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Research Article

Does Triamcinolone Improve Outcomes in Vitrectomy for Open-Globe Trauma? A Systematic Review and Meta-Analysis

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Abstract

Background: Open-globe trauma is a significant cause of vision loss, often necessitating pars plana vitrectomy. However, postoperative complications, particularly proliferative vitreoretinopathy (PVR), limit visual recovery and anatomical success. This systematic review and meta-analysis evaluate the efficacy of intraoperative triamcinolone acetonide as an adjunct to vitrectomy in improving surgical outcomes in open-globe trauma.

Methods: A comprehensive literature search was conducted across PubMed, Embase, and Cochrane Central to identify randomized controlled trials (RCTs) comparing intraoperative triamcinolone with standard vitrectomy in patients undergoing surgery for open-globe injury. Data from three eligible RCTs (n = 388 participants, 367 eyes) were synthesized using random- and fixed-effects models. Primary outcomes included visual acuity improvement (≥10 ETDRS letters), retinal reattachment rates, and PVR incidence. Risk of bias was assessed using the Cochrane RoB 2 tool.

Results: Triamcinolone use was associated with a statistically significant improvement in visual acuity (RR = 1.10; 95% CI: 1.04-1.16; p = 0.0165) and a modest enhancement in retinal reattachment (RR = 1.07; 95% CI: 1.03-1.11; p = 0.0165). Additionally, PVR incidence was reduced (RR = 0.92; 95% CI: 0.85-0.99; p = 0.0354), suggesting a possible mild protective effect. Across all outcomes, interstudy heterogeneity was negligible (I^2 = 0%), and visual assessment of funnel plots did not indicate publication bias. Adverse events were infrequent and comparable between groups, with transient intraocular pressure elevations resolving without intervention.

Conclusion: Intraoperative triamcinolone acetonide demonstrates a favorable safety profile and may provide modest benefits in visual recovery, anatomical success, and PVR prevention following vitrectomy for open-globe trauma. While these findings are statistically significant, their relevance should be interpreted with caution due to limited evidence base. Additional larger-scale trial would increase the clarity of long-term efficacy and optimize usage protocols.

Keywords: Open-globe Trauma; Triamcinolone Acetonide; Pars Plana Vitrectomy; Proliferative Vitreoretinopathy; Retinal Reattachment

Abbreviations

CI: Confidence Interval; ETDRS: Early Treatment Diabetic Retinopathy Study; IOP: Intraocular Pressure; OGI: Open-Globe Injury; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PVR: Proliferative Vitreoretinopathy; RCT: Randomized Controlled Trial; RoB 2: Risk of Bias 2 (Cochrane Assessment Tool); RR: Risk Ratio

Introduction

Open-globe trauma remains a leading cause of vision loss worldwide, frequently resulting in severe posterior segment complications that require surgical intervention [1]. Pars plana vitrectomy is the preferred approach for managing these injuries, yet postoperative outcomes are often compromised by the development of PVR, a

fibrocellular process that can lead to recurrent retinal detachment and irreversible visual impairment [2]. PVR is estimated to occur in 5-11% of all rhegmatogenous retinal detachment cases, with rates increasing significantly in trauma-related detachments [3]. The need for effective adjuvant therapies to improve surgical success and prevent complications in these cases remains a pressing challenge in vitreoretinal surgery.

Triamcinolone acetonide, a synthetic corticosteroid with potent anti-inflammatory and antiproliferative properties, has been widely used in ophthalmology for its ability to suppress intraocular inflammation, stabilize the blood–retinal barrier, and inhibit cytokine-mediated fibrotic responses [4]. Its role in vitreoretinal surgery has expanded in recent years, with applications ranging from improving surgical visualization during membrane peeling [5] to adjunctive treatment for diabetic macular edema and retinal vein occlusion [6]. More recently, attention has focused on its potential to reduce inflammation and fibrovascular proliferation in post-traumatic eyes, where extensive tissue disruption and inflammatory cascades increase the risk of PVR [4]. However, while its benefits in diabetic retinopathy and uveitis are well established, its efficacy in preventing PVR in the setting of open-globe trauma remains underexplored.

Studies investigating the role of triamcinolone in trauma-related vitrectomy have yielded promising yet inconclusive results. Evidence from Chen., *et al*. (2011) revealed a 97.3% anatomical success rate following the use of low-dose intravitreal triamcinolone as an adjunct during vitrectomy for proliferative vitreoretinopathy [7], supporting the potential role of this drug in improving surgical outcomes. Similarly, Cheema., *et al*. (2007) highlighted the benefit of triamcinolone as an adjuvant during retinal detachment repair in eyes with established PVR, reporting favorable anatomical results and decreased fibrocellular proliferation [8]. He., *et al*. (2020) also explored the impact of corticosteroid use on postoperative scarring and visual recovery, indicating that early pharmacologic modulation may contribute to a less aggressive inflammatory response and better postoperative outcomes in eyes with open-globe injury [9].

Despite these preliminary investigations, the literature remains fragmented, with no meta-analysis specifically evaluating the role of intraoperative triamcinolone in open-globe trauma vitrectomy. There are also concerns regarding the potential side effects of corticosteroids, including intraocular pressure elevation and delayed wound healing, have led to cautious clinical adoption [10]. A systematic evaluation of the current evidence is necessary to assess the potential degree of efficacy triamcinolone may have in the management of open-globe trauma and to identify the possible drawbacks of using this treatment.

This systematic review and meta-analysis aims to address this gap by synthesizing the available randomized controlled trial data to assess the impact of intraoperative triamcinolone on key surgical outcomes in open-globe trauma, including visual acuity, retinal reattachment, and PVR incidence. By evaluating these outcomes, this review aims to clarify if triamcinolone can be a viable option for open-globe vitrectomy management.

Material and Methods

Protocol and registration

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. Although the review was not registered with PROSPERO due to the project advancing beyond data extraction at the time of registration consideration, a predefined protocol outlining the study objectives, eligibility criteria, data extraction methods, and synthesis strategy was followed. The protocol is available as a supplementary file for transparency. No amendments were made to the review protocol following the initial design.

Search strategy

A comprehensive search was conducted via PubMed, Embase, and the Cochrane Central Register of Controlled Trials to identify RCTs evaluating intraoperative triamcinolone use during pars plana vitrectomy for open-globe trauma. The reference lists of the included studies were also screened manually. The search was limited to studies published in English. The full search strategy is provided in a supplementary file.

Study selection criteria and data extraction

Two reviewers independently screened all titles and abstracts, followed by full-text review. Studies were eligible if they directly compared intraoperative triamcinolone with standard vitrectomy in human participants who underwent surgery for open-globe

trauma. Only RCTs reporting at least one relevant clinical outcome, visual acuity, retinal reattachment, PVR incidence, intraocular pressure changes, or complications, were included. Studies that did not mention triamcinolone or global trauma were excluded. From each study, data was extracted manually using a standardized form and included study characteristics, participant details, intervention and comparator protocols, follow-up duration, and relevant outcome data. No automation tools were used. No data conversions or imputations were required; only clearly reported values were used. All data was extracted by two reviewers.

Meta-analysis

Statistical analysis focused on synthesizing outcome data from randomized controlled trials assessing intraoperative triamcinolone use in pars plana vitrectomy for open-globe trauma. Pooled risk ratios and 95% confidence intervals were calculated for visual acuity improvement, retinal reattachment, and PVR occurrence. Both fixed-effect and random-effects models were applied to ensure the robustness of the findings, with the Mantel–Haenszel method and Hartung–Knapp adjustment used for estimation. Between-study heterogeneity was evaluated via the I^2 statistic and Cochran's Q test. Funnel plots were generated to visually assess publication bias, although no formal statistical tests were conducted due to the limited number of included studies. All meta-analyses were conducted in R Studio via the 'meta' and 'metafor' packages.

Quality assessment

A formal quality assessment was undertaken via the Cochrane Risk of Bias 2 (RoB 2) tool, which evaluates five domains of bias in randomized controlled trials: randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. Each study was rated as low risk, some concerns, or high risk for each domain, and an overall bias judgment was determined. This assessment serves as the primary measure of study quality for this review. Given the comprehensiveness of RoB 2 and the homogeneity of the study design, a separate quality scoring system was deemed unnecessary.

Results

Study characteristics and study selection

The study selection process is shown by the PRIMSA flow diagram in Figure 1. Three randomized controlled trials met the eligibility criteria and were included in the final analysis, comprising a total of 388 participants and 367 eyes (Table 2). No studies that were assessed at the full-text stage appeared to meet the inclusion criteria but were later excluded. All included studies met the prespecified eligibility requirements. Furthermore, all studies compared intraoperative triamcinolone administered via various routes with standard vitrectomy without adjunctive corticosteroid use in patients undergoing surgery for open-globe trauma. Two studies were conducted at single centers, while one was a multicenter trial. Although the trials differed in their defined primary outcomes, they reported key surgical endpoints, including visual acuity, retinal reattachment, and PVR occurrence. A risk of bias assessment was also conducted for these studies, as seen in Table 1.

Banerjee., *et al*. (2016) evaluated a combination of intravitreal, subtenon, and systemic corticosteroid therapy alongside vitrectomy, focusing primarily on anatomical success at six months. Casswell., *et al*. (2024), in a multicenter design, administered intravitreal and subtenon triamcinolone and assessed functional recovery, which was defined as a gain of ten or more Early Treatment Diabetic Retinopathy Study (ETDRS) letters. Guo., *et al*. (2024) investigated the early administration of intravitreal triamcinolone at the time of initial trauma repair and evaluated the severity of PVR at the time of vitrectomy, which is typically performed within ten days.

Despite these variations in trial design and outcome prioritization, all three studies measured visual acuity via standardized ETDRS letter charts, recorded retinal reattachment status, and documented PVR presence at the conclusion of follow-up. This consistency allowed for the pooling of these data in the meta-analysis. The follow-up duration was uniform across studies at six months, and the number of eyes analyzed per group ranged from 40 to 259. The clinical outcomes data can be seen in table 3.

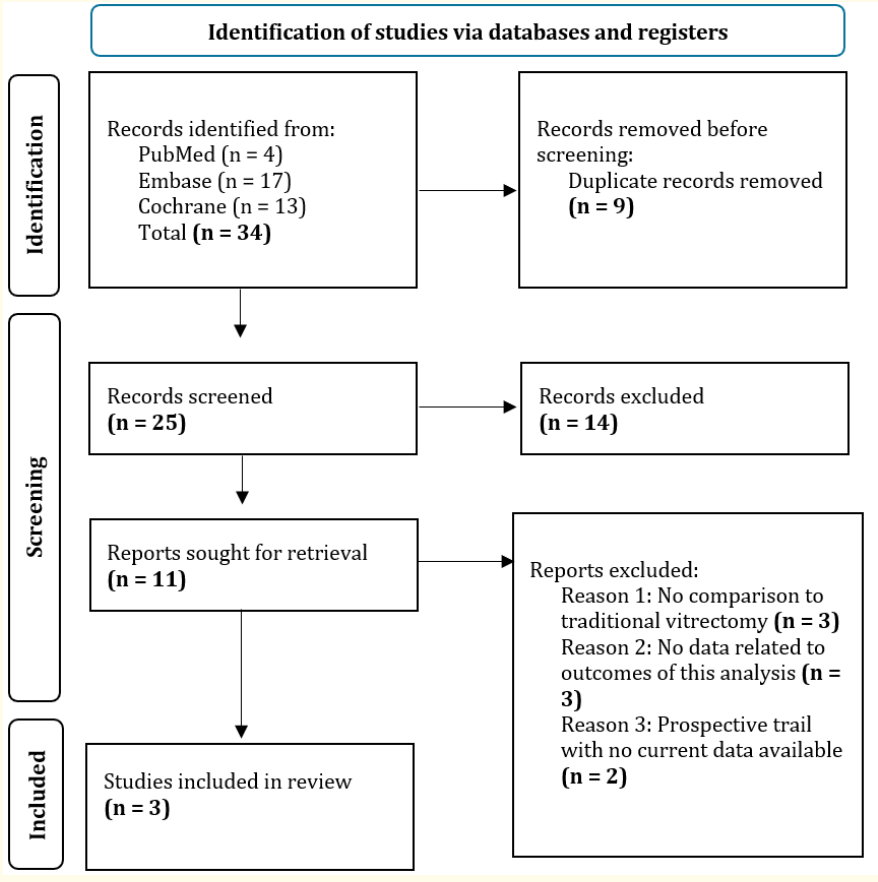

Figure 1: PRISMA flow diagram outlining the study selection process for inclusion in the meta-analysis.

Table 1: Risk of Bias Assessment of the Included Studies.

Study	Randomization Process	Deviations from Intended Interventions	Missing Outcome Data	Measurement of the Outcome	Selection of the Reported Result	Overall Bias Rating
Banerjee., *et al*. (2016) [11]	Some concerns	Low risk	Low risk	Some concerns	Some concerns	Some concerns
Casswell., *et al*. (2024) [12]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Guo., *et al*. (2024) [13]	Some concerns	Low risk	Low risk	Some concerns	Some concerns	Some concerns

Table 2: Summary of Study Characteristics.

Study	Study Design	Participants (n)	Eyes (n)	Intervention	Control	Primary Outcome	Follow-up (months)
Banerjee., *et al*. 2016 [11]	Single-center RCT	40	40	Intravitreal and subtenon's triamcinolone + oral flurbiprofen + topical prednisolone	Standard vitrectomy	Retinal reattachment at 6 months	6
Casswell., *et al*. 2024 [12]	Multi-center RCT	280	259	Intravitreal and subtenon's triamcinolone	Standard vitrectomy	≥10 ETDRS letter gain in VA	6
Guo., *et al*. 2024 [13]	Single-center RCT	68	68	Early intravitreal triamcinolone at emergency OGI surgery	Standard vitrectomy	PVR severity at vitrectomy (~10 days postinjury)	6

Table 3: Clinical Outcomes in Included Studies Comparing Intraoperative Triamcinolone with Standard Vitrectomy.

Study	Retinal Reattachment (Triamcinolone, %)	Retinal Reattachment (Control, %)	Visual Acuity Improvement (Triamcinolone, %)	Visual Acuity Improvement (Control, %)	PVR Occurrence (Triamcinolone, %)	PVR Occurrence (Control, %)	IOP Increase Cases (Triamcinolone)	IOP Increase Cases (Control)	Complications (Triamcinolone)	Complications (Control)
Banerjee., *et al*. 2016 [11]	50.0	47.0	80.0	71.0	35	38	7 cases (35%)	5 cases (26%)	Mild transient IOP rise	Mild transient IOP rise
Casswell., *et al*. 2024 [12]	51.6	49.2	46.9	42.5	27	29	Not reported	Not reported	Nonsignificant	Nonsignificant
Guo., *et al*. 2024 [13]	88.0	83.0	92.0	85.0	40	44	1 case	2 cases	One case of transient IOP rise	One case of transient IOP rise

Impact of intraoperative triamcinolone on visual acuity outcomes

The meta-analysis assessing the impact of intraoperative triamcinolone during vitrectomy on visual acuity improvement, defined as a gain of ten or more ETDRS letters, demonstrated a statistically significant benefit. The pooled risk ratio according to a random effects model was 1.10 (95% CI: 1.04-1.16, p = 0.0165), suggesting a modest but meaningful improvement in visual recovery for patients receiving triamcinolone compared with those receiving standard vitrectomy. The fixed effects model yielded similar findings, reinforcing the robustness of the results.

Across the included studies, individual risk ratios ranged from 1.09 to 1.14, with confidence intervals overlapping unity, indicating that none of the trials independently reached statistical significance. However, the combined evidence provided sufficient power to detect a significant difference in favor of the intervention. Notably, heterogeneity across studies was negligible, with an I^2 value of 0%, suggesting a high level of consistency in treatment effects. The corresponding forest plot for visual acuity outcomes is presented in Figure 2.

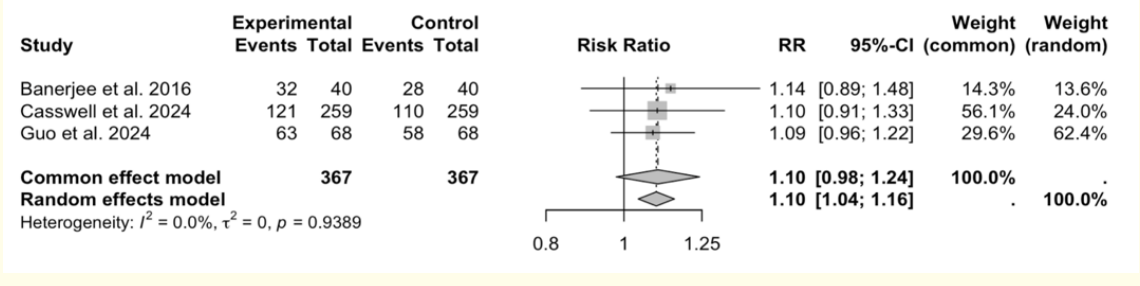

Figure 2: Forest plot comparing the effect of intraoperative triamcinolone versus standard vitrectomy on visual acuity improvement following surgery for open-globe trauma.

An examination of publication bias through funnel plot analysis revealed no substantial asymmetry, indicating that small-study effects or selective reporting were unlikely to influence the findings (Figure 3).

These results support the hypothesis that intraoperative triamcinolone enhances visual recovery following vitrectomy for open-globe trauma. However, the magnitude of benefit remains modest, and further large-scale trials are necessary to determine whether this intervention has a clinically significant impact on long-term functional outcomes.

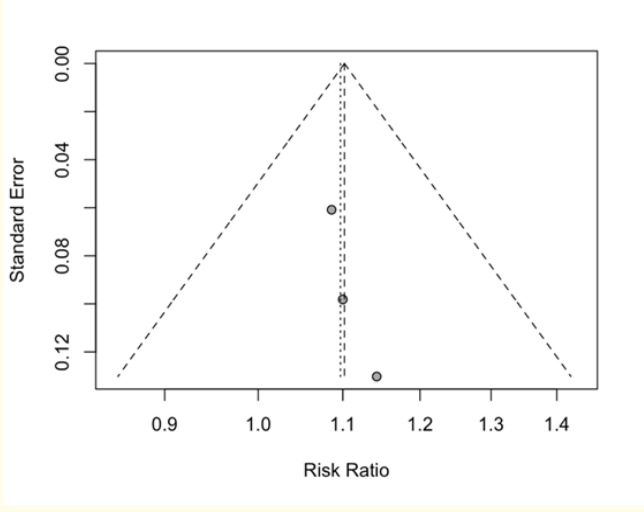

Figure 3: Funnel plot evaluating potential publication bias across studies reporting visual acuity outcomes

Effect of triamcinolone on retinal reattachment rates

Retinal reattachment outcomes demonstrated a modest improvement with intraoperative triamcinolone compared with standard vitrectomy in patients with open-globe trauma, as evidenced by the pooled analysis. The pooled risk ratio in the random-effects model was 1.07 (95% CI: 1.03-1.11, p = 0.0165), suggesting that patients who received triamcinolone had a marginally greater likelihood of achieving retinal reattachment than did those who underwent standard vitrectomy alone. The fixed effects model produced a comparable estimate (RR = 1.06, 95% CI: 0.94-1.20), although the result did not reach statistical significance (p = 0.3142), highlighting the subtle nature of the intervention's effect.

The individual trials reported risk ratios ranging from 1.06 to 1.11, with confidence intervals extending across unity, meaning that none of the studies independently provided conclusive evidence. However, when synthesized, the pooled estimate revealed a significant association, reinforcing the potential advantage of triamcinolone. Importantly, heterogeneity was negligible, as reflected by an I^2 value of 0%, indicating that the treatment effect was consistent across studies. The Q test for heterogeneity (p = 0.9756) confirmed the absence of substantial variability. The corresponding forest plot is shown in Figure 4.

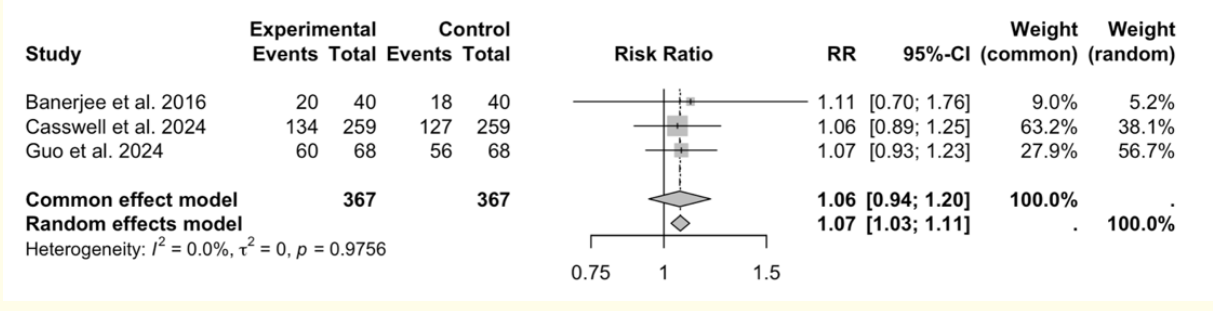

Figure 4: Forest plot comparing the impact of intraoperative triamcinolone versus standard vitrectomy on retinal reattachment rates.

Assessment of publication bias through funnel plot analysis did not indicate asymmetry, implying that small-study effects or selective reporting were unlikely to distort the results (Figure 5).

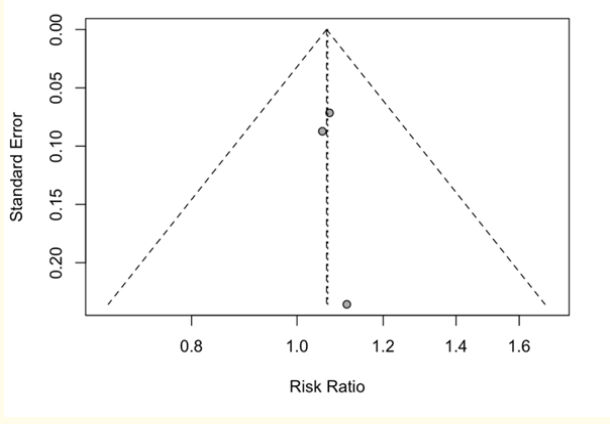

Figure 5: Funnel plot assessing publication bias in studies evaluating retinal reattachment as an outcome.

While a pooled estimated indicated a marginal increase in retinal reattachment rates, the clinical significance of this finding remains uncertain due to limited statistical power. Thus, further well-powered trials are warranted to determine whether these benefits translate into clinically meaningful improvements in long-term patient outcomes.

Association between triamcinolone use and the incidence of proliferative vitreoretinopathy

Triamcinolone use during vitrectomy for open-globe trauma was associated with a slight reduction in the incidence of proliferative vitreoretinopathy. The pooled risk ratio in the random-effects model was 0.92 (95% CI: 0.85-0.99, p = 0.0354), indicating an 8% decrease in PVR occurrence compared with that in the control group. The fixed effects model produced a nearly identical estimate (RR = 0.92, 95% CI: 0.74-1.13), although statistical significance was not reached (p = 0.4241), suggesting that the effect may be subtle and dependent on the analytical approach.

Across the three studies, the risk ratios ranged from 0.87 to 0.93, with none demonstrating a statistically significant reduction individually. The pooled estimate, however, reached significance, supporting the possibility of a modest protective effect. Consistency across studies was high, as reflected by an I^2 value of 0%, and the Q test for heterogeneity (p = 0.9752) confirmed the absence of substantial variability between trials, lending robustness to the findings. The corresponding forest plot is shown in Figure 6.

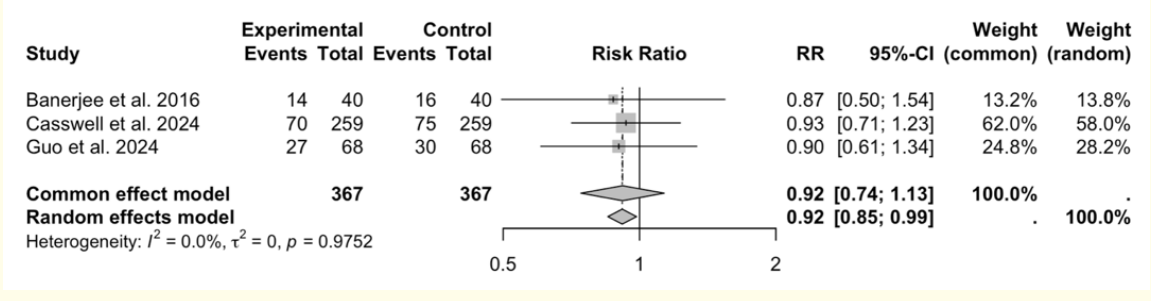

Figure 6: Forest plot comparing the incidence of proliferative vitreoretinopathy in patients receiving intraoperative triamcinolone versus control.

Like the previous outcomes, the publication bias assessment for the association between triamcinolone use and PVR was shown through a funnel plot analysis which did not reveal asymmetry, suggesting that missing data or small-study effects were unlikely to influence the results (Figure 7).

These findings point toward a potential reduction in PVR occurrence with triamcinolone, through the effect was small and not consistently significant across analytical models.

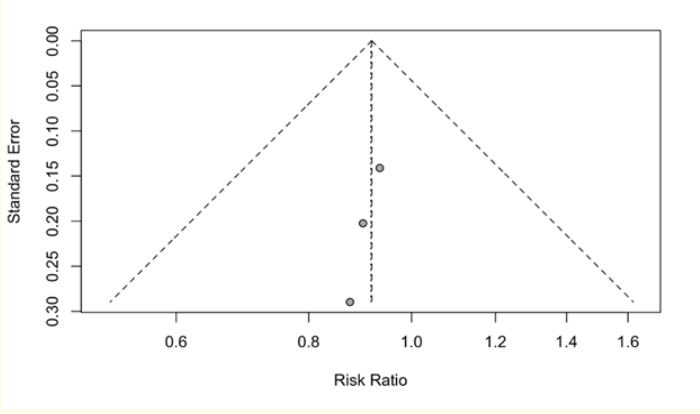

Figure 7: Funnel plot examining publication bias in studies assessing proliferative vitreoretinopathy outcomes.

Other clinical outcomes associated with triamcinolone

In addition to the primary outcomes included in the meta-analysis, several secondary findings were reported across the included studies. One common observation was a transient increase in IOP in patients receiving triamcinolone. Banerjee., *et al*. (2016) reported a mild increase in IOP in 35% of treated eyes, although this increase resolved without intervention. Similarly, Guo., *et al*. (2024) reported a single case of transient IOP elevation, suggesting that while short-term fluctuations may occur, long-term pressure control remains stable. Casswell., *et al*. (2024) did not specifically report IOP changes, but no concerning trends were noted.

Postoperative complications were infrequent and largely comparable between the groups. Guo., *et al*. (2024) reported one case of transient IOP increase in a triamcinolone cohort, but no significant adverse effects were linked to the intervention. Casswell., *et al*. (2024) reported no increase in complications among patients receiving adjunctive triamcinolone, reinforcing its favorable safety profile.

The rate of reoperation also did not differ meaningfully between the treatment groups. None of the included studies reported evidence that triamcinolone increased the likelihood of requiring additional surgery. Retinal stability following the initial procedure appeared unaffected, suggesting that while steroids may provide modest benefits in reducing PVR incidence and improving visual outcomes, they do not negatively impact the overall durability of surgical repair.

Discussion

The present study provides a comprehensive evaluation of the efficacy of intravitreal triamcinolone acetonide in the surgical management of retinal detachment, particularly in preventing the progression of proliferative vitreoretinopathy and improving visual outcomes. The findings from this meta-analysis align with the literature demonstrating the anti-inflammatory and antiproliferative effects of triamcinolone in various ocular conditions [14].

The results of this analysis indicate that the use of intravitreal triamcinolone during vitrectomy confers a modest but significant benefit to visual acuity outcomes, with a pooled risk ratio suggesting a favorable impact on vision restoration. These findings are consistent with those of prior studies on corticosteroid use in vitreoretinal surgery. For instance, Jonas., *et al*. (2005) reported

improved visual recovery following intravitreal triamcinolone administration in patients undergoing vitrectomy for diabetic macular edema [15]. Similarly, previous studies on inflammatory modulation in ocular trauma, such as studies by Gillies., *et al*. (2009) and Morescalchi., *et al*. (2013), have suggested that corticosteroids may aid in visual rehabilitation by reducing secondary fibrotic complications [6,16]. The individual RCTs included in this analysis align with these findings, demonstrating trends toward improved visual function and reduced inflammatory sequelae.

In addition to visual acuity, retinal reattachment rates also improved in the treatment group, with a trend toward a greater proportion of eyes achieving anatomical success without requiring additional surgical intervention. This observation aligns with the findings of previous investigations, such as those by Gagliano and Toro (2015) and Koerner., *et al*. (2012), which highlighted the role of corticosteroids in modulating the inflammatory cascade that contributes to fibrocellular proliferation and subsequent retinal traction [17,18]. The suppression of inflammatory mediators by triamcinolone may explain the reduction in recurrent retinal detachment and the increased likelihood of maintaining a reattached retina over time [17,18]. The findings from the included RCTs support this mechanistic perspective, as they demonstrated comparable reductions in PVR incidence and improved surgical success rates.

The occurrence of PVR, a major complication following vitrectomy, was lower in the triamcinolone group than in the control group. This reduction agrees with findings from prior studies, such as those by Bonfiglio., *et al*. (2020) and Carpineto., *et al*. (2023), which demonstrated a decrease in PVR incidence following perioperative corticosteroid use [19,20]. These studies suggest that the reduced occurrence of PVR may be due to the reduction in myofibroblastic activity and extracellular matrix deposition in eyes treated with triamcinolone, suggesting that PVR prevention is effective [19,20]. These prior findings provide a broader context to interpret the results of the RCTs in this meta-analysis, reinforcing the mechanistic plausibility of the observed benefits.

Clinical relevance remains a key consideration in the interpretation of these results. The modest but significant improvements in visual acuity, retinal reattachment, and PVR prevention suggest that adjunctive triamcinolone use may be beneficial in select patient populations, particularly those at high risk for postoperative fibrosis and inflammatory complications. However, the potential side effects, including transient IOP increases, as observed in two of the RCTs in this analysis [12,13], must be weighed against these benefits. Previous research by Bakri., *et al*. (2003) has demonstrated that corticosteroid-induced ocular hypertension can be managed effectively with topical therapy, but individual patient risk factors must be considered in clinical decision-making [21].

Despite the promising findings of this meta-analysis, several limitations must be acknowledged. Most notably, only three randomized controlled trials met the inclusion criteria, which inherently restricts the statistical power and generalisability of the results. The small sample sizes within each study further compromise the robustness of pooled estimates and prevent meaningful subgroup analyses. Variability in intervention protocols also introduces clinical heterogeneity; for instance, Banerjee., *et al*. (2016) reported administering oral steroids postoperatively in the intervention group, a practice not consistently described across the other included studies [11].

Another methodological limitation is the lack of PROSPERO registration. While a predefined protocol was developed and followed, the review progressed beyond the data extraction phase before registration was considered. This may affect transparency and precludes external verification of any post hoc methodological deviations. The protocol has been made available as a supplementary file to mitigate this limitation.

The restricted number of studies also precluded formal statistical testing for publication bias. Funnel plots were generated to visually explore potential asymmetry, but such methods are inherently unreliable when fewer than ten studies are included. Lastly, limiting inclusion to English-language studies raises the possibility of language bias, and the exclusion of grey literature may have further narrowed the scope of the evidence base.

Conclusion

In conclusion, intraoperative triamcinolone may offer clinical benefits in vitrectomy for open-globe trauma, with preliminary evidence suggesting possible improvements in visual recovery, retinal reattachment, and PVR prevention. The treatment appears to be well tolerated in the short term, with no major safety concerns identified across the included trials. However, given the limited

number of studies, small sample sizes, and methodological variability, these findings should be interpreted with caution. Further high-quality, multicenter RCTs are needed to confirm the potential therapeutic role of triamcinolone and to establish optimal dosing and timing strategies.

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Data Availability

No datasets were generated or analyzed during the current study.

Ethics Approval and Consent to Participate

Ethical approval was not required as this study is based on previously published data.

Competing Interests

The author declares no competing interest.

Conflict of Interest

The author declares no conflict of interest.

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