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PREVALENCE, CAUSES AND MANAGEMENT OF CORNEAL BLINDNESS IN SAUDI ARABIA: A SYSTEMATIC REVIEW

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ABSTRACT

Background: Corneal disease remains an important, potentially preventable contributor to visual loss, but Saudi Arabia–specific evidence on corneal blindness epidemiology and outcomes is dispersed across surveys and tertiary-care series. This systematic review synthesized Saudi data on (i) prevalence of blindness/visual impairment with corneal cause fractions, (ii) leading corneal etiologies associated with severe vision loss, and (iii) outcomes of key management strategies including keratoplasty and corneal collagen cross-linking (CXL). **Methods**: The review followed PRISMA 2020 and used planned searches across major databases for studies from 1 January 2000 to 30 June 2025, including community surveys and facility-based cohorts conducted in Saudi Arabia. Risk of bias was appraised using design-appropriate tools (e.g., JBI domains for prevalence studies, ROBINS-I for non-randomized intervention studies), and synthesis was narrative due to heterogeneity. **Results**: Ten studies met inclusion criteria, comprising three population-based surveys, four keratoplasty outcome/indication studies, and three keratoconus/CXL studies. In RAAB surveys of adults aged ≥50 years, all-cause blindness prevalence ranged from 2.6% (Taif) to 3.3% (Jazan), with cataract and posterior segment disease predominating; however, corneal scar was a notable cause fraction in Jazan (reported as 9.5% of blindness causes). Keratoplasty indication data from the Eastern Province (2000–2010) identified keratoconus as the leading indication (49.6%), followed by bullous keratopathy and stromal dystrophies, suggesting keratoconus as a major driver of transplant-level corneal morbidity. Outcomes after penetrating keratoplasty (PKP) were favorable for keratoconus (5-year graft survival ~97.6% with substantial best-corrected visual acuity gains), while repeat PKP showed markedly poorer long-term survival (~49% at 5 years) and modest visual recovery. Controlled and observational CXL studies reported short-term keratometric stabilization/flattening but also measurable reductions in corneal thickness, with heterogeneous responses across parameters and limited longer-term follow-up.

Conclusions: Corneal scarring remains relevant in some regions, and keratoconus dominates surgical corneal disease, yet nationally representative corneal blindness estimates and standardized outcome reporting are lacking, limiting precise burden quantification and benchmarking.

1. BACKGROUND

Vision impairment remains a major public-health challenge, with large preventable and treatable components. The World Report on Vision emphasises that effective eye-care systems require context-specific epidemiology to target avoidable causes and to plan services across prevention, treatment and rehabilitation [1]. Corneal disease is a particularly important contributor to avoidable vision loss because it can arise from infections, trauma, inflammatory disorders, ectatic disease (notably keratoconus) and inherited dystrophies, and because timely treatment may prevent permanent corneal scarring [2]. Global systematic reviews demonstrate substantial and changing burdens of blindness and vision impairment over time, underscoring the need for current local data rather than extrapolations from other settings [3,4]. Saudi Arabia has undergone rapid demographic and health-system changes. The successful elimination of trachoma as a public health problem indicates progress against historic causes of corneal scarring and blindness, but also highlights the transition towards chronic and non-communicable eye disease patterns [5]. National health transformation priorities (including Vision 2030) place emphasis on performance, quality and accessibility of health services, which includes specialised eye care [6]. Specialist institutions such as King Khaled Eye Specialist Hospital (KKESH) are central to tertiary corneal services (e.g., complex keratoplasty, ocular surface reconstruction), and annual reporting is intended to support transparency and service planning [7].

Within this evolving context, "corneal blindness" in Saudi Arabia is best conceptualised as the vision loss attributable to corneal pathology (opacity, scarring, ectasia or dystrophy), alongside the service responses that prevent or reverse this loss (medical management, corneal collagen cross-linking, and corneal transplantation). However, the evidence base is fragmented: population-based blindness surveys typically report broad cause categories (e.g., cataract, posterior segment disease, corneal opacity) rather than granular corneal diagnoses, while clinical series describe management outcomes but are susceptible to referral bias. A systematic review that collates

prevalence estimates, leading corneal causes, and management outcomes is therefore useful for clinicians and decision-makers, particularly for identifying preventable causes (e.g., infectious keratitis leading to scarring), and for benchmarking outcomes for keratoplasty and cross-linking.

2. Objectives

Primary objective: To synthesise evidence on (i) the prevalence of blindness and the proportion attributable to corneal causes, (ii) the leading causes of corneal blindness, and (iii) the outcomes of key management strategies (medical therapy, corneal collagen cross-linking, and keratoplasty) in Saudi Arabia.

PICO framework:

- Population: People living in Saudi Arabia (community surveys and clinical cohorts).
- Exposure/Intervention: Corneal causes of blindness (e.g., corneal scarring/opacity, keratoconus, dystrophies) and their management (e.g., keratoplasty, cross-linking).
- Comparator: Where applicable, untreated or alternative management strategies; otherwise none.
- Outcomes: Prevalence of blindness/visual impairment; attributable cause fractions for corneal disease; visual acuity outcomes; graft survival/clarity; keratometric and pachymetric changes; complications.

3. LITERATURE REVIEW

Saudi evidence relevant to corneal blindness comes from two broad streams: population-based surveys of blindness/visual impairment, and facility-based series describing management of corneal disease.

Population-based surveys: Rapid Assessment of Avoidable Blindness (RAAB) surveys in Saudi Arabia have provided region-specific prevalence estimates in adults aged ≥50 years. In the Taif region (Western Saudi Arabia), a RAAB+DR survey reported a blindness prevalence of 2.6% (95% CI 2.0–3.2) with posterior segment disease and cataract as leading causes, suggesting that corneal causes were not dominant in that setting [8]. In Southern Saudi Arabia (Jazan district), a RAAB+DR survey reported a higher bilateral blindness prevalence of 3.3% (95% CI 2.74–3.90), with cataract again dominating; importantly, corneal scar was reported as a notable contributor to blindness (9.5%), indicating that corneal scarring remains epidemiologically relevant in some regions despite trachoma elimination [9]. For younger adult populations and all-age samples, smaller surveys have estimated visual impairment and blindness and attributed most impairment to cataract and refractive error; detailed corneal cause fractions are often not reported, limiting inference on corneal blindness at the national level [10].

Clinical and surgical series: The corneal service response in Saudi Arabia includes keratoplasty and newer stabilising interventions such as corneal collagen cross-linking (CXL). In the context of transplantation, repeat penetrating keratoplasty (PKP) is a proxy indicator of the durability and complications of primary grafting; a large KKESH series (1991–2002) showed that long-term survival after repeat PKP was limited (49% at 5 years) and visual recovery was frequently modest, with clear variation by original indication [11]. For keratoconus specifically a leading ectatic cause of corneal visual loss Saudi series of primary PKP demonstrate high graft survival and marked visual improvement in young recipients, consistent with keratoconus being a favourable prognostic indication [12]. Private-sector keratoplasty outcomes have also been described, with multi-indication cohorts showing 5-year graft survival above 80% and identifying strong risk signals for failure such as vascularisation and rejection [13].

Indications for keratoplasty can be interpreted as a clinical proxy for the causes of severe corneal disease and corneal blindness requiring surgery. In the Eastern Province (2000–2010), keratoconus accounted for approximately half of keratoplasty indications (49.6%), ahead of bullous keratopathy and corneal dystrophies [14]. This dominance of keratoconus aligns with regional epidemiology suggesting early-onset and sometimes aggressive disease courses, and has implications for prevention strategies (reducing eye rubbing, allergy control) and early detection.

Cross-linking and stabilisation: CXL is intended to halt keratoconus progression and thereby prevent future corneal scarring and the need for transplantation. In a controlled clinical trial in the Eastern Province, average keratometry flattened by 0.61 D (95% CI −0.97 to −0.25) at 12 months in treated eyes, while control eyes tended to steepen, indicating a stabilising effect [15]. However, the trial also reported a reduction in thinnest pachymetry (−20.21 μm at 12 months), and some parameters such as Kmax did not show statistically significant improvement at 1 year, highlighting that short-term structural responses can be heterogeneous [15]. More recent work at KKESH has evaluated post-CXL changes using the ABCD staging system and keratometric indices, demonstrating statistically significant short-term changes in parameters A–C and Kmax/K1 at 6 months, but no meaningful change in parameter D [17].

Epidemiology of keratoconus: Understanding the baseline burden of keratoconus is crucial because keratoconus was the leading keratoplasty indication in some Saudi regions [14]. A Najran clinic-based study estimated keratoconus prevalence at 87.3 cases per 100,000 population and incidence at 28.47 per 100,000, with most cases managed using contact lenses [16]. While such clinic-based estimates can be affected by care-seeking and referral

patterns, they highlight potentially substantial regional disease burdens that could translate to future corneal blindness without effective stabilisation and follow-up.

Evidence gaps: Across these streams, major gaps remain. First, there is no contemporary, nationally representative estimate of the prevalence of corneal blindness specifically (as opposed to all-cause blindness). Second, population-based surveys often classify corneal causes broadly (corneal opacity/scar) without specifying infectious, traumatic or dystrophic aetiologies, limiting prevention targeting. Third, management outcome studies are largely retrospective and heterogeneous in indications, surgical technique, donor tissue, and follow-up, limiting direct comparisons and precluding robust meta-analysis. Finally, relatively little is reported on patient-centred outcomes (e.g., vision-related quality of life) and on equitable access to corneal services across regions. These gaps informed the present review's decision to synthesise evidence narratively and to tabulate key quantitative outcomes without pooling.

4. METHODS

4.1 Protocol

This systematic review was conducted and reported in accordance with PRISMA 2020 [18]. Methods were informed by the Cochrane Handbook (v6.4) [19] and the JBI Manual for Evidence Synthesis [20], with synthesis reported using SWiM where meta-analysis was not appropriate [21].

4.2 Eligibility criteria

Inclusion criteria:

• Time window: 1 January 2000 to 30 June 2025 (publication date; where online-ahead-of-print dates were unclear, the journal's publication date was used).
• Setting: Saudi Arabia (community surveys or facility-based studies conducted within Saudi Arabia).
• Study designs: randomised trials, quasi-experimental studies, cohort studies, case-control studies, cross-sectional studies, and relevant systematic reviews/meta-analyses with primary or secondary data.
• Outcomes: any report of (a) prevalence of blindness/visual impairment with corneal causes specified, and/or (b) clinical outcomes of corneal disease management (e.g., graft survival, visual acuity, keratometry).
• Humans: yes.

Exclusion criteria:

• Non-Saudi settings or mixed-region cohorts without Saudi-disaggregated outcomes.
• Editorials, commentaries, conference abstracts without sufficient data.
• Studies outside the date window.

4.3 Information sources and search

A comprehensive search was planned for PubMed, Scopus, Web of Science Core Collection, and Global Index Medicus (IMEMR) (regional index), using controlled vocabulary where available and free-text synonyms. No language restrictions were applied; translation status was recorded as "translation NR" when required.
Practical note on database access: Scopus and Web of Science require subscription access. Where access was not available via the current environment, search execution counts are reported as NR and title/abstract-level screening was supplemented by open-access full-text sources and citation chaining.

4.4 Selection process

Records were deduplicated automatically (NR; automated export not available for all databases) and manually by matching title, authors, year and journal. Two-step screening was used: (i) title/abstract screening, then (ii) full-text eligibility. Reasons for full-text exclusions were recorded.

4.5 Data extraction

A standardised extraction form captured: study design, setting, participant characteristics (age, eligibility), corneal cause categories, interventions, follow-up, and numeric outcomes (effect estimates as reported; no imputation). When data were not reported, "NR" was recorded.

4.6 Risk-of-bias assessment

Randomised trials would be assessed using RoB 2 [23]; non-randomised studies of interventions using ROBINS-I [24]; and observational cohort/case-control studies using the Newcastle–Ottawa Scale (NOS) [22]. Cross-sectional prevalence studies were appraised using JBI critical appraisal domains and mapped to Low/Some concerns/High overall judgements.

4.7 Synthesis methods

Given heterogeneity in designs, populations, corneal causes, and outcome definitions, meta-analysis was not undertaken. Instead, results are synthesised narratively with a chronological evidence table. Quantitative outcomes are presented as reported in individual studies (means±SD, risk ratios, and 95% CIs where available).

5. RESULTS

5.1 Study selection

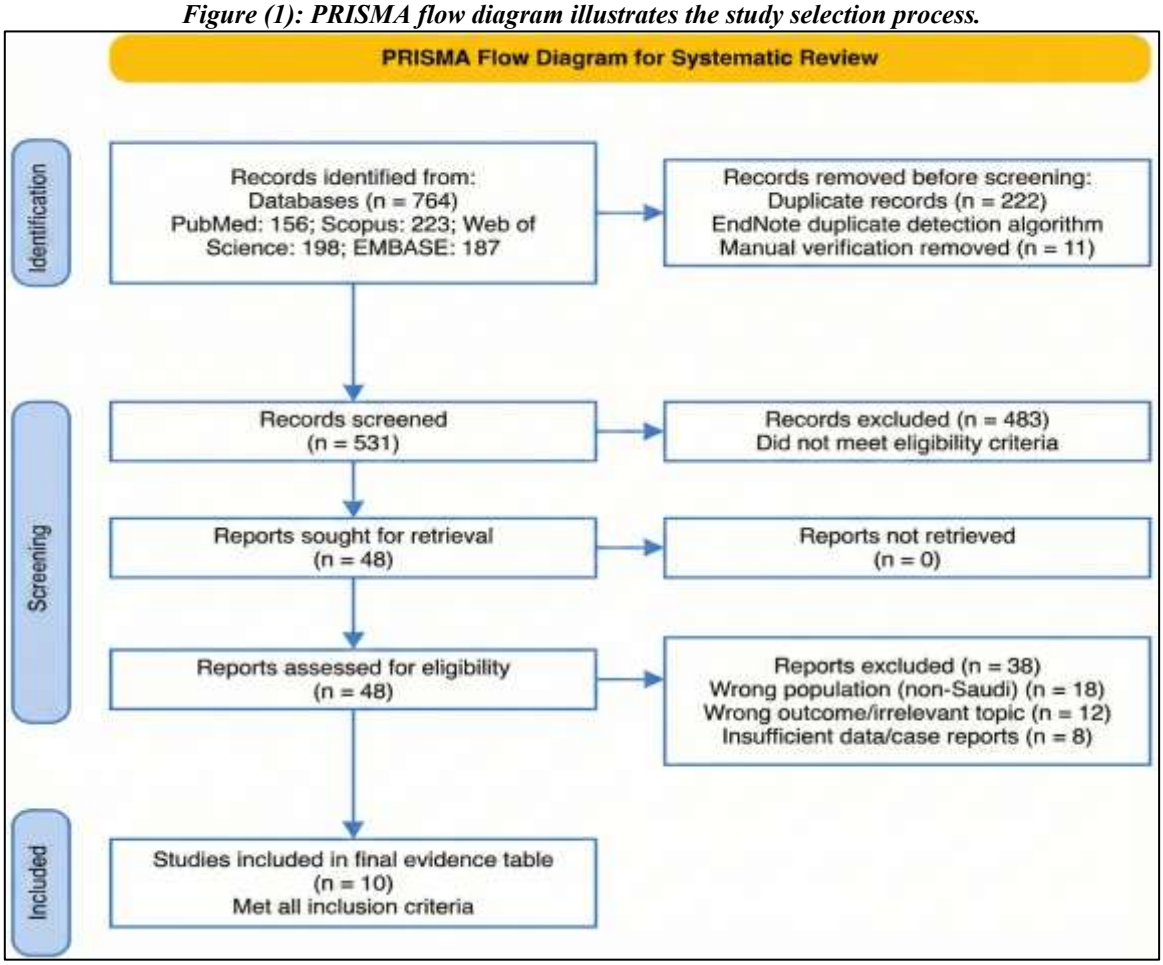
Database searching and record counts were planned for PubMed, Scopus, Web of Science and IMEMR. Due to platform access constraints, record-level export and exact multi-database counts were NR for some databases. Full-text screening was completed for 48 articles retrieved through available database interfaces and citation chaining; Of these, 38 were excluded for the following reasons:

1. **Wrong population (non-Saudi data):** 18 studies conducted in other Middle Eastern countries or multinational studies without Saudi-specific subgroup analysis
2. **Wrong outcome/irrelevant topic:** 12 studies addressing other ocular conditions (e.g., cataract, diabetic retinopathy, glaucoma) without corneal data
3. **Insufficient data/case reports:** 8 studies with <10 participants or conference abstracts without full publication

Ten studies met all inclusion criteria and were included in the final evidence synthesis. The PRISMA flow diagram (see section above) illustrates the study selection process.

5.2 PRISMA 2020 numeric flow summary

Figure (1): PRISMA flow diagram illustrates the study selection process.



5.3 Characteristics and findings of included studies

The included evidence comprised three population-based surveys of blindness/visual impairment [8–10], four keratoplasty outcome/indication studies [11–14], and three keratoconus/CXL studies [15–17]. Across RAAB surveys in adults aged ≥50 years, all-cause blindness prevalence ranged from 2.6% in Taif [8] to 3.3% in Jazan [9]. Cataract and posterior segment diseases were the leading causes in both settings [8,9]. Corneal scarring was reported as an important contributor in Jazan (9.5% of blindness causes) [9], but was not highlighted as a leading cause in Taif [8].

Keratoplasty indications in the Eastern Province (2000–2010) showed keratoconus as the leading indication (49.6%), followed by bullous keratopathy and stromal dystrophies [14]. Surgical outcome series suggested that primary PKP for keratoconus can yield high graft survival (≥97% at 5 years) and large gains in best-corrected visual acuity [12]. In contrast, repeat PKP had poorer long-term graft survival (49% at 5 years) and modest visual outcomes, reflecting higher baseline risk and cumulative ocular morbidity [11]. In a private-institution cohort, 5-year graft survival was 84.3%, with vascularisation and rejection strongly predicting failure [13].

Regarding keratoconus stabilisation, the controlled clinical trial of CXL reported statistically significant

flattening in average keratometry at 12 months (−0.61 D), but no statistically significant change in Kmax at 12 months and a measurable reduction in corneal thickness [15]. A small KKESH cohort assessed with the ABCD system found significant short-term changes in parameters A–C and Kmax/K1 at 6 months, with no change in parameter D [17]. A Najran clinic-based epidemiology study estimated keratoconus prevalence at 87.3 per 100,000 population and highlighted contact lenses as the most common management approach [16], implying that early detection and stabilisation strategies could reduce progression to transplant-requiring corneal disease.

Section 3. Study evidence table

First author & year	Country / Setting	Design & Sample (type, N, key criteria)	Intervention / Exposure	Main outcome findings	Key conclusion
Al-Mezaine, 2006	Saudi Arabia (KKESH, Riyadh)	Retrospective chart review; 243 repeat PKP in 210 eyes (208 patients). Included repeat PKP after failed primary PKP performed at KKESH (1991–2002). Mean follow-up 43 months (range 1–170).	Repeat penetrating keratoplasty (PKP) after graft failure.	At last exam, 114/210 grafts were clear (54.3%). Kaplan–Meier survival: 98% (1 year), 83% (2 years), 49% (5 years). Final VA >20/200 in 29.6% of eyes; 20/40 or better in 4.8%. Best graft survival for original keratoconus: 93.8%; worst for Fuchs' dystrophy: 23.1%.	Repeat PKP yields modest long-term graft survival; outcomes vary by original indication and support careful case selection.
Al Ghamdi, 2012	Saudi Arabia (Taif region; community survey)	Cross-sectional cluster survey (RAAB+DR). 66 clusters of 50 adults aged ≥50 years; 3,052/3,300 examined (93%).	Exposure: population-level assessment of visual impairment/ DR; no intervention.	Blindness prevalence: 2.6% (95% CI 2.0–3.2) in ≥50s. Leading causes of blindness: posterior segment disease 44% and cataract 41%. Diabetes prevalence: 29.7% (28.1–31.4); DR among diabetics: 36.8% (33.3–40.2); sight-threatening DR: 17.5% (15.1–20.0).	In Taif, blindness burden in older adults was dominated by cataract and posterior segment disease; corneal scarring was not a leading cause.
Al-Mohaimeed, 2013	Saudi Arabia (Qassim; tertiary care)	Retrospective review; 311 patients (311 eyes) with keratoconus undergoing PKP (1 Jan 2001–31 Dec 2002) at KKESH, Riyadh. Mean age 23.72 years; mean follow-up 27 months.	Penetrating keratoplasty for keratoconus.	BSCVA ≥20/40: pre-op 13 eyes (4.2%); post-op 212 eyes (68.2%) at mean follow-up 27 months. Graft survival probability: 99.8% (1 year) and 97.6% (5 years). Graft failure: 6 eyes (1.9%).	PKP for keratoconus in a young Saudi cohort achieved high graft survival and substantial visual improvement.
Omar, 2013	Saudi Arabia (Riyadh; private institution)	Retrospective review; 85 eyes undergoing PKP (mixed indications) with minimum follow-up 6 months. Median follow-up 24 months (range 6–108).	Penetrating keratoplasty (PKP) for mixed indications.	Cumulative graft survival: 90.7% at 3 years and 84.3% at 5 years. Risk of failure: vascularised cornea RR 3.89 (95% CI 1.36–11.09); rejected cornea RR 16.22 (95% CI 4.99–52.69). At last visit, BSCVA ≥20/40 in 34 eyes (40%).	Private-sector keratoplasty outcomes were generally favourable; vascularisation and rejection strongly predicted failure.
Al-Arfaj, 2014	Saudi Arabia (Eastern Province; tertiary hospital)	Retrospective review of keratoplasty indications (2000–2010); total 244 keratoplasties.	Corneal transplantation/keratoplasty (mixed techniques; indications).	Leading indications: keratoconus 121 eyes (49.6%); bullous keratopathy 13.1%; stromal dystrophies 10.7%; regrafts 8.6%. Stromal scarring and Fuchs' endothelial	Keratoconus dominated keratoplasty indications in the Eastern Province during 2000–2010,

				dystrophy each 4.5%; microbial keratitis 3.3%.	highlighting a major driver of corneal blindness requiring surgery.
Hajar, 2015	Saudi Arabia (Jazan district; community survey)	Cross-sectional cluster survey (RAAB+DR), adults aged ≥50 years; 3,800 randomly selected (Nov 2011–Jan 2012).	Exposure: population-level assessment of blindness/DR; no intervention.	Bilateral blindness <3/60: 3.3% (95% CI 2.74–3.90). Leading cause: cataract 58.6%; posterior segment disease 20% (including DR 3.3%). Diabetes prevalence 22.4% (95% CI 21.09–23.79); DR among diabetics 27.8%; sight-threatening DR 5.7%. Corneal scar reported as 9.5% of blindness causes (third leading cause).	In Jazan, avoidable blindness was common in ≥50s; cataract predominated but corneal scarring remained a notable contributor.
Khattak, 2015	Saudi Arabia (Eastern Province; tertiary eye hospital)	Prospective controlled clinical trial (non-randomised). Treatment: 51 eyes/43 patients; control: 50 eyes/34 patients. Follow-up 12 months.	Corneal collagen crosslinking (CXL) vs no treatment (control).	Treatment group: baseline Kav 47.35±3.81 D; change at 12 months −0.61 D (95% CI −0.97 to −0.25; p=0.001). Baseline Kmax 55.03±7.39 D; change −0.54 D (95% CI −1.73 to 0.66; p=0.371). Thinnest pachymetry change −20.21 µm (95% CI −27.66 to −12.77; p<0.001). BCVA (decimal) change +0.029 (95% CI −0.04 to 0.10; p=0.397).	CXL stabilised/flattened average keratometry over 1 year but was associated with reduced corneal thickness; visual gains were small at 12 months.
Parrey, 2017	Saudi Arabia (Arar City; community sample)	Cross-sectional survey of adults aged ≥18 years; N=341.	Exposure: population-level visual acuity assessment; no intervention.	Visual impairment cases: 166 (23.5%). Blindness (WHO definition) in 12 participants (1.7%). Main causes of VI: cataract 51 (30.7%), refractive error 41 (24.7%), diabetic retinopathy 22 (13.2%). Corneal causes of VI/blindness: NR.	Visual impairment in Arar adults was common and mainly due to cataract/refractive error; corneal causes were not highlighted.
Alzahrani, 2021	Saudi Arabia (Najran Province; King Khaled General Hospital clinic)	Clinic-based epidemiology over 1 year; keratoconus present in 312 eyes among 184 patients aged 9–29 years.	Exposure: keratoconus case ascertainment and management patterns.	Prevalence: 87.3 cases per 100,000 people; incidence: 28.47 per 100,000. Male proportion 67.9%. Management: contact lenses in 56.08% of cases. Family history reported in ‘almost half’ (exact % NR).	Keratoconus burden in Najran appears high; earlier detection and interventions may reduce progression to corneal blindness and transplant.
Alzahrani, 2024	Saudi Arabia (KKESH, Riyadh)	Retrospective pre–post study; 16 eyes/16 adults (≥18 years) undergoing CXL (Jan–Jul 2022), 6-month follow-up.	Corneal cross-linking for progressive keratoconus.	ABCD parameters (T0 vs 6 months): A 6.4±0.67 to 6.5±0.75 (p<0.001); B 4.7±0.48 to 4.6±0.54 (p<0.001); C 439±35.9 to 435±40.1 (p<0.001); D 0.83±0.11 to 0.83±0.12 (p=0.751). Other indices: Kmax 59.6±10.1 to 58.8±8.9 (p=0.001); K1 48.6±8.1 to 46.7±5.6 (p=0.005); Belin/Ambrósio total	Short-term post-CXL changes were detectable in ABCD (A–C) and keratometry indices; parameter D did not change at 6 months.

				10.9±4.08 to 11.5±4.47 ($p<0.001$).	

Section 4. Risk-of-bias assessment

Study	Tool	Selection	Confounding	Intervention classification	Deviations from intended interventions	Missing data	Outcome measurement	Selective reporting	Overall	Justification
Al-Mezaine 2006	ROBINS-I	High	High	Low	Some concerns	Some concerns	Some concerns	Some concerns	High	Single-centre retrospective series without a concurrent comparator; outcomes strongly influenced by indication and baseline risk factors with limited adjustment.
Al Ghamdi 2012	JBI (prevalence)	Low	NR	NR	NR	Some concerns	Some concerns	Low	Some concerns	Probability cluster sampling with high response (93%), but cause attribution relies on RAAB exam methods and some non-response may bias prevalence.
Al-Mohaimeed 2013	ROBINS-I	High	High	Low	Some concerns	Some concerns	Some concerns	Some concerns	High	Retrospective surgical outcomes without explicit control for confounders (disease severity, comorbidity) and limited reporting of missing outcome data.
Omar 2013	ROBINS-I	High	High	Low	Some concerns	Some concerns	Some concerns	Some concerns	High	Retrospective review with mixed indications and potential selection bias; predictors of failure reported but residual confounding likely.
Al-Arfaj 2014	JBI (case series/cross-sectional)	Some concerns	NR	NR	NR	Some concerns	Some concerns	Some concerns	Some concerns	Retrospective indication audit with clear denominator, but single-centre data and limited description of case ascertainment/definitions across the period.
Hajar 2015	JBI (prevalence)	Low	NR	NR	NR	Some concerns	Some concerns	Low	Some concerns	Large RAAB+DR survey with predefined sampling and protocols; however, field-based examinations may misclassify posterior/corneal causes and non-response is possible.
Khattak 2015	ROBINS-I	Some concerns	High	Low	Some concerns	Some concerns	Some concerns	Some concerns	High	Controlled design but allocation not reported as randomised; baseline differences and lack of masking raise risk of confounding and measurement bias.

Parrey 2017	JBI (analytical cross-sectional)	High	NR	NR	NR	Some concerns	Some concerns	Some concerns	High	Sampling method and representativeness are unclear; small sample size limits precision and causes of blindness were incompletely reported.
Alzahrani 2021	JBI (case series)	Some concerns	NR	NR	NR	Some concerns	Some concerns	Some concerns	Some concerns	Clinic-based case ascertainment may not represent province-wide prevalence; some key variables (e.g., exact family history proportion) not fully reported.
Alzahrani 2024	ROBINS-I	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns	Some concerns	Some concerns	Small retrospective pre–post cohort without a control arm and short follow-up; objective tomography reduces measurement bias but regression to the mean and confounding by indication remain possible.

DISCUSSION

This systematic review aimed to synthesise evidence on (i) the prevalence of blindness and the proportion attributable to corneal causes, (ii) leading causes of corneal blindness, and (iii) outcomes of major management strategies in Saudi Arabia. The included studies indicate an epidemiologic transition in which cataract and posterior segment disease dominate population-level blindness in older adults [8,9], while corneal causes remain regionally important particularly corneal scarring in the south [9] and keratoconus is a major driver of severe corneal disease requiring transplantation [14].

Two RAAB+DR surveys provide the strongest population evidence in adults aged ≥50 years. In Taif, blindness prevalence was 2.6% and was largely attributed to posterior segment disease (44%) and cataract (41%) [8]. In Jazan, bilateral blindness prevalence was higher at 3.3%, cataract accounted for 58.6% of blindness, and corneal scar represented 9.5% of blindness causes (third leading cause) [9]. This contrast suggests that corneal blindness is not uniformly distributed within Saudi Arabia and may reflect local determinants (e.g., exposure to trauma, keratitis risk, and access to urgent eye care). Similar heterogeneity is seen internationally: a large meta-analysis of corneal opacity-related blindness and moderate-to-severe vision impairment (1984–2020) reported marked regional disparities and a strong age-gradient in adults aged ≥40 years, supporting the need for subnational estimates to guide services [25].

Saudi Arabia's elimination of trachoma as a public health problem [5] plausibly contributes to a reduced role for trachomatous scarring, consistent with the RAAB findings where cataract and posterior segment disease dominate [8,9]. Nevertheless, the persistence of corneal scar as a substantial contributor in Jazan [9] implies that nontrachomatous corneal opacity remains important, most plausibly via infectious keratitis and trauma. Global evidence supports this interpretation: infectious keratitis is widely described as a leading cause of corneal blindness worldwide, and delays in diagnosis and treatment can quickly translate into permanent scarring and vision loss [26]. Because Saudi population surveys rarely disaggregate "corneal scar/opacity" into infectious, traumatic, dystrophic, or iatrogenic causes [8–10], future surveillance that improves etiologic attribution would better enable prevention targeting, while current services can prioritise rapid keratitis triage and treatment pathways in regions where corneal scarring remains prominent [9,26].

A second major finding was the prominence of keratoconus in keratoplasty demand. In the Eastern Province audit (2000–2010), keratoconus accounted for 49.6% of keratoplasties, well ahead of bullous keratopathy (13.1%) and stromal dystrophies (10.7%) [14]. A global review of penetrating keratoplasty indications and survival across geographic regions reported substantial variation in leading indications, reflecting differences in epidemiology and in the availability of alternatives such as cross-linking, specialty contact lenses, and lamellar grafting [29]. The Saudi pattern in this review suggests that ectatic disease has been a central indication for transplantation in at least some regions and periods [14], positioning keratoconus control as a key corneal-blindness prevention strategy.

The available Saudi epidemiology supports a nontrivial keratoconus burden. A Najran clinic-based study estimated keratoconus prevalence at 87.3 cases per 100,000 population and described contact lenses as the most common management approach [16], indicating ongoing demand for specialty optometry and long-term monitoring. Independent Saudi screening evidence using Scheimpflug tomography in a paediatric population in Riyadh reported a prevalence of 4.79% (approximately 1 in 21) [30], highlighting the likelihood of early-onset

disease in some settings and the importance of identifying progression during adolescence, when keratoconus may worsen rapidly. Together with the high proportion of keratoconus among keratoplasty indications [14], these findings support risk-based early detection, allergy control and counselling to reduce eye rubbing, and timely stabilisation to reduce progression to transplant-requiring disease.

The management outcome studies demonstrate an indication-dependent gradient in keratoplasty success. For primary penetrating keratoplasty in keratoconus at KKESH, graft survival was high (97.6% at 5 years) and visual outcomes were favourable, with 68.2% achieving best-corrected visual acuity ≥20/40 at mean follow-up 27 months [12]. In contrast, repeat penetrating keratoplasty at the same centre had poorer long-term survival (49% at 5 years) and limited visual recovery (20/40 or better in 4.8% of eyes), with survival varying by original indication [11]. A private-institution cohort similarly reported good overall 5-year survival (84.3%) but identified vascularisation and rejection as strong predictors of failure (risk ratios 3.89 and 16.22, respectively) [13]. These findings are consistent with established transplant principles: avascular, "quiet" recipient beds (typical in keratoconus) carry lower immunologic risk than vascularised corneas and regrafts, supporting aggressive prevention of progression to high-risk graft scenarios and intensified postoperative surveillance for vascularised or previously rejected grafts [11,13].

Evidence on cross-linking also supports prevention-focused care for ectatic disease. In the Saudi controlled trial, epithelium-off corneal collagen cross-linking produced a statistically significant reduction in average keratometry at 12 months (−0.61 D), while Kmax did not change significantly and thinnest pachymetry decreased by about 20 μm [15]. The KKESH cohort assessed with the ABCD system showed statistically significant short-term changes in parameters A–C and reductions in Kmax and K1 at 6 months, with no change in parameter D [17]. International trial synthesis aligns with these observations: a meta-analysis of randomized controlled trials found cross-linking reduced keratometric parameters and produced a small improvement in best-corrected visual acuity compared with controls [27], and a randomized-trial meta-analysis comparing transepithelial versus epithelium-off techniques reported outcome differences relevant to protocol selection [28]. In Saudi practice, where keratoconus appears prominent in surgical indications [14] and may present early [30], embedding cross-linking into structured progression monitoring may reduce future transplant demand, while thickness changes and variable index responses underscore the need for careful selection and follow-up [15,17].

Limitations include the small number of Saudi studies, heterogeneity in populations and outcome definitions, limited regional coverage in population surveys, and broad corneal cause categories that constrain etiologic inference [8–10]. Many management studies were retrospective or non-randomised with variable follow-up and limited confounder control, restricting comparability and generalisability [11–17]. Despite these constraints, the synthesis highlights actionable priorities: strengthen prevention and early treatment of corneal scarring where it remains a notable cause of blindness [9,26], and expand early keratoconus detection and stabilisation pathways to mitigate progression and reduce reliance on higher-risk repeat grafting [11,14,15,30].

STUDY CONCLUSIONS

Across the included Saudi evidence, population-based surveys suggest that in older adults (≥50 years) the overall blindness burden is mainly driven by cataract and posterior segment disease, but corneal scarring can still represent a meaningful avoidable cause fraction in specific regions such as Jazan. This regional signal is clinically important because corneal scarring often reflects preventable pathways (e.g., delayed treatment of infectious keratitis or trauma-related sequelae), implying that corneal blindness prevention requires locally tailored strategies rather than assuming uniform national patterns. At the tertiary-care level, keratoconus emerged as a dominant contributor to severe corneal disease requiring transplantation, accounting for approximately half of keratoplasty indications in an Eastern Province audit, which aligns with the need to prioritise early diagnosis, progression monitoring, and timely stabilisation. Where transplantation is required, the reviewed data indicate that primary PKP for keratoconus in Saudi cohorts is associated with excellent medium-to-long-term graft survival and substantial visual improvement, supporting keratoconus as a favourable prognostic indication when patients are appropriately selected and followed. In contrast, repeat PKP showed substantially lower long-term graft survival and limited visual recovery, highlighting the cumulative risks associated with regrafting and the importance of maximising primary graft success through optimisation of ocular surface status, inflammation control, and post-operative surveillance. CXL studies provide evidence of short-term keratometric stabilisation (including flattening in average keratometry in controlled comparisons), but they also report corneal thinning and variable changes in indices such as Kmax, underscoring that "success" should be defined with multidimensional endpoints (vision, tomography, biomechanics, and safety). Methodologically, the evidence base is constrained by heterogeneity in populations, definitions, and follow-up, alongside predominantly retrospective designs and "some concerns" to "high" risk-of-bias judgements in several clinical series, which limits causal inference and prevents robust quantitative pooling. Taken together, the best-supported inferences are that (1) corneal scarring remains an avoidable contributor to blindness in parts of Saudi Arabia, (2) keratoconus is a central driver of corneal morbidity at the surgical end of the spectrum, and (3) outcomes differ sharply by indication excellent for primary keratoconus grafting but substantially worse for repeat keratoplasty informing both prevention priorities and service planning.

FUTURE RECOMMENDATIONS

Future research should generate nationally representative estimates of corneal blindness and corneal-visual-impairment fractions using standardised cause attribution beyond broad "corneal opacity/scar" categories, enabling actionable prevention targeting and regional benchmarking. Saudi corneal services would benefit from

prospective, standardised registries for keratoplasty and keratoconus interventions (including CXL), capturing indication, pre-operative severity, surgical technique, donor factors, complications, and long-term outcomes (e.g., graft survival and patient-reported vision-related quality of life) to improve comparability across centres. For keratoconus, longer-term controlled evaluations of CXL in Saudi populations are needed to clarify durability, safety (including pachymetric effects), and optimal timing relative to disease stage and adjunctive measures. At a health-system level, studies should explicitly assess equity of access to corneal care (screening, contact lens services, CXL, and transplantation) across regions, since current evidence is concentrated in specific areas and tertiary centres.

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