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MAJOR REVIEW

Infections Following Laser in Situ Keratomileusis: An Integration of the Published Literature

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Abstract. Infections occurring after laser in situ keratomileusis (LASIK) surgery are uncommon, but the number of reports have steadily increased in recent years. This systematic, comprehensive review and analysis of the published literature has been performed in order to develop an integrative perspective on these infections. We have stratified the data by potential associations, microbiology, treatment, and the degree of visual loss, using Fisher's exact tests and Student's t-tests for analysis. In this review, we found that Gram-positive bacteria and mycobacterium were the most common causative organisms. Type of postoperative antibiotic and steroid use was not associated with particular infecting organisms or severity of visual loss. Gram-positive infections were more likely to present less than 7 days after LASIK, and they were associated with pain, discharge, epithelial defects, and anterior chamber reactions. Fungal infections were associated with redness and tearing on presentation. Mycobacterial infections were more likely to present 10 or more days after LASIK surgery. Moderate or severe visual reductions in visual acuity occurred in 49.4% of eyes. Severe reductions in visual acuity were significantly more associated with fungal infections. Flap lift and repositioning peformed within 3 days of symptom onset may be associated with better visual outcome. (**Surv Ophthalmol 49**:269–280, 2004. © 2004 Elsevier Inc. All rights reserved.)

Key words. bacterial • complications • infection • keratitis • LASIK

I. Introduction

Nearly 1.3 million laser in situ keratomileusis (LASIK) procedures were performed in the United States during the year 2000. Although LASIK is a relatively safe procedure,[8,14] infection can be a rare but sight-threatening complication. Case reports of infection after LASIK have appeared periodically in the literature. Although limited in scope, a few descriptive reviews that have been published as part of articles reporting new cases recognize the importance of effective management of this potentially serious complication after LASIK.[2,4,17,47,65] However, no methodical, integrative analysis has been performed thus far. Because the frequency of infections after LASIK is low,[12,28,44] an integrative analysis may amplify several clinically relevant parameters and provide a better understanding of the presentation, etiology, and management of these infections.

In this study, we have systematically reviewed all published case reports of infection occurring after LASIK, and examined the associations between the microbiologic profile of the infection, risk factors for infection, presentation symptoms and signs, treatment strategies, and the severity of reduction in visual acuity.

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II. Methods

A. LITERATURE REVIEW

A thorough, multistage, systematic literature search was performed using the online PubMed databases (National Library of Medicine, Bethesda, MD) for the period extending from July 1991 to May 2003, in order to identify all pertinent articles relating to infection after LASIK. In designing this study, we used inputs from previously published integrative reviews.[24,25] The search term "keratomileusis, laser in situ and infection" from the Medical Subject Headings (MeSH) supplement to *Index Medicus* (National Library of Medicine, Bethesda, MD), as well as the keyword searches, "LASIK infection" and "LASIK case series," were used for a broad and sensitive search. In addition, current issues of *Ophthalmology, Archives of Ophthalmology, American Journal of Ophthalmology, Cornea, Journal of Cataract and Refractive Surgery,* and *Journal of Refractive Surgery* were thoroughly examined for any articles that may have been missed by the PubMed search. Abstracts were carefully reviewed to identify case reports, review articles, and case series describing infectious keratitis after LASIK surgery. Diffuse lamellar keratitis and viral keratitis were excluded from our search. Whole copies of these articles were obtained, and the bibliographies were manually searched for additional articles. All articles reporting new case(s) of infections were identified and were included in the study. Articles reporting previously published cases were excluded. An online search of the abstracts from the meetings of the American Society of Cataract and Refractive Surgery (ASCRS) and Association for Research in Vision and Ophthalmology (ARVO) was also performed to identify unpublished abstracts reporting infections after LASIK.

B. DATA ABSTRACTION AND ANALYSIS

Two ophthalmologists performed a systematic, comprehensive review of each identified article. All pertinent data about the characteristics of infection were abstracted into a spreadsheet program (Microsoft Excel 2000, Microsoft Corp., Redmond, WA).

The age, sex, eye affected, previous refractive surgery, and systemic and ocular co-morbidities were recorded. LASIK surgery for each patient was categorized as sequential or simultaneous. For bilateral simultaneous cases, the sequence of surgery and blade changes were documented. The best spectacle corrected visual acuity (BSCVA) and manifest refraction before LASIK were recorded. Perioperative observations such as the presence of epithelial defects or interface debris before the development of infection, the postoperative care offered such as application of bandage contact lens, topical antibiotic instilled, use of steroids, and non-steroidal anti-inflammatory agents (NSAIDs) prescribed were noted.

Precipitants to infection, the presenting symptoms, and the interval between last surgical intervention and the first documentation of clinical signs were noted. The slit-lamp examination findings regarding the infiltrate characteristics, including the size, shape and extent, were recorded. The presence and size of the epithelial defect, the presence of abscess, and the presence and severity of anterior chamber (AC) reaction were noted. The presence of ulcer was defined as an epithelial defect overlying necrotic corneal tissue with associated tissue loss and thinning. Associated findings of epithelial ingrowth and flap separation were noted.

Staining and culture results, time course of antibiotic administration, flap lifting and irrigation, and flap removal, were documented. The worst BSVCA obtained during the course of the infection, and the final BSCVA, were recorded. Indications for and type of keratoplasty were noted. Sequelae of infection, including residual scarring and surface irregularity or astigmatism in those eyes without keratoplasty, were recorded.

In published cases where information was unavailable or missing, we attempted to contact the corresponding author by fax or email for more information. This information was added to the published data for analysis.

LASIK surgeries were further characterized as primary surgeries or reoperations. Reoperations were defined as enhancements, or flap lifts for irrigation or striae management. The time of onset of infection was defined as the interval between the last surgical intervention and the appearance of initial symptoms (1 day = 24 hours). Onset was classified as early if it occurred within 7 days, and late if occurring 10 days or more after the last surgical intervention. Flap separation on presentation was defined as the displacement of the flap from the stromal bed. Flap lift and replacement procedures were categorized as early if they were performed within 3 days of symptom onset, and late if performed 5 or more days afterwards. Organism identification by Gram stain or culture was defined as early if it occurred within 7 days of symptom onset, and late if it occurred after 7 days.

The severity of visual acuity reduction was based on the final visual angle (Table 1). We based the lower limit of the moderate reduction category on the ETDRS criteria for moderate visual loss,[13] defined as a doubling of the initial visual angle. Increases in visual angle less than two times the initial visual angle, or greater than five times the initial visual angle, defined the clinically nonsignificant and severe visual acuity reduction categories, respectively, as follows:

Clinically nonsignificant reduction in visual acuity:

1. No reduction in visual acuity occurred, or
2. Final visual angle was less than two times the initial visual angle, or
3. Final BSCVA was 20/30 or less.

Moderate reduction in visual acuity:

1. Final visual angle greater or equal to two times the initial visual angle, but less than five times, or
2. Final BSCVA of 20/40 to 20/80.

Severe reduction in visual acuity:

1. A loss in visual angle of a magnitude of five or more, or
2. A final BSCVA of 20/100 or worse.

The BSCVA was used as the criteria for inclusion into a particular category only if the pre-infection BSCVA was unavailable. For those eyes requiring keratoplasty, final BSCVA in the analysis was that last noted before the keratoplasty.

To obtain the average Snellen acuity of each defined category of visual loss, we converted the Snellen equivalent BSCVA recorded in all reported cases into visual angle and decimal equivalents.[22] We obtained LogMAR equivalents by taking the negative log of the decimal acuity: LogMAR = −Log (Decimal Acuity). We then averaged the LogMAR equivalents of each visual loss category, and converted the average LogMAR back to decimal acuities: Decimal acuity = antilog (−LogMAR) = $10^{-\text{LogMAR}}$. Cases that were missing final visual acuities were not included in the calculations of average Snellen visual acuity. If the eye required penetrating keratoplasty, but a final acuity was not recorded before PK, the case was classified as severe, but was not included in the averaging of visual acuity.

TABLE 1

Definitions of the Severity of Visual Loss

I. Clinically Non-significant
   A. No visual loss occurred, or
   B. Final visual angle is less than two times the initial visual angle, or
   C. Final BSCVA of 20/30 or better[a]
II. Moderate
   A. Final visual angle greater or equal to two times, but less than five times the initial visual angle, or
   B. Final BSCVA of 20/40 to 20/80[a]
III. Severe
   A. Final visual angle greater or equal to five times the initial visual angle, or
   B. Final BSCVA of 20/100 or worse[a,b]

[a]BSCVA used as the inclusion criteria into the category only when pre-infection BSCVA was unavailable.

[b]BSCVA of eyes undergoing keratoplasty is the final BSCVA noted before the keratoplasty.

All statistical analysis was performed using STATA, version 6.0 (Stata Corp., College Park, TX). Summary statistics were calculated for all variables. Fisher's exact test was used to measure the strength of association between categorical variables. To assess the relationship between dichotomous and continuous variables, a Student's t-test was performed. For statistical purposes, the right eye of all cases of bilateral infection was excluded from all tests of association. However, all eyes were included in all other analyses.

III. Results

A. YIELD OF LITERATURE SEARCH

Fifty-six original manuscripts were identified by our search strategy. Thirty-seven were case reports,[1,3,5,9–12,18,19,21,23,27,29–34,37–39,41,43,48–54,57,58,60,62–64,66] 17 were original articles,[2,4,6,7,15–17,26,35,40,42,44,46,47,56,59,65] and two were letters to the editor.[55,61] A search of the ARVO and ASCRS abstracts yielded three unpublished case reports describing six cases of infection after LASIK (Kang SJ, Kim EK, Seo KY, et al: Two cases of mycobacterial keratitis at the interface after LASIK. ARVO Abstract No. 2675, 2001; Seedor JA, Shapiro DE, Ritterband DC, et al: LASIK Complication Rates. ARVO Abstract No. 2668, 2001; Miller D, Newton J, Alfonso E: Surveillance and infection control standards for refractive surgery centers? ARVO Abstract No. 1679, 2000). However, four reports were very limited in scope, and could not be used in analysis because no details of the infection were reported (Kang SJ, Kim EK, Seo KY, et al: Two cases of mycobacterial keratitis at the interface after LASIK. ARVO Abstract No. 2675, 2001).[59,61,66] One letter to the editor,[61] and five review articles[2,4,7,46,65] did not report new cases, and were excluded. Two other papers were not included in the analysis, because both cases of infection were secondary to trauma sustained several months after surgery.[29,49] One case was linked to a pre-existing internal hordeolum and was not included,[37] and another four cases were excluded because infection occurred more than 1 year from the date of surgery.[26,38,47] It was felt unlikely that such infections were due to the actual LASIK surgery. Forty-two papers and one ARVO abstract satisfied all inclusion criteria, and were analyzed in our study.

B. STUDY CHARACTERISTICS

A total of 103 infections involving 87 patients were described in the 42 articles analyzed. Of all 87 patients, 65 (74.7%) were referrals. Sixteen patients had bilateral infection, and unilateral infection occurred in 71 patients. Forty-one patients were men (48.8%), 43 were women (57.2%), and sex was not specified in two cases (Table 2). The age of patients ranged from 18 to 64, with a mean age of 38.3 ± 12.0 years (data missing for 8 cases). Fifty-seven (57.0%) infections involved the right eye, and 43 (43.0%) involved the left (data missing for 3 eyes). Eighty-seven of 100 (87.0%) infections occurred after primary LASIK, and 13 (13.0%) occurred after reoperations (data missing for 3 eyes).

C. ONSET AND FREQUENCY OF INFECTION

Of the 83 eyes for which information was available, 41 (49.4%) had symptom onset within 7 days of the last refractive procedure. The mean time of presentation in this early onset group was 2.7 ± 4.2 days (range: 0–7 days). Gram-positive bacteria were cultured in 22 (53.7%) of the infections, Candida was found in 5 eyes (12.2%), fungus was isolated in 4 (9.8%), and mycobacterium was found in 3 (7.3%) eyes. Two cases of polymicrobial infection were found. Six (14.6%) eyes were culture negative, and one was not cultured.

Forty-two (50.6%) eyes presented more than 10 days after surgery. The mean time of presentation in this late onset group was 27.4 ± 3.6 days (range: 10–90 days). Twenty-four (57.1%) of the late infections were due to mycobacterium, 9 (21.4%) involved Gram-positives, 8 (19.0%) were due to fungus, 2 (4.8%) were polymicrobial, and 1 (2.4%) was culture negative. Mycobacterial infections were significantly more likely to present 10 or more days after surgery than other organisms ($p < 0.001$), whereas Gram-positive were more likely to present within 7 days ($p = 0.001$). The average final Snellen visual acuity for early onset infections was 20/83, compared to 20/42 for late onset infections ($p = 0.07$).

The frequency of LASIK infection reported in case series varied from 0.02% to 1.5% (Table 3); Seedor JA, Shapiro DE, Ritterband DC, et al: LASIK Complication Rates. ARVO Abstract No. 2668, 2001; Miller D, Newton J, Alfonso E: Surveillance and infection control standards for refractive surgery centers? ARVO Abstract No. 1679, 2000).[12,35,43,44,59] Several large LASIK case series have reported no infectious complications.[20,28,45]

D. CHARACTERISTICS OF INFECTION

Information about specific presenting symptoms was available for 78 of the eyes infected after LASIK. Thirty-eight (48.7%) of the 78 eyes presented with pain, 30 (38.5%) had decreased or blurry vision, 23 (29.5%) had photophobia, 20 (25.6%) presented with irritation, 19 (24.4%) had redness, 7 (9.0%) complained of discharge, and 10 (12.8%) were asymptomatic.

Corneal infiltrate was present in 99 of 103 (96.1%) eyes. Of the eyes without infiltrate, pain, photophobia, and discharge were presenting symptoms. Eleven (11.5%) infiltrates were entirely within the lamellar flap, 69 (72.6%) were found in the interface, 3 (3.2%) were located in the stroma, 6 (6.3%) involved the flap, interface, and stroma, and 6 (6.3%) involved the flap margin and adjacent cornea (data missing for 4 eyes). Twelve of 103 (11.7%) eyes were noted to have ulcers, and 4 (3.9%) had abscesses. Anterior chamber (AC) reactions were documented in 24 (23.3%) eyes, and 37 (35.9%) new-onset epithelial defects were found on initial presentation. Infiltrates were present in all eyes without epithelial defects. Flap separation was noted in 11 (10.7%) eyes, and 6 (5.8%) had epithelial ingrowth on presentation. One case of endophthalmitis was reported. In 12 (13.3%) cases, the lamellar flap melted due to the infection.

Using Fisher's exact test as a test of association, we found that Gram-positive infections were significantly more likely to present with pain ($p = 0.01$) and discharge ($p < 0.001$) than other microorganisms (Table 4). They were also more strongly associated with epithelial defects ($p = 0.004$), flap separation ($p = 0.04$), and anterior chamber reactions ($p = 0.002$). Fungal infections were significantly

TABLE 2

Patient Demographics

Characteristic	Total
Number of Eyes	103
Number of Patients	87
Age (years)	
Mean	38.3 ± 12.0
Range	18–64
Sex	
Female	43 (57.2%)
Male	41 (48.8%)
Type of Surgery	
Primary	87 (87.0%)
Reoperation	13 (13.0%)

TABLE 3

Frequency of Infection after LASIK

	Frequency of infection (number of cases/total)
Miller et al. (ARVO abstract)	1.50% (1/1679)
Pirzada et al.[44]	1.20% (1/83)
Dada et al.[12]	0.20% (1/500)
Stulting et al.[59]	0.19% (2/1062)
Perez-Santonja et al.[43]	0.12% (1/801)
Lin and Maloney[35]	0.10% (1/1019)
Seedor et al. (ARVO Abstract)	0.02% (1/6312)
Gimbel et al.[20]	0 (0/2142)
Kawesch and Kezirian[28]	0 (0/290)
Price et al.[45]	0 (0/1747)

more likely than others to present with redness ($p = 0.05$) and tearing ($p = 0.008$). Mycobacterial infections were not significantly associated with a particular symptom or sign. Decreased vision, photophobia, and irritation were nonspecific symptoms of infection that were not associated with any particular microorganism.

E. MICROBIOLOGICAL PROFILE

Infections caused by a single Gram-positive organism were found in 26 (26.0%) of the 100 eyes that were cultured, and included *S. aureus* (17), *S. pneumoniae* (3), *S. viridans* (2), *S. epidermidis* (2), *Rhodococcus* (1), and *Nocardia* (1) (Table 5). Fungus, such as *Fusarium* (3), *Aspergillus* (2), *Curvularia* (2), and *Scedosporium* (1), was the sole cause of infection in 9 (9.0%) eyes (one was not further classified). Forty-seven (47%) mycobacterial infections due to *M. chelonae* (32), *M. abscessus* (6), *M. szulgai* (5), *M. fortuitum* (2), and *M. mucogenicum* (2) were found. There were four polymicrobial infections. Seven (7.0%) cultures were sterile.

Information on the time of organism identification was available for 72 culture-positive cases. Of these, 28 (38.9%) cases were identified within 7 days of symptom onset, and 44 (61.1%) were identified after 7 days (Table 6). The average final Snellen visual acuity of those cases with early identification was 20/37, compared to 20/83 for the late identification group ($p = 0.05$).

Twenty-three of the 28 organisms identified within 1 week of symptom onset were Gram-positive bacteria; three were mycobacterial. Twenty-five of the 44 late identifications were mycobacterial infections, 8 were fungal, 5 were due to Candida, 3 were Gram-positive infections, and 3 were polymicrobial.

F. RISK FACTORS AND POTENTIAL ASSOCIATIONS OF INFECTION

Two of the patients were HIV-positive; both had bilateral infections after LASIK. No other systemic associations were found. One patient had a history of glaucoma, another had a history of dry eyes, and a history of blepharitis was noted in two other cases. Three (2.9%) eyes had undergone previous radial keratotomy (RK), and 1 (0.9%) had previous RK and photorefractive keratectomy (PRK). No povidone iodine was used in one case because of allergy, and in a bilateral case, no postoperative antibiotics were given due to potential allergy. Breach in aseptic technique was noted in one case of bilateral keratitis in an HIV-positive patient.[23] Epithelial defects during the LASIK procedure, perioperative interface debris, and postoperative bandage contact lens placement each occurred in 3 (2.9%) of the 55 eyes. Postoperatively, there was a history of eye rubbing prior to the onset of infection in one case, and there was one case of an epithelial abrasion caused by a fingernail. Three clusters of mycobacterial infections have been reported from LASIK centers with several possible sources of contamination, including ice used to cool lavage syringes, and the steamer used to clean the microkeratomes.

Information on postoperative antibiotic and steroid use was available for 39 of the 103 eyes. Fluoroquinolones (16/39) and tobramycin (14/39) were

TABLE 4

Symptoms and Signs associated with Specific Microorganisms

Symptoms/Signs	Gram-Positive	Fungus	AFB
Discharge	(7/28)[a]	(0/10)	(0/30)
Redness	(9/28)	(5/10)[a]	(7/30)
Tearing	(4/28)	(4/10)[a]	(5/30)
Pain	(19/28)[a]	(6/10)	(14/30)
Epithelial Defect	(21/29)[a]	(5/8)	(12/27)
Flap Separation	(7/29)[a]	(2/10)	(2/27)
AC Reaction	(16/24)[a]	(4/9)	(5/26)

[a]$p \leq 0.05$ (statistically but not necessarily clinically significant).

TABLE 5

Microbiological Profile

Organism Type	Number of Eyes
Gram-positive bacteria	26
S. aureus	17
S. pneumoniae	3
S. viridans	2
S. epidermidis	2
Nocardia	1
Rhodococcus	1
Fungus[a]	9
Fusarium	3
Aspergillus	2
Curvularia	2
Scedosporium	1
Candida	5
Mycobacterium[b]	47
M. chelonae	32
M. abscessus	6
M. szulgai	5
M. fortuitum	2
M. mucogenicum	2
Other	2
Pseudomonas aeruginosa	1
Acanthamoeba	1
Polymicrobial	4
S. epidermidis and *Fusarium solani*	1
S. epidermidis and *Aspergillus*	1
S. epidermidus/Curvularia/AFB	1
Staphylococcus and *M. chelonae*	1

[a]One case was not further speciated.
[b]An additional three cases were not cultured, of which two were presumed to be mycobacterial by the authors, because it was part of a cluster of cases.

TABLE 6

Outcomes and Features Associated with Early and Late Identification of Microorganisms

Time of Organism Identification	Total Number Eyes	Microbiological Profile (cases/total)	Number of Keratoplasties	Mean Snellen VA
Early (≤7 days)	28	23/28 Gram-positive 3/28 Mycobacterium 1/28 Fungal 1/28 *Pseudomonas*	7	20/37
Late (>7 days)	44	25/44 Mycobacterium 8/44 Fungus 5/44 Yeast 3/44 Polymicrobial 2/44 Gram-positive 1/44 *Acanthamoeba*	7	20/83

most commonly prescribed. Steroids were not prescribed for 13 patients; the other 26 were given fluorometholone (9/39), dexamethasone (10/39), or other steroids (7/39). No statistically significant association between type of postoperative antibiotic or steroid used and infecting organism or severity of visual loss was found.

Of the 71 unilateral cases of infection occurring after primary LASIK, 19 (26.8%) occurred after sequential or unilateral LASIK, 57 (80.3%) cases occurred after bilateral simultaneous treatment, and information was unavailable for the rest. Fifteen of 16 patients with bilateral infection underwent bilateral simultaneous LASIK; the blade was not changed between eyes in 7 cases, and it was changed in 1 case. Information about blade change was unavailable for the other cases. Of these 57 eyes undergoing bilateral simultaneous LASIK, the microkeratome blade was changed between eyes in 1 (1.8%) case, the blade was not changed in 21 (36.8%) cases, and information was missing in 35 (61.4%) (Fig. 1). Of the 21 cases where the blade was not changed, 10 (47.6%) infections each occurred in the first and second eyes treated, and information on treatment sequence in the remaining eye was not available.

G. TREATMENT

Information about the initial treatment regimen after first presentation was known in 97 eyes. Twenty-two infections were initially thought to be sterile: 8 were treated with a combination antibiotic and corticosteroids for 2 or more weeks, 8 were given only steroids for a period of 2 or more weeks, 4 were given steroids for 1 week, and the treatment regimen was unknown in 2 cases. The antibiotic treatment regimen for various organisms is summarized in Table 7.

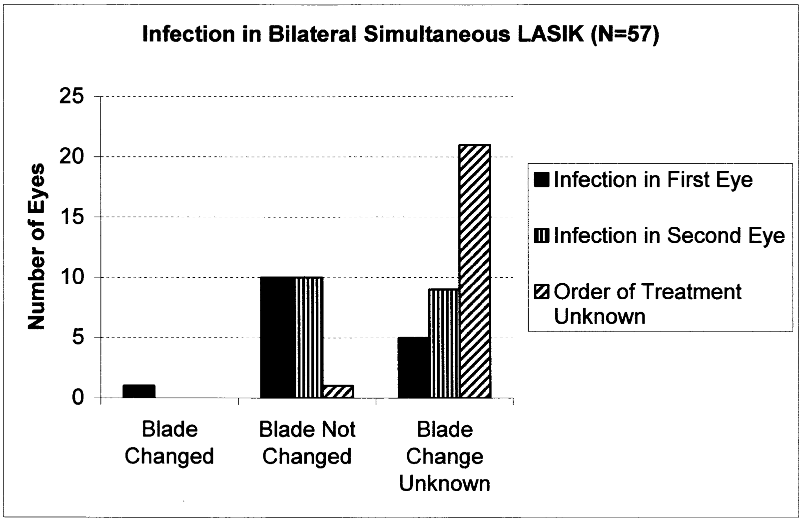

Fig. 1. Infection in bilateral simultaneous LASIK (n = 57).

TABLE 7

Antibiotic Treatment Regimen Used, by Organism

	Fluoro-quinolones	Cephalosporin in Combo	Vancomycin in Combo	Amikacin in Combo	Imipenem in Combo	Natamycin in Combo	Other Combos
Streptococcus	1	3	1				
Staphylococcus	5	6	9		2		
Mycobacterium	13	1		26			2
Fungal						8	4

Note: Combinations of antibiotic therapy comprised several different drug classes.

Systemic antibiotics were used in 35 (45.5%) of the 77 eyes for which information is available. There was no significant relationship between systemic antibiotic use and final visual outcome.

A flap lift for irrigation, scraping, and/or culture, with repositioning of the flap, was performed in 55 of 101 (54.5%) eyes for which information was available. Seventeen of these flaps were later amputated to remove the source of infection or for better antibiotic penetration. In total, 37 (36.6%) flaps were eventually removed: 5 flaps melted and sloughed secondary to infection, 2 flaps were accidentally removed during corneal scraping or flap lift, and 27 flaps were removed therapeutically. Twenty-six (25.7%) flaps were not lifted or removed. Information about flap lift or removal was unavailable in 2 cases. Saline and antibiotic irrigation was performed in 27 (26.7%) eyes, betadine irrigation was used in 2 eyes, and saline solution was used for 1 eye. Information about irrigation was not available for the other eyes.

We categorized flap lift with repositioning as early if it was first performed within 3 days of symptom onset, and late if first flap lift occurred 5 or more days after symptom onset (Table 8). For the 48 eyes for which information about time of flap lift and repositioning was available, 27 (57.4%) were lifted early, and 20 (42.6%) were lifted late. One eye was not categorized because the lift occurred 4 days after symptom presentation.

Twenty-five of the 27 (92.6%) early flap lift cases were associated with infiltrates. Of those, 22 (88.0%) involved the interface, and 1 (4.0%) infiltrate each was entirely within the flap, confined to the stroma, or only on the flap edge. Of the 18 late flap lift cases associated with infiltrates, 2 (8.0%) had infiltrates confined to the flap on presentation, 13 (65.0%) were within the interface, 2 (8.0%) were stromal, and 1 (4%) was on the flap edge. Of the 22 cases without flap lift, 5 (22.7%) had infiltrates that were confined to the flap without involvement of the interface, 4 (18.2%) were located at the flap edge, 8 (36.4%) were within the interface, and 4 (18.2%) were full-thickness infiltrates (information missing for 1 eye). Two full-thickness infiltrates were associated with ulcers, and they were scraped for culture.

Gram-positive infections comprised 16 of the 27 (59.3%) early flap lift and repositioning cases, and mycobacterium were found in 9 (33.3%) eyes. Mycobacterium was implicated in 10 of the 20 (50.0%)

TABLE 8

Microbiological Profile and Outcomes after Early and Late Flap Lifting with Replacement

Category of Flap Lift	Total No. of Eyes	Microbiological Profile (cases/total)	No. of Keratoplasties	Mean Final Snellen VA
Early (≤3 days) Mean: 0.4 ± 0.2 Range: 0–3	27	16/27 Gram-positive (59.3%) 9/27 Mycobacterium (33.3%) 1/27 Negative culture (3.7%) 1/27 Fungal (3.7%)	4/27 (14.8%)	20/41
Late (>5 days) Mean: 20.9 ± 5.8 Range: 5–120	20	10/20 Mycobacterium (50.0%) 4/20 Candida (20%) 2/20 Gram-positive (10%) 2/20 Fungus (10.0%) 1/20 Polymicrobial (5.0%) 1/20 Negative Culture (5.0%)	3/20 (15.0%)	20/68
Not lifted	22	6/22 Gram-positive (27.3%) 4/22 Negative culture (18.2%) 5/22 Fungus (22.7%) 5/22 Mycobacterium (22.7%) 1/22 Polymicrobial (4.5%) 1/22 Candida (4.5%)	4/22 (18.2%)	20/48

late flap lift cases, and 4 involved Candida (20.0%). The mean final Snellen visual acuity was 20/41 in the early flap lift group, and 20/68 in the late flap lift group, a difference that was not statistically significant ($p = 0.14$). The average Snellen visual acuity of the group that did not have flap lift was 20/48. Four keratoplasties were performed in the early flap lift group, and 3 were performed in the late flap lift group.

The lamellar flap was removed in 37 eyes; in 5 eyes (13.4%), the lamellar flap melted secondary to necrosis from the infectious process, flaps in 2 eyes (5.4%) were accidentally removed during flap lift, and 27 flaps (73.0%) were removed therapeutically when the flap was considered the nidus of infection (information about reason for flap removal and final visual acuity was missing for 3 eyes). The mean Snellen acuity of the 34 eyes available was 20/86. Eleven (32.4%) of these eyes had non-significant visual loss, 14 (41.2%) had moderate visual loss, and 6 (17.6%) had severe visual loss. Of the 5 eyes with lamellar flap melt, 1 eventually required a therapeutic penetrating keratoplasty, 1 eye was only able to see hand motion, 2 cases improved to a final BCVA of 20/40, and 1 improved to 20/20. Final visual acuity was 20/25 for one of the eyes with accidental flap removal, but therapeutic PK was needed in the other case. The average BCVA of the 25 eyes with therapeutic flap removal for which information was available was 20/74. No penetrating keratoplasties were required in this group.

Trends in use of systemic antibiotics for infection after LASIK, frequency of flap lift and repositioning, and keratoplasty from 1997–2003 are found in Fig. 2.

H. OUTCOMES AND SEQUELAE

Final visual acuity was available in 97 of the 103 eyes. Clinically nonsignificant reductions in visual acuity occurred in 49 (50.5%) eyes, 24 (24.7%) had moderate reductions, and 24 (24.7%) suffered severe reductions in visual acuity (Table 9). The mean Snellen visual acuity across all groups was 20/58. The average final Snellen visual acuity in the clinically nonsignificant reduction in visual acuity category was 20/24, that for the moderate reduction group was 20/51, and the mean final visual acuity for eyes with severe reductions in visual acuity was 20/519. Seventeen of the 49 (34.7%) infections resulting in nonsignificant reductions in acuity were caused by Gram-positive bacteria, 20 (40.8%) by mycobacterium, 2 (4.1%) were caused by fungus, 2 (4.1%) were polymicrobial, and 3 (6.1%) were culture-negative.

Of the eyes with moderate visual acuity reduction, 7 of 24 (29.2%) infections were due to Gram-positives, mycobacterium was found in 13 (54.2%) eyes, 2 (8.3%) were culture-negative, 1 (4.2%) was fungal, and 1 (4.2%) was not cultured. Gram-positives caused 3 (12.5%) infections in the severe reduction group, 6 (25.0 %) were due to fungus, 8 (33.3%) were mycobacterial, 2 (8.3%) were polymicrobial, 1 (4.2%) eye was culture-negative, and 2 (8.3%) eyes were not cultured.

Of the 31 Gram-positive infections for which information was available, including polymicrobial infections involving Gram-positive organisms, the mean final Snellen VA was 20/45 (Table 10). The mean visual acuity of eyes after fungal infections was 20/297, and after mycobacterial infections the mean acuity was 20/55. Fungus was significantly associated with severe reductions in visual acuity ($p = 0.002$).

Fifteen total keratoplasties, including 2 lamellar keratoplasty and 13 penetrating keratoplasties, were performed (Table 11). Twelve were performed for therapeutic reasons, and 3 were performed for optical reasons (scarring and irregular astigmatism). Seven of the 12 therapeutic keratoplasties were performed for persistent, worsening infiltrate despite 2–12 weeks of intensive medical therapy; 3 keratoplasties were performed after perforation after 3–4 weeks of medical therapy, 1 was performed for corneal thinning and progression of infection after 7 months, and there was no indication available for 1 keratoplasty.

Three (2.9%) of 103 eyes were noted to develop epithelial ingrowth after resolution of infection. Information about scarring and irregular astigmatism was available for 75 eyes, after excluding those with therapeutic penetrating keratoplasty. Fifty-three of the 75 (70.7%) eyes were left with residual scars, and 25 (33.3%) had irregular astigmatism after resolution of infection. One eye eventually required phototherapeutic keratectomy (PTK).

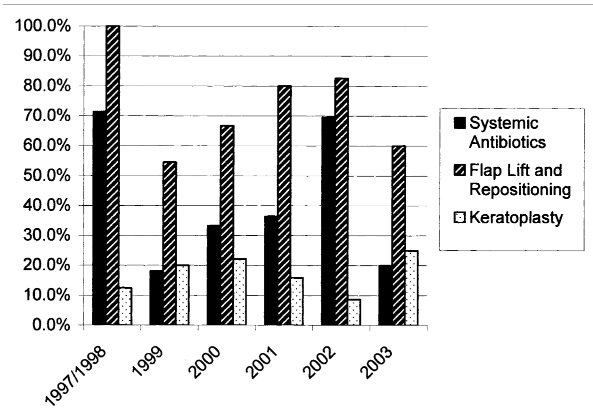

Fig. 2. Variation in treatment of infectious keratitis after LASIK across different years.

TABLE 9

Severity of Visual Loss and Associated Microbiological Profile

Category of Visual Loss	No. of Eyes	Mean Final BSCVA	Gram-Positive	Fungus	AFB	Polymicrobial	Candida
Clinically nonsignificant	49	20/24	17	2	20	2	5
Moderate	24	20/51	7	1	13	0	0
Severe	24	20/519	3	6	8	2	0

Of eyes with negative culture, 3 had nonsignificant loss, 2 had moderate loss, 1 had severe loss. Of the 3 eyes not cultured, 1 had moderate visual loss, 2 had severe loss.

IV. Discussion

Infection after LASIK is a rare complication, though undoubtedly many cases are not reported. In our comprehensive search of the literature, we were only able to find 103 reported cases. In addition, it is difficult to estimate the frequency of infection. Infections are rarely reported in large published case series. The rest appear as case reports, without mention of the number of total LASIK procedures performed, thus making it difficult to estimate frequency or incidence of infection. Reported frequency of infection ranged from zero[20,28,45] to 1.5% (Seedor JA, Shapiro DE, Ritterband DC, et al: LASIK Complication Rates. ARVO Abstract No. 2668, 2001; Miller D, Newton J, Alfonso E: Surveillance and infection control standards for refractive surgery centers? ARVO Abstract No. 1679, 2000)[12,35,43,44,59] in this comprehensive review.

Although prophylactic postoperative antibiotics were prescribed in almost every case for which information was available, with more than 75% using broad-spectrum antibiotics like fluoroquinolones and tobramycin, infections still occurred. Gram-positive and mycobacterial infections were most common in this study. Interestingly, only one Gram-negative infection was reported; however, that will surely change as the number of cases increase.

Sources for infection after LASIK are multiple, and may include the patient's eyelids, the microkeratome blade or other surgical instruments, and postoperative inoculation by the patient. Possible predisposing factors to infection such as HIV status, break in aseptic technique, previous refractive surgery including RK, and change in microkeratome blade were assessed in this study. Three clusters of *Mycobacterium* infection were reported from three separate LASIK centers, with contaminated tap water as a likely source. There may also be some association between bilateral infection and HIV positivity and lack of microkeratome blade change. However, due to the small number of cases in this study, no statistical conclusions can be drawn from this data.

It is possible that epithelial retention in the four patients with previous RK predisposed to infection after LASIK; however, in order to compare risks with the general population, one must ascertain the number of patients with RK who subsequently undergo LASIK. That information is not currently available. It is also unclear whether lack of microkeratome blade change between eyes in simultaneous bilateral LASIK is a risk factor for infection. We found that more infections in this study occurred after no blade change between eyes, but we cannot make definitive conclusions based on this data. Some surgeons operate without changing the blade between eyes; more LASIK performed under these conditions would explain the higher number of infections, independent of whether blade change is a factor. More information is needed to better analyze the data. Unfortunately, many corresponding authors could not provide additional information, due to the referral nature of the cases. Other potential risk factors for infection, such as epithelial defects during surgery, interface debris, and bandage contact lens usage, each occurred in only three eyes. Type of postoperative antibiotic and postoperative steroid use were not related to the type of infecting organism or severity of visual loss in our study.

Although infection after LASIK is a rare complication, our analysis shows that serious consequences such as moderate or severe reductions in visual acuity are not uncommon after infection. It may be difficult in some cases to distinguish between infective infiltrates and diffuse lamellar keratitis. However, we emphasize that a high index of suspicion must be maintained whenever an infiltrate is detected during

TABLE 10

Visual Outcomes of Infections by Specific Microorganisms

	Gram-Positive	Fungus	Mycobacterium	Negative Culture
No. of eyes	31	12	48	7
Mean final Snellen VA	20/45	20/297	20/55	20/38

TABLE 11

Indications for Keratoplasty and Association with Specific Microorganisms

Indication	Gram-Positive	Fungus	AFB	Polymicrobial	Other	Not Cultured
Therapeutic	0	4	4	2	2	0
Optical	2	0	0	0	0	1
Total = 15	2	4	4	2	2	1

the postoperative course of a LASIK primary or enhancement procedure, especially when the infiltrate is not confined to the interface. Twenty-two of our 103 cases of infection were initially presumed to be sterile, and were treated with corticosteroids before infection was suspected. Although corticosteroids have been shown to be effective treatment in cases of diffuse lamellar keratitis occurring after LASIK,[36] such therapy for infectious cases may delay proper treatment, and indeed exacerbate the infection. Indeed, if no organisms are found on initial culture, steroids must be used with caution: many of the initial culture-negative cases treated with corticosteroids in this study were later found to be due to mycobacteria and fungus, which resulted in poor outcomes.

Although symptoms and signs such as pain, discharge, flap separation, epithelial defects, and anterior chamber reaction were strongly associated with Gram-positive infections, and redness and tearing were more common with fungal infections, common symptoms such as pain, photophobia, decreased vision, and irritation were not associated with a particular organism. These may in fact be nonspecific symptoms, but associations with particular infections may be difficult to detect due to the small sample size.

In many cases, corneal infiltrates were not accompanied by an epithelial defect. This is contrary to the dogma that an epithelial defect is necessary for the diagnosis of an infectious infiltrate. In other types of refractive surgery, epithelial defects usually serve as a portal for organisms to establish infections in the stroma. However, in LASIK patients, creating the lamellar flap may introduce organisms into the stroma, and an epithelial defect may not be necessary for infection to occur. Infection should be suspected if infiltrates are seen in LASIK patients, and antibiotic therapy should be commenced before an epithelial defect occurs.

Infections presenting early after LASIK were associated with more severe reductions in visual acuity. Gram-positive bacteria and *Mycobacterium* were the most common infections, with fungal, yeast, polymicrobial, *Acanthamoeba, Pseudomonas* infections, and sterile cultures making up the remainder of cases. However, severe visual acuity reductions were significantly more associated with fungal infections than with Gram-positive or mycobacterial infections. Based on this analysis, it seems likely that in cases of suspected infection, if no response or worsening is observed despite 7 days of broad-spectrum antibiotics, the possibility of a fungal infection should be entertained. Overall, moderate or severe reductions in visual acuity occurred in nearly half of cases, and keratoplasty was performed in almost a sixth of eyes for either therapeutic or optical reasons.

Due to the sequestered nature of infections following LASIK, it may be difficult to rely solely on topical treatment. Antibiotic penetration, especially anti-fungal agents, may not be sufficient to reach infections that lie at the interface. There may be an association between early flap lift and identification of the organism with a better outcome. We recommend lifting and repositioning of the flap early after symptom onset for culture, scraping, and irrigation of the stromal bed, especially when the infiltrate involves the interface. This allows greater antibiotic penetration, and removes the sequestered nidus of infection. Cultures for fungus and mycobacteria should not be neglected. Gram stains, giemsa stains, and KOH preparations at the time of scraping may provide valuable insight into the proper antibiotic therapy before culture results become available. Infiltrates confined to the flap, or those associated with full-thickness ulcers, may not benefit greatly from early flap lift, although scrapings for culture should still be taken. Biopsy may be considered in those circumstances, especially if there is no improvement with medical treatment.

Flap amputation for therapeutic reasons may limit the amount of vision regained after resolution of infection. Almost 60% had moderate or severe visual loss. However, it is also possible that the extent of injury to the cornea due to the infectious process may be limited by flap amputation, and that there may be greater penetration of antimicrobials. In addition, the lamellar flap may be sent for culture, which may help clarify the cause of infection.

A thorough, methodical study that incorporates and synthesizes data from many small case reports is valuable because the combined information reveals associations that may otherwise be unnoticed. Only descriptive observations can be obtained from small case series and case reports. Our systematic integration of the literature allows us to draw conclusions about infection following LASIK that would otherwise be impossible. However, there are some limitations to this method. During the course of our review, we found that case reports and case series were of varying quality. It is possible that certain signs and symptoms of infection, and details of treatment may have been omitted in some case reports. We attempted to contact the corresponding authors directly when important information was missing. However, more than half of the reported cases were referrals from other institutions; thus, information about surgical technique and perioperative findings was often limited. This variability and the small case number may limit the results of this study.

In conclusion, infection after LASIK surgery, although rare, may cause significant visual loss. Infections presenting early after LASIK (<7 days) are commonly caused by Gram-positive organisms whereas *Mycobacterium* is a common causative organism in cases of infection presenting after 10 days. Specific signs and symptoms may be indicative of certain types of infection. Fungal infections should be considered in those cases lacking improvement after early broad-spectrum therapy, as they are associated with severe visual loss. Early lifting of the flap, scrapings for microbiological investigation, and irrigation may lead to a better outcome.

References

1. al-Reefy M: Bacterial keratitis following laser in situ keratomileusis for hyperopia. J Refract Surg 15:216–7, 1999
2. Alio JL, Perez-Santonja JJ, Tervo T: Postoperative inflammation, microbial complications, and wound healing following laser in situ keratomileusis. J Refract Surg 16:523–38, 2000
3. Alvarenga L, Freitas D, Holfing-Lima AL: Infectious post-LASIK crystalline keratopathy caused by nontuberculous mycobacteria. Cornea 21:426–9, 2002
4. Ambrosio R Jr, Wilson SE: Complications of laser in situ keratomileusis: etiology, prevention, and treatment. J Refract Surg 17:350–79, 2001
5. Aras C, Ozdamar A, Bahcecioglu H, Sener B: Corneal interface abscess after excimer laser in situ keratomileusis. J Refract Surg 14:156–7, 1998
6. Chandra NS, Torres MF, Winthrop KL: Cluster of Mycobacterium chelonae keratitis cases following laser in-situ keratomileusis. Am J Ophthalmol 132:819–30, 2001
7. Chang SW, Ashraf FM, Azar DT: Wound healing patterns following perforation sustained during laser in situ keratomileusis. J Formos Med Assoc 99:635–41, 2000
8. Choi RY, Wilson SE: Hyperopic laser in situ keratomileusis: primary and secondary treatments are safe and effective. Cornea 20:388–93, 2001
9. Chung MS, Goldstein MH, Driebe WT Jr, Schwartz B: Fungal keratitis after laser in situ keratomileusis: a case report. Cornea 19:236–7, 2000
10. Chung MS, Goldstein MH, Driebe WT Jr, Schwartz BH: Mycobacterium chelonae keratitis after laser in situ keratomileusis successfully treated with medical therapy and flap removal. Am J Ophthalmol 129:382–4, 2000
11. Cuello OH, Carolin MJ, Reviglio VE: Rhodococcus globerulus keratitis after laser in situ keratomileusis. J Cataract Refract Surg 28:2235–7, 2002
12. Dada T, Sharma N, Dada VK, Vajpayee RB: Pneumococcal keratitis after laser in situ keratomileusis. J Cataract Refract Surg 26:460–1, 2000
13. Early Treatment Diabetic Retinopathy Study Research: ETDRS Report Number 7. Ophthalmology 98:741–56, 1991
14. Farah SG, Azar DT, Gurdal C, Wong J: Laser in situ keratomileusis: literature review of a developing technique. J Cataract Refract Surg 24:989–1006, 1998
15. Freitas D, Alvarenga L, Sampaio J: An outbreak of Mycobacterium chelonae infection after LASIK. Ophthalmology 110: 276–85, 2003
16. Fulcher SFA, Fader RC, Rosa RH, Holmes GP: Delayed-onset mycobacterial keratitis after LASIK. Cornea 21:546–54, 2002
17. Garg P, Bansal AK, Sharma S, Vemuganti GK: Bilateral infectious keratitis after laser in situ keratomileusis: a case report and review of the literature. Ophthalmology 108:121–5, 2001
18. Gelender H, Carter HL, Bowman B: Mycobacterium keratitis after laser in situ keratomileusis. J Refract Surg 16:191–5, 2000
19. Giaconi J, Pham R, Ta CN: Bilateral Mycobaterium abscessus keratitis after laser in situ keratomileusis. J Cataract Refract Surg 28:887–90, 2002
20. Gimbel HV, van Westengrugge JA, Penno EE: Simultaneous bilateral laser in situ keratomileusis: safety and efficacy. Ophthalmology 106:1461–7, 1999
21. Gupta V, Dada T, Vajpayee RB: Polymicrobial keratitis after laser in situ keratomileusis. J Refract Surg 17:147–8, 2001
22. Holladay JT: Proper method for calculating average visual acuity. J Refract Surg 13:388–91, 1997
23. Hovanesian JA, Faktorovich EG, Hoffbauer JD: Bilateral bacterial keratitis after laser in situ keratomileusis in a patient with human immunodeficiency virus infection. Arch Ophthalmol 117:968–70, 1999
24. Jain S, Arora I, Azar DT: Success of monovision in presbyopes: review of the literature and potential applications to refractive surgery. Surv Ophthalmol 40:491–9, 1996
25. Jain S, Azar DT: Ocular Infections after Refractive Keratotomy. J Refract Surg 12:148–55, 1996
26. Karp CL, Tuli SS, Yoo SH: Infectious keratitis after LASIK. Ophthalmology 110:503–10, 2003
27. Karp KO, Hersh PS, Epstein RJ: Delayed keratitis after laser in situ keratomileusis. J Cataract Refract Surg 26:925–8, 2000
28. Kawesch GM, Kezirian GM: Laser in situ keratomileusis for high myopia with the VISX star laser. Ophthalmology 107: 653–61, 2000
29. Kim EK, Lee DH, Lee K, et al: Nocardia keratitis after traumatic detachment of a laser in situ keratomileusis flap. J Refract Surg 16:467–9, 2000
30. Kim HM, Song JS, Han HS, Jung HR: Streptococcal keratitis after myopic laser in situ keratomileusis. Korean J Ophthalmol 12:108–11, 1998
31. Kouyoumdjian GA, Forstot SL, Durairaj VD, Damiano RE: Infectious keratitis after laser refractive surgery. Ophthalmology 108:1266–8, 2001
32. Kuo IC, Margolis TP, Cevallos V, Hwang DG: Aspergillus fumigatus keratitis after laser in situ keratomileusis. Cornea 20:342–4, 2001
33. Lam DS, Leung AT, Wu JT: Culture-negative ulcerative keratitis after laser in situ keratomileusis. J Cataract Refract Surg 25:1004–8, 1999
34. Levartovsky S, Rosenwasser G, Goodman D: Bacterial keratitis following laser in situ keratomileusis. Ophthalmology 108: 321–5, 2001
35. Lin RT, Maloney RK: Flap complications associated with lamellar refractive surgery. Am J Ophthalmol 127:129–36, 1999
36. MacRae SM, Rich LF, Macaluso DC: Treatment of interface keratitis with oral corticosteroids. J Cataract Refract Surg 28:454–61, 2002
37. Maldonado MJ, Juberias JR, Moreno-Montanes J: Extensive corneal epithelial defect associated with internal hordeolum

after uneventful laser in situ keratomileusis. J Cataract Refract Surg 28:1700–2, 2002
38. Moon SJ, Mann PM, Matoba AY: Microsporidial keratoconjunctivitis in a healthy patient with a history of LASIK surgery. Cornea 22:271–2, 2003
39. Mulhern MG, Condon PI, OKeefe M: Endophthalmitis after astigmatic myopic laser in situ keratomileusis. J Cataract Refract Surg 23:948–50, 1997
40. Pache M, Schipper I, Flammer J, Meyer P: Unilateral fungal and mycobacterial keratitis after simultaneous laser in situ keratomileusis. Cornea 22:72–5, 2003
41. Parolini B, Marcon G, Panozzo GA: Central necrotic lamellar inflammation after laser in situ keratomileusis. J Refract Surg 17:110–2, 2001
42. Peng Q, Holzer MP, Kaufer PH: Interface fungal infection after laser in situ keratomileusis presenting as diffuse lamellar keratitis. J Cataract Refract Surg 28:1400–8, 2002
43. Perez-Santonja JJ, Sakla HF, Abad JL: Nocardial keratitis after laser in situ keratomileusis. J Refract Surg 13:314–7, 1997
44. Pirzada WA, Kalaawry H: Laser in situ keratomileusis for myopia of −1 to −3.50 diopters. J Refract Surg 13:S425–26, 1997
45. Price FW, Willes L, Price M: A prospective, randomized comparison of the use versus non-use of topical corticosteroids after laser in situ keratomileusis. Ophthalmology 108:1236–44, 2001
46. Pushker N, Dada T, Sony P: Microbial keratitis after lasik in situ keratomileusis. J Refract Surg 18:280–6, 2002
47. Quiros PA, Chuck RS, Smith RE: Infectious ulcerative keratitis after laser in situ keratomileusis. Arch Ophthalmol 117:1423–7, 1999
48. Ramirez M, Hernandez-Quintela E, Betran F, Naranjo-Tackman R: Pneumococcal keratitis at the flap interface after laser in situ keratomileusis. J Cataract Refract Surg 28:550–2, 2002
49. Read RW, Chuck RS, Rao NA, Smith RE: Traumatic Acremonium atrogriseum keratitis following laser-assisted in situ keratomileusis. Arch Ophthalmol 118:418–21, 2000
50. Reviglio V, Rodriguez ML, Picotti GS: Mycobacterium chelonae keratitis following laser in situ keratomileusis. J Refract Surg 14:357–60, 1998
51. Ritterband D, Kelly J, McNamara T: Delayed-onset multifocal polymicrobial keratitis after laser in situ keratomileusis. J Cataract Refract Surg 28:898–9, 2002
52. Rubinfeld RS, Negvesky GJ: Methicillin-resistant Staphylococcus aureus ulcerative keratitis after laser in situ keratomileusis. J Cataract Refract Surg 27:1523–5, 2001
53. Rudd JC, Moshirfar M: Methicillin-resistant Staphylococcus aureus keratitis after laser in situ keratomileusis. J Cataract Refract Surg 27:471–3, 2001
54. Seo KY, Lee JB, Lee K: Non-tuberculous mycobacterial keratitis at the interface after laser in situ keratomileusis. J Refract Surg 18:81–5, 2002
55. Sharma N, Dada T, Dada VK, Vajpayee RB: Acute hemorrhagic keratoconjunctivitis after LASIK. J Cataract Refract Surg 344–5, 2001
56. Solomon A, Karp CL, Miller D: Mycobacterium interface keratitis after laser in situ keratomileusis. Ophthalmology 108:2201–8, 2001
57. Sridhar MS, Garg P, Bansal AK, Gopinathan U: Aspergillus flavus keratitis after laser in situ keratomileusis. Am J Ophthalmol 129:802–4, 2000
58. Sridhar MS, Garg P, Bansal AK, Sharma S: Fungal keratitis after laser in situ keratomileusis. J Cataract Refract Surg 26: 613–5, 2000
59. Stulting RD, Carr JD, Thompson KP: Complications of laser in situ keratomileusis for the correction of myopia. Ophthalmology 106:13–20, 1999
60. Suresh PS, Rootman DS: Bilateral infectious keratitis after a laser in situ keratomileusis enhancement procedure. J Cataract Refract Surg 28:720–1, 2002
61. Tripathi A: Fungal keratitis after LASIK. J Cataract Refract Surg 26:1433, 2000
62. Verma S, Tuft SJ: Fusarium solani keratitis following LASIK for myopia. Br J Ophthalmol 86:1190–1, 2002
63. Watanabe H, Sato S, Maeda N: Bilateral corneal infection as a complication of laser in situ keratomileusis. Arch Ophthalmol 115:1593–4, 1997
64. Webber SK, Lawless MA, Sutton GL, Rogers CM: Staphylococcal infection under a LASIK flap. Cornea 18:361–5, 1999
65. Wilson SE: LASIK: Management of common complications. Laser in situ keratomileusis. Cornea 17:459–67, 1998
66. Winthrop KL, Steinberg EB, Holmes G: Epidemic and sporadic cases of nontuberculous mycobacterial keratitis associated with laser in situ keratomileusis. Am J Ophthalmol 135: 223–4, 2003

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Outline