| Doxycycline | 10 | 9 | 90.0 | 1 | 10.0 | 107 | 89 | 83.2 | 18 | 16.8 | 36 | 27 | 75.0 | 9 | 25.0 | 0.428 | >0.999 | 0.420 | 0.326 |
| Erythromycin | 34 | 20 | 58.8 | 15 | 44.1 | 109 | 49 | 45.0 | 58 | 53.2 | 36 | 18 | 50.0 | 18 | 50.0 | 0.501 | 0.330 | 0.637 | 0.702 |
| Clindamycin | *35* | 18 | 51.4 | 17 | 48.6 | 108 | 61 | 56.5 | 47 | 43.5 | 36 | 23 | 63.9 | 13 | 36.1 | 0.562 | 0.697 | 0.341 | 0.559 |
| Ciprofloxacin | 37 | 25 | 67.6 | 12 | 32.4 | 110 | 59 | 53.6 | 51 | 46.4 | 36 | 23 | 63.9 | 12 | 33.3 | 0.215 | 0.179 | >0.999 | 0.243 |
| Levofloxacin | 35 | 23 | 65.7 | 12 | 34.3 | 108 | 60 | 55.6 | 48 | 44.4 | 32 | 21 | 65.6 | 11 | 34.4 | 0.416 | 0.329 | >0.999 | 0.415 |
| Moxifloxacin | 35 | 23 | 65.7 | 12 | 34.3 | 107 | 62 | 57.9 | 45 | 42.1 | 32 | 21 | 65.6 | 11 | 34.4 | 0.596 | 0.436 | >0.999 | 0.539 |
| *Staphylococcus hominis* | | | | | | | | | | | | | | | | | | | |
| Vancomycin | 8 | 8 | 100.0 | 0 | 0.0 | 22 | 21 | 95.5 | 1 | 4.5 | 12 | 11 | 91.7 | 1 | 8.3 | 0.691 | >0.999 | >0.999 | >0.999 |
| Gentamicin | 9 | 9 | 100.0 | 0 | 0.0 | 22 | 20 | 90.9 | 2 | 9.1 | 12 | 8 | 66.7 | 4 | 33.3 | 0.059 | >0.999 | 0.104 | 0.154 |
| Doxycycline | 5 | 5 | 100.0 | 0 | 0.0 | 20 | 17 | 85.0 | 3 | 15.0 | 11 | 8 | 72.7 | 3 | 27.3 | 0.381 | >0.999 | 0.509 | 0.638 |
| Erythromycin | 9 | 2 | 22.2 | 7 | 77.8 | 22 | 6 | 27.3 | 16 | 72.7 | 12 | 6 | 50.0 | 6 | 50.0 | 0.304 | >0.999 | 0.367 | 0.266 |
| Clindamycin | 8 | 3 | 37.5 | 5 | 62.5 | 20 | 9 | 45.0 | 11 | 55.0 | 12 | 9 | 75.0 | 3 | 25.0 | 0.165 | >0.999 | 0.168 | 0.147 |
| Ciprofloxacin | 9 | 4 | 44.4 | 5 | 55.6 | 22 | 16 | 72.7 | 6 | 27.3 | 12 | 8 | 66.7 | 4 | 33.3 | 0.322 | 0.218 | 0.396 | 0.714 |
| Levofloxacin | 9 | 4 | 44.4 | 5 | 55.6 | 21 | 15 | 71.4 | 6 | 28.6 | 8 | 6 | 75.0 | 2 | 25.0 | 0.298 | 0.225 | 0.335 | >0.999 |
| Moxifloxacin | 9 | 5 | 55.6 | 4 | 44.4 | 19 | 15 | 78.9 | 4 | 21.1 | 8 | 6 | 75.0 | 2 | 25.0 | 0.426 | 0.372 | 0.620 | >0.999 |
| *Staphylococcus aureus* | | | | | | | | | | | | | | | | | | | |
| Vancomycin | 4 | 4 | 100.0 | 0 | 0.0 | 59 | 56 | 94.9 | 3 | 5.1 | 8 | 8 | 100.0 | 0 | 0.0 | 0.727 | >0.999 | >0.999 | >0.999 |
| Gentamicin | 4 | 4 | 100.0 | 0 | 0.0 | 60 | 48 | 80.0 | 12 | 20.0 | 7 | 6 | 85.7 | 1 | 14.3 | 0.581 | >0.999 | >0.999 | >0.999 |
| Erythromycin | 4 | 4 | 100.0 | 0 | 0.0 | 61 | 30 | 49.2 | 31 | 50.8 | 8 | 4 | 50.0 | 4 | 50.0 | 0.142 | 0.115 | 0.208 | >0.999 |
| Clindamycin | 4 | 4 | 100.0 | 0 | 0.0 | 57 | 40 | 70.2 | 17 | 29.8 | 8 | 4 | 50.0 | 4 | 50.0 | 0.201 | 0.569 | 0.208 | 0.420 |
| Ciprofloxacin | 4 | 3 | 75.0 | 1 | 25.0 | 63 | 35 | 55.6 | 28 | 44.4 | 8 | 6 | 75.0 | 2 | 25.0 | 0.456 | 0.628 | >0.999 | 0.453 |
| Levofloxacin | 4 | 3 | 75.0 | 1 | 25.0 | 56 | 31 | 55.4 | 25 | 44.6 | 6 | 4 | 66.7 | 2 | 33.3 | 0.666 | 0.626 | >0.999 | 0.689 |
| Moxifloxacin | 4 | 3 | 75.0 | 1 | 25.0 | 55 | 34 | 61.8 | 21 | 38.2 | 6 | 4 | 66.7 | 2 | 33.3 | 0.854 | >0.999 | >0.999 | >0.999 |
| *Kocuria* sp | | | | | | | | | | | | | | | | | | | |
| Ampicillin | 10 | 10 | 100.0 | 0 | 0.0 | 27 | 21 | 77.8 | 6 | 22.2 | 12 | 8 | 66.7 | 4 | 33.3 | 0.146 | 0.162 | 0.096 | 0.693 |
| Vancomycin | 12 | 12 | 100.0 | 0 | 0.0 | 29 | 21 | 72.4 | 8 | 27.6 | 13 | 6 | 46.2 | 7 | 53.8 | **0.011** | 0.079 | **0.005** | 0.164 |
| Gentamicin | 11 | 5 | 45.5 | 6 | 54.5 | 28 | 16 | 57.1 | 12 | 42.9 | 13 | 6 | 46.2 | 7 | 53.8 | 0.718 | 0.723 | >0.999 | 0.737 |
| Ciprofloxacin | 11 | 5 | 45.5 | 6 | 54.5 | 29 | 13 | 44.8 | 16 | 55.2 | 13 | 5 | 38.5 | 8 | 61.5 | 0.918 | >0.999 | >0.999 | 0.748 |
| Gram − | | | | | | | | | | | | | | | | | | | |
| *Pseudomonas aeruginosa* | | | | | | | | | | | | | | | | | | | |
| Ceftriaxone | 8 | 2 | 25.0 | 6 | 75.0 | 14 | 2 | 14.3 | 12 | 85.7 | 4 | 1 | 25.0 | 3 | 75.0 | 0.788 | 0.602 | >0.999 | >0.999 |
| Gentamicin | 18 | 18 | 100.0 | 0 | 0.0 | 44 | 43 | 97.7 | 1 | 2.3 | 8 | 8 | 100.0 | 0 | 0.0 | 0.741 | >0.999 | >0.999 | >0.999 |
| Ciprofloxacin | 18 | 18 | 100.0 | 0 | 0.0 | 47 | 46 | 97.9 | 1 | 2.1 | 7 | 7 | 100.0 | 0 | 0.0 | 0.764 | >0.999 | >0.999 | >0.999 |

Data are numbers and percentages unless otherwise indicated.

resistance was noted during the COVID period. Polymyxin, an antibiotic commonly prescribed by general practitioners, exhibits high bacterial resistance.[26–29]

In settings where clinics or ophthalmologists lack access to microbiological cultures, our study suggests a high likelihood (66%) that the prevalent bacteria are *S. epidermidis*, *Kocuria* sp., *S. hominis*, *P. aeruginosa*, or *S. aureus*. Given this information, empirical antibiotic treatment could initiate using fluoroquinolones like moxifloxacin or levofloxacin, which have resistance rates of 29.1% and 29.3%, respectively, and a high chance (70.9% and 70.7%, respectively) of being successful as initial therapy. Should these antibiotics prove ineffective, a combination of fortified antibiotics should be attempted in the absence of cultures and antibiogram.

Understanding the clinical and microbiological profile of microbial keratitis and its antimicrobial resistance in our

**TABLE 8.** Most Frequent Microbial Keratitis Microorganisms and Antibiogram Reported by Group

| Order | Microorganism | Pre-COVID 2019 n | Pre-COVID 2019 % | Microorganism | COVID 2020-2022 n | COVID 2020-2022 % | Microorganism | Post-COVID 2023 n | Post-COVID 2023 % |
|---|---|---|---|---|---|---|---|---|---|
| 1 | *Staphylococcus epidermidis* | 38 | 28.1 | *Staphylococcus epidermidis* | 117 | 28.5 | *Staphylococcus epidermidis* | 36 | 22.5 |
| 2 | *Pseudomonas aeruginosa* | 18 | 13.3 | *Pseudomonas aeruginosa* | 51 | 12.4 | *Fusarium* sp. | 21 | 13.1 |
| 3 | *Kocuria* sp. | 12 | 8.9 | *Staphylococcus aureus* | 32 | 7.8 | *Kocuria* sp. | 14 | 8.8 |
| 4 | Other CoNS | 11 | 8.1 | *Kocuria* sp. | 30 | 7.3 | *Staphylococcus hominis* | 12 | 7.5 |
| 5 | *Staphylococcus hominis* | 9 | 6.7 | *Staphylococcus hominis* | 25 | 6.1 | Other CoNS | 12 | 7.5 |
| 6 | *Fusarium* sp. | 6 | 4.4 | *Fusarium* sp. | 21 | 5.1 | Other Gram + | 11 | 6.9 |
| 7 | Other *Streptococcus* | 5 | 3.7 | Other Gram + | 20 | 4.9 | *Pseudomonas aeruginosa* | 8 | 5.0 |
| 8 | Other Gram − | 5 | 3.7 | Other CoNS | 18 | 4.4 | *Staphylococcus aureus* | 8 | 5.0 |
| 9 | *Staphylococcus aureus* | 4 | 3.0 | Other *Streptococcus* | 18 | 4.4 | Other *Streptococcus* | 7 | 4.4 |
| 10 | Other Gram + | 4 | 3.0 | Other Gram − | 13 | 3.2 | *Aspergillus* sp | 7 | 4.4 |
| | Total | 112 | 83.0 | Total | 345 | 83.9 | Total | 136 | 85.0 |

| Order | Antibiotic | Sensitive n | Sensitive % | Resistant n | Resistant % | Antibiotic | Sensitive n | Sensitive % | Resistant n | Resistant % | Antibiotic | Sensitive n | Sensitive % | Resistant n | Resistant % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ceftriaxone | 29 | 100 | 0 | 0.0 | Linezolid | 173 | 100 | 0 | 0.0 | Linezolid | 55 | 100 | 0 | 0.0 |
| 2 | Linezolid | 60 | 100 | 0 | 0.0 | Vancomycin | 225 | 86.9 | 34 | 13.1 | Vancomycin | 83 | 79.0 | 22 | 21.0 |
| 3 | Vancomycin | 88 | 98.9 | 1 | 1.1 | Ceftriaxone | 29 | 85.3 | 5 | 14.7 | Moxifloxacin* | 39 | 70.9 | 16 | 29.1 |
| 4 | Ciprofloxacin* | 68 | 75.6 | 22 | 24.4 | Gentamicin* | 185 | 73.4 | 67 | 26.6 | Levofloxacin* | 41 | 70.7 | 17 | 29.3 |
| 5 | Gentamicin* | 67 | 74.4 | 23 | 25.6 | Moxifloxacin* | 116 | 66.7 | 58 | 33.3 | Clindamycin | 62 | 60.2 | 41 | 39.8 |
| 6 | Moxifloxacin * | 42 | 70.0 | 18 | 30.0 | Levofloxacin* | 115 | 63.9 | 65 | 36.1 | Oxacillin* | 33 | 60.0 | 22 | 40.0 |
| 7 | Oxacillin* | 60 | 67.4 | 29 | 32.6 | Clindamycin | 136 | 62.4 | 82 | 37.6 | Ciprofloxacin* | 59 | 55.1 | 48 | 44.9 |
| 8 | Levofloxacin* | 40 | 64.5 | 22 | 35.5 | Ciprofloxacin* | 162 | 61.6 | 101 | 38.4 | Gentamicin* | 56 | 52.8 | 50 | 47.2 |
| 9 | Clindamycin | 34 | 58.6 | 24 | 41.4 | Oxacillin* | 106 | 52.7 | 95 | 47.3 | Ceftriaxone | 1 | 50.0 | 1 | 50.0 |
| 10 | Polymyxin* | 13 | 43.3 | 17 | 56.7 | Polymyxin* | 16 | 47.1 | 18 | 52.9 | Polymyxin* | 1 | 50.0 | 1 | 50.0 |

Data are number and percentage unless otherwise indicated.
*Commercially available as eye drops.
CoNS, coagulase-negative staphylococci.

hospital before and after the COVID-19 pandemic is crucial for making informed treatment decisions. Future research should prioritize key areas to enhance our understanding and management of microbial keratitis. This includes developing and implementing robust antibiotic stewardship programs tailored to ophthalmologic settings, aimed at promoting prudent antibiotic use and mitigating the risk of antibiotic resistance escalation. In addition, exploring novel therapeutic approaches such as phage therapy, immunomodulators, and antimicrobial peptides as adjuncts or alternatives to traditional antibiotics in managing microbial keratitis is essential. Finally, enhancing patient education and awareness campaigns on the significance of early recognition, timely treatment, and adherence to prescribed medications can significantly improve outcomes and reduce complications associated with microbial keratitis.

However, it is important to acknowledge the limitations of our study, primarily because of its retrospective nature and the data being collected at a referral center. These factors may introduce selection bias, as the cases included may not be representative of the general population but rather of the more severe or complex cases typically seen at such specialized centers. This can affect the external validity of the findings, making it challenging to generalize the results to a broader context.

In conclusion, our study provides valuable insights into the evolving landscape of microbial keratitis and its management in the context of the COVID-19 pandemic in Mexico. The pandemic has led to substantial changes in health care practices, patient behavior, and antimicrobial resistance patterns, influencing the clinical and microbiological profiles of microbial keratitis. Our findings emphasize a decline in antibiotic sensitivity, especially for betalactamic antibiotics and fluoroquinolones, signaling a concerning trend of growing resistance. This highlights the critical need for prudent antibiotic use, implementation of antibiotic stewardship programs, and exploration of alternative therapies to effectively address antibiotic resistance.

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