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REVIEW PAPER

Optimal Timing for Surgical Intervention in Orbital Fracture Management: A Systematic Review and Meta-Analysis

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Abstract

Background The optimal timing for surgical repair of orbital floor and combined orbital wall fractures remains a subject of clinical debate. While early surgery may prevent fibrosis, muscle entrapment, and enophthalmos, delayed intervention after edema resolution can sometimes yield comparable outcomes. This systematic review and meta-analysis aimed to evaluate the influence of surgical timing on functional and esthetic outcomes following orbital fracture repair.

Methods The present systematic review followed PRISMA 2020 guidelines and was prospectively registered on PROSPERO (CRD42024502791). A comprehensive search across PubMed, Scopus, Elicit, Web of Science, ScienceDirect, Semantic Scholar, EBSCOhost, and Google Scholar identified relevant literature up to October 2025. Eligible studies included prospective and retrospective cohort designs comparing early (≤ 14 days) versus delayed (> 14 days) surgical repair. Risk of bias was assessed using the Newcastle–Ottawa Scale, and the certainty of evidence was rated via the GRADE framework. Quantitative synthesis was performed using a random-effects model.

Results Fifteen cohort studies encompassing 2666 patients were included. Early intervention (≤ 14 days) was consistently associated with superior recovery of diplopia and extraocular motility, particularly in fractures with muscle entrapment or large defects. Delayed repair beyond two weeks yielded acceptable results in select cases without entrapment. The risk of bias across studies was low to moderate, and the certainty of evidence was graded as moderate for most outcomes.

Conclusion Early surgical repair within 7–14 days offers the most favorable functional recovery in orbital fractures, though individualized timing remains essential based on defect size, entrapment severity, and clinical presentation.

Keywords Orbital floor fracture · Surgical timing · Diplopia · Extraocular motility · Enophthalmos

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Introduction

Orbital fractures represent a frequent consequence of midfacial trauma, often resulting from road traffic accidents, assaults, or sports-related injuries [1]. These fractures can lead to functional and aesthetic complications such as diplopia, enophthalmos, restricted ocular motility, infraorbital nerve hypesthesia, and altered orbital volume, which significantly impair quality of life [2, 3]. The management of fractures involving the orbital floor has evolved considerably with advances in imaging, biomaterials, and surgical techniques [4]. Even so, the optimal timing of surgical intervention remains one of the most debated aspects of clinical decision-making.

Traditionally, early surgical repair within two weeks of injury was recommended to prevent fibrosis, muscle entrapment, and long-term deformities [5]. Yet, recent literature presents conflicting evidence, suggesting that delayed repair

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after edema and inflammation resolution may yield comparable or even superior outcomes in selected cases [6]. Moreover, while some surgeons emphasize immediate surgery for trapdoor or "white-eyed blowout" fractures to prevent ischemic myopathy of entrapped muscles, others advocate for a more conservative approach in cases with minimal diplopia or minor defects, allowing time for spontaneous improvement [7, 8].

The complexity of orbital anatomy further compounds the challenge, as the thin bony walls of the orbit are closely associated with vital neurovascular and muscular structures [9]. Surgical intervention, therefore, demands precise timing and technique to achieve anatomical restoration while minimizing complications such as residual diplopia, globe malposition, or sensory loss [5]. With the increasing use of computed tomography (CT) for diagnosis and the availability of resorbable and titanium mesh implants, clinical outcomes have improved; nonetheless, discrepancies remain regarding when surgical repair offers the most favourable balance between functional recovery and risk of complications [10, 11].

Given these inconsistencies, a comprehensive synthesis of available evidence is essential to guide clinicians in determining the most appropriate timing for surgical repair. Previous reviews on this topic, taken holistically, encompassed the entire complex orbit, thereby introducing heterogeneity into the analysis of the data. The present systematic review and meta-analysis were designed to critically evaluate and compare clinical and functional outcomes of early versus delayed surgical repair of orbital floor fractures and combined orbital wall fractures from the perspective of an oral surgeon. The review focuses on the analysis of up-to-date literature on temporal factors influencing postoperative recovery, patient function, and long-term prognosis, with the ultimate goal of assisting oral and maxillofacial surgeons in evidence-based treatment planning for orbital fracture management.

Methodology

The present systematic review and meta-analysis was conducted in accordance with the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020* guidelines [12]. The protocol was prospectively registered with the *International Prospective Register of Systematic Reviews (PROSPERO)* under the registration number CRD42024502791.

Eligibility Criteria

Studies were included if they met the following criteria: (1) involved human participants aged 18 years and above diagnosed with orbital floor or combined orbital wall fractures; (2) compared different surgical timing intervals, such as early ($\leq$7–14 days) versus delayed ($>$14 days) repair; and (3) reported clinical outcomes such as diplopia resolution, enophthalmos correction, extraocular motility recovery, sensory improvement, or postoperative complications. Clinical trials, prospective and retrospective cohort studies were considered eligible for inclusion. Case reports, case series, non-human or cadaveric studies, pilot studies, conference abstracts, reviews, and studies not reporting timing or relevant outcomes were excluded.

Search Strategy and Selection Process

A comprehensive literature search was performed across PubMed, Scopus, Elicit, Web of Science, Sciencedirect, Semantic Scholar, EBSCOhost, and Google Scholar. Additional grey literature was identified through Google Scholar and cross-referencing of the bibliographies of included studies. The search strategy combined both MeSH terms and free-text keywords. The PubMed search strategy was as follows:

("orbital floor fracture"[MeSH Terms] OR "orbital blowout fracture" OR "trapdoor fracture" OR "orbital wall fracture") AND ("surgical timing" OR "early repair" OR "delayed repair" OR "timing of surgery" OR "time of intervention") AND ("diplopia" OR "enophthalmos" OR "extraocular motility" OR "sensory disturbance" OR "complications") AND ("humans"[MeSH Terms]) with filters applied for No restrictions for date and language of publication were placed and all articles from inception to 31 October 2025 were identified.

The Elicit AI-assisted screening platform was used for study identification and initial screening. A pre-defined structured inclusion checklist ensured that each study met the specified criteria for surgical repair, timing analysis, inclusion of human participants, sufficient sample size ($\geq$15), and availability of relevant clinical outcomes. All search results were screened independently by two reviewers (C.I. and S.S.S.) using the Elicit systematic review tool. The articles were assigned a screening score from 0 to 5 based on the abovementioned criteria, and those scoring 4 or more were included in the review. Articles scoring lower were screened to ensure that an eligible article was not excluded, and the decision was overridden where necessary.

Data Extraction and Management

Data were extracted into a structured extraction sheet developed for this review. Extracted parameters included study author and year, country, sample size, study design, participant demographics, fracture characteristics, timing of surgery, outcome measures, and follow-up duration. Clinical outcomes included diplopia, enophthalmos, extraocular motility restriction, infraorbital nerve sensory deficits, and postoperative complications. Both reviewers performed data extraction independently, and results were cross-verified to ensure consistency and accuracy.

Risk of Bias Assessment

As all included studies were observational (prospective or retrospective cohort designs), the Newcastle–Ottawa Scale (NOS) was applied uniformly for quality assessment [13]. The NOS evaluates studies based on three domains: (1) selection of study groups, (2) comparability of cohorts, and (3) ascertainment of outcomes. Each study was scored out of a maximum of nine points, with scores of 7–9 indicating high quality, 5–6 moderate quality, and $\leq$4 low quality. Risk of bias assessments were conducted independently by two reviewers, and any differences in scoring were resolved through discussion until consensus was reached.

Data Synthesis and Statistical Analysis

A qualitative narrative synthesis was first conducted to summarize patterns and consistency of outcomes across studies. Subsequently, where data were sufficiently homogeneous, quantitative synthesis was performed using a random-effects model (DerSimonian–Laird method). Pooled estimates were expressed as risk ratios (RRs) or mean differences (MDs) with 95% confidence intervals (CIs). Heterogeneity among studies was assessed using the I^2 statistic, where values of 25%, 50%, and 75% indicated low, moderate, and high heterogeneity, respectively. Given that the number of included studies was fewer than ten, publication bias assessment (e.g., funnel plots or Egger's test) was not performed, in accordance with Cochrane recommendations, due to the unreliability of such tests for small datasets [14]. All analyses were conducted using Review Manager (RevMan) version 5.4.

Certainty of Evidence

The overall strength and certainty of evidence for each outcome were evaluated using the GRADE (Grading of Recommendations Assessment, Development, and Evaluation) approach [15]. The evidence was assessed across five domains: risk of bias, inconsistency, indirectness, imprecision, and publication bias. Each outcome was rated as high, moderate, low, or very low certainty based on collective appraisal. Two reviewers independently performed the GRADE assessment, and discrepancies were resolved by consensus. The final ratings were summarized in a *Summary of Findings* table, presenting the certainty of evidence alongside corresponding pooled effect sizes.

Results

Study Selection

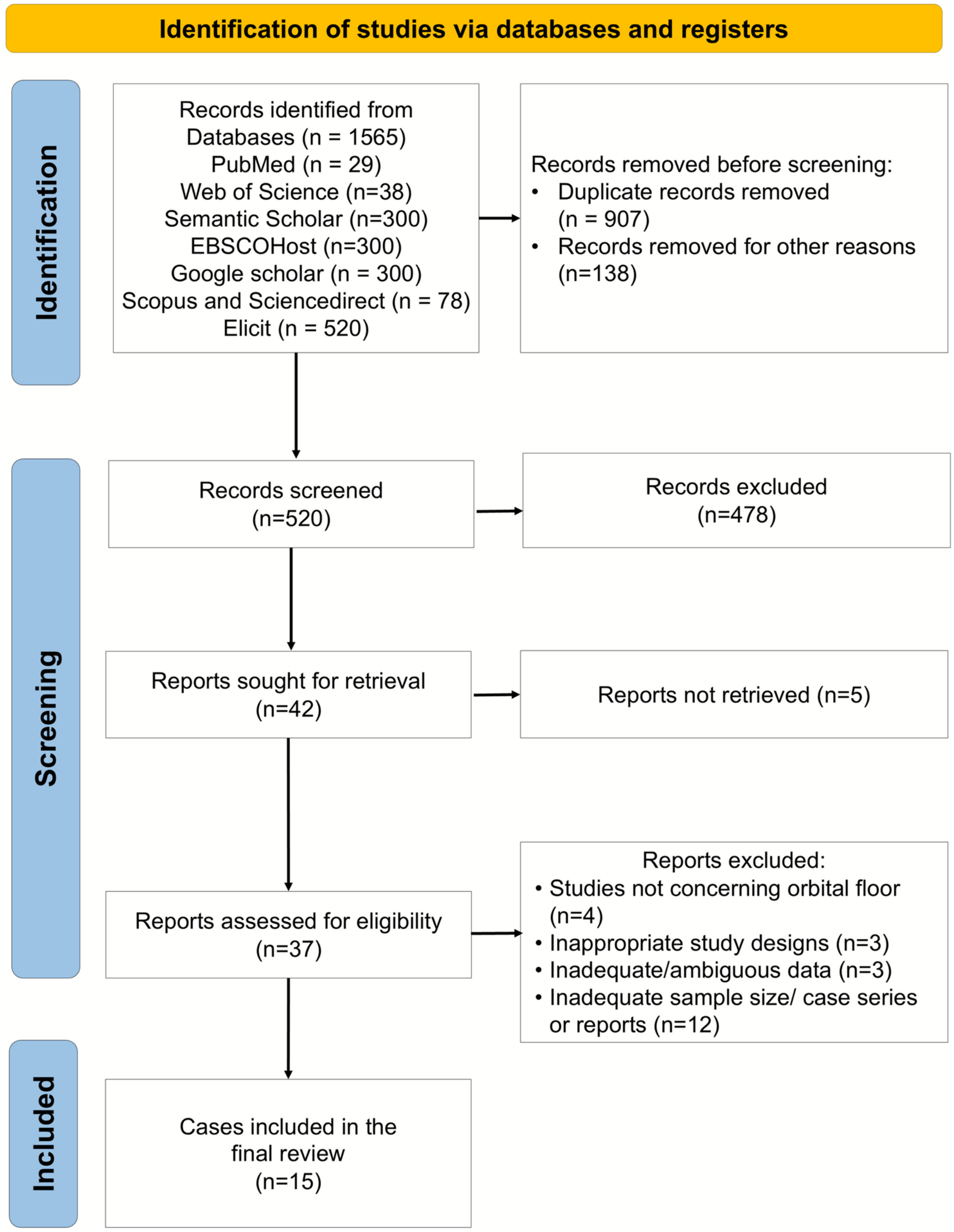
The electronic search yielded a total of 1,565 records from PubMed, Scopus, Elicit, Web of Science, Sciencedirect, Semantic Scholar, EBSCOhost, and Google Scholar. For the last three, the first 300 search results sorted by relevance were screened. After duplicate removal, 520 records underwent title and abstract screening. Of these, 37 full-text articles were reviewed for eligibility, and 15 studies published between 2002 and 2024 met the inclusion criteria for qualitative and quantitative synthesis (Fig. 1) [16–30].

Study Characteristics

The included studies (Table 1) encompassing a cumulative sample of 2,666 patients were geographically diverse, originating from Asia (Iran, Japan, South Korea, and Egypt), Europe (Austria, Sweden, Finland, Italy, and France), and North America (United States). All were designed as prospective (n=6) or retrospective cohort studies (n=9). Sample sizes ranged from 17 to 591 participants, with a predominant male representation (overall M/F ratio ≈ 2.5:1). The mean age of participants varied from 24 to 47 years, reflecting a population primarily within the active adult trauma age range [16–30].

Fracture patterns were predominantly isolated orbital floor fractures, with several studies including medial wall or combined orbital floor–medial wall fractures. Computed tomography (CT) was used universally to confirm fracture morphology, quantify defect size, and detect muscle entrapment. Surgical approaches were mainly transconjunctival or subciliary, and the most common reconstructive materials were resorbable meshes, titanium plates, autologous bone grafts, and Ethisorb® patches. Follow-up durations ranged from 6 weeks to 39 months, permitting both short- and long-term outcome evaluation.

Fig. 1 PRISMA Flow diagram indicating the selection process of the articles in the present systematic review



Surgical Timing and Comparative Framework

The timing of surgical repair varied across studies from immediate intervention (<24 h) to delayed repair (>1 month). Most studies dichotomized timing into early (≤7–14 days) and delayed (>14 days) categories, while some introduced refined thresholds, such as ultra-early (<3–4 days) or intermediate (15–30 days) interventions [16–30].

Across the evidence base, a consistent trend favored early repair, particularly within the first two weeks post-injury. Kasaee et al. (2016) and Koide et al. (2003) demonstrated that surgical intervention within 4–5 days significantly reduced postoperative diplopia and restriction of extraocular motility ($p<0.01$) [17, 27]. Hossal et al. (2002) reported that repair within two weeks minimized residual diplopia (83% preoperative vs. 17% postoperative), while Yamanaka et al. (2017) found that surgery within eight days yielded superior ocular motility recovery (Hess Area Ratio = 98% vs. 94%, $p<0.01$) [16, 29].

Conversely, three studies found no significant differences between early and delayed repair when entrapment was absent, suggesting that delayed intervention after edema resolution remains acceptable for selected patients [22, 24, 28]. The large-scale study by Hassan et al. (2024) clarified this distinction: surgery within two days for extraocular muscle entrapment and within one week for large or near-total defects resulted in markedly fewer postoperative complications ($p<0.01$), whereas less severe fractures tolerated

Table 1 Data extracted from the included studies related to their characteristics and outcomes

Author (Year)	Country	Sample size (n)	Age (yrs, mean ± SD)	Gender (M/F)	Study design	Surgical timing	Fracture characteristics	Primary outcomes	Timing–outcome relationship	Timing recommendations	Follow-up	Groups studied	Postoperative complications
Hossal et al. (2002) [16]	USA	42 (total); 25 ≤ 14 days, 17 > 14 days	12–74 (32 ± NR)	30/12	Retrospective	≤ 14 days (25) vs > 14 days (17); median 10 days; early repair advised	Floor 45%, medial 5%, combined 50%; large defects; entrapment 29 pts; CT + enophthalmos > 2 mm	Diplopia, enophthalmos > 2 mm	≤ 14 d reduced postoperative diplopia ($p < 0.05$)	Repair within 2 wk of trauma	6–39 mo (mean 11 mo)	42 blow-out fractures; 25 ≤ 14 days, 17 > 14 days	NR
Koide R et al. (2003) [17]	Japan	200 (total); 64 ≤ 3 days, 68 4–14 days, 46 15 days–2 mo, 22 s surgery	4–71 (24 ± NR)	165/35	Prospective	≤ 3 days (64), 4–14 days (68), 15 d–2 mo (46); ≤ 3 days best	Linear/defect type; floor; large defect; EOM entrapment CT	Diplopia, enophthalmos	≤ 3 d best for diplopia; ≤ 14 d for enophthalmos	Operate ≤ 3 d for diplopia; ≤ 14 d for enophthalmos	Mean 20 mo	≤ 3 days (n = 64), 4–14 days (n = 68), 15 days–2 months (n = 46), 2nd surgery for diplopia	≤ 14 days: none; > 14 days: 1 diplopia
Kontio et al. (2006) [18]	Finland	24 (total)	17.2–54.8 (37.3 ± NR)	15/09	Prospective	Delay 0–26 days (mean 7); no fixed cut-off	Pure floor 46%; defects > 10 mm 54%; fat prolapse CT	Diplopia, motility	No timing–outcome correlation	Mean delay 7 d acceptable	Mean 7.8 mo	24 unilateral orbital wall fractures	NR
Dal Canto A J & Linberg J V (2008) [19]	USA	58 (total); 36 early, 22 delayed	Early 5–68 (28.8 ± 14.9); Delayed 8–58 (28.5 ± 16.1)	NR	Retrospective	1–14 d (36) vs 15–29 d (22); ≤ 29 d effective	Floor ± medial; small/medium/large; CT size estimation	Diplopia, motility	Early (1–14 d) = Delayed (15–29 d); no difference ($p > 0.5$)	Repair up to 29 d effective; observe 3–4 wk if improving	1, 6, 12–18 wk	Early (0–14 d, mean 9 d) vs delayed (15–29 d, mean 19 d)	≤ 14 days: 2; > 14 days: 1
Alinasab B et al. (2011) [20]	Sweden	79 (total); 10 entrapment, 11 impingement, 16 surgical, 71 non-surgical	11–77 (NR ± NR)	71/55	Prospective	Entrapment 36 h; impingement 168 h; early for entrapment	Trap/open-door; inferior/medial; herniation < 1 mL; CT measured	Diplopia, motility	No timing correlation; similar early/late results	Operate within 2 wk if visible deformity	Up to 2 y	Entrapment (n = 10) vs impingement (n = 11)	NR
Brucoli M et al. (2011) [21]	Italy	40 (total); ≤ 24 h 2, ≤ 7 days 34, > 14 days 4	30–60 (47.7 ± NR)	29/11	Retrospective	≤ 24 h, ≤ 7 d, 7–14 d, > 14 d; cut-off = 2 wk	Floor/medial; 24 floor-only, 2 medial-only, 14 combined; CT + forced duction	Diplopia, enophthalmos, hypesthesia	≤ 2 wk improved all outcomes ($p < 0.05$)	Repair ≤ 2 wk for large/combined fractures	Mean 39 mo (6–81 mo)	40 isolated blow-out fractures; floor 24, medial 2, both 14; subciliary/transconjunctival; Tutopatch/titanium/bone graft	≤ 14 days: 38 events (13 diplopia, 7 enophthalmos, 18 nerve deficits); > 14 days: 12 events (4 each)

Table 1 (continued)

Author (Year)	Country	Sample size (n)	Age (yrs, mean ± SD)	Gender (M/F)	Study design	Surgical timing	Fracture characteristics	Primary outcomes	Timing–outcome relationship	Timing recommendations	Follow-up	Groups studied	Postoperative complications
Poeschl P W et al. (2011) [22]	Austria	60 (total)	4–84 (36 ± NR)	38/22	Retrospective	Immediate vs > 7 days; delayed > 7 days preferred except white-eyed cases	Punched-out, burst, trap-door; isolated floor; herniation on CT	Diplopia, motility, enophthalmos	Late > 7 d improved motility except white-eyed cases	Delay > 7 d except for white-eyed blow-outs	Mean 3 mo (1–14 mo)	60 isolated orbital floor fractures; M/F 38:22; preseptal transconjunctival approach with Ethisorb, mesh, titanium, or bone	NR
Shin K H et al. (2011) [23]	South Korea	591 (total); 485 early, 106 delayed	Early group (32.2 ± 15.9); Delayed group (33.7 ± 12.8)	Early 367/118; Delayed 76/30	Retrospective	≤ 14 d (485) vs 15–30 d (106); mean 7.3 vs 18.8; ≤ 1 mo adequate	Blow-out; inferior/medial; enophthalmos > 2 mm; CT large defects	Diplopia, enophthalmos	Similar improvement early vs late (p > 0.2)	Perform within 1 mo; urgent if muscle trapped	Up to 6 mo	≤ 14 days (n = 485) vs 15–30 days (n = 106)	≤ 14 days: 23; > 14 days: 6
Hwang K et al. (2012) [24]	South Korea	362 (total); 242 operated, 120 observed	6–77 (33.4 ± NR)	NR	Retrospective	≤ 7 d, 8–14 d, ≥ 15 d; majority early; delay if swelling	Floor/medial; small–large; medial rectus entrapment	Diplopia, enophthalmos	No significant timing difference (p > 0.05)	Delay until swelling subsides	1, 3, 6, 12 mo	Operated (n = 242) vs observed (n = 120)	NR
Laurent-joye M et al. (2014) [25]	France	47 (total); 26 non-op, 21 op	13–87 (34 ± NR)	40/7	Prospective	5–10 d; urgent if diplopia or > 50% collapse	Trap-door; floor; collapse > 50%; CT verified	Diplopia, EOM, vision	Diplopia resolved by 1 mo in non-ops; 2 mo postop	Orthoptic eval 5–10 d; operate 2 mo if needed	10 d–6 mo	Non-operated (n = 26) vs operated (n = 21)	NR
Abd El-Ghafar A (2015) [26]	Egypt	17 (total); 7 ≤ 3 wk, 10 > 3 wk	A: 18–35 (25 ± 5.9); B: 20–37 (29.5 ± 6.9)	12/05	Prospective	≤ 3 wk (7) vs > 3 wk (10); optimal ≤ 2 wk	Pure floor; EOM entrapment; CT verified	Diplopia, motility	Early ≤ 3 wk resolved diplopia; late improved 20% only (p = 0.015)	Early repair ≤ 3 wk; ideally ≤ 2 wk	6 mo	Group A ≤ 3 wk (n = 7), Group B > 3 wk (n = 10)	≤ 14 days: none; > 14 days: 8 diplopia
Kasaee et al. (2016) [27]	Iran	132 (total); 60 surgical, 72 non-surgical	10–60 (30.5 ± 11.7)	102/30	Prospective	1–196 days (mean 18.6); early ≤ 4.5 days for diplopia, ≤ 7.5 days for EOM; all ≤ 2 weeks	Medial, inferior, combined; extensive; muscle entrapment; CT confirmed	Diplopia, EOM limitation, enophthalmos measured at 1, 3, 6 mo	Surgery ≤ 4.5 d reduced diplopia; ≤ 7.5 d improved EOM (p < 0.01)	Operate ≤ 4.5 d for best functional recovery	1, 3, 6 mo	Surgical (n = 60) vs non-surgical (n = 72)	NR

Table 1 (continued)

Author (Year)	Country	Sample size (n)	Age (yrs, mean ± SD)	Gender (M/F)	Study design	Surgical timing	Fracture characteristics	Primary outcomes	Timing–outcome relationship	Timing recommendations	Follow-up	Groups studied	Postoperative complications
Alinasab et al. (2017) [28]	Sweden	21 (total); 10 entrapment, 11 impingement	NR (NR ± NR)	12/09	Prospective	Entrapment ≈ 36 h; impingement ≈ 168 h; early = entrapment	Trap-door/open-door; inferior + medial; herniation > 1.5 mL; CT verified	Diplopia, motility, hypesthesia	No correlation of timing with outcomes	Immediate for entrapment; elective for impingement	1–68 wk	Entrapment (n = 10) vs impingement (n = 11)	NR
Yamanaka Y et al. (2017) [29]	Japan	197 (total); 145 floor, 29 medial, 23 combined	7–85 (29.0 ± NR)	154/43	Retrospective	≤ 8 d vs > 8 d; mean 10.7; early ≤ 8 d better	Trap-door + depressed; floor/medial/combined; CT	Ocular motility (HAR %)	≤ 8 d improved HAR % (98% vs 94%, $p < 0.01$)	Repair ≤ 8 d for incarcerated trap-door fractures	Mean 8.4 mo (3–59 mo)	Mixed fracture types (trap-door, depressed, combined); adults and children	NR
Hassan et al. (2024) [30]	USA	253 (total); EOM entrapment 13; ≤ 2 days 8; 8–14 days 3; > 14 days 10	NR (39.3 ± 16.9)	183/70	Retrospective cohort	0–7, 8–14, 15–28, > 28 d; ≤ 2 d (entrapment), ≤ 1 wk (large); ≤ 4 wk mild	Floor ± medial; large/total; EOM entrapment; CT	Diplopia, enophthalmos, sensory loss	≤ 2 d (entrapment) and ≤ 1 wk (large defects) had fewer complications ($p < 0.01$)	OFR ≤ 2 d for entrapment; ≤ 1 wk for large defects	Median 79 d (~2.6 mo)	Early (0–14 d), 8–14 d, 15–28 d, > 28 d	≤ 14 days: 21 enophthalmos, 51 diplopia; > 14 days: 2 enophthalmos, 3 diplopia

up to four weeks of delay without significant functional compromise [24].

Clinical and Functional Outcomes

Diplopia was the most consistently reported outcome, followed by extraocular motility limitation, enophthalmos, and infraorbital nerve dysfunction. Most studies confirmed that earlier surgery led to faster and more complete functional recovery. Hossal et al. (2002) and Koide et al. (2003) observed a sharp reduction in postoperative diplopia and enophthalmos when repair was completed within two weeks [16, 17], while Abd El-Ghafar (2015) demonstrated complete resolution of diplopia in all patients treated within three weeks versus only 20% improvement with later intervention ($p = 0.015$) [26].

In contrast, Dal Canto and Linberg (2008) and Shin et al. (2011) found no significant difference between early and delayed groups ($p > 0.05$), provided that extraocular muscle entrapment was excluded preoperatively [19, 23]. Several Scandinavian cohorts (Kontio 2006; Alinasab 2011, 2017) similarly emphasized surgical precision and experience over timing, noting that outcomes correlated more with the adequacy of orbital reconstruction than with the day of surgery [18, 20].

Postoperative Complications

Postoperative complications varied in type and frequency across studies. The most common adverse events were residual diplopia, infraorbital hypesthesia, implant malposition, and persistent enophthalmos [16–30]. Brucoli et al. (2011) reported the highest overall complication count, while Koide et al. (2003) and Kasaee et al. (2016) noted minimal postoperative morbidity in their early-surgery cohorts [17, 21, 27]. Hassan et al. (2024) demonstrated a clear correlation between delayed intervention and increased risk of diplopia and enophthalmos, particularly in cases involving large or entrapped fractures [30]. Across studies, complication risk appeared to depend more on fracture size, herniation extent, and entrapment severity than on exact surgical timing, underscoring the multifactorial nature of postoperative outcomes.

Risk of Bias Assessment

Total scores for the included studies on the NOS scale ranged from 6 to 9, indicating a moderate-to-low overall risk of bias (Table 2) [13]. Ten studies (67%) achieved scores of ≥ 7, reflecting robust methodological quality with clearly defined inclusion criteria, imaging-based diagnoses, and adequate follow-up of outcomes. Four studies (27%) exhibited moderate risk (scores = 6), mainly due to small sample sizes and incomplete control of confounders, while none were classified as high risk.

The most common methodological limitations included lack of assessor blinding, partial reporting of attrition rates, and insufficient statistical adjustment for age or defect size in older retrospective cohorts. However, the consistency of the inclusion criteria, the precise definition of timing categories, and the use of objective imaging outcomes contributed to the overall credibility of the evidence base. Accordingly, the cumulative evidence was deemed methodologically sound and suitable for meta-analytic synthesis.

Table 2 Risk of bias across all included studies gauged using the Newcastle Ottawa Scale

Author (Year)	Design	Selection (0–4)	Comparability (0–2)	Outcome (0–3)	Total (0–9)	Overall risk of bias
Hossal et al. (2002) [16]	Retrospective cohort	4	1	2	**7**	**Low**
Koide et al. (2003) [17]	Prospective cohort	4	2	3	**9**	**Low**
Kontio et al. (2006) [18]	Prospective cohort	3	1	2	**6**	**Moderate**
Dal Canto A J & Linberg J V (2008) [19]	Retrospective cohort	3	2	2	**7**	**Low**
Alinasab B et al. (2011) [20]	Prospective cohort	3	2	2	**7**	**Low**
Brucoli M et al. (2011) [21]	Retrospective cohort	4	2	3	**9**	**Low**
Poeschl et al. (2011) [22]	Retrospective cohort	3	2	3	**8**	**Low**
Shin K H et al. (2011) [23]	Retrospective cohort	4	2	2	**8**	**Low**
Hwang K et al. (2012) [24]	Retrospective cohort	3	2	2	**7**	**Low**
Laurentjoye M et al. (2014) [25]	Prospective cohort	3	1	2	**6**	**Moderate**
Abd El-Ghafar A (2015) [26]	Prospective cohort	3	1	2	**6**	**Moderate**
Kasaee et al. (2016) [27]	Prospective cohort	4	2	3	**9**	**Low**
Alinasab et al. (2017) [28]	Prospective cohort	3	2	2	**7**	**Low**
Yamanaka Y et al. (2017) [29]	Retrospective cohort	4	2	3	**9**	**Low**
Hassan et al. (2024) [30]	Retrospective cohort	4	2	3	**9**	**Low**

Meta-Analysis

Five studies [16, 19, 21, 22, 30] involving 208 patients reported on postoperative diplopia. Among these, 149 patients underwent surgical repair within 14 days, and 49 patients underwent delayed repair. The meta-analysis (Fig. 2a) demonstrated that early surgery significantly reduced the risk of postoperative diplopia (RR 0.49, 95% CI 0.33–0.72, $p<0.05$). This indicates that the likelihood of diplopia was approximately halved when surgery was performed within two weeks of trauma.

Four studies [16, 21, 22, 30] comprising 150 patients assessed enophthalmos as an outcome. A total of 113 patients underwent early repair, while 37 underwent delayed intervention. Early surgery was associated with a significant reduction in enophthalmos (RR 0.53, 95% CI 0.36–0.79, $p<0.05$), corresponding to a 47% lower risk compared with delayed repair (Fig. 2b).

Two studies [21, 30] reported on postoperative dysthesia, with a combined sample of 88 patients. Of these, 78 underwent repair within 14 days, and 10 underwent surgery after 14 days. The pooled results (Fig. 2c) showed that early repair significantly reduced the risk of dysthesia (RR 0.59, 95% CI 0.39–0.90, $p<0.05$).

The standardized mean difference was calculated at 0.207 (95% CI − 0.184 to 0.599) under a fixed-effects model. This value reflects a small but favorable benefit of early repair compared with delayed repair. Based on Cohen's interpretation, an SMD of 0.2 denotes a small effect, 0.5 medium, and 0.8 large. Thus, while early intervention appears advantageous, the effect size is modest. Moreover, the limited number of homogeneous studies suggested that the findings of the meta-analysis should be interpreted with caution.

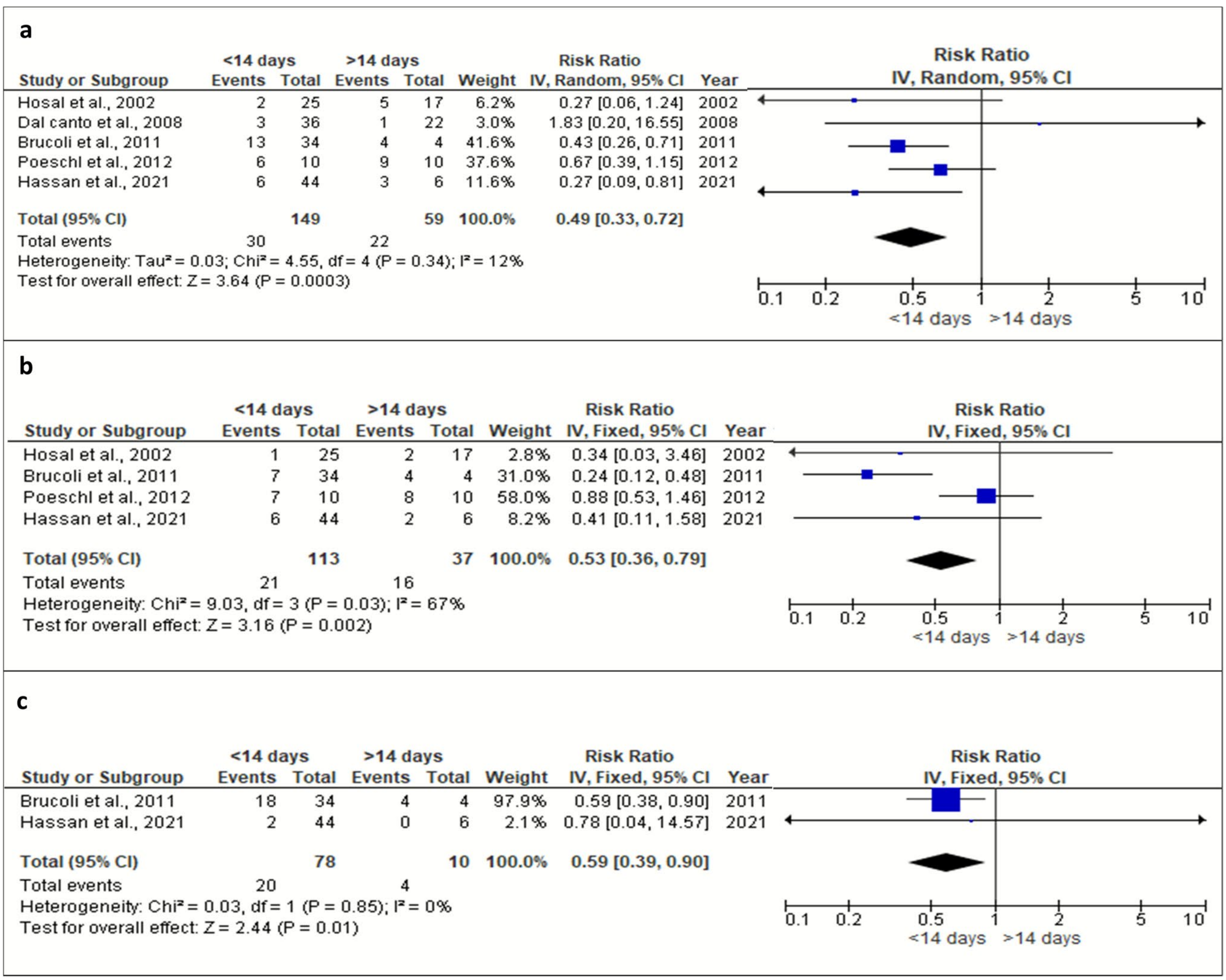


Fig. 2 Forest plots demonstrating the comparative incidences of postoperative complications between early (<14 days) and delayed (>14 days) orbital fracture repair, consisting of **a** diplopia, **b** enophthalmos, and **c** dysthesi

Table 3 Certainty of findings assessed by GRADE framework

Outcome	No. of studies (n)	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Overall certainty	Summary of findings
Diplopia improvement	14	Prospective & Retrospective Cohort	Low	Low	Low	Moderate	Undetected	Moderate	Early surgery (≤14 days) led to better diplopia resolution; consistent benefit across studies
Extraocular motility recovery	12	Prospective & Retrospective Cohort	Low	Moderate	Low	Moderate	Undetected	Moderate	Early repair improved EOM recovery, particularly in cases with muscle entrapment
Enophthalmos correction	10	Cohort Studies	Moderate	Moderate	Low	High	Undetected	Low	Early intervention favored for preventing enophthalmos, but findings were inconsistent
Infraorbital nerve sensory recovery	3	Cohort Studies	Moderate	Low	Low	High	Undetected	Low	Limited data indicated early repair may enhance sensory recovery, though evidence was imprecise
Overall complication rate	8	Cohort Studies	Low	Low	Low	Moderate	Undetected	Moderate	Early intervention associated with fewer postoperative complications compared to delayed repair

Certainty of Evidence

The GRADE assessment demonstrated that the overall certainty of evidence for outcomes related to orbital fracture repair timing ranged from low to moderate (Table 3). The evidence supporting improvement in diplopia and recovery of extraocular motility was rated as *moderate*, suggesting a fair level of confidence that early surgical intervention within 7 to 14 days of trauma leads to superior functional outcomes compared with delayed repair. These findings were consistent across multiple well-designed cohort studies with relatively low risk of bias and limited heterogeneity in reported results.

For enophthalmos correction and infraorbital nerve sensory recovery, the certainty of evidence was rated as *low*, mainly due to variability in follow-up periods, small sample sizes, and inconsistent reporting of measurement methods. Although a general trend favored early surgery to prevent long-term globe displacement and improve sensory outcomes, the precision of these estimates was limited. The evidence for overall complication rates achieved a *moderate* certainty rating, indicating that early intervention was associated with fewer postoperative complications, including residual diplopia and persistent enophthalmos.

Discussion

The present systematic review and meta-analysis synthesized evidence from fifteen cohort studies to clarify the influence of surgical timing on functional and esthetic outcomes following orbital floor and combined orbital wall fractures [16–30]. Across diverse geographic and clinical settings, a consistent pattern emerged, wherein early surgical intervention within the first two weeks in cases involving muscle entrapment or extensive defects resulted in superior functional recovery and fewer postoperative complications compared with delayed repair. Although definitions of "early" and "late" intervention varied, the pooled evidence supported the principle that timely correction of orbital volume and extraocular muscle position is critical to achieving optimal outcomes.

The association between early surgery and improved diplopia resolution observed in this review is supported by the pathophysiological understanding of orbital trauma. Prolonged herniation and entrapment of extraocular muscles can lead to ischemia, fibrosis, and restricted ocular motility if left untreated. Several included studies demonstrated that intervention within the first week significantly reduced postoperative diplopia and improved ocular motility, highlighting the importance of preventing irreversible fibrotic changes [16, 17, 27]. In contrast, studies that found no timing-related differences generally included patients without entrapment or with minor defects, suggesting that case selection, rather than timing alone, modulates the benefit of early repair [19, 23].

Previous biomechanical and radiologic analyses emphasized early restoration of orbital volume to prevent adipose tissue atrophy and posterior globe displacement [31]. Findings from the present review and meta-analysis also favored early correction of enophthalmos, with a lower incidence of late enophthalmos when repair was performed within two weeks. Timely surgery not only restores ocular alignment and binocular function but also minimizes the need for secondary corrective procedures, which are technically more challenging due to post-traumatic scarring [32].

However, not all patients require urgent intervention. In the absence of entrapment, oculocardiac reflex, or severe orbital floor collapse, a short delay may allow edema to resolve, improving surgical access and visualization [33, 34]. This approach, reflected in the protocols of Poeschl (2011) and Hwang (2012), underscores that individualized timing, balancing tissue recovery with the prevention of fibrosis, is essential. Thus, early surgery should be prioritized for functional indications, while mild fractures with stable ocular motility may safely undergo delayed elective repair within three to four weeks without adverse outcomes.

The studies included in the present review demonstrated generally moderate to high quality, as indicated by NOS scores, with most providing well-defined inclusion criteria and objective radiologic confirmation [13]. The GRADE assessment rated the overall certainty of evidence as moderate for diplopia and enophthalmos, and low to moderate for extraocular motility and composite complications [15]. This reflects residual heterogeneity in outcome definitions, follow-up durations, and timing thresholds, as well as the inherent limitations of observational designs. Despite these factors, the consistency of directionality across studies, coupled with large sample sizes and coherent biological plausibility, strengthens the credibility of the conclusions.

Clinically, these findings support the use of a structured decision algorithm in orbital trauma care. Immediate repair (within 24–72 h) should be reserved for "white-eyed" or entrapped fractures with oculocardiac symptoms, while standard early intervention within one to two weeks is appropriate for fractures with diplopia or large defects on CT [5–8]. Deferral beyond three to four weeks should be limited to cases without functional impairment. Such stratification aligns surgical urgency with anatomical and symptomatic severity, optimizing both outcomes and resource use.

Future research should focus on multicentric prospective cohorts employing standardized timing intervals, objective motility grading (e.g., Hess chart quantification), and validated patient-reported outcome measures. Randomized controlled trials may not be ethically feasible in trauma contexts, but harmonized prospective data could refine the timing threshold further and reduce current heterogeneity.

Conclusion

The findings of the present systematic review suggest that early surgical intervention, particularly within the first one to two weeks after trauma, is generally associated with better functional outcomes in patients with orbital floor and combined wall fractures, especially in cases with muscle entrapment or large defects. However, delayed repair may be equally effective when edema or inflammation needs to subside, provided that surgical precision and postoperative rehabilitation are optimized. The current evidence supports a case-dependent approach, balancing the urgency of intervention against soft-tissue recovery and patient-specific factors. Further well-designed prospective studies with standardized outcome measures are warranted to establish definitive clinical guidelines on the optimal timing of orbital fracture repair.

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Declarations

Conflict of interest The authors have no conflicts of interest to declare. The authors are solely responsible for the content and writing of the paper. The authors have no affiliation with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript.

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