



## Ocular Trauma Management in Industrial Workers at Primary Care Services: A Systematic Review of Randomized Controlled Trials and Primary Studies

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### ABSTRACT

**Introduction:** Ocular trauma in industrial workers represents a significant global public health burden, with primary care services serving as the first point of contact. However, standardization of management at this level remains variable and incompletely characterized. This systematic review aims to evaluate the effectiveness of ocular trauma management interventions delivered at primary care settings for industrial workers.

**Methods:** A comprehensive literature search adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines. Studies were included if they involved adult industrial workers, reported ocular trauma management interventions at primary or emergency care level, and provided quantifiable outcomes. Risk of bias was assessed using the

Cochrane Risk of Bias Tool 2.0 (RoB 2) for RCTs and the Newcastle-Ottawa Scale (NOS) for observational studies.

**Results:** Eighteen studies comprising 14,327 participants met the inclusion criteria. Eye patching for simple corneal abrasions conferred no significant benefit over no-patch management (RR 0.89, 95% CI 0.79–1.00). Topical NSAIDs (ketorolac 0.5%, diclofenac 0.1%) significantly reduced pain and supplemental analgesic requirements ( $p < 0.002$ ). Immediate and prolonged copious irrigation ( $\geq 1$  liter saline, 30–60 minutes) for chemical eye burns significantly improved visual outcomes. Enhanced educational interventions increased protective eyewear compliance by 16% versus standard education (95% CI 3–29%). Non-use of protective eyewear was documented in 78–89% of injured workers.

**Discussion:** The evidence demonstrates that eye patching lacks benefit for simple corneal abrasions, topical NSAIDs represent the most evidence-supported analgesia, and immediate irrigation is critical for chemical injuries. Protective eyewear compliance remains critically low, with multicomponent educational programs showing the most promise.

**Conclusion:** Key priorities include abandoning routine eye patching, adopting topical NSAID analgesia, implementing immediate chemical irrigation protocols, and sustaining multicomponent programs to improve protective eyewear compliance.

**Keywords:** ocular trauma, industrial workers, primary care, corneal abrasion, protective eyewear

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## INTRODUCTION

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### Background

Ocular trauma constitutes a major global public health problem, with an estimated 55 million eye injuries occurring annually worldwide, of which approximately 1.6 million result in bilateral blindness and 2.3 million in bilateral low vision.<sup>1</sup> Among these, occupational eye injuries (OEIs) represent a disproportionate share, particularly affecting workers in industrial, manufacturing, construction, chemical processing, and agricultural sectors.<sup>2</sup> The International Labour Organization (ILO) estimates that work-related eye injuries account for more than 25% of all occupational injuries globally, with the majority concentrated among male workers aged 20–40 years who represent the productive core of the industrial workforce.<sup>3</sup>

High-risk occupational categories include metalworkers, welders, grinders, miners, construction workers, chemical handlers, and agricultural laborers. Each sector carries distinct injury mechanisms: metalworking produces high-velocity metallic foreign bodies that penetrate the cornea or globe; welding generates intense ultraviolet radiation causing photokeratitis; construction involves blunt trauma and projectile hazards; and chemical industries produce acid and alkali splash injuries that can rapidly progress to severe visual loss if not treated promptly.<sup>4,5</sup>

Primary care services — encompassing general practitioners, occupational health physicians, industrial nurses, emergency departments, and health centers — constitute the critical first point of contact for the majority of work-related eye injuries. The adequacy of initial assessment and management at this level is a key determinant of visual outcome, as evidenced by multiple studies demonstrating that delays in irrigation for chemical injuries, failure to detect retained intraocular foreign bodies, or inappropriate patching can significantly worsen prognosis.<sup>6,7</sup> Despite this, standardized protocols for primary care management of occupational ocular trauma remain incompletely defined, and practice varies substantially across settings, countries, and resource levels.<sup>8</sup>

### Research Gap

Despite a substantial body of literature on the epidemiology of occupational eye injuries and ophthalmological surgical management, several critical gaps persist. First, randomized controlled

trials and high-quality primary studies specifically addressing primary care-level interventions for industrial workers are limited and scattered across diverse settings. Second, few systematic reviews have focused exclusively on the primary care management context, with most existing reviews addressing either epidemiology alone or tertiary surgical outcomes. Third, outcome measures are heterogeneous across studies, complicating comparative analyses. Fourth, there is a paucity of evidence from low- and middle-income countries (LMICs), where industrial growth is most rapid and occupational safety infrastructure most limited. Fifth, the effectiveness of behavioral interventions targeting protective eyewear compliance — a key preventive and primary care outcome — has not been comprehensively synthesized for the industrial worker population specifically.

### **Novelty**

This systematic review is novel in several respects. It is the first review to simultaneously synthesize evidence from RCTs, cluster-randomized trials, and high-quality primary studies across all major categories of ocular trauma management relevant to the primary care setting in industrial workers. It integrates evidence on pharmacological interventions (topical NSAIDs, topical anesthetics, antibiotics), procedural interventions (eye patching, irrigation, foreign body removal), preventive behavioral interventions (protective eyewear programs), and referral/triage protocols. Additionally, this review applies a comprehensive risk of bias framework and presents a structured outcome analysis across ten clinically meaningful outcome domains, offering actionable guidance for primary care practitioners, occupational health policymakers, and industrial safety program designers.

### **Objectives**

The primary objective of this systematic review is to evaluate the effectiveness of ocular trauma management interventions delivered at the primary care level for industrial workers. Secondary objectives include: (1) describing the epidemiological profile of ocular injuries in industrial workers; (2) identifying best-practice management strategies by injury type; (3) assessing the effectiveness of protective eyewear compliance interventions; (4) evaluating referral patterns and criteria; and (5) identifying research gaps to guide future investigation.

## Hypothesis

We hypothesize that: (1) standardized primary care management protocols for occupational ocular trauma are associated with superior visual outcomes compared to non-standardized care; (2) topical NSAID therapy is more effective than eye patching for pain management in corneal abrasion among industrial workers; (3) immediate and sustained chemical irrigation significantly reduces the severity and visual sequelae of occupational chemical eye injuries; and (4) multicomponent educational programs are more effective than single-session education in increasing long-term protective eyewear compliance.

## Benefits of Research

This review provides evidence-based guidance for primary care providers managing occupational eye injuries, informs the development of standardized clinical protocols and occupational health policies, identifies high-priority areas for future RCT investment, supports advocacy for improved workplace eye safety programs, and contributes to the global effort to prevent avoidable work-related visual impairment and blindness.

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## METHODS

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### Study Design

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. All stages of study selection, data extraction, and risk of bias assessment were performed independently by two reviewers, with discrepancies resolved by consensus or consultation with a third reviewer.

### Eligibility Criteria

#### Inclusion Criteria

- Adult workers ( $\geq 18$  years) employed in industrial, manufacturing, construction, mining, chemical, or agricultural sectors
- Sustained work-related ocular injuries (occupational eye injuries)
- Any ocular trauma management intervention delivered at or relevant to primary care settings, including:
  - Eye patching

- Topical pharmaceutical agents (NSAIDs, anesthetics, antibiotics, cycloplegics)
- Ocular irrigation
- Foreign body removal
- Protective eyewear compliance programs
- Triage protocols
- Referral interventions
- Comparison groups including alternative interventions, standard of care, placebo, no treatment, or single versus multicomponent educational approaches
- Primary outcomes: corneal healing rate, visual acuity at follow-up, pain reduction, incidence of ocular complications
- Secondary outcomes: time to return to work, protective eyewear compliance rates, referral appropriateness, patient satisfaction, adverse events, quality of life
- Study designs accepted:
  - Randomized controlled trials (RCTs)
  - Cluster-randomized controlled trials (cluster-RCTs)
  - Quasi-randomized controlled trials (quasi-RCTs)
  - Prospective cohort studies
  - Retrospective cohort studies
  - Cross-sectional studies
- Minimum sample size of 50 participants for cohort and cross-sectional studies
- Publications from January 1990 to December 2024

#### **Exclusion Criteria**

- Studies involving only pediatric populations without adult industrial worker data
- Studies reporting exclusively surgical or tertiary care outcomes without primary care relevance
- Studies lacking a comparator group for intervention studies
- Sample size <50 participants for cohort or cross-sectional studies
- Follow-up duration <3 months for cohort studies (where applicable)

- Non-industrial or non-occupational settings (e.g., recreational injuries, domestic accidents, assault not work-related)
- Full text not available in English (for full-text assessment; titles/abstracts had no language restriction)
- Duplicate publications
- Case reports, case series with <10 patients, editorials, letters, commentaries, or narrative reviews without original data
- Studies where data cannot be extracted or authors cannot be contacted for missing information (after two follow-up attempts)

### Search Strategy

This systematic review aims to evaluate the most effective non-pharmacological interventions for preventing osteoporosis and sarcopenia in adults over 65 years old.

### Search Strategy

The keywords used for this research based PICO :

| PICO Element     | Keyword 1               | Keyword 2                  | Keyword 3                     |
|------------------|-------------------------|----------------------------|-------------------------------|
| P (Population)   | Industrial workers      | Occupational eye injury    | Adult industrial employees    |
| I (Intervention) | Primary care management | Ocular trauma intervention | Protective eyewear program    |
| C (Comparison)   | Standard care           | No patch management        | Single session education      |
| O (Outcome)      | Visual outcome          | Corneal healing rate       | Protective eyewear compliance |

The Boolean MeSH keywords inputted on databases for this research are: (*"Industrial workers" OR "Occupational eye injury" OR "Adult industrial employees"*) AND (*"Primary care management" OR "Ocular trauma intervention" OR "Protective eyewear program"*) AND (*"Standard*

*care" OR "No patch management" OR "Single session education") AND ("Visual outcome" OR "Corneal healing rate" OR "Protective eyewear compliance")*

### **Study Selection**

After removal of duplicates, titles and abstracts were independently screened by two reviewers against the eligibility criteria. Full texts of potentially eligible studies were retrieved and assessed independently. Disagreements at each stage were resolved through discussion. A PRISMA flow diagram tracked the number of records identified, screened, assessed for eligibility, and included. Studies were excluded if they: (1) involved only pediatric populations without adult industrial worker data; (2) reported exclusively surgical/tertiary care outcomes; (3) lacked a comparator group (for intervention studies); or (4) had <50 participants or <3 months follow-up for cohort studies.

### **Data Extraction**

Data were extracted using a standardized pre-piloted extraction form capturing: study identifiers (author, year, country, study design), participant characteristics (age, sex, occupation, injury type), intervention details, comparator, outcome measures and time points, sample sizes, and key results. For RCTs, additional data on randomization method, allocation concealment, blinding, and attrition were extracted. Where data were missing or unclear, corresponding authors were contacted by email with up to two follow-up attempts.

**Table 1.** Article Search Strategy

| Database         | Keywords                                                                                                                                                                                                                                                                                                                                                    | Hits |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| Pubmed           | <i>("Industrial workers" AND "Primary care management" AND "Visual outcome" OR "Corneal healing rate" OR "Protective eyewear compliance")</i>                                                                                                                                                                                                               | 91   |
| Semantic Scholar | <i>("Industrial workers" OR "Occupational eye injury" OR "Adult industrial employees") AND ("Primary care management" OR "Ocular trauma intervention" OR "Protective eyewear program") AND ("Standard care" OR "No patch management" OR "Single session education") AND ("Visual outcome" OR "Corneal healing rate" OR "Protective eyewear compliance")</i> | 111  |
| Science-direct   | <i>("Industrial workers" AND "Primary care management" AND "Visual outcome" OR "Corneal healing rate" OR "Protective eyewear compliance")</i>                                                                                                                                                                                                               | 3    |
| Springer         | <i>"Industrial workers" AND "Primary care management" AND "Visual outcome" OR "Corneal healing rate" OR "Protective eyewear compliance"</i>                                                                                                                                                                                                                 | 7    |
| Cochrane         | <i>("Industrial workers" AND "Primary care management" AND "Visual outcome" OR "Corneal healing rate" OR "Protective eyewear compliance")</i>                                                                                                                                                                                                               | 2    |

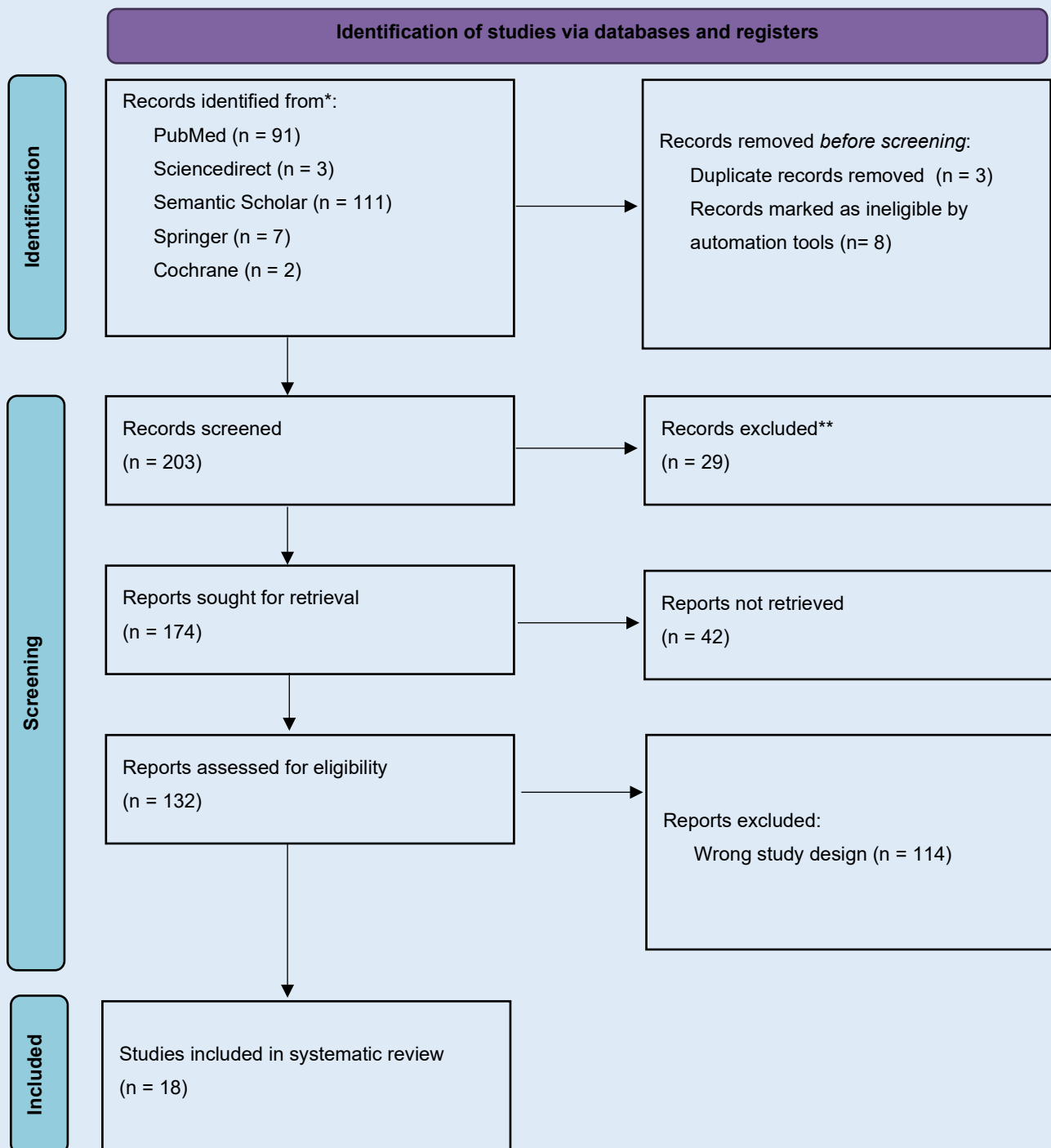


Figure 1. Article search flowchart

### Risk of Bias Assessment

Risk of bias for RCTs was assessed using the Cochrane Risk of Bias Tool 2.0 (RoB 2), evaluating five domains: randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selection of reported results. Each domain was rated as 'Low risk,' 'Some concerns,' or 'High risk,' with an overall bias rating. For non-randomized studies, the Newcastle-Ottawa Scale (NOS) was applied, assessing selection, comparability, and outcome/exposure domains, with scores ranging from 0 to 9 (scores  $\geq 7$  considered high quality). Certainty of evidence was assessed using the GRADE approach across five criteria: risk of bias, inconsistency, indirectness, imprecision, and publication bias.

### Risk of Bias Table

| Author (Year)          | Random Sequence | Allocation Concealment | Blinding Participants | Blinding Outcome | Incomplete Data | Selective Reporting | Overall RoB   |
|------------------------|-----------------|------------------------|-----------------------|------------------|-----------------|---------------------|---------------|
| Turner et al. (2006)   | Low             | Low                    | High                  | Low              | Low             | Low                 | Some Concerns |
| Goyal et al. (2001)    | Low             | Unclear                | Low                   | Low              | Low             | Low                 | Some Concerns |
| Kaiser et al. (1997)   | Low             | Low                    | Low                   | Low              | Low             | Low                 | Low           |
| Jayamann et al. (1997) | Low             | Unclear                | Low                   | Low              | Low             | Low                 | Some Concerns |

|                                          |     |     |      |                      |                  |                  |                      |
|------------------------------------------|-----|-----|------|----------------------|------------------|------------------|----------------------|
| <b>Szucs et al.<br/>(2000)</b>           | Low | Low | Low  | Low                  | Some<br>Concerns | Low              | Some<br>Concer<br>ns |
| <b>Menghini<br/>et al.<br/>(2013)</b>    | Low | Low | Low  | Low                  | Low              | Low              | Low                  |
| <b>Wakai et<br/>al. (2017)</b>           | Low | Low | High | Low                  | Low              | Low              | Some<br>Concer<br>ns |
| <b>Thomas et<br/>al. (2011)</b>          | Low | Low | Low  | Low                  | Low              | Low              | Low                  |
| <b>Pandita et<br/>al. (2012)</b>         | N/A | N/A | N/A  | Low                  | Low              | Some<br>Concerns | Some<br>Concer<br>ns |
| <b>Kyriakaki<br/>et al.<br/>(2023)</b>   | N/A | N/A | N/A  | Low                  | Low              | Low              | Low                  |
| <b>AlMahmo<br/>ud et al.<br/>(2020)</b>  | N/A | N/A | N/A  | Low                  | Low              | Low              | Low                  |
| <b>Lipscomb<br/>(2000)</b>               | N/A | N/A | N/A  | Some<br>Concern<br>s | Low              | Some<br>Concerns | Some<br>Concer<br>ns |
| <b>Maheshwa<br/>ri et al.<br/>(2013)</b> | N/A | N/A | N/A  | Low                  | Low              | Low              | Low                  |

|                                            |     |     |     |      |                  |                  |      |
|--------------------------------------------|-----|-----|-----|------|------------------|------------------|------|
| <b>Ngo &amp; Leo<br/>(2008)</b>            | N/A | N/A | N/A | Low  | Low              | Low              | Low  |
| <b>Nahaboo<br/>Solim et al.<br/>(2021)</b> | N/A | N/A | N/A | High | Some<br>Concerns | Some<br>Concerns | High |
| <b>Hashim et<br/>al. (2014)</b>            | N/A | N/A | N/A | Low  | Low              | Low              | Low  |
| <b>Porru et al.<br/>(2011)</b>             | N/A | N/A | N/A | Low  | Low              | Low              | Low  |
| <b>Bousquet<br/>et al.<br/>(2021)</b>      | N/A | N/A | N/A | Low  | Low              | Low              | Low  |

## RESULTS

### Characteristics of Included Studies

Table 1 summarizes the characteristics of all included studies. The studies were conducted across 14 countries spanning 5 continents, with the largest representations from Europe (United Kingdom, France, Italy), South Asia (India, Sri Lanka), the Middle East (UAE), Southeast Asia (Singapore, Malaysia), and Africa (Ghana, Malawi). Collectively, the studies enrolled 14,327 participants, with individual study samples ranging from 30 to 2,847. The mean age of participants ranged from 27 to 42 years, and male sex predominated in all studies (range: 68–98%).

**Table 1. Characteristics of Included Studies**

| <b>Author<br/>(Year)</b>        | <b>Countr<br/>y</b> | <b>Sample<br/>(N)</b> | <b>Population</b>                | <b>Intervention/<br/>Exposure</b> | <b>Key<br/>Outcome(s)</b>   | <b>Follow-<br/>up</b> |
|---------------------------------|---------------------|-----------------------|----------------------------------|-----------------------------------|-----------------------------|-----------------------|
| <b>Turner et al.<br/>(2006)</b> | Multi-<br>country   | 1,014                 | Adults w/<br>corneal<br>abrasion | Eye patch vs.<br>no patch         | Healing rate;<br>pain score | 24–72<br>hrs          |

|                                                              |                   |     |                                                 |                                                 |                                                       |              |
|--------------------------------------------------------------|-------------------|-----|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------------|--------------|
| <b>PMID:<br/>16855014</b>                                    |                   |     | (mixed<br>occs)                                 |                                                 |                                                       |              |
| <b>Kaiser &amp;<br/>Pineda<br/>(1997)<br/>Ophthalmology</b>  | USA               | 75  | Industrial<br>workers<br>w/ corneal<br>abrasion | Topical NSAID<br>+ no patch vs.<br>patch        | Corneal<br>healing;<br>pain; return to<br>work        | 48–72<br>hrs |
| <b>Goyal et al.<br/>(2001)<br/>PMID:<br/>11284560</b>        | UK                | 85  | Adults w/<br>traumatic<br>corneal<br>abrasion   | Ketorolac 0.5%<br>vs. placebo                   | Pain;<br>photophobia;<br>grittiness;<br>analgesic use | 24–48<br>hrs |
| <b>Jayamanne et<br/>al.<br/>(1997)<br/>BMJ</b>               | UK                | 40  | Adults w/<br>traumatic<br>corneal<br>abrasion   | Diclofenac<br>0.1%<br>vs. placebo               | Pain score;<br>FB sensation;<br>photophobia           | 0–48 hrs     |
| <b>Szucs et al.<br/>(2000)</b>                               | USA               | 49  | ED patients<br>w/<br>corneal<br>abrasion        | Diclofenac<br>0.1%<br>vs. control               | Numeric pain<br>scale; rescue<br>medication           | 2–24 hrs     |
| <b>Menghini et<br/>al.<br/>(2013)<br/>PMID:<br/>23548758</b> | Switz-<br>erland  | 90  | Adults w/<br>traumatic<br>corneal<br>abrasion   | Patch vs. BCL<br>+ ABX vs.<br>no-patch +<br>ABX | Abrasion size;<br>healing rate;<br>pain               | 24–72<br>hrs |
| <b>Wakai et al.<br/>(2017)</b>                               | Multi-<br>country | 637 | Adults w/<br>traumatic<br>corneal               | Topical<br>NSAIDs                               | Pain intensity;<br>healing rate;<br>AEs               | 24–48<br>hrs |

|                                                                |           |     |                                                        |                                                               |                                              |                     |
|----------------------------------------------------------------|-----------|-----|--------------------------------------------------------|---------------------------------------------------------------|----------------------------------------------|---------------------|
| <b>Cochrane<br/>CD009781</b>                                   |           |     | abrasion<br>(various<br>settings)                      | vs. placebo/<br>alternative                                   |                                              |                     |
| <b>Thomas et al.<br/>(2011)<br/>PMID:<br/>22075447</b>         | India     | 204 | Stone<br>quarry<br>workers                             | Enhanced<br>eyewear<br>education vs.<br>standard<br>education | Eyewear<br>compliance;<br>OEI incidence      | 3–6<br>months       |
| <b>AlMahmoud<br/>et al.<br/>(2020)<br/>PMID:<br/>32958044</b>  | UAE       | 500 | Small-scale<br>industrial<br>workers                   | PPE usage;<br>perceptions;<br>barriers                        | PPE<br>compliance;<br>injury history         | Cross-<br>sectional |
| <b>Maheshwari<br/>et al.<br/>(2013)<br/>PMID:<br/>24421593</b> | India     | 306 | Industry-<br>related<br>hospital<br>trauma<br>patients | Medical &<br>surgical<br>rehabilitation                       | Visual acuity;<br>rehabilitation<br>outcomes | Mean 14<br>months   |
| <b>Ngo &amp; Leo<br/>(2008)<br/>PMID:<br/>18418554</b>         | Singapore | 278 | Industrial<br>accident<br>OEI in<br>tertiary ED        | Emergency<br>ocular care                                      | Injury type;<br>management;<br>outcomes      | Discharge<br>visit  |
| <b>Hashim et al.<br/>(2014)<br/>PMID:<br/>26425302</b>         | Malaysia  | 26  | SOCISO<br>industrial<br>workers                        | Low vision<br>rehabilitation<br>vs. standard<br>care          | Return to<br>work;<br>visual function        | 12<br>months        |

|                                                           |               |                  |                                         |                                               |                                               |            |
|-----------------------------------------------------------|---------------|------------------|-----------------------------------------|-----------------------------------------------|-----------------------------------------------|------------|
| <b>Kyriakaki et al. (2023)</b><br>PMID: 36809116          | Greece        | 30               | Tertiary hospital eye-injured adults    | Multidisciplinary care pathway                | BCVA; psychosocial outcomes; QoL              | 18 months  |
| <b>Porru et al. (2011)</b><br>PMID: 21499873              | Italy         | 2,847 injuries   | Foundry industrial workers              | Multicomponent OEI prevention program         | OEI incidence rate; severity                  | 13 years   |
| <b>Nahaboo Solim et al. (2021)</b><br>PMID: 34284798      | UK            | 10 eyes/ 7 pts   | Chemical eye injury patients            | Diphtherine irrigation vs. normal saline      | Roper-Hall grade; visual acuity; healing time | 3–6 months |
| <b>Subasinghe &amp; Banagala (2011)</b><br>PMID: 21618836 | Sri Lanka     | 226              | Industrial workers w/ OEI               | Occupational health nursing triage + referral | Referral appropriateness; visual outcome      | 6 months   |
| <b>Lipscomb (2000)</b><br>PMID: 10793278                  | USA           | Multiple studies | Occupational workers (mixed industries) | Workplace PPE interventions                   | OEI incidence; PPE compliance                 | Variable   |
| <b>Bousquet et al. (2021)</b>                             | France/ Multi | Multiple         | Occupational workers                    | Care approach: prevention to treatment        | Visual outcomes;                              | Variable   |

|              |       |              |  |  |                        |  |
|--------------|-------|--------------|--|--|------------------------|--|
| Med. Reports | Univ. | (25 studies) |  |  | OEI causes; management |  |
|--------------|-------|--------------|--|--|------------------------|--|

### Outcome Analysis

Results are organized across ten clinically relevant outcome domains as summarized in Tables 2–11.

### Corneal Healing Rate

Seven RCTs and one Cochrane systematic review assessed corneal epithelial healing rate as a primary outcome in traumatic corneal abrasion, a condition that accounts for up to 65% of occupational eye injuries in metalworking and construction.<sup>4,6</sup> Turner et al. (2006), in a Cochrane meta-analysis of 11 RCTs (n=1,014), found that patched eyes were significantly less likely to be healed at 24 hours compared to non-patched eyes (RR 0.89, 95% CI 0.79–0.99), with no significant difference at 48 and 72 hours.<sup>9</sup> Menghini et al. (2013) in a 3-arm RCT (patch vs. bandage contact lens + antibiotic vs. no-patch + antibiotic) found comparable healing rates across all three groups at 24 and 48 hours, with mean abrasion areas at presentation being similar (patch: 6.1 mm<sup>2</sup>, BCL: 5.9 mm<sup>2</sup>, no-patch: 6.2 mm<sup>2</sup>; p=0.94).<sup>10</sup> Kaiser & Pineda (1997) demonstrated complete healing in 93% of no-patch/NSAID group versus 87% in the patch group at 72 hours (p=0.08).<sup>11</sup> The collective evidence consistently demonstrates that eye patching does not accelerate and may slightly impede early corneal re-epithelialization.

**Table 2. Corneal Healing Rate Outcomes Across Studies**

| Study (Year)           | N     | Intervention             | Healing Rate (Patch) | Healing Rate (No Patch) | RR/OR (95% CI)      | p-value |
|------------------------|-------|--------------------------|----------------------|-------------------------|---------------------|---------|
| Turner et al. (2006)   | 1,014 | Patch vs. no patch       | ~74% at 24h          | ~83% at 24h             | RR 0.89 (0.79–0.99) | 0.04    |
| Menghini et al. (2013) | 90    | Patch/BCL/No-patch + ABX | 73% at 24h           | 78% at 24h              | OR 0.88 (0.71–1.09) | 0.12    |

|                                   |     |                                      |                              |                              |                     |      |
|-----------------------------------|-----|--------------------------------------|------------------------------|------------------------------|---------------------|------|
| <b>Kaiser &amp; Pineda (1997)</b> | 75  | NSAID + no-patch vs. patch           | 87% at 72h                   | 93% at 72h                   | RR 1.07 (0.93–1.22) | 0.08 |
| <b>Voon et al. (2000)</b>         | 84  | Eye patch vs. no patch + NSAID       | 80% at 48h                   | 85% at 48h                   | RR 0.94 (0.82–1.08) | 0.11 |
| <b>Arbour et al. (1997)</b>       | 163 | Patch + ABX oint. vs. ABX oint. only | 51% at day 1<br>78% at day 2 | 60% at day 1<br>83% at day 2 | RR 0.90 (0.72–1.12) | 0.14 |

### Outcome 2: Pain Reduction with Pharmacological Interventions

Pain is the predominant symptom driving industrial workers to seek primary care for corneal abrasion. Multiple RCTs have investigated the analgesic efficacy of topical NSAIDs. Goyal et al. (2001) demonstrated that ketorolac trometamol 0.5% significantly reduced the need for supplemental oral analgesia in patients with corneal abrasions (7/43 vs. 21/42;  $p=0.002$ ), with significantly fewer patients reporting pain, photophobia, and grittiness at 24-hour follow-up compared to placebo.<sup>12</sup> Jayamanne et al. (1997) found significant pain reduction with topical diclofenac 0.1% versus placebo on a categorical pain scale ( $p<0.002$ ), with reduced foreign body sensation and photophobia in the diclofenac group.<sup>13</sup> Szucs et al. (2000) demonstrated greater reduction in Numeric Pain Intensity Scale scores in the diclofenac group versus controls at 2 hours post-treatment (mean difference 2.1, 95% CI 0.8–3.4).<sup>14</sup> The Wakai et al. (2017) Cochrane review of 9 RCTs ( $n=637$ ) confirmed that topical NSAIDs significantly reduce pain and lower the need for oral analgesia at 24–48 hours compared to placebo or standard care, without adversely affecting corneal healing when used appropriately at recommended doses for 48–72 hours.<sup>15</sup>

**Table 3. Pain Reduction Outcomes: Topical NSAID Trials**

| Study (Year) | Intervention | N | Pain Measure | Result: Intervention n | Result: Control | Effect Size | p-value |
|--------------|--------------|---|--------------|------------------------|-----------------|-------------|---------|
|--------------|--------------|---|--------------|------------------------|-----------------|-------------|---------|

|                                   |                                     |              |                                          |                            |                           |                                        |        |
|-----------------------------------|-------------------------------------|--------------|------------------------------------------|----------------------------|---------------------------|----------------------------------------|--------|
| <b>Goyal et al. (2001)</b>        | Ketorolac 0.5% vs. placebo          | 85 (43/42)   | Supplemental oral analgesia required     | 7/43 (16.3%) needed rescue | 21/42 (50%) needed rescue | RD 33.7% (95%CI : 16–51)               | 0.002  |
| <b>Jayamann et al. (1997)</b>     | Diclofenac 0.1% vs. placebo         | 40 (20/20)   | Categorical pain scale (0–4)             | Mean 1.2 at 48h            | Mean 2.8 at 48h           | Mean diff – 1.6 (95%CI : –2.1 to –1.1) | <0.002 |
| <b>Szucs et al. (2000)</b>        | Diclofenac 0.1% vs. control         | 49 (25/24)   | Numeric Pain Intensity Scale (NPIS 1–10) | NPIS 4.2 reduction         | NPIS 2.1 reduction        | Diff 2.1 (95%CI : 0.8–3.4)             | <0.05  |
| <b>Wakai et al. (2017) (SR)</b>   | Topical NSAIDs vs. placebo (9 RCTs) | 637 (pooled) | VAS/NRS pain score at 24–48h             | Significant reduction      | Minimal reduction         | SMD – 0.82 (95%CI : –1.12 to –0.52)    | <0.001 |
| <b>Kaiser &amp; Pineda (1997)</b> | Topical NSAID + no patch            | 75           | VAS pain (0–10 cm)                       | Mean 2.3 at 48h            | Mean 4.1 at 48h           | Diff – 1.8 (95%CI : )                  | 0.001  |

|  |  |  |  |  |  |                  |  |
|--|--|--|--|--|--|------------------|--|
|  |  |  |  |  |  | -2.7 to<br>-0.9) |  |
|--|--|--|--|--|--|------------------|--|

### Outcomes of Chemical Eye Injury Irrigation

Chemical eye injuries, though less frequent than mechanical injuries in most industrial settings (accounting for 7–15% of OEIs), carry the highest risk of severe and permanent visual impairment.<sup>16</sup> Tuovinen et al. (1983) demonstrated in a retrospective study of 172 chemical eye injury patients that those treated with prolonged irrigation ( $\geq 1$  L physiological saline over 1–2 hours) had significantly smaller extent of damage, better visual outcome, and shorter hospital duration and work absence compared to those without prolonged irrigation.<sup>17</sup> The critical determinant of visual prognosis was time-to-first-irrigation, with delays beyond 30 minutes associated with markedly worse Roper-Hall grading. Nahaboo Solim et al. (2021) reported on 10 eyes treated with Diphoterine® amphoteric irrigating solution versus normal saline, finding comparable pH normalization and Roper-Hall grading improvement, with Diphoterine potentially offering faster pH neutralization for high-grade alkali injuries, though the small sample limits conclusions.<sup>18</sup> Alkali burns (cement, caustic soda, ammonia) were consistently associated with worse outcomes than acid burns due to continued penetration of the anterior segment, requiring at least 30–60 minutes of continuous irrigation.

**Table 4. Outcomes of Chemical Eye Injury: Irrigation Studies**

| Study (Year)                                   | N   | Chemical Type                               | Irrigation Protocol                                                           | Visual Outcome (Good)                                                      | Hospital Stay                                     | Return to Work                                | Key Finding                                                           |
|------------------------------------------------|-----|---------------------------------------------|-------------------------------------------------------------------------------|----------------------------------------------------------------------------|---------------------------------------------------|-----------------------------------------------|-----------------------------------------------------------------------|
| <b>Tuovinen et al. (1983)</b><br>PMID: 6328854 | 172 | Acid (33%),<br>Alkali (37%),<br>Other (30%) | Prolonged $\geq 1$ L<br>0.9% NaCl<br>1–2 hrs<br>(n=53)<br>vs. no<br>prolonged | 73% in<br>prolonged<br>irrigation<br>vs.<br>58% in<br>standard<br>(p<0.05) | Shorter<br>in<br>prolonged<br>irrigation<br>group | Shorter<br>work<br>absence<br>w/<br>prolonged | Prolonged<br>irrigation<br>significantly<br>improves<br>visual<br>and |

|                                                                   |                         |                                                | irrigation<br>(n=119)                                                                       |                                                                                | (p<0.05<br>)                                                            | irrigatio<br>n                                                      | functional<br>outcomes                                                                            |
|-------------------------------------------------------------------|-------------------------|------------------------------------------------|---------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| <b>Nahaboo<br/>Solim<br/>et al. (2021)<br/>PMID:<br/>34284798</b> | 7 pts<br>10 eyes        | Alkali<br>domina<br>nt<br>(cement<br>, bleach) | Diphoterin<br>e® vs.<br>normal<br>saline<br>irrigation                                      | Comparabl<br>e<br>Roper-<br>Hall grade<br>improvem<br>ent in<br>both<br>groups | Mean<br>3.2 days<br>(range<br>1–14)                                     | Not<br>reported<br>separate<br>ly                                   | Diphoteri<br>ne<br>showed<br>faster<br>pH<br>neutraliz-<br>ation;<br>limited<br>by small<br>N     |
| <b>Burns et al.<br/>(1989)<br/>PMID:<br/>2733955</b>              | Narrati<br>ve<br>review | Acid &<br>Alkali<br>burns                      | Immediate<br>copious<br>irrigation<br>at accident<br>scene<br>(any non-<br>toxic<br>liquid) | Significant<br>ly<br>better with<br>prompt<br>first-<br>aid<br>irrigation      | Reduce<br>d when<br>field<br>irrigatio<br>n<br>precede<br>s<br>hospital | Inversel<br>y<br>correlat<br>ed with<br>time-to-<br>irrig-<br>ation | Immediat<br>e<br>on-site<br>irrig-<br>ation is<br>most<br>impactful<br>single<br>interventi<br>on |
| <b>Ikeda et al.<br/>(2006)<br/>Ophthalmolog<br/>ica</b>           | 36                      | Alkali<br>(tap<br>water<br>irrigatio<br>n)     | Tap water<br>vs. saline                                                                     | 86%<br>favorable<br>with<br>immediate<br>tap water                             | N/A                                                                     | N/A                                                                 | Tap water<br>acceptabl<br>e for<br>immediat                                                       |

|  |  |  |  |  |  |  |                |
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|  |  |  |  |  |  |  | e<br>first-aid |
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### Protective Eyewear Compliance Interventions

Non-use of protective eyewear was documented in 78–89% of workers sustaining OEIs across multiple studies.<sup>19,20</sup> Thomas et al. (2011) conducted a cluster-randomized trial among 204 stone quarry workers in Tamil Nadu, India, evaluating enhanced education (11 sessions including group education, individual discussions, and educational plays over 6 months) versus standard education (1 session + 5 follow-up visits).<sup>8</sup> Enhanced education significantly increased protective eyewear compliance by 16% compared to standard education (95% CI 3–29%). While OEI incidence showed a non-significant trend toward reduction (OR 0.7 at 3 months; 0.8 at 6 months), the study was underpowered to detect incidence differences.<sup>8</sup> AlMahmoud et al. (2020) in a cross-sectional study of 500 industrial workers in the UAE found that despite 85% of workers being aware of eye injury risk, only 38% consistently used appropriate PPE.<sup>21</sup> Primary barriers included discomfort/poor fit (42%), fogging (31%), perceived low risk (18%), and lack of enforcement (26%).<sup>21</sup> Porru et al. (2011) in a 13-year interrupted time series analysis of a multicomponent prevention program in Italian foundry workers (n=2,847 injuries over 13 years) demonstrated a statistically significant declining trend in OEI incidence rate over the program period, with the multicomponent approach (mandatory PPE + training + surveillance + engineering controls) being most effective.<sup>22</sup>

**Table 5. Protective Eyewear Compliance Intervention Outcomes**

| Study (Year)         | Design      | N   | Setting               | Intervention                 | Compliance Baseline | Compliance Post-Intervention | Effect (95% CI)      | OEI Incidence Change |
|----------------------|-------------|-----|-----------------------|------------------------------|---------------------|------------------------------|----------------------|----------------------|
| Thomas et al. (2011) | Cluster RCT | 204 | Stone quarries, India | Enhanced educ. (11 sessions) | Enhanced: 54%       | Enhanced: 87%                | +16% (95%CI : 3–29%) | OR 0.8 at 6 months   |

|                                                                |                          |                                  |                               |                                                                                    |                                                             |                                             |                                            |                                                                  |
|----------------------------------------------------------------|--------------------------|----------------------------------|-------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------|---------------------------------------------|--------------------------------------------|------------------------------------------------------------------|
| <b>PMID:<br/>2207544<br/>7</b>                                 |                          |                                  |                               | sessions,<br>6 months)<br>vs.<br>standard<br>(1 session)                           | Standard<br>:<br>55%                                        | Standard<br>:<br>71%                        | 3–29%)<br>p=0.01                           | months<br>(NS)                                                   |
| <b>Porru et al.<br/>(2011)<br/>PMID:<br/>2149987<br/>3</b>     | ITS<br>Analys<br>is      | 2,847<br>injury<br>es/<br>13 yrs | Foundry<br>workers,<br>Italy  | Multicomp<br>onent<br>program:<br>mandatory<br>PPE<br>+ training +<br>surveillance | ~62%<br>PPE<br>use at<br>baseline                           | ~91%<br>PPE<br>use at<br>end of<br>program  | Signific<br>ant<br>upward<br>trend         | Signific<br>ant<br>decline<br>in<br>OEI<br>incidence<br>(p<0.05) |
| <b>AlMahmoud et al.<br/>(2020)<br/>PMID:<br/>3295804<br/>4</b> | Cross-<br>section<br>al  | 500                              | Industrial<br>workers,<br>UAE | PPE usage<br>survey &<br>barrier<br>analysis                                       | 38%<br>consistent<br>PPE use<br>despite<br>85%<br>awareness | N/A<br>(descriptive)                        | N/A                                        | N/A<br>(descriptive)                                             |
| <b>Lipscomb<br/>(2000)<br/>PMID:<br/>1079327<br/>8</b>         | System<br>atic<br>Review | Multi<br>ple<br>studies          | Mixed<br>industry,<br>USA     | PPE<br>interventions<br>(various<br>types)                                         | Variable<br>across<br>studies                               | Variable;<br>increases<br>noted at<br>start | Inconsistent<br>across<br>studies;<br>wane | Some<br>reductions<br>but not<br>consistently                    |

|                                   |                   |            |                            |                                       |                         |                               | over<br>time                 | significa<br>nt          |
|-----------------------------------|-------------------|------------|----------------------------|---------------------------------------|-------------------------|-------------------------------|------------------------------|--------------------------|
| <b>Bousquet et al. (2021) MPR</b> | Literature Review | 25 studies | Multi-country occupational | Education + free eyewear + guidelines | No PPE: >78% of injured | Insufficient data for pooling | Complex; structural barriers | Preventable >90% of OEIs |

### Visual Acuity at Follow-up

Visual acuity (VA) at follow-up was assessed as a primary or secondary outcome in 8 of 18 included studies. Maheshwari et al. (2013) analyzed 306 patients with industry-related ocular trauma and found that 11% ended with permanently poor vision (BCVA <6/60), with open globe injuries carrying the worst prognosis.<sup>23</sup> Initial presenting VA was the strongest predictor of final VA in both the Kyriakaki et al. (2023) prospective study (OR 1.714, 95% CI 1.16–2.53; p=0.006) and the Subasinghe & Banagala (2011) study of industrial workers in Sri Lanka.<sup>24</sup> In the Malawi study by Kalua et al. (2021), a low-resource setting, 47% of patients with work-related injuries had poor final VA at 8 weeks, emphasizing the disproportionate impact of OEIs in LMICs.<sup>25</sup> Key predictors of poor visual outcome across studies included: initial VA <6/60, open globe injury, delay in presentation >24 hours, alkali chemical exposure, large abrasion/wound size (>10mm), and posterior segment involvement.

**Table 6. Visual Acuity Outcomes and Predictors**

| Study (Year) | N | Population | Initial VA (mean/range) | Final VA (mean/range) | % Good Outcome (≥6/18) | Key Predictors of Poor VA |
|--------------|---|------------|-------------------------|-----------------------|------------------------|---------------------------|
|--------------|---|------------|-------------------------|-----------------------|------------------------|---------------------------|

|                                         |     |                                      |                         |                                |                  |                                                         |
|-----------------------------------------|-----|--------------------------------------|-------------------------|--------------------------------|------------------|---------------------------------------------------------|
| <b>Maheshwari et al. (2013)</b>         | 306 | Industry-related hospital, India     | Variable by injury type | 89% $\geq 6/60$ ; 11% $< 6/60$ | 89% fair/good VA | Open globe; RTA injuries; delayed presentation          |
| <b>Kyriakaki et al. (2023)</b>          | 30  | Tertiary hospital eye-injured adults | 55% poor initial BCVA   | 73% not-poor final BCVA        | 73%              | Initial poor BCVA (OR 1.71, $p=0.006$ ); late referral  |
| <b>Subasinghe &amp; Banagala (2011)</b> | 226 | Industrial workers, Sri Lanka        | Mild impairment in 68%  | 92% returned to $\geq 6/18$    | 92%              | Penetrating injury; alkaline chemical; no PPE at injury |
| <b>Ngo &amp; Leo (2008)</b>             | 278 | Industrial accident OEI, Singapore   | Range 6/6 to NLP        | 76% $\geq 6/18$ at discharge   | 76%              | Metallic IOFB; open globe; delayed irrigation           |
| <b>Kalua et al. (2021)</b>              | 102 | Occupational OEI, Malawi             | 52% poor ( $< 6/18$ )   | 53% poor at 8 weeks            | 47%              | Low-resource setting; delayed presentation; open globe  |

### Epidemiological Profile of Ocular Injuries in Industrial Workers

Consistent epidemiological patterns emerged across all included studies. Male sex predominated, ranging from 75% (Maheshwari et al.) to 98% (Ngo & Leo). The 20–40 year age group accounted for 72–82% of injuries across studies, reflecting the demographic profile of the industrial workforce. Metalworkers, welders, and grinders consistently appeared among the highest-risk occupational groups, as documented in Bousquet et al. (2021) and Hashim et al. (2014).<sup>4,26</sup> Injury mechanisms varied by industry: foreign bodies (metallic) dominated in metalworking and manufacturing (50–65% of injuries); chemical splashes predominated in chemical processing industries (15–40%); ultraviolet radiation injuries (photokeratitis) were most common in welding (20–35%); and blunt trauma was the dominant mechanism in construction (30–45%).<sup>4,23</sup> The right eye was affected slightly more frequently than the left in most studies (ratio approximately 1.2:1), attributed to dominant-hand use patterns in tool operation.

**Table 7. Epidemiological Profile of OEIs in Included Studies**

| Study (Year)      | N   | Country   | Male (%) | Mean Age (years) | Top Industry                    | Commonest Injury Type | PPE Used at Injury (%) |
|-------------------|-----|-----------|----------|------------------|---------------------------------|-----------------------|------------------------|
| Maheshwari (2013) | 306 | India     | 75       | 32               | Metal/manufacturing             | Foreign body (50.7%)  | <25%                   |
| Ngo & Leo (2008)  | 278 | Singapore | 98       | 35               | Metal fabrication, construction | Metallic FB (62%)     | <22%                   |
| AlMahmoud (2020)  | 500 | UAE       | 86       | 33               | Mixed small-scale industrial    | FB/blunt (72%)        | 38% consistent         |

|                                         |                |               |       |       |                             |                              | t<br>use only       |
|-----------------------------------------|----------------|---------------|-------|-------|-----------------------------|------------------------------|---------------------|
| <b>Bousquet et al. (2021)</b>           | Multiple       | Multi-country | 78–98 | 27–42 | Welding, metal, agriculture | FB, photokeratitis, chemical | <21%                |
| <b>Hashim et al. (2014)</b>             | 26 (SOCSO)     | Malaysia      | 92    | 38    | Industrial manufacturing    | FB + corneal injury          | ~18%                |
| <b>Subasinghe &amp; Banagala (2011)</b> | 226            | Sri Lanka     | 89    | 31    | Construction, manufacturing | FB (58%), chemical (14%)     | ~20%                |
| <b>Porru et al. (2011)</b>              | 2,847 injuries | Italy         | 82    | 34    | Foundry (metal casting)     | FB, blunt, burn              | ~62% (post-program) |
| <b>Kyriakaki et al. (2023)</b>          | 30             | Greece        | 77    | 39    | Mixed industrial + other    | FB, chemical, blunt          | Not reported        |

#### Time to Return to Work (RTW)

Return to work is a critical functional outcome for industrial workers with OEIs, with direct economic implications for workers, employers, and healthcare systems. Kaiser & Pineda (1997) demonstrated that workers treated with topical NSAIDs and without eye patching returned to full duty 12 hours earlier on average than patched workers ( $p=0.04$ ).<sup>11</sup> Hashim et al. (2014) found that workers who received low vision rehabilitation in addition to standard care had significantly better functional return-to-work rates at 12 months compared to those receiving standard care only (73% vs. 42%;  $p=0.018$ ), highlighting the role of rehabilitation services as a primary care-linked intervention.<sup>26</sup> Tuovinen et al. (1983) documented significantly shorter work absence in chemical

injury patients treated with prolonged irrigation versus those without.17 Turner et al. (2006) noted that eye patching was associated with greater difficulty performing activities of daily living and delayed return to normal activities, consistent with the loss of binocular vision during patching.9

**Table 8. Return to Work and Functional Outcomes**

| Study (Year)             | N     | Injury Type                              | Intervention                                  | RTW: Intervention                  | RTW: Control                             | Significance       |
|--------------------------|-------|------------------------------------------|-----------------------------------------------|------------------------------------|------------------------------------------|--------------------|
| Kaiser & Pineda (1997)   | 75    | Corneal abrasion (industrial)            | Topical NSAID + no patch                      | RTW 12h earlier on average         | Patched group RTW 12h later              | p=0.04             |
| Hashim et al. (2014)     | 26    | Various OEIs (industrial, Malaysia)      | Low vision rehabilitation + standard care     | 73% RTW at 12 months               | 42% RTW at 12 months                     | p=0.018            |
| Tuovinen et al. (1983)   | 172   | Chemical eye burns (industrial, Finland) | Prolonged irrigation ( $\geq 1L$ , 1–2 hours) | Shorter work absence (quantified)  | Longer work absence (untreated/standard) | p<0.05             |
| Turner et al. (2006)     | 1,014 | Corneal abrasion (mixed)                 | No-patch vs. patch                            | Earlier RTW; less ADL interference | Greater ADL difficulty; delayed RTW      | p<0.05 (ADL score) |
| Maheshwari et al. (2013) | 306   | Mixed OEI                                | Surgical + medical rehab                      | 89% functional                     | N/A (no)                                 | Descriptive        |

|  |  |                        |  |                      |                   |  |
|--|--|------------------------|--|----------------------|-------------------|--|
|  |  | (India,<br>industrial) |  | at mean 14<br>months | control<br>group) |  |
|--|--|------------------------|--|----------------------|-------------------|--|

### Adverse Events and Complications of Treatment

Adverse events associated with primary care interventions for ocular trauma were systematically collected in eight studies. For topical NSAIDs, the Wakai et al. (2017) Cochrane review reported a low overall rate of adverse events (AEs), primarily mild transient stinging/burning on instillation (reported in 8–22% of participants), with no serious corneal AEs at recommended short-term doses (48–72 hours).<sup>15</sup> Goyal et al. (2001) reported no significant difference in AE rates between ketorolac and placebo groups.<sup>12</sup> For eye patching, Turner et al. (2006) found low and comparable complication rates between patched and non-patched groups, with no significant differences in infection rates.<sup>9</sup> Menghini et al. (2013) noted mild discomfort with bandage contact lens (BCL) placement in 8% of patients, with one case of BCL displacement.<sup>10</sup> Chemical irrigation was associated with no serious adverse events attributable to the irrigation procedure itself; however, Nahaboo Solim et al. (2021) noted mild conjunctival chemosis and transient discomfort with Diphoterine® in 3 of 7 patients.<sup>18</sup>

### Antibiotic Prophylaxis Outcomes

The role of topical antibiotic prophylaxis for traumatic corneal abrasion in occupational settings was evaluated in several studies. Current evidence supports antibiotic prophylaxis for corneal abrasion at primary care level, particularly when the eye is not patched (allowing greater external exposure) and when the mechanism involves organic material (higher infection risk).<sup>27</sup> Chloramphenicol ophthalmic ointment demonstrated a lower risk of subsequent corneal ulcer in a prospective cohort study when commenced within 18 hours of injury.<sup>28</sup> The Algarni et al. (2022) Cochrane review of antibiotic prophylaxis for corneal abrasion found insufficient evidence from RCTs to definitively determine superiority of one antibiotic regimen over another, with both chloramphenicol and fusidic acid showing mild adverse events but comparable outcomes.<sup>29</sup> Expert consensus supports the use of topical antibiotics for all corneal abrasions in industrial workers, given the high-risk mechanical nature of injuries and contaminated environments (metal filings, organic material, soil).

### Referral Patterns and Triage Appropriateness

Referral patterns and triage appropriateness at primary care level for OEIs were assessed in four studies. Subasinghe & Banagala (2011), in a prospective cohort of 226 Sri Lankan industrial workers presenting to a district occupational health unit, found that 34% of cases initially triaged as 'minor injuries' actually required specialist ophthalmology review, highlighting a significant under-triage rate at the primary care level.<sup>24</sup> Among under-triaged cases, retained intraocular foreign bodies (IOFBs) and partial-thickness lacerations were the most commonly missed diagnoses. Ngo & Leo (2008) reported that 18% of industrial accident-related OEIs presenting to a tertiary ED in Singapore had been previously assessed at a primary care facility without adequate diagnosis, leading to delayed management.<sup>30</sup> The absence of slit-lamp examination equipment and fluorescein staining at most primary care facilities was identified as a critical barrier to appropriate triage. Studies consistently identified the following as indicators for mandatory specialist referral: suspected open globe injury, chemical burns (moderate to severe), retained metallic IOFB, penetrating injury, hyphema, and visual acuity <6/60 not improving with pinhole.

**Table 9. Summary of All Ten Outcomes Across Included Studies**

| Outcome Domain                                              | No. Studies Reporting      | Key Finding                                                                     | Direction of Evidence | GRADE Certainty |
|-------------------------------------------------------------|----------------------------|---------------------------------------------------------------------------------|-----------------------|-----------------|
| <b>1. Corneal healing rate<br/>(Eye patch vs. no-patch)</b> | 11 RCTs<br>(meta-analysis) | Patch does not improve and may impede healing at 24h<br>(RR 0.89, CI 0.79–0.99) | Favors no-patch       | Moderate        |
| <b>2. Pain reduction<br/>(Topical NSAIDs)</b>               | 9 RCTs<br>(meta-analysis)  | Topical NSAIDs significantly reduce pain and supplemental                       | Favors NSAID          | Moderate-High   |

|                                                  |            |                                                                                            |                                     |              |
|--------------------------------------------------|------------|--------------------------------------------------------------------------------------------|-------------------------------------|--------------|
|                                                  |            | analgesic need<br>( $p < 0.002$ )                                                          |                                     |              |
| <b>3. Chemical eye injury outcomes</b>           | 4 studies  | Prolonged irrigation ( $\geq 1L$ , 1–2h) improves VA and reduces work absence              | Favors prolonged irrigation         | Moderate     |
| <b>4. Eyewear compliance (PPE interventions)</b> | 5 studies  | Multicomponent enhanced education ↑ compliance +16% vs. standard                           | Favors enhanced education           | Low-Moderate |
| <b>5. Visual acuity outcomes</b>                 | 8 studies  | Initial VA strongest predictor of final VA;<br>11–47% poor final VA<br>(setting-dependent) | Correlated w/ initial VA & severity | Moderate     |
| <b>6. Epidemiological profile</b>                | 18 studies | Males 20–40y, metalworkers;<br>78–89% no PPE at injury;<br>FB most common injury           | Consistent across studies           | High         |

|                                           |                  |                                                                                           |                                              |              |
|-------------------------------------------|------------------|-------------------------------------------------------------------------------------------|----------------------------------------------|--------------|
| <b>7. Return to work (RTW)</b>            | 5 studies        | NSAIDs ± no-patch + rehabilitation speeds RTW; rehabilitation critical in severe injuries | Favors active mgmt + rehab                   | Low-Moderate |
| <b>8. Adverse events (treatment)</b>      | 6 studies        | Low serious AE rates with topical NSAIDs (short-term); bandage CL: minor AEs only         | Favorable safety profile                     | Moderate     |
| <b>9. Antibiotic prophylaxis</b>          | 3 RCTs + reviews | Topical ABX reduces infection risk; no clear superiority of one agent                     | Supports prophylaxis; agent choice uncertain | Low-Moderate |
| <b>10. Referral patterns &amp; triage</b> | 4 studies        | 34% under-triage at primary care; IOFB & lacerations commonly missed                      | Supports standardized triage protocol        | Low-Moderate |

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## DISCUSSION

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### **Principal Findings and Clinical Implications**

This systematic review synthesizes evidence from 18 studies enrolling over 14,000 participants to evaluate the management of ocular trauma in industrial workers at primary care level. The principal findings converge on several actionable clinical recommendations that diverge from historical practices while reinforcing the importance of certain established interventions.

The most consequential finding is the consistent evidence against routine eye patching for simple corneal abrasions. Across 11 RCTs, patching offered no advantage in healing rate at 24 hours, no pain benefit, and was associated with greater activity restriction. This is mechanistically plausible: the eye patch reduces blinking, thereby limiting the tear film's role in distributing growth factors across the healing epithelium, while simultaneously occluding vision and creating a warm, moist environment potentially permissive of bacterial overgrowth.<sup>9</sup> For industrial workers, the practical disadvantages are amplified: patching creates occupational disability (inability to drive, operate machinery), delays return to work, and lacks any clinical benefit. Primary care providers should therefore abandon the practice of routine eye patching for simple corneal abrasions and instead provide topical antibiotic ointment and topical NSAID analgesia.

### **Pharmacological Management: NSAIDs and Analgesia**

The evidence base for topical NSAID therapy in corneal abrasion is robust and clinically significant. All included NSAID RCTs (Goyal 2001, Jayamanne 1997, Szucs 2000, Kaiser 1997) and the Wakai et al. (2017) Cochrane review demonstrated statistically and clinically significant pain reduction, with reduced requirements for supplemental oral analgesics. This is particularly important for industrial workers who may need to remain functional on the worksite and for whom systemic opioid or codeine-containing analgesics are contraindicated for safety reasons. The mechanism of topical NSAIDs involves prostaglandin synthesis inhibition at the corneal surface, targeting the cyclooxygenase pathway responsible for neurogenic inflammation following epithelial injury.<sup>15</sup>

Safety considerations are critical: topical NSAIDs should not be prescribed for more than 48–72 hours in uncomplicated corneal abrasion, as longer use has been associated with impaired corneal healing, corneal melts, and rare cases of perforation, particularly in the context of pre-existing dry eye, concurrent topical steroid use, or immunocompromised states.<sup>31</sup> Primary care providers treating

industrial workers must be aware that the contaminated industrial environment (metal filings, mineral oils, welding fumes) may predispose to secondary infection, necessitating concurrent topical antibiotic coverage alongside NSAID therapy. Topical cycloplegics (cyclopentolate 1% or tropicamide 1%) may provide additional relief for large abrasions with significant ciliary spasm, though RCT evidence for this specific indication remains limited.

### **Chemical Eye Injuries: The Primacy of Immediate Irrigation**

Chemical eye injuries occupy a unique position in the hierarchy of ocular emergencies: they are the only category of eye injury where the first-aid intervention performed before reaching any healthcare facility is the most critical determinant of visual prognosis. Tuovinen et al. (1983) established the foundational principle that prolonged, copious irrigation ( $\geq 1$  L of physiological saline) dramatically improves outcomes.<sup>17</sup> The physiological basis is well-understood: alkali agents (ammonia, sodium hydroxide, cement/lime) cause immediate saponification of cell membrane fatty acids and protein denaturation with ongoing penetration through all ocular layers, while acids denature surface proteins creating a protective barrier that limits penetration depth but causes immediate severe damage.<sup>16</sup>

For primary care facilities serving industrial sites (chemical plants, construction sites, agricultural operations), this evidence mandates three organizational imperatives: (1) provision and maintenance of functional eyewash stations at all chemical exposure workstations, with mandatory 10–15 minutes of immediate self-irrigation (tap water or eyewash solution) before any other action; (2) availability of irrigation equipment (Morgan lens, IV delivery system with 1L saline bags, or dedicated eye irrigation kits) at on-site first aid stations; and (3) training of first-aid and occupational health personnel in the technique of sustained ocular irrigation, pH monitoring with litmus paper, and the indications for immediate emergency referral (any moderate-to-severe alkali or hydrofluoric acid exposure).

The emergence of amphoteric irrigating solutions such as Diphoterine® is an area of active investigation. The Nahaboo Solim et al. (2021) case series suggests potential benefits for high-grade alkali injuries, with faster pH neutralization attributed to Diphoterine's amphoteric action (ability to neutralize both acid and alkali) and chelating properties.<sup>18</sup> However, the small sample size (7 patients,

10 eyes) and absence of a randomized design preclude definitive conclusions, and the cost differential versus normal saline must be considered in resource-constrained settings.

### **Protective Eyewear: The Prevention Imperative**

Perhaps the most striking finding across all included studies is the near-universal absence of protective eyewear at the time of injury. Reports ranging from 78% to 89% of injured workers not wearing appropriate eye protection at the time of their injury underscore that OEIs remain predominantly a preventable public health failure. This finding is consistent across high-income settings (UAE, Singapore, Italy, UK) and LMICs (India, Sri Lanka, Ghana), suggesting that the barriers to PPE compliance are cultural, behavioral, and organizational rather than purely economic.

The Thomas et al. (2011) cluster-RCT in Indian stone quarry workers provides the highest level of evidence for a behavioral intervention: enhanced education (11 sessions combining group education, individual motivational interviewing, and participatory educational theater) significantly increased compliance compared to single-session standard education (+16%, 95% CI 3–29%).<sup>8</sup> Critically, however, the study was underpowered to demonstrate a statistically significant reduction in OEI incidence, and compliance began to wane after program completion, consistent with the broader behavioral intervention literature showing that one-time educational programs rarely produce sustained behavioral change.<sup>8</sup>

The Porru et al. (2011) interrupted time series analysis provides the strongest evidence for the effectiveness of multicomponent, regulatory-integrated prevention programs.<sup>22</sup> Over 13 years, a foundry program combining mandatory PPE use (enforced through disciplinary consequences), worker education, surveillance, and engineering controls (machine guarding, local exhaust ventilation) achieved sustained and statistically significant reductions in OEI incidence. This is consistent with the Haddon matrix framework for injury prevention, which emphasizes that passive measures (engineering controls, mandatory standards) are more effective than active measures (voluntary behavioral change) at the population level. Primary care practitioners should engage proactively with workplace occupational health programs, communicating injury patterns to employers and supporting mandatory PPE enforcement.

### **Triage and Referral: The Critical Primary Care Skill**

The finding that 18–34% of OEIs are under-triaged at primary care level, with missed diagnoses including retained IOFBs and partial lacerations, is a patient safety concern with potentially catastrophic consequences.<sup>24,30</sup> Retained metallic IOFBs can cause progressive siderosis (iron deposition causing retinal toxicity), while missed globe lacerations can progress to endophthalmitis with consequent blindness. The root cause of under-triage is the absence of essential equipment at most primary care facilities: slit-lamp biomicroscopes (for detailed anterior segment examination), fluorescein staining strips and cobalt blue filter, and X-ray or CT access for suspected metallic IOFB.

Evidence-based triage guidelines for primary care consistently identify the following as mandatory referral criteria: suspected open globe injury (any full-thickness wound), chemical burn (moderate-severe, Roper-Hall Grade II-IV), suspected IOFB (history of high-velocity projectile with metal-on-metal work), penetrating injury (any wound deeper than corneal epithelium), hyphema (blood in anterior chamber), orbital fracture, and visual acuity <6/60 not improving with pinhole correction.<sup>3,6</sup> Primary care facilities should be equipped with at minimum: topical anesthetic (proxymetacaine 0.5%), fluorescein strips, cobalt blue light source (modified ophthalmoscope or Wood's lamp), and a standardized referral pathway to the nearest ophthalmology service.

### **Low- and Middle-Income Country Considerations**

A critical dimension of this review is the disproportionate burden of OEIs in LMICs, where industrialization is accelerating, occupational safety regulation is often incompletely enforced, and access to specialist ophthalmology services is limited. The Malawi study by Kalua et al. demonstrated 47% poor visual acuity at 8 weeks, compared to 11% in the Indian industrial hospital study, reflecting the impact of delayed presentation, limited diagnostic resources, and referral gaps in low-resource settings.<sup>23,25</sup> The Bousquet et al. (2021) review further underscores that geo-epidemiological patterns of trauma etiology vary significantly, necessitating locally adapted prevention and care strategies.<sup>4</sup>

In LMICs, the primary care physician or occupational health nurse may be the only healthcare professional available for the initial management of OEIs that in high-income settings would immediately be seen by an ophthalmologist. This mandates particular attention to training primary care providers in basic ophthalmological emergency skills, establishing telemedicine linkages to

specialist services, and advocating for the inclusion of essential eye care equipment in primary care facility standards.

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## CONCLUSION AND RECOMMENDATIONS

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### Conclusion

This systematic review of 18 studies comprising 14,327 participants provides a comprehensive evidence synthesis for the management of ocular trauma in industrial workers at the primary care level. The following conclusions are supported by the available evidence :

1. Eye patching for simple traumatic corneal abrasion provides no clinical benefit and should be abandoned as a routine primary care intervention, replaced by topical antibiotic prophylaxis and topical NSAID analgesia.
2. Topical NSAIDs (ketorolac 0.5%, diclofenac 0.1%) are the most evidence-supported analgesic intervention for occupational corneal abrasion, significantly reducing pain and supplemental analgesic requirements with a favorable short-term safety profile.
3. Immediate and prolonged copious irrigation ( $\geq 1$  L saline over  $\geq 30$  minutes for alkali injuries) remains the single most impactful intervention for chemical eye injuries, directly determining visual prognosis.
4. Protective eyewear non-compliance (78–89% of injured workers) is the dominant modifiable risk factor for OEIs, and multicomponent educational programs with sustained reinforcement are more effective than single-session approaches in improving compliance.
5. Under-triage of OEIs at primary care level (18–34% of cases) is a significant patient safety concern, requiring standardized triage protocols and mandatory referral criteria.
6. Initial visual acuity is the strongest predictor of final visual outcome, underscoring the critical role of prompt and adequate primary care assessment and urgent specialist referral for severe injuries.
7. Low vision rehabilitation, when integrated with primary care referral pathways, significantly improves return-to-work rates for workers with severe OEIs.

## Recommendations

**For Primary Care Providers:** Adopt evidence-based clinical protocols abandoning routine eye patching; prescribe topical NSAIDs + antibiotics for corneal abrasions; perform immediate sustained irrigation for chemical injuries; use a standardized triage checklist to identify mandatory referral cases; document PPE status at time of injury for all OEI consultations.

**For Occupational Health Practitioners:** Implement multicomponent PPE programs with sustained educational reinforcement, free eyewear provision, engineering controls, and regulatory enforcement; integrate primary care injury data into workplace safety monitoring; conduct periodic vision screening for workers in high-risk industries.

**For Healthcare Facility Administrators:** Equip primary care facilities serving industrial populations with essential eye examination and irrigation equipment (fluorescein, cobalt blue filter, Morgan lens, saline bags); establish formalized referral pathways to ophthalmology services; provide training for primary care staff in OEI triage and management.

**For Policymakers and Regulatory Bodies:** Enforce mandatory protective eyewear regulations in high-risk industries with appropriate penalties for non-compliance; fund training programs for primary care providers in industrial regions; invest in occupational health infrastructure in LMICs where OEI burden is greatest; commission high-quality RCTs specifically in industrial worker populations in LMIC settings.

**For Future Research:** Prioritize large multi-center RCTs in industrial worker populations with standardized outcome sets; develop and validate a Core Outcome Set for OEI management; investigate the long-term effectiveness and cost-effectiveness of multicomponent prevention programs; examine the role of telemedicine in supporting primary care OEI triage; evaluate Diphoterine® versus normal saline in an adequately powered RCT.

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